The Microscopic Origin of the Record Current in VERSF

Topological Commitment Flow, Persistent Excitations, and the Emergence of Electromagnetic Sourcing

Keith Taylor — VERSF Theoretical Physics Programme Companion paper to *Matter Coupling and the Inertia Route in VERSF* (Part II of the matter-sector programme)

General Reader Summary

The previous paper in this strand — *Matter Coupling and the Inertia Route in VERSF* — established that the persistent cohomological sector of VERSF couples to a substrate-level record current J^μ via the unique admissible leading-order interaction $-J^\mu A_\mu$. Three theorems and one proposition fixed the coupling structure, the Maxwell-form dynamics, and the structural masslessness of the gauge field. The construction was tight, but it left one dominant gap unaddressed, identified explicitly in §15 of that paper: what physically carries the current J^μ?

This paper proposes a substrate ontology for that current. The proposal is that J^μ is the coarse-grained transport of refinement-persistent, topologically protected commitment structure — specifically, topological commitment loops, which are non-recombinable cycles of irreversibly committed substrate distinguishability stabilised by the topological threshold $\beta_1 \geq 1$ established in earlier VERSF work and grounded ontologically in the Fold programme (§10).

The central result is that the source current takes the form

$$J^\mu = \rho_{pers} u^\mu,$$

where ρ_{pers} is the Lorentz-invariant projected committed-distinguishability density in the local rest frame of the loop ensemble and u^μ is the four-velocity of that rest frame, with $u^\mu u_\mu = 1$. The decomposition is the standard relativistic dust four-current applied to the topologically protected commitment sector, valid in the single-species (comoving) regime; the generic multi-species ensemble carries a multi-fluid current, discussed in §6.2. Current conservation $\partial_\mu J^\mu = 0$ follows from commitment continuity together with the refinement-persistence of the projector that defines ρ_{pers}, formalised as a projection–transport intertwining lemma. Integer-valued loop winding supplies a structural route toward quantised charge via the integer cohomology $H^1(\mathcal{G}(\Lambda); \mathbb{Z})$, through the holonomy pairing with H_1 used in the Maxwell admissibility paper's Wilson-loop construction.

The substrate ontology proposed here discharges the §15 matter-question framing of *Matter Coupling* at the level of the substrate carrier of J^μ, and §10 provides an ontological integration with the Fold programme that grounds the loop construction in the broader VERSF architecture.

The construction does not discharge the full matter-sector programme: species decomposition, spinorial structure, the connection between loop winding and observed elementary electromagnetic charge, and the quantum field structure that promotes the construction to QED all remain open. This paper supplies the first of the four deliverables enumerated in *Matter Coupling* §15, leaves the remaining three for subsequent work, and establishes the structural framework within which those subsequent constructions must be carried out.

Abstract

The *Matter Coupling* paper established that the persistent cohomological sector couples to a substrate-level record current J^μ via the unique admissible interaction $-J^\mu A_\mu$, with the Catalogue Closure Theorem fixing $J^\mu = \rho u^\mu$ as the unique admissible substrate Lorentz-covariant primitive vector of mass dimension 3. The microscopic substrate origin of J^μ — what carries it, why it is conserved, and how it satisfies the source-admissibility constraints implicit in *Matter Coupling* Theorems 1–3 — remained open and was identified in *Matter Coupling* §15 as the dominant remaining gap of the electromagnetic programme.

This paper supplies that ontology. The construction rests on four independently derived VERSF inputs — the topological threshold for irreversibility ($\beta_1 \geq 1$), primitive occupancy and committed-density scaling, commitment continuity ($\partial_\mu C^\mu = 0$), and persistent cohomological transport on $H^1(\mathcal{G}(\Lambda))$ — together with the admissibility principles (P1)–(P5) of *Matter Coupling* §6, and is grounded ontologically in the Fold programme via §10. We establish, in the operational construction, one proposition framing source admissibility, one equivalence lemma, one definition with an associated proposition, three theorems, and one secondary intertwining lemma; we provide an ontological integration with the Fold programme in §10.

Proposition 1 (Source admissibility). A current J^μ supports an admissible coupling $-J^\mu A_\mu$ if and only if it satisfies five source-admissibility clauses: locality, additive conservation, refinement persistence, admissible coarse-graining, and finite primitive support.

Lemma 1 (Equivalence of admissibility frameworks). A current J^μ supports a coupling $-J^\mu A_\mu$ satisfying *Matter Coupling*'s (P1)–(P5) if and only if J^μ satisfies the five source-admissibility clauses of Proposition 1.

Definition 1 (Primitive commitment loop). A primitive commitment loop is a non-recombinable cycle of transported committed distinguishability satisfying irreversible closure, admissible persistence ($\beta_1 \geq 1$), refinement stability, and finite primitive support. §10 identifies these loops ontologically as transported persistent fold structures.

Proposition 2 (Source admissibility of loops). Within the currently identified VERSF substrate catalogue, primitive commitment loops are the unique class of substrate structures simultaneously satisfying all five source-admissibility clauses.

Theorem 3 (Hydrodynamic limit of loop transport). In the separation-of-scales regime where the observation scale $L \gg \xi$ (coherence scale) and the persistence-filtered ensemble of loops is statistically homogeneous on intermediate scales, the covariant microscopic loop current

$$J_{micro}^{\mu}(x) = \Sigma_i q_i \int d\tau\, u_i^{\mu}(\tau)\, \delta^{(4)}(x - x_i(\tau))$$

coarse-grains, under the relativistic dust-fluid identification and in the single-species (comoving) regime, to the hydrodynamic form

$$J^{\mu}(x) = \rho_{pers}(x)\, u^{\mu}(x),$$

with $\rho_{pers}(x)$ the Lorentz-invariant projected committed-distinguishability density in the local rest frame of the ensemble, $u^{\mu}(x)$ the four-velocity of that rest frame ($u^{\mu} u_{\mu} = 1$), and the rest-frame normalisation committed in §2. This concretely realises the $J^{\mu} = \rho u^{\mu}$ decomposition that *Matter Coupling* §5 left as the simplest SST-admissible form and that *Matter Coupling* Lemma 7.0.1 left conditional on a substrate-level definition of u^{μ}.

Lemma 2 (Projection–transport intertwining). The persistence projector Π_{pers}, taken as a degree-0 chain map of the graded commitment complex, intertwines the transport differential ∂ with itself: in components, for the commitment four-current C^{μ},

$$\partial_{\mu} (\Pi_{pers}^{(1)} C^{\mu}) = \Pi_{pers}^{(0)} (\partial_{\mu} C^{\mu}),$$

where $\Pi_{pers}^{(1)}$ acts on the current (grade 1) and $\Pi_{pers}^{(0)}$ on its divergence (grade 0).

Theorem 4 (Conservation). Defining $J^{\mu} = \Pi_{pers}^{(1)} C^{\mu}$ as the grade-1 projection of the full commitment four-current $C^{\mu} = (\rho, J_c^i)$ onto the refinement-persistent topologically protected sub-complex, conservation $\partial_{\mu} J^{\mu} = 0$ follows from commitment continuity $\partial_{\mu} C^{\mu} = 0$ by Lemma 2. §10 reinterprets this as conservation of persistent fold-supported distinguishability under admissible transport.

Theorem 5 (Topological charge via the holonomy pairing). The transported topological charge $Q = \Sigma_i w_i$, with $w_i \in \mathbb{Z}$ the integer winding of loop i, is conserved under admissible transport and is identified with a $\mathbb{Z}$-valued class in $H^1(\mathcal{G}(\Lambda); \mathbb{Z})$ via the holonomy pairing between $H_1(\mathcal{G}(\Lambda); \mathbb{Z})$ (where loops live) and $H^1(\mathcal{G}(\Lambda); \mathbb{Z})$ (where A_{μ} lives), as used in the Wilson-loop construction of the Maxwell admissibility paper. This is the structural route toward charge quantisation identified in *Matter Coupling* §17, and §10 grounds the integer-valued character ontologically in fold closure classes.

§10 — Ontological integration with the Fold programme (interpretive, not a formal result). Identifies loops as transported persistent fold structures via one-to-one correspondences between the (L1)–(L4) admissibility conditions of Definition 1 and Fold-programme requirements (§10.2), and unifies the construction in a single ontological chain from Void to Gauge transport (§10.6). The operational results above are unchanged regardless of the §10 reading.

Scope and epistemic labelling. Lemma 1, Lemma 2, and Theorems 3–5 are proven given the cited prior results, the admissibility framework of *Matter Coupling*, and the loop ontology of Definition 1. Proposition 2's uniqueness clause is conditional on no further admissible source structures being identified within VERSF. The single-velocity form of Theorem 3 is conditional on the single-species (comoving) regime. The Fold integration of §10 is interpretive rather than derivational: the operational results are unchanged, and what is added is ontological alignment with the Fold programme. The connection between loop winding and observed elementary electromagnetic charge is conjectural and belongs to the species-decomposition stage of the matter-sector programme. This paper does not derive fermions, Dirac structure, the Standard Model spectrum, or QED.

Contents

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1. Setting: What *Matter Coupling* Established and What It Left Open

The *Matter Coupling* paper closed three structural problems and opened one. Its closures, recapitulated here in compressed form for use below:

- **Coupling uniqueness** (*Matter Coupling* Theorem 1). Under the Catalogue Closure Theorem (derived in *Matter Coupling* §7.0 from SST and admissibility principles) and the admissibility principles (P1)–(P5), the unique admissible leading-order interaction between A_μ on $H^1(\mathcal{G}(\Lambda))$ and substrate field content is $\mathscr{L}_{int} = -J^\mu A_\mu$.

- **Gauge ⇔ conservation** (*Matter Coupling* Theorem 2). The interaction action is invariant under $A_\mu \to A_\mu + \partial_\mu \chi$ for arbitrary smooth χ iff $\partial_\mu J^\mu = 0$.
- **Maxwell-form dynamics** (*Matter Coupling* Theorem 3). The variational principle on $S = \int(-\frac{1}{4} F^2 - J\cdot A)\, d^4x$ yields $\partial_\mu F^{\mu\nu} = J^\nu$, with the Bianchi identity automatic from $F = dA$.
- **Structural masslessness** (*Matter Coupling* Proposition 4). The mass-term exclusion in Theorem 1B re-read in physical language: the persistent gauge sector requires no intrinsic mass-like term, and observable dynamics arise through coupling.

The opening — *Matter Coupling* §15, "The Matter Question" — is the gap this paper addresses. The question, stated sharply:

You postulated a conserved current J^μ and recovered the Maxwell equations. Any U(1) gauge theory with a conserved source yields the same structure. What has actually been achieved?

Matter Coupling's response was that the substrate-side derivations of (a) the gauge structure, (b) the conserved current, (c) the coupling forcing, and (d) the structural masslessness are non-trivial regardless of the elementary final variational step. But *Matter Coupling* itself acknowledged that the construction was a structural waypoint without a microscopic substrate ontology for J^μ: the current was treated as the conserved commitment-flow vector, undecomposed, with no specified substrate carriers.

Matter Coupling §15 enumerated four deliverables for the matter-sector programme that would close this gap:

1. Charged excitations as identifiable substrate structures.
2. Species decomposition of J^μ into matter-resolved currents.
3. Spinorial structure connecting to the existing spin-as-double-cover programme.
4. Quantum field structure promoting the construction to QED.

The present paper addresses item (1) operationally (§§5–8) and ontologically (§10), and prepares the structural framework for item (2). Items (3) and (4) remain explicitly open. The paper is therefore narrow in scope by design: it supplies the substrate-ontology layer of the matter-sector programme, leaves the species, spinorial, and QFT layers for subsequent work, and makes explicit the structural constraints that any future matter-sector construction must respect.

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2. Notation and Conventions

We adopt the conventions of *Matter Coupling* §2 throughout. The four-dimensional Lorentzian continuum emerges from the refinement-stable limit of the substrate lattice Λ, with metric signature (+, −, −, −); in keeping with the VERSF ontology, time is emergent rather than primitive, and "continuum," "geometry," and "4-manifold" are used in preference to any term presupposing a fundamental temporal dimension. Greek indices $\mu, \nu, \ldots$ run over 0, 1, 2, 3; Latin indices $i, j, \ldots$ over 1, 2, 3. Natural Heaviside–Lorentz units ($\hbar = c = \varepsilon_0 = 1$) are used; all numerical prefactors are absorbed into field normalisations.

The persistent cohomological transport potential is A_μ, with $F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$, or equivalently $F = dA$ in form language. The persistent cohomological sector is $H^1(\mathcal{G}(\Lambda))$ for real coefficients and $H^1(\mathcal{G}(\Lambda); \mathbb{Z})$ for integer coefficients; the integer cohomology will be relevant for the charge-quantisation discussion of §8 and the Fold-winding identification of §10.5.

The full commitment four-current is $C^\mu \equiv (\rho, J_c^i)$, with ρ the SST committed-record density (mass dimension 3) and J_c^i its spatial transport flow. The record current sourcing the persistent gauge sector is J^μ, defined as the grade-1 projection of C^μ onto the refinement-persistent topologically protected sub-complex via a chain-map projector Π_{pers} introduced in §6.3. (Forward reference: we refine ρ to ρ_{pers} in §6.3 once the persistence projector is defined; until that point, ρ denotes the full SST committed-record density of *Matter Coupling* §5.)

Dust-fluid normalisation commitment. Throughout this paper, the loop transport four-velocity satisfies

$$u^\mu u_\mu = 1,$$

with u^μ taken as the four-velocity of the local rest frame of the loop ensemble (Eckart frame). The local density ρ_{pers} is the Lorentz-invariant projected committed-distinguishability density in that rest frame. In the single-species (comoving) regime, the decomposition $J^\mu = \rho_{pers} u^\mu$ is the standard relativistic dust four-current applied to the topologically protected commitment sector. This commitment resolves a normalisation ambiguity in *Matter Coupling* §5: ρ_{pers} is a Lorentz scalar density, not a coordinate-frame number density, and the hydrodynamic identification of §6.2 invokes the relativistic dust-fluid construction explicitly. With this commitment, J^μ has mass dimension 3 as required for the coupling $-J^\mu A_\mu$ to have Lagrangian density dimension 4, since ρ_{pers} has mass dimension 3 and u^μ is dimensionless.

The coherence scale is denoted ξ. The refinement scale at level n is a_n, with $a_n \to 0$ the continuum limit. The first Betti number of the admissible substrate complex (relevant for topological closure) is β_1.

By **primitive commitment loop** we mean the substrate object defined formally in §5.1, identified in §10.2 as a transported persistent fold structure. By **loop ensemble** we mean a refinement-stable collection of such loops in a region of the continuum. By **topological winding** of a loop we mean its integer class in $H_1(\mathcal{G}(\Lambda); \mathbb{Z})$, paired via the holonomy pairing of §8.2 with $H^1(\mathcal{G}(\Lambda); \mathbb{Z})$, and corresponding under the §10.5 reinterpretation to a conserved fold closure class.

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3. Structural Dependencies

This section states without re-derivation the prior VERSF results on which the construction depends. Five are inherited from the broader programme; the sixth is the *Matter Coupling* result itself.

3.1 Persistent cohomological transport

From the refinement-persistence and Wilson-loop identification papers, the refinement-persistent observable sector is

$$H^1(\mathcal{G}(\Lambda)) = C^1(\Lambda) / \mathrm{Im}(d_0),$$

with continuum transport reducing uniquely to Maxwell-form structure satisfying $dF = 0$. The sector is reversible, refinement-stable, gauge-redundant, and cannot be sourced consistently by transient (non-persistent) substrate fluctuations. The Wilson-loop construction associated with this sector — $W(\gamma) = \exp(i \oint_\gamma A_\mu dx^\mu)$ for closed cycles γ — provides the holonomy pairing used in §8.

3.2 Commitment continuity

The full commitment four-current $C^\mu = (\rho, J_c^i)$ satisfies

$$\partial_\mu C^\mu = 0,$$

following from irreversibility, finite distinguishability, and the impossibility of spontaneous uncommitment — the latter being the operative content of the **BCB axiom** (the foundational substrate axiom prohibiting spontaneous uncommitment of distinguishability), inherited from the foundational programme and not re-derived here. As emphasised in *Matter Coupling* §5, this conservation is ontological rather than dynamical: it is enforced by the structure of admissible commitment, not by a Noether symmetry of an action.

3.3 Topological threshold for irreversibility

Irreversible commitment requires nontrivial cycle structure in the admissible substrate complex:

$$\beta_1 \geq 1.$$

Irreversible facts cannot exist in purely simply-connected transport sectors. This result is the structural pivot of the loop ontology developed in §5; the transition from the global $\beta_1 \geq 1$ to the individual-loop form of Definition 1 is made explicit in §5.2, and the underlying Fold-theoretic reading — that folds select sectors of the substrate where $\beta_1 \geq 1$, since only there can irreversible commitment persist — is supplied in §10.1.

3.4 Primitive occupancy and committed-density scaling

The primitive occupancy theorem establishes one primitive commitment event per coherence patch and a finite commitment-capacity density. With ξ the coherence scale, the scaling

$$\rho \sim 1/\xi^3$$

(mass dimension 3 in natural units; restoring conventional units multiplies by the appropriate powers of $\hbar$ and c) sets the substrate scale at which macroscopic coarse-grained currents inherit their density normalisation. The projected density ρ_{pers} introduced in §6 is bounded above by ρ pointwise under the natural construction of Π_{pers} as a positivity-preserving contraction on the density grade (justified in §6.3 and §9): ρ_{pers} is the projection of the full commitment density onto its topologically protected fraction.

3.5 The Fold programme

The Fold programme — the architectural foundation developed elsewhere in VERSF and consolidated in *The Fold and the Record* — establishes that a fold is the minimal irreversible distinguishability event: the first committed asymmetry separating the committed sector from the reversible void substrate. Three Fold-programme results are used in §10:

1. Reversible substrate evolution alone cannot sustain stable physical distinctions (fundamental Fold-programme result).
2. Persistent distinguishability requires topological trapping, coincident with the $\beta_1 \geq 1$ condition of §3.3 (Fold-programme theorem establishing the persistence-topology coincidence). This is the load-bearing result for §10.1's identification of folds as selecting $\beta_1 \geq 1$ substrate sectors.
3. A fold is the minimal physically committed topological asymmetry capable of persisting under admissible dynamics (Fold-programme definition of fold).

The record-current uniqueness result of the Fold programme additionally supplies the technical coincidence target identified in §14 and §16. Inheritance of these results means the present paper does not re-derive the Fold-programme architecture; readers seeking the underlying derivations should consult the Fold programme directly. The §10 integration depends on results 1–3 and the record-current uniqueness result as listed.

3.6 *Matter Coupling*: source admissibility from (P1)–(P5)

The most important inherited result is the admissibility framework of *Matter Coupling* §6, which constrains any candidate coupling between the persistent gauge sector and the substrate by five principles:

- **(P1) Locality**: the interaction Lagrangian $\mathscr{L}_{int}(x)$ depends only on field values at x and finitely many derivatives in the continuum refinement limit.
- **(P2) Refinement persistence**: $\mathscr{L}_{int}$ descends consistently under the lattice coarsening map and lies in the refinement-stable image of the persistence functor.
- **(P3) Gauge redundancy compatibility**: the action S_{int} is invariant under $A_\mu \to A_\mu + \partial_\mu \chi$ modulo boundary terms.

- **(P4) Distinguishability preservation**: the coupling does not generate distinguishability-violating evolution on the persistent sector when J^μ is treated as a prescribed external source.
- **(P5) Lowest-order closure consistency**: the coupling is of lowest mass dimension and lowest order in the fields that yields non-trivial source coupling.

Together with the Catalogue Closure Theorem (*Matter Coupling* §7.1), (P1)–(P5) imply that J^μ is the unique admissible substrate Lorentz-covariant primitive vector of mass dimension 3 and that $\mathscr{L}_{int} = -J^\mu A_\mu$ is the unique admissible interaction. The present paper takes this as given and asks: what substrate structure supplies J^μ?

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4. The Source-Admissibility Constraint and Its Equivalence with (P1)–(P5)

Matter Coupling's (P1)–(P5) constrain the interaction Lagrangian. We now state a dual constraint on the current itself, and prove the two are equivalent. The equivalence makes precise what the structural framework demands of any substrate carrier of J^μ.

4.1 The source-admissibility proposition

Proposition 1 (Source admissibility). A current J^μ supports an admissible leading-order coupling $-J^\mu A_\mu$ if and only if J^μ satisfies all of the following:

1. **Locality (SA1).** J^μ has compactly supported contributions per primitive domain in the continuum refinement limit.
2. **Additive conservation (SA2).** $\partial_\mu J^\mu = 0$ as a smooth distribution.
3. **Refinement persistence (SA3).** J^μ survives under the refinement coarsening map; equivalently, J^μ lies in the persistence-stable image of C^μ.
4. **Admissible coarse-graining (SA4).** J^μ converges under the persistence-filtered averaging measure as $a_n \to 0$ at fixed observation scale $L \gg \xi$.
5. **Finite primitive support (SA5).** Each contribution to J^μ carries bounded distinguishability content per coherence patch.

4.2 Lemma 1 (Equivalence of admissibility frameworks)

Lemma 1. Let J^μ be a candidate current and consider the interaction Lagrangian $\mathscr{L}_{int} = -J^\mu A_\mu$. Then $\mathscr{L}_{int}$ satisfies *Matter Coupling*'s (P1)–(P5) if and only if J^μ satisfies SA1–SA5.

Proof. *Forward direction.* Assume $\mathscr{L}_{int}$ satisfies (P1)–(P5).

- (P1) requires $\mathscr{L}_{int}$ local in the continuum limit; with A_μ a smooth field on the persistent sector, this forces J^μ local — yielding SA1.

- (P3) requires $\delta S\_int = 0$ under $A\_\mu \rightarrow A\_\mu + \partial\_\mu \chi$ for arbitrary smooth χ. By *Matter Coupling* Theorem 2, this holds iff $\partial\_\mu J^\mu = 0$ — yielding SA2.
- (P2) requires $\mathscr{L}\_int$ refinement-persistent; with A_μ refinement-stable (it lives on $H^1(\mathcal{G}(\Lambda))$), this forces J^μ refinement-stable — yielding SA3.
- (P4) requires distinguishability preservation on the persistent sector under coupling. For J^μ treated as a prescribed external source, distinguishability preservation requires J^μ to be a well-defined external field at the continuum scale at which A_μ is defined. Well-definedness alone is necessary but not by itself sufficient for the specific convergence asserted by SA4; the additional content is that A_μ lives on the refinement-stable limit $H^1(\mathcal{G}(\Lambda))$, so the coupling $-J^\mu A\_\mu$ is well-defined as a refinement-stable object only if J^μ admits a convergent coarse-graining sequence into that same limit. It is this matching of refinement limits — not mere pointwise well-definedness — that yields SA4. (The convergence is exhibited explicitly in Theorem 3 for the loop ensemble.)
- (P5) requires $\mathscr{L}\_int$ to be the leading-order admissible interaction; via the Catalogue Closure Theorem this means J^μ is the unique leading-order admissible substrate dimension-3 vector, which by *Matter Coupling* Lemma 7.0.1 requires the substrate primitives composing J^μ to have finite primitive support — yielding SA5.

Reverse direction. Assume J^μ satisfies SA1–SA5. Then by SA1 the coupling $-J^\mu A\_\mu$ is local; by SA2 it is gauge-invariant under arbitrary smooth χ; by SA3 it is refinement-persistent; by SA4 distinguishability is preserved on the persistent sector under coupling to J^μ as an external source; by SA5 it carries finite primitive support and is therefore lowest-order admissible by *Matter Coupling* Theorem 1B. (P1)–(P5) follow.

Structural reading. The five clauses of source admissibility are exactly the conditions *Matter Coupling*'s framework imposes on J^μ once the coupling structure is fixed. Lemma 1 makes precise what was implicit in the original formulation: the source-admissibility constraints and the interaction-admissibility principles are dual lenses on the same underlying structural demand. Any substrate ontology proposed for J^μ must satisfy SA1–SA5 if it is to participate in the *Matter Coupling* admissibility framework.

4.3 Why arbitrary substrate fluctuations are excluded

Transient substrate disturbances recombine, decohere, and fail persistence under coarse-graining. They violate SA3 and generically SA4, regardless of how locally energetic they are. The argument is structural rather than dynamical: even an arbitrarily large transient cannot supply persistent sourcing if its distinguishability content does not survive refinement.

This leaves a sharp question for the remainder of the paper: which substrate structures within VERSF satisfy SA1–SA5? The proposal of §5 is that primitive commitment loops do, and that they are — within the currently identified substrate catalogue — the only class of substrate structures that does. The Fold integration of §10 identifies these loops ontologically as transported persistent fold structures, so the answer to the source-admissibility question becomes, in Fold-theoretic terms: the substrate carriers of J^μ are the transport-stable manifestations of fold commitment.

5. Persistent Commitment Loops

5.1 Definition

Definition 1 (Primitive commitment loop). A primitive commitment loop $\mathcal{C}_i$ is a substrate structure satisfying:

- **(L1) Irreversible closure.** The loop is generated by a sequence of commitment events whose joint distinguishability content cannot be locally unwound.
- **(L2) Admissible persistence.** The loop is supported by nontrivial cycle structure ($\beta_1 \geq 1$ of §3.3) and is therefore protected against continuous contraction.
- **(L3) Refinement stability.** The loop survives the refinement coarsening map δ^* and lies in the refinement-persistent sub-complex.
- **(L4) Finite primitive support.** The loop carries bounded distinguishability content per coherence patch, satisfying the primitive occupancy bound of §3.4.

The loop is not primarily a geometric object. It is informationally trapped commitment structure: an irreducible packet of irreversible distinguishability whose persistence is enforced by the topology of the admissible complex rather than by any local energy barrier. The Fold integration of §10 grounds this characterisation in the broader VERSF architecture: loops are the transport-stable manifestations of fold commitment, and the (L1)–(L4) conditions are the closure-trapping conditions any such transported fold structure must satisfy.

A loop carries three attributes:

- a commitment weight q_i, measuring its protected distinguishability content;
- an admissible transport four-velocity u_i^μ with $u_{i\mu} u_i^\mu = 1$, the substrate analogue of a normalised four-velocity;
- a winding number $w_i \in \mathbb{Z}$, identified via the holonomy pairing of §8.2 with a class in $H^1(\mathcal{G}(\Lambda); \mathbb{Z})$, corresponding under §10.5 to a conserved fold closure class.

Reading of loops. Primitive commitment loops should be read as candidate topological soliton sectors of the commitment-continuity field, not as freely postulated substrate objects. A full dynamical derivation would require an explicit substrate evolution equation whose stable, finite-support, non-contractible solutions are precisely the loops of Definition 1. The present paper establishes the admissibility and conservation requirements such solutions must satisfy, while leaving their explicit solitonic construction to a future loop-dynamics paper (§16 item 9 supplies the concrete target theorem). Under this reading, the (L1)–(L4) conditions are the boundary conditions any candidate soliton sector must satisfy to qualify as a primitive commitment loop, rather than independent postulates about substrate ontology.

5.2 Why commitment requires loop topology

If the distinguishability content generated by a commitment event is simply connected and continuously contractible within the admissible complex, refinement dynamics erase the distinction over time and the structure is not refinement-persistent. The $\beta_1 \geq 1$ threshold of §3.3 applied at the level of individual commitment structures forces nontrivial topological support for any persistent commitment.

The transition from §3.3's global statement to Definition 1's individual-loop statement deserves explicit notice. The $\beta_1 \geq 1$ result of §3.3 applies to the admissible complex as a whole. Its consequence for individual commitment structures is sharper: a structure whose distinguishability content is simply connected within the admissible complex is contractible by refinement and fails (L3). Persistent commitment structures must therefore wind on the non-trivial cycles whose existence $\beta_1 \geq 1$ guarantees, and this is loop form in the sense of Definition 1. The loop ontology is not an additional postulate beyond the $\beta_1 \geq 1$ result; it is that result instantiated at the level of substrate carriers, with the global topological condition forcing the individual-structure topological form.

5.3 Loops satisfy source admissibility

Proposition 2 (Source admissibility of loops). A primitive commitment loop $\mathcal{C}$_i contributes to a current that satisfies all five source-admissibility clauses of Proposition 1.

Clause	Verification
SA1 (Locality)	(L4) finite primitive support per coherence patch
SA2 (Conservation)	Commitment continuity §3.2 applied to topologically protected commitment, formalised in Theorem 4
SA3 (Refinement persistence)	(L3) loops survive δ* by definition
SA4 (Admissible coarse-graining)	Hydrodynamic limit established in Theorem 3
SA5 (Finite primitive support)	(L4) directly

Uniqueness within the substrate catalogue. Within the currently identified VERSF substrate catalogue — the primitive substrate fields of *Matter Coupling* Lemma 7.0.1 (ρ and the conditional u^μ) together with the loop structures introduced here — primitive commitment loops are the only class of substrate structures simultaneously satisfying all five SA clauses. Any alternative would require either (a) a non-topological persistent structure (excluded by the refinement-erosion argument of §5.2 applied to non-topological commitments), (b) an extension of the substrate catalogue beyond what is currently established (a hypothetical extension flagged in *Matter Coupling* §16 but not realised), or (c) a relaxation of one of (P1)–(P5) (which would propagate through Lemma 1 and weaken the framework).

This uniqueness is conditional in exactly the same sense as *Matter Coupling* Theorem 1: it holds within the current substrate catalogue, and is open to revision if the catalogue is extended. The Fold integration of §10 supplies an ontological complement: under the §10 reading, loops are the transport-stable manifestation of fold commitment, so alternative substrate carriers of J^μ would need to be alternative transport-stable manifestations of fold structure. This narrows the catalogue-extension space under the §10 interpretation, though the structural uniqueness clause itself rests on Lemma 1 independently of §10.

5.4 Loops and the $J^\mu = \rho\, u^\mu$ decomposition

Matter Coupling §5 introduced $J^\mu = \rho\, u^\mu$ as the simplest SST-admissible form of the record current and identified u^μ's substrate-level definition as the matter-sector gap. The loop ontology supplies a candidate definition: u^μ at a point is the four-velocity of the Eckart rest frame of the persistence-weighted ensemble of loop transport four-velocities u_i^μ in a neighbourhood of that point, in the separation-of-scales limit of §6.

This is not yet a fully independent substrate-level definition: u^μ is defined in terms of loop transport, where loop transport is itself characterised by admissible flow on the persistent complex. The circularity is benign at the hydrodynamic level — the ensemble average is well-defined once the loop ontology and persistence projector are accepted — but it means that *Matter Coupling* Lemma 7.0.1's conditional clause on u^μ is narrowed rather than closed by the present construction.

Closure direction. A full closure would characterise loop transport as solitonic dynamics of ρ-functionals under commitment-continuity flow, with loops emerging as the topologically protected sector of that dynamics. The well-defined target is to identify u^μ with the soliton four-velocity field of an SST-admissible field theory whose continuity equation is precisely $\partial_\mu C^\mu = 0$. The Fold integration of §10.4 supplies the structural reason this characterisation should work: loops as transported fold structures are the natural soliton sector of any field theory whose dynamics are constrained by fold irreversibility and closure trapping. The closure direction (soliton characterisation of u^μ) and the Fold integration are therefore two routes to the same structural completion; this is recorded as §16 item 4.

Target stability functional. A concrete form of the candidate dynamics is: continuity-preserving substrate evolution $\partial_\mu C^\mu = 0$ (already established as §3.2), together with a topological stability functional

$$E_{loop}[\rho] = \int \left(\alpha\, |\nabla\rho|^2 + V(\rho) + \lambda_{top}\, \beta_1[\rho]\right) d^3x,$$

whose nontrivial finite-energy sectors satisfy $\beta_1 \geq 1$ and cannot relax to the trivial sector under admissible evolution.[1] The first term gives kinetic stability under spatial variation, $V(\rho)$ is a potential admitting nontrivial ground states, and $\lambda_{top}\, \beta_1[\rho]$ is a topological term penalising trivial topology in the support of ρ. This functional form is a target, not a derivation; the loop-dynamics paper (§16 item 9) must establish whether such a functional admits an SST-admissible construction and whether its stable sectors coincide with Definition 1's primitive commitment loops.

[1] Precise definition of $\beta_1[\rho]$ as a functional of the field configuration is left to the loop-dynamics paper; persistent-homology-based definitions over sublevel sets of ρ are a natural

starting point, with the loop-dynamics paper responsible for fixing the sublevel threshold and showing that the resulting $\beta_1[\rho]$ is admissibly stable under refinement.

5.5 Transport of commitment topology

Loops propagate, interact, and flow through the substrate under admissible transport dynamics, subject to finite distinguishability, continuity, and admissible coarse-graining. Because commitment is irreversible, loops cannot terminate arbitrarily, vanish locally, or unwind continuously: their transport inherits continuity from the commitment continuity law of §3.2. A loop is therefore a transported topological excitation, and its propagation is the microscopic carrier of current-like behaviour at the substrate level. Under the §10.4 ontological reading, this transport-stability admits an additional grounding in fold closure: in the absence of non-contractible fold-supported topology no irreversible persistence exists, and once such topology is in place recombination is topologically obstructed. The transport-stability of §5.5 stands independently on §3.2's commitment continuity; §10.4 supplies the Fold-theoretic interpretation.

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6. From Discrete Loops to a Continuum Current

6.1 Microscopic transport current (covariant form)

Consider a region containing loops $\{\mathcal{C}_1, \mathcal{C}_2, \ldots, \mathcal{C}_N\}$. The covariant microscopic transport current is

$$J_{micro}^\mu(x) = \Sigma_i\, q_i \int d\tau\, u_i^\mu(\tau)\, \delta^{(4)}(x - x_i(\tau)),$$

where the integral is along the loop's worldline $x_i(\tau)$ parametrised by proper time τ, and $u_i^\mu = dx_i^\mu/d\tau$ satisfies $u_{i\mu} u_i^\mu = 1$ by the dust-fluid normalisation of §2. This is the standard covariant form for a relativistic dust contribution: each loop contributes the four-current of a point worldline with charge weight q_i and four-velocity u_i^μ.

6.2 Theorem 3 — Hydrodynamic limit

Theorem 3 (Hydrodynamic limit of loop transport). Let L be an observation scale satisfying $L \gg \xi$, and assume:

- **(H1) Statistical homogeneity at intermediate scales.** The persistence-filtered ensemble of loops is statistically homogeneous on scales between ξ and L.
- **(H2) Local Eckart frame.** The charge-weighted distribution of loop transport four-velocities admits a timelike coarse-grained mean current on scale L, hence a well-defined local mean rest frame, with bulk four-velocity $u^\mu(x)$ ($u^\mu u_\mu = 1$) defined as the velocity of that frame.

Then the microscopic loop current of §6.1 coarse-grains under the persistence-filtered averaging measure to the hydrodynamic form

$$J^\mu(x) = \rho_{pers}(x)\, u^\mu(x),$$

where $\rho_{pers}(x)$ is the Lorentz-invariant projected committed-distinguishability density measured in the local rest frame of the ensemble.

Argument. Under (H1) the density of loops admits a well-defined limit on scale L as the microscopic scale $\xi \to 0$ at fixed L. Under (H2) the charge-weighted coarse-grained current $N^\mu(x) = \langle q_i u_i^\mu \rangle$ is timelike, so a local Eckart rest frame exists and $u^\mu(x)$ is its four-velocity, with N^μ parallel to u^μ. Writing $N^\mu(x) = \rho_{pers}(x) u^\mu(x)$ defines ρ_{pers} as the Lorentz scalar $\sqrt{N^\mu N_\mu}$, the rest-frame density. Non-persistent contributions to the microscopic current vanish under the persistence-filtered measure by the chain-map property of the projector Π_{pers} (formalised in §6.3 below), so the surviving continuum current is exactly $\rho_{pers} u^\mu$.

Multi-species caveat (load-bearing for the species programme). Assumption (H2) is not innocuous. The microscopic current of §6.1 is *charge-weighted* by q_i, so for an ensemble containing loops of opposite winding flowing in different directions the coarse-grained N^μ can be spacelike, null, or vanishing — in which case no Eckart rest frame exists and $\rho_{pers} = \sqrt{N^\mu N_\mu}$ is ill-defined. The single-velocity form $J^\mu = \rho_{pers} u^\mu$ is therefore the **single-species (comoving) limit**. Generically, once the species-decomposition stage (§16 item 1) delivers distinct, possibly oppositely flowing populations, the coarse-grained current is multi-fluid,

$$J^\mu = \Sigma_a \rho_a u_a^\mu,$$

which reduces to $\rho_{pers} u^\mu$ only when all species comove. The single-velocity decomposition is exactly the form *Matter Coupling* §5 was trading on; the species stage will generically replace it with the multi-fluid sum, and Theorem 3 should be read as supplying the comoving limit rather than the general kinematics.

Epistemic note. The expression $J^\mu = \rho_{pers} u^\mu$ is proven as a coarse-grained limit conditional on (H1), (H2), the dust-fluid normalisation, and the single-species regime. These are standard hydrodynamic input; full justification within VERSF belongs to the admissible coarse-graining programme, and the conditional character matches *Matter Coupling* §16's labelling of the $J^\mu = \rho u^\mu$ decomposition as conditional on the matter-sector programme. Under the Fold reading of §10.3, ρ_{pers} is the local density of persistent fold-supported distinguishability and u^μ the transport four-velocity of the corresponding closure structure; this grounds Theorem 3 ontologically without modifying it.

6.3 The projector Π_{pers} and the relation to the full commitment current

The full commitment current C^μ of §3.2 captures all committed distinguishability transport, including non-topologically-protected contributions that fail SA3. The electromagnetic current J^μ is the grade-1 projection of C^μ onto the refinement-persistent topologically protected sub-complex:

$J^\mu = \Pi\_pers^{(1)} C^\mu$,

where Π_pers is the projection onto $\ker(\delta^*) \cap \{\beta_1 \geq 1 \text{ support}\}$.

Π_pers as a graded chain map. To make the conservation argument of §6.4 typecheck, Π_pers must be specified as a degree-0 endomorphism of the *graded* refinement complex, acting at each grade — on the density (grade 0) and on the current (grade 1) — rather than only on vector fields. Write the relevant fragment of the complex as

$\ldots \to \mathcal{C}^{(1)} \to \mathcal{C}^{(0)} \to \ldots$ (differential ∂ lowering grade by one)

where ∂ is the transport differential (the divergence on the current grade). We require Π_pers to act as $\Pi\_pers^{(1)}$ on $\mathcal{C}^{(1)}$ and $\Pi\_pers^{(0)}$ on $\mathcal{C}^{(0)}$, each as the projection onto the refinement-persistent topologically protected sub-complex at that grade. The substantive claim (Lemma 2) is that Π_pers so defined is a **chain map** — it commutes with ∂ across grades.

Idempotency, positivity, contractivity. We adopt a provisional working construction pending the persistence-paper completion, and we require it to carry three properties jointly, since §9's pointwise bound depends on more than idempotency alone:

1. **Idempotent projection.** $(\Pi\_pers)^2 = \Pi\_pers$ at each grade, with image the refinement-persistent topologically protected sub-complex and kernel the non-persistent complement.
2. **Positivity-preserving.** On the density grade, $\Pi\_pers^{(0)}$ maps non-negative densities to non-negative densities.
3. **Contractive (sub-Markovian) on the density grade.** $\Pi\_pers^{(0)}$ acts as a 0/1 indicator selecting the topologically protected fraction of a positive-sum decomposition of the commitment content, so $0 \leq \Pi\_pers^{(0)} \rho \leq \rho$ pointwise.

Concretely, a substrate vector field V^μ has $\Pi\_pers^{(1)} V^\mu$ equal to the contribution from refinement-persistent topologically protected configurations, with zero contribution from non-topologically-protected or non-persistent configurations; the density grade acts analogously. Properties 2–3 are extra requirements beyond idempotency — a bare idempotent need be neither positive nor contractive — and it is properties 2–3, not property 1, that yield the §9 bound $\rho\_pers \leq \rho$. The projector is well-defined whenever the refinement functor of the persistence papers is well-defined; its rigorous explicit construction is recorded as §16 item 5.

Notational note. Throughout this paper, ρ_pers denotes the projected density $\Pi\_pers^{(0)} \rho$. Where the full commitment density is needed unprojected, we write ρ as in *Matter Coupling* §5 and the SST paper.

6.4 Lemma 2 (Projection–transport intertwining) and Theorem 4 (Conservation)

Lemma 2 (Projection–transport intertwining). With Π_pers the graded chain-map projector of §6.3, for the commitment four-current C^μ in the domain of Π_pers,

$$\partial\_\mu (\Pi\_pers^{(1)} C^\mu) = \Pi\_pers^{(0)} (\partial\_\mu C^\mu),$$

with $\Pi\_pers^{(1)}$ acting on the current and $\Pi\_pers^{(0)}$ on its scalar divergence.

Justification. Two structurally distinct claims combine.

(i) The persistent sub-complex is closed under the transport differential at every grade. By the refinement-persistence theorems, admissible transport on the substrate maps refinement-stable configurations to refinement-stable configurations: if a grade-1 configuration lies in $\ker(\delta^*) \cap \{\beta_1 \geq 1 \text{ support}\}$, its image under admissible transport does too (the demotion direction). The complementary direction — that a configuration failing refinement persistence cannot acquire it by being transported — is the more substantive claim: acquisition would amount to spontaneous commitment of distinguishability content not present in the source configuration, exactly the BCB-prohibited transition (the promotion direction). Persistence and non-persistence are therefore stable categories under refinement-admissible flow at every grade, with demotion supplied by refinement-persistence closure and promotion forbidden by BCB. A graded projection onto a sub-complex that is closed under the differential at every grade is, by definition, a chain map: $\Pi\_pers\ \partial = \partial\ \Pi\_pers$ as maps of graded modules. In components this is precisely the displayed intertwining, the grade bookkeeping being that ∂ lowers grade by one, so the projector on the right acts one grade below the projector on the left.

(ii) Continuum identification of ∂ as the generator of admissible transport. In the continuum refinement limit, the generator of admissible transport on the persistent sector is precisely the continuum derivative ∂_μ. This is a continuum-limit identification rather than a substantive dynamical claim: it is what "∂_μ" means on the persistent sector once the refinement-stable limit has been taken.

Combining (i) and (ii) gives the intertwining as stated. The earlier "commutation" phrasing — $\Pi\_pers(\partial\_\mu V^\mu) = \partial\_\mu(\Pi\_pers V^\mu)$ — is correct only once Π_pers is read as the graded chain map with its two grade-specific actions; written with a single ungraded Π_pers it does not typecheck, since the two sides then live at different grades. The chain-map formulation removes that ambiguity.

Theorem 4 (Conservation). With $J^\mu = \Pi\_pers^{(1)} C^\mu$ as in §6.3,

$$\partial\_\mu J^\mu = 0.$$

Proof. By Lemma 2,

$$\partial\_\mu J^\mu = \partial\_\mu (\Pi\_pers^{(1)} C^\mu) = \Pi\_pers^{(0)} (\partial\_\mu C^\mu) = \Pi\_pers^{(0)}(0) = 0,$$

using $\partial\_\mu C^\mu = 0$ from §3.2 and the linearity of $\Pi\_pers^{(0)}$.

Structural reading. Conservation of J^μ is not a Noether-symmetry consequence in the conventional sense — it follows directly from (a) the ontological conservation of committed distinguishability and (b) Lemma 2's chain-map intertwining. The *Matter Coupling* Theorem 2 equivalence (gauge invariance ⇔ current conservation) therefore acquires a substrate-level grounding: gauge invariance on the persistent sector is the persistent-sector shadow of substrate distinguishability conservation, and the two are identified not coincidentally but because they originate in the same projection structure. Under the §10.3 Fold reading, Theorem 4 is interpreted as *record conservation is transported fold conservation*; Theorem 4 itself stands independently of §10 and is established here by the Lemma 2 / commitment-continuity chain above.

Explicitly, on the density grade,

$$\partial_t \rho_{pers} + \nabla\cdot(\rho_{pers} u) = 0,$$

the standard continuity equation for the projected density.

6.5 Citation of the Derivative Suppression Lemma

The hydrodynamic limit of §6.2 implicitly uses the elimination of higher-derivative variants of the microscopic transport current under the persistence projection. This is the Derivative Suppression Lemma of *Matter Coupling* §7, which establishes $(k\cdot a_n)^{(2m)}$ suppression per 2m extra derivatives under the smooth-form-factor regularity assumption of the refinement functor. The same lemma justifies the leading-order character of $J^\mu = \rho_{pers} u^\mu$: higher-derivative corrections to the hydrodynamic form (terms involving $\partial^2(\rho_{pers} u^\mu)$, and so on) are suppressed by powers of $(k\cdot a_n)$ under refinement and vanish in the continuum limit. If the refinement functor is sharp-cutoff rather than smooth, the suppression weakens to $(k\cdot a_n)$ per derivative pair and the leading-order character of Theorem 3 needs to be restated; this matches the regularity caveat in *Matter Coupling* §7.

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7. Coupling to the Persistent Gauge Sector

7.1 Structural compatibility

By Proposition 2 and Theorem 4, $J^\mu = \rho_{pers} u^\mu = \Pi_{pers}^{(1)} C^\mu$ satisfies SA1–SA5. By Lemma 1, the coupling $-J^\mu A_\mu$ therefore satisfies *Matter Coupling*'s (P1)–(P5). By *Matter Coupling* Theorem 1, the leading-order admissible interaction is

$$\mathscr{L}_{int} = -J^\mu A_\mu,$$

modulo total derivatives, with the sign convention of *Matter Coupling* §7.[²] By *Matter Coupling* Theorem 3, variational treatment of the full action

$$S[A] = \int \left(-\tfrac{1}{4} F_{\mu\nu} F^{\mu\nu} - J^\mu A_\mu \right) d^4x$$

yields

$\partial_\mu F^{\mu\nu} = J^\nu$,

while the Bianchi identity $\partial_{[\alpha} F_{\beta\gamma]} = 0$ holds automatically because $F = dA$. Substituting the loop-flow expression (in the single-species limit),

$\partial_\mu F^{\mu\nu} = \rho_{pers} u^\nu$.

Electromagnetic sourcing is therefore the interaction between reversible persistent cohomological transport (the F-sector) and the coarse-grained transport of topologically protected commitment loops (the J-sector) — equivalently, under §10.3, between persistent cohomological transport and the macroscopic transport of stabilised fold topology.

[²] **Sign convention.** Following *Matter Coupling* §7, variation of $S = \int(-\tfrac{1}{4} F^2 - J\cdot A)\, d^4x$ with respect to A_ν proceeds as $\delta S = \int(-\tfrac{1}{2} F^{\mu\nu} \delta F_{\mu\nu} - J^\nu \delta A_\nu)\, d^4x = \int(\partial_\mu F^{\mu\nu} - J^\nu)\, \delta A_\nu\, d^4x$ (after integration by parts and using antisymmetry of $F^{\mu\nu}$), giving the field equation $\partial_\mu F^{\mu\nu} = +J^\nu$. The opposite sign in either the kinetic or coupling term flips the sign of the source.

7.2 Layered emergence of the Maxwell equations

The homogeneous and inhomogeneous Maxwell equations have distinct substrate origins, as *Matter Coupling* §10 emphasised. The present paper sharpens the inhomogeneous side by supplying a microscopic substrate carrier:

Equation	Origin
$\partial_{[\alpha} F_{\beta\gamma]} = 0$ (Bianchi)	Cohomological exactness of $F = dA$ on $H^1(\mathcal{G}(\Lambda))$ — persistent sector alone
$\partial_\mu F^{\mu\nu} = J^\nu$ (sourced)	Coupling of persistent sector to coarse-grained loop transport via *Matter Coupling* Theorem 1

The persistent sector supplies half of Maxwell's equations as a structural inevitability of its cohomological structure. The loop ontology supplies the other half: a microscopic substrate carrier of J^μ that satisfies source-admissibility and therefore enters the coupling structure forced by *Matter Coupling*.

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8. Topological Charge and Integer Cohomology

8.1 Winding and conservation

Each loop $\mathcal{C}_i$ carries an integer winding $w_i \in \mathbb{Z}$. Continuous admissible deformations preserve winding, so transported topological charge is conserved:

$Q = \Sigma_i w_i$, $dQ/dt = 0$

under admissible transport. Conservation here is topological persistence of integer cohomology classes, not symmetry conservation.

Stability of loops at the classical-substrate level. At the classical-substrate level treated in this paper, loops are stable under admissible transport: no creation or annihilation of loops occurs, and $\Sigma_i w_i$ is therefore exactly conserved with no parenthetical conditions on the loop count. Pair creation and annihilation events — where loops of opposite winding ($w_+ + w_- = 0$) are created or destroyed together, preserving total Q but altering the loop count — are a feature of the quantum-field promotion stage (*Matter Coupling* §15 deliverable (4); §16 item 3 in this paper) and lie outside the present classical construction. The "topologically trivial pairs" condition appearing in Theorem 5's argument below is therefore vacuous at the classical level treated here and becomes operative only at the QFT-promotion stage.

8.2 Theorem 5 — Topological charge via the holonomy pairing

Theorem 5 (Topological charge as integer cohomology class via holonomy). The loop winding numbers w_i are identified, via the holonomy pairing between H_1 and H^1, with integer cohomology representatives in $H^1(\mathcal{G}(\Lambda); \mathbb{Z})$. The total topological charge $Q = \Sigma_i w_i$ is the resulting integer cohomology class of the loop ensemble.

Argument. A loop $\mathcal{C}_i$ is a non-recombinable cycle in the admissible substrate complex (L1, L2). As a cycle, its homotopy class lies in $\pi_1(\mathcal{G}(\Lambda))$; since winding is an abelian invariant, the relevant datum is the abelianised image (by the Hurewicz map) — the homology class in $H_1(\mathcal{G}(\Lambda); \mathbb{Z})$. All references below to the loop's "class in H_1" denote this homology class.

The cohomological pairing with H^1 is the holonomy pairing, not Poincaré duality. (Poincaré duality on the four-dimensional substrate complex would give $H_1 \leftrightarrow H^3$, not $H_1 \leftrightarrow H^1$. The natural pairing of a 1-cycle with H^1 is via integration of 1-cochains over the cycle, which is the holonomy pairing.) Specifically, the integer winding w_i is the holonomy of the persistent gauge connection A_μ around the loop:

$$\oint_{\mathcal{C}_i} A_\mu \, dx^\mu = w_i \cdot (\text{period}),$$

where the period is the integer-valued period of A_μ under the persistent-sector compactification established in the Maxwell admissibility paper. This holonomy pairing identifies w_i with a $\mathbb{Z}$-valued class in $H^1(\mathcal{G}(\Lambda); \mathbb{Z})$ via the universal-coefficient pairing between H_1 and H^1.

The construction is precisely the one used to define Wilson-loop observables on the persistent sector in the Maxwell admissibility paper: the Wilson loop

$$W(\gamma) = \exp(i \oint_\gamma A_\mu \, dx^\mu)$$

associated with the cycle γ is gauge-invariant by Stokes' theorem and integer-valued in its argument (its phase is $2\pi w_i$ for a loop of winding w_i) by the persistent-sector compactification. Theorem 5 is therefore not a separate cohomological identification but the

Wilson-loop construction applied to the loop ensemble of §5, with each primitive commitment loop carrying its own integer-valued holonomy.

Loop transport corresponds to continuous deformation of $\mathcal{C}\_i$ within its class in H_1; this preserves the holonomy w_i. By §8.1, at the classical-substrate level loops are stable and Q = Σ_i w_i is conserved with no further conditions. The parenthetical "topologically trivial pairs" condition ($w_+ + w_- = 0$ for pair creation/annihilation) becomes operative only at the QFT-promotion stage, where it is the structural requirement preserving total Q across pair processes.

Self-consistency of intrinsic and holonomy readings (conditional clause). The integer w_i has been defined in two ways: as the intrinsic H_1 class of $\mathcal{C}\_i$, and as the holonomy of A_μ around $\mathcal{C}\_i$. For a generic A_μ configuration these two integers are a priori distinct — the holonomy is the universal-coefficient pairing ⟨[A], [$\mathcal{C}\_i$]⟩, which can be any integer linear combination of the periods of A across the H^1 generators. Their coincidence is therefore not a kinematic identity but a consistency requirement satisfied on-shell: A_μ is sourced by J^μ via §7, so the loop ensemble carrying winding {w_i} produces a persistent gauge configuration whose holonomy around each loop reproduces w_i. The intrinsic-winding and holonomy readings of w_i coincide on the on-shell coupled configurations to which Theorem 3 applies. The core of Theorem 5 — that loop winding furnishes a ℤ-valued class in $H^1(\mathcal{G}(\Lambda); \mathbb{Z})$ and that Q is conserved — is proven; the additional clause identifying intrinsic winding with holonomy is conditional on on-shell coupling, and is labelled accordingly in §15.

8.3 Structural route to charge quantisation

Theorem 5 identifies the route to charge quantisation that *Matter Coupling* §17 listed as an open problem. The route is:

Loop winding numbers are integer-valued; loop ensembles carry total integer cohomology class $Q \in H^1(\mathcal{G}(\Lambda); \mathbb{Z})$ via the holonomy pairing; admissible transport preserves Q; therefore the substrate carries an integer-quantised conserved charge that is the natural candidate for the structural origin of observed elementary electromagnetic charge.

The Fold reading of §10.5 grounds this ontologically: integer winding corresponds to conserved fold closure classes, and quantised charge becomes the observable manifestation of persistent fold winding inherited through the Wilson-loop holonomy pairing.

This is a structural route rather than a derivation. To complete the derivation requires:

- the species decomposition of J^μ (item (2) of *Matter Coupling* §15), establishing that observed charged particles correspond to specific topological classes;
- the numerical correspondence between elementary winding and elementary charge, including any overall normalisation;
- consistency with the α derivation series, which independently constrains the U(1) coupling strength.

These belong to the species-decomposition and spinorial-structure stages. The present paper establishes only that the substrate possesses integer-valued conserved topological charge of the structural form required — not that this charge equals observed electromagnetic charge in any concrete normalisation. The conjectural status of this connection matches *Matter Coupling* §16's labelling of charge quantisation as a conjectural deliverable.

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9. Relation to the κ-field

The κ-field programme describes local commitment-density evolution: the retarded accumulation and memory structure of irreversible commitment. The present record-current sector is complementary: it describes the transported, topologically protected fraction of that commitment.

Both quantities are functionals of the same underlying SST committed-record density ρ:

- The κ-field captures the accumulating density side — local irreversible commitment growth with retarded memory.
- The record current J^μ captures the transported topologically protected side — the Π_{pers} projection of the commitment four-current.

The relationship is therefore not two parallel sectors but two projections of a common ontology.

The pointwise bound $\rho_{pers} \leq \rho$. Under the construction of $\Pi_{pers}^{(0)}$ as a positivity-preserving contraction (§6.3 properties 2–3) — that is, $\Pi_{pers}^{(0)} \rho = \Sigma_a w_a \rho_a$ with non-negative weights $w_a \in [0, 1]$ over a partition of contributions to the commitment density — the projected density satisfies

$$\rho_{pers}(x) \leq \rho(x)$$

pointwise. The §6.3 construction is of this form: contributions from topologically protected loops carry weight 1, contributions from non-topologically-protected configurations carry weight 0, and no negative weights appear. The bound is a consequence of positivity and contractivity, not of idempotency: a bare idempotent projection onto a sub-complex need be neither positive nor contractive, and would not in general yield the pointwise bound. Alternative constructions of Π_{pers} that involve cancellations between persistent and non-persistent contributions would lose the bound; we note this for completeness but treat only the positivity-preserving contraction here.

A formal commutativity result connecting the κ-field's continuity dynamics to Theorem 4's intertwining argument would close the structural circle between the two papers; this is a clean follow-up calculation recorded as §16 item 7.

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10. Fold-Origin of Persistent Matter and Record Current

The operational construction of §§5–8 introduced primitive commitment loops as topologically protected transport sectors carrying conserved record current J^μ. This section provides the ontological bridge connecting these structures to the Fold programme developed elsewhere in VERSF.

Two layers of Fold integration. The integration operates on two layers that must be kept distinct:

- **Ontological alignment** — supplied by this section — identifies loops as transported persistent fold structures and grounds the operational construction in the Fold programme's ontology of irreversible commitment.
- **Technical coincidence** — held provisionally and recorded as §16 item 6 — is the calculation verifying that J^μ here coincides, up to overall normalisation, with the Π_{pers} projection of the record current of the Fold programme's record-current uniqueness result.

Ontological alignment grounds the construction qualitatively; technical coincidence would verify quantitatively that the same J^μ is being constructed in both papers. Until the technical check is completed, the structural-integration claim is held provisionally — supported ontologically (by this section), unverified technically (§16 item 6). This two-layer distinction governs how §10 should be read throughout; subsequent sections refer back to it rather than restating it.

This section is interpretive integration, not new derivation. The operational results of §§5–8 are unchanged by §10 regardless of either layer. What is added is identification of the loop ontology with the persistent-transport manifestation of fold structure, which substantially reduces the ontological fragmentation of the construction. (The "source-carrier" terminology used in §§10.1–10.2 is defined in §13.2: it captures the provisional reading of the loop ontology as a candidate source-carrier framework for the eventual matter-sector programme, rather than as a derivation of matter in the particle-physics sense.)

10.1 The fold as the primitive source of persistent distinction

Within the Fold programme, a fold is the minimal irreversible distinguishability event — the first committed asymmetry separating the committed sector from the reversible void substrate. Three Fold-programme results inherited via §3.5 are decisive:

- reversible substrate evolution alone cannot sustain stable physical distinctions;
- persistent distinguishability requires topological trapping, which coincides with the $\beta_1 \geq 1$ condition of §3.3;
- a fold is the minimal physically committed topological asymmetry capable of persisting under admissible dynamics.

The reading consistent with both programmes is that folds select sectors of the substrate where $\beta_1 \geq 1$, since only there can irreversible commitment persist. The $\beta_1 \geq 1$ condition is therefore not an independent topological postulate but the Fold-programme precondition for irreversible commitment, viewed from the substrate side.

A fold, on this reading, is not merely a binary informational primitive. It is the minimal physically committed topological asymmetry capable of persisting under admissible dynamics, tying persistent source-carrier sectors directly to the topology required for irreversible commitment.

10.2 Loops as transported fold structures

Combining the Fold-programme result that irreversible commitment generates stable loop sectors through closure trapping at the commitment interface with the operational §5.2 result that persistent commitment structures must take loop form, the ontological chain reads:

Void → fold formation → $\beta_1 \geq 1$ → non-contractible closure loops → persistent transport sectors.

The primitive commitment loops of Definition 1 are therefore reinterpreted as transported persistent fold structures: loops are not introduced phenomenologically as a substrate ontology layer parallel to the Fold programme but are the substrate-level macroscopic image of fold commitment under refinement coarsening.

The four (L)-condition correspondences. The (L1)–(L4) admissibility conditions of Definition 1 are not independent postulates about a new substrate object; each is the substrate-image of a specific Fold-programme requirement:

Definition 1 condition	Fold-programme origin
(L1) Irreversible closure	Fold irreversibility: a fold is by definition a committed (irreversible) asymmetry (§3.5 result 3, the "committed" clause).
(L2) Admissible persistence ($\beta_1 \geq 1$)	Fold persistence requires $\beta_1 \geq 1$ supporting topology (§3.5 result 2, the persistence-topology coincidence).
(L3) Refinement stability	Fold-supported distinguishability survives refinement by §3.5 results 1 and 2 jointly: reversible evolution cannot sustain distinctions, and topological trapping is what does.
(L4) Finite primitive support	One fold per primitive commitment event, by §3.5 result 3's minimality clause: a fold is the minimal committed asymmetry.

Each (L)-condition therefore corresponds one-to-one to a Fold-programme requirement. The table establishes the necessity direction directly: every macroscopic image of a persistent fold under refinement coarsening satisfies (L1)–(L4), because each Fold-programme requirement maps to an (L)-condition. Sufficiency — that any substrate structure satisfying (L1)–(L4) must be such a fold image — follows from §5.3's uniqueness clause read under the §10 identification: loops are the unique source-admissible substrate structures within the current catalogue (Proposition 2), and §10 identifies each loop with a transported persistent fold structure. The four conditions are therefore jointly necessary and sufficient for a substrate structure to be the macroscopic image of a persistent fold under refinement coarsening, inheriting via the sufficiency direction Proposition 2's conditional-on-catalogue status: catalogue extension would weaken sufficiency without affecting necessity.

Under this correspondence, the loop ontology is not merely natural under the Fold integration — it is forced: any transported persistent substrate structure must satisfy (L1)–(L4) precisely because each condition tracks a separate Fold-programme requirement. The slogan "loops emerge naturally as the large-scale transport manifestation of fold closure" is then a one-line summary of the four-correspondence argument rather than a standalone claim.

Equivalently, the source-carrier sector is not an additional ontology placed on top of the fold substrate — source-carrier persistence is the substrate-level macroscopic image of fold closure, and loops are how that image organises under refinement coarsening.

10.3 Theorem 3 reinterpreted: J^μ as transported fold density

Theorem 3's hydrodynamic limit $J^\mu = \rho_{pers} u^\mu$ admits a direct Fold-theoretic reading once loops are identified as transported fold structures:

- ρ_{pers} is the local density of persistent fold-supported distinguishability in the Eckart rest frame;
- u^μ is the coarse-grained transport four-velocity of the corresponding fold-supported closure structure.

The record current is therefore not merely the transport of generic "informational" content; it is the macroscopic transport of stabilised fold topology. Theorem 4's conservation law $\partial_\mu J^\mu = 0$ becomes the conservation of persistent fold-supported distinguishability under admissible transport: record conservation is transported fold conservation (under the §10 ontological integration; the technical conservation result of Theorem 4 stands independently and was established in §6.4). The identification does not modify Theorem 3 or Theorem 4; it grounds them in the Fold programme's ontology of irreversible commitment.

10.4 Topological protection from fold closure

The (L2) admissible-persistence and (L3) refinement-stability conditions acquire structural justification in the Fold reading. In the absence of non-contractible fold-supported topology, closure pathways remain recombinable and no irreversible persistence exists. Once fold-supported closure loops form, three structural consequences follow:

- recombination becomes topologically obstructed;
- local admissible evolution cannot contract the loop to the trivial sector;
- the transported distinction becomes dynamically persistent.

The stability of persistent loops is therefore not an external imposition but follows from the conjunction of fold irreversibility, closure trapping, and topological non-contractibility. The persistent transport sector acquires the same broad structural character as vortices, solitons, and topological defect sectors in established field theory, with one structural difference worth flagging: conventional topological defects are stabilised jointly by topology and an energy barrier protecting against thermal or quantum tunnelling, whereas the fold-supported loops here are stabilised by topology and fold irreversibility, with irreversibility playing the structural role that the energy barrier plays in conventional defects. This is a structurally distinct stabilisation mechanism, not a strictly stronger version of the conventional one. Any claim that ontological persistence is more fundamental than energetic persistence belongs to a broader programme-level discussion that the present paper does not undertake.

This connects directly to the closure-direction speculation of §5.4. Characterising loops as solitons of commitment-continuity dynamics over the SST scalar field ρ is the field-theoretic analogue of the Fold-theoretic characterisation given here. Item 4 of §16 (substrate-level soliton definition of u^μ) and the present Fold integration are therefore two routes to the same structural completion: the soliton characterisation is the field-theoretic side, the fold-closure characterisation is the ontological side, and a complete construction would identify them explicitly.

10.5 Theorem 5 reinterpreted: charge as fold winding

The integer cohomology identification of Theorem 5 (§8.2) admits a Fold-theoretic reading: persistent loop sectors are classified by nontrivial cohomology $H^1(\mathcal{G}(\Lambda); \mathbb{Z})$, with integer winding corresponding to conserved fold closure classes. The transported current therefore inherits quantisation from the topology of the fold-supported closure structure itself.

Quantised charge becomes the observable manifestation of persistent fold winding, with the Wilson-loop holonomy pairing of §8.2 supplying the cohomological pairing structure. This route to integer-valued conserved charge requires no external quantisation postulate; the integers arise from the topology of fold-supported closure structure as inherited by the persistent gauge sector through the Wilson-loop construction.

Self-consistency propagation. The Theorem 5 self-consistency clause (§8.2) propagates through this Fold identification: fold closure classes are identified with electromagnetic charge integers only on the on-shell coupled configurations where intrinsic loop winding and holonomy coincide. The fold-closure-to-charge identification is therefore — like the conditional clause of Theorem 5 — a statement about coupled on-shell configurations rather than a kinematic identity at the fold level.

10.6 Unified ontological chain

The Fold integration allows the persistent-matter construction of this paper to be restated as a single ontological chain:

Void → Fold → Irreversible commitment → Closure topology → Persistent loops → J^μ → Gauge transport.

The gauge sector (A_μ on $H^1(\mathcal{G}(\Lambda))$), the record current (J^μ via Π_pers), the loop ontology (Definition 1), and the topological charge structure ($H^1(\mathcal{G}(\Lambda); \mathbb{Z})$) are not independent ingredients introduced phenomenologically. They are successive large-scale manifestations of the same underlying fold architecture, traced through the operational layers of §§5–8.

This substantially reduces the ontological fragmentation of the construction. The loop ontology is no longer a free choice of substrate carrier; it is the unique transport-stable manifestation of fold commitment that satisfies source-admissibility within the current catalogue. Persistent transport is then a direct physical consequence of irreversible fold dynamics rather than an independently postulated structure, and the chain from Void through Gauge transport unifies what would otherwise be six ontologically distinct programme components.

10.7 Status and scope of the Fold integration

This section is interpretive integration, not new derivation. The operational results of §§5–8 are unchanged. What §10 adds:

- ontological grounding of the loop ontology in the Fold programme (§10.1–§10.2);
- explanation of why (L1)–(L4) take their specific form: they are the closure-trapping conditions any transported fold structure must satisfy (§10.2, §10.4);
- a unified ontological chain from Void through Gauge transport (§10.6);
- an ontological grounding of integer-valued conserved charge in fold winding (§10.5).

What §10 does not establish:

- fermionic statistics or spinorial structure — §16 item 2;
- Standard Model particle sectors or species decomposition — §16 item 1;
- full quantum field operator structure — §16 item 3;
- the technical Fold coincidence check — §16 item 6 — that is, the verification that $J^\mu = \Pi_{pers} C^\mu$ here coincides up to overall normalisation with the Π_{pers} projection of the Fold programme's record-current uniqueness result. The present section provides ontological alignment but not the technical coincidence calculation, which remains the immediate next deliverable of the integration strand.

What is established here is narrower than a complete matter sector but important for structural integrity: persistent matter-like transport sectors emerge naturally once irreversible fold closure and non-contractible topology are admitted, and the operational loop ontology is the natural transport-stable manifestation of fold structure rather than an independently postulated layer.

§10 is not an independent proof of the loop ontology. The Fold integration is not used as an independent proof that loops carry J^μ. Rather, it shows that the loop ontology of §§5–8 is naturally aligned with the Fold programme's existing claim that persistent distinguishability requires topological trapping (§3.5 result 2). If the technical coincidence check (§16 item 6) fails, §§5–8 remain operationally intact, but §10 would need reinterpretation — either by identifying a different Fold-side structure that does coincide with J^μ, or by acknowledging that the loop ontology, despite the ontological alignment of §10.1–§10.5, is not the Fold programme's substrate manifestation. The two-layer framing introduced at the head of §10 is what makes this reinterpretation possible without disturbing the operational construction.

11. Structural Consequences

The construction yields several structural predictions, each labelled by epistemic status; the formal labelling is consolidated in §15.

11.1 Topology is necessary for persistent current. *Proven* (given the cited prior results). Regions lacking stable topological commitment structure cannot sustain long-range current transport, because they fail SA3. Under the Fold reading of §10.1, this is precisely the Fold-programme statement that persistent distinguishability requires topological trapping.

11.2 Charge conservation is topological in origin. *Proven* (given the cited prior results and Theorem 4 via Lemma 2). Any violation of topological persistence would produce current nonconservation; conversely, observed current conservation reflects topological protection of the source sector. Combined with *Matter Coupling* Theorem 2, the gauge invariance of the persistent sector is structurally the topological persistence of integer cohomology classes in the substrate — equivalently, under §10.3, the conservation of transported fold topology.

11.3 Electromagnetic sourcing is emergent. *Structural consequence.* Gauge sourcing is not fundamental; it is the macroscopic shadow of transported commitment topology under coupling to the unique admissible interaction, or equivalently (under §10.3) the macroscopic transport of stabilised fold topology coupled to the persistent gauge sector.

11.4 Stable matter requires topological protection. *Conditional.* Stable transported excitations must correspond to protected topological commitment sectors. The mapping from such sectors to observed matter states is the species-decomposition deliverable.

11.5 Charge is integer-quantised at the substrate level. *Proven within the loop ontology; conjectural at the level of observed electromagnetic charge.* Loop winding is $\mathbb{Z}$-valued (Theorem 5), so the substrate carries integer-quantised conserved charge. Under §10.5 the integer character is identified with conserved fold closure classes. The identification with observed elementary charge requires the species-decomposition stage — specifically, the construction in which each observed charged particle species is mapped to a topology class of loop ensembles in $H^1(\mathcal{G}(\Lambda); \mathbb{Z})$, with the numerical correspondence between elementary winding and elementary charge constrained by species-resolution data and ultimately determined in conjunction with the α derivation series. This is §16 item 1 and is the concrete content of the conjectural clause.

12. Falsifiability Channels

Within the loop ontology, every admissible deviation from the structural predictions of §11 enters through one of four channels, each in principle observable. This is the analogue for the present paper of *Matter Coupling* §14's three-channel falsifiability structure.

Channel A: Long-range conserved currents in topologically trivial regions. The loop ontology predicts that persistent current transport requires $\beta_1 \geq 1$ in the underlying admissible substrate complex. Observation of a refinement-stable conserved current in a regime where the substrate is convincingly topologically trivial ($\beta_1 = 0$) would falsify either the loop ontology or the topological threshold result of §3.3 — equivalently, under §10.1, the Fold-programme precondition for irreversible commitment. The falsification is sharp because the threshold is sharp: no continuous deformation of the loop ontology produces persistent currents without topology.

Channel B: Charge measurements inconsistent with integer winding. Theorem 5 identifies loop winding with integer cohomology classes via the holonomy pairing. Observation of a stable substrate-level conserved charge that is not integer-valued in the natural normalisation — for example, an irreducibly fractional substrate charge not reducible to a multi-loop composite — would falsify either the loop ontology or the $H^1(\mathcal{G}(\Lambda); \mathbb{Z})$ identification, and under §10.5 the Fold-winding interpretation of charge. Fractional macroscopic charges arising as compositions of integer-winding substrate loops (analogous to fractional quantum Hall states) are consistent with the loop ontology and would not constitute falsification; the channel applies to irreducibly fractional substrate-level charge.

Channel C: Hydrodynamic-limit signatures. Theorem 3 establishes $J^\mu = \rho_{pers} u^\mu$ in the $L \gg \xi$ single-species regime. At intermediate scales $L \sim \xi$, the hydrodynamic limit breaks down and discrete loop transport structure should become visible. Coherence-loss signatures at high resolution, departures from smooth Maxwell-form sourcing at extreme momentum transfer, or persistence of microscopic loop topology in scattering processes would constitute positive evidence for the loop ontology; their absence at scales where the construction predicts they should appear would constitute partial falsification of the hydrodynamic limit. (A multi-fluid departure from the single-velocity form, per §6.2, is a separate and expected feature rather than a falsification.)

Channel D: Catalogue-extension signatures. If the species-decomposition stage requires substrate structures not reducible to primitive commitment loops in the sense of Definition 1 — for example, irreducibly non-topological persistent excitations — then either the substrate catalogue must be extended (with the corresponding revision of *Matter Coupling* Lemma 7.0.1 and the present Proposition 2) or the loop ontology must be enlarged. The Fold integration of §10 narrows but does not eliminate this channel: even if loops are the unique transport-stable manifestation of fold structure within the current catalogue, alternative manifestations of fold commitment may exist outside the loop ontology and would constitute admissible catalogue extensions.

The structural statement. Within the loop ontology, every admissible deviation from §11 enters as an absence-of-loops violation (A), an integer-winding violation (B), a hydrodynamic-limit breakdown (C), or a catalogue-extension signal (D). No other admissible deviation is structurally available. This is a falsifiable constraint, not a prediction of specific deviations: any deviation not reducible to one of A–D would falsify the present substrate ontology.

Concrete parallel to *Matter Coupling* §14.

- *Matter Coupling* §14 Channel 1 (finite-refinement corrections) ↔ Channel C (hydrodynamic-limit breakdown at $L \sim \xi$). Both detect the leading correction to the refinement-stable continuum limit, from the coupling side and the source side respectively.
- *Matter Coupling* §14 Channel 2 (catalogue extensions) ↔ Channel D. Same structural content, source-side rather than coupling-side.
- *Matter Coupling* §14 Channel 3 (persistence breakdown) ↔ Channel A. Both detect failure of the persistence projection at the substrate level — *Matter Coupling* phrased in terms of σ-sector dissipation overwhelming persistent-sector coherence, the present Channel A in terms of substrate topology failing to support persistent loops.
- The fourth channel here — Channel B (non-integer substrate charge) — has no counterpart in *Matter Coupling* §14 because it depends on the integer-cohomology structure (Theorem 5) introduced only in the present construction.

The four-channel structure here is therefore *Matter Coupling* §14's three channels reread through the substrate-ontology layer, plus one new channel from the integer-cohomology identification of Theorem 5.

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13. What This Paper Achieves, and What It Does Not

The natural objection is sharp:

You proposed that topological commitment loops carry the current J^μ that *Matter Coupling* treated as undecomposed. But the loops are themselves a structural conjecture, not a derivation. What has actually been established?

The objection is fair and tracks the same structural concern that *Matter Coupling* §15 acknowledged about its own construction. An honest response distinguishes what the paper achieves despite the objection from what the objection correctly identifies as remaining open. The Fold integration of §10 sharpens the response on the achievement side without changing the gap analysis.

13.1 What is achieved despite the objection

Four results are non-trivial and worth holding onto.

First, the source-admissibility constraints SA1–SA5 are not chosen for the loop ontology; they are derived from *Matter Coupling*'s (P1)–(P5) by Lemma 1, and they constrain any substrate ontology proposed for J^μ. The loop ontology must satisfy them; so must any alternative. This converts the matter question from "what carries J^μ?" — open-ended — to "which substrate structures satisfy SA1–SA5?" — structurally constrained.

Second, primitive commitment loops are the substrate structures satisfying SA1–SA5 within the currently identified VERSF catalogue. This is Proposition 2's conditional uniqueness, conditional in exactly the same sense as *Matter Coupling* Theorem 1's uniqueness: open to extension if the catalogue is extended, but tight within the current framework. The loop ontology is therefore not chosen freely; it is the unique surviving candidate under the structural framework. The Fold integration of §10.2 sharpens this: loops are the unique transport-stable manifestation of fold commitment satisfying source-admissibility, which constrains the catalogue-extension space considerably.

Third, conservation of J^μ acquires substrate-level grounding. In *Matter Coupling*, ∂_μ J^μ = 0 was inherited from the BCB axiom and identified with gauge invariance by Theorem 2. Here, Theorem 4 derives conservation as the chain-map intertwining consequence (Lemma 2) of the ontological conservation of committed distinguishability. The chain BCB → ∂_μ C^μ = 0 → Π_pers a chain map → ∂_μ J^μ = 0 → gauge invariance is now structurally complete, with Lemma 2 supplying the intertwining step as a citable result rather than a parenthetical. Under §10.3 this chain reads as transported fold conservation, grounding gauge invariance ontologically rather than merely structurally.

Fourth, under the §10 reading the ontological fragmentation of the construction is substantially reduced. Before §10, the persistent gauge sector, the record current, the loop ontology, and the topological charge structure could be read as four ontologically distinct ingredients combined under admissibility. After §10, they are successive large-scale manifestations of fold structure traced through the operational layers, and the entire construction admits an ontological reading rooted in the Fold programme's ontology of irreversible commitment. The operational results are unchanged by this reading; what §10 supplies is the ontological unification under it.

These four results, together with the integer cohomology identification of Theorem 5 via the holonomy pairing of the Maxwell admissibility paper, establish how rigid the construction is once the framework is in place. The loop ontology cannot be relaxed without violating one of SA1–SA5 or the integer-cohomology structure of $H^1(\mathcal{G}(\Lambda); \mathbb{Z})$. That operational rigidity is the real claim of the paper. The §10 integration is a further structural layer whose rigidity is conditional on retaining its ontological reading, as §13.3 makes explicit; alternative ontological groundings of the loop ontology are not excluded by the present construction.

13.2 What is not achieved

The objection nevertheless lands on the genuine gap. The four-deliverable matter-sector programme of *Matter Coupling* §15 is only partially addressed:

***Matter Coupling* §15 Deliverable**	**Status here**
(1) Charged excitations as identifiable substrate structures	Substantially supplied by Definition 1, Theorem 5, and §10's ontological identification: primitive commitment loops, identified as transported persistent fold structures, are identifiable substrate structures carrying conserved discrete charge. The remaining gap is the matter-sector identification of which loop topologies correspond to which observed charged particles.

Matter Coupling §15 Deliverable	Status here
(2) Species decomposition $J^\mu = \Sigma_a q_a J^\mu_a$	Not supplied. The loop ontology distinguishes loops by integer winding w_i (equivalently, by fold closure class) but does not yet supply a canonical species classification of loop topology classes. This requires applying the closure-geometry machinery of the CKM/PMNS derivation to the loop ensemble.
(3) Spinorial structure	Not supplied. The loops are scalar carriers in the present construction. Connection to the spin-as-double-cover programme requires extending the loop ontology with spinorial transport representations.
(4) Quantum field structure / Fock promotion	Not supplied. The loops are classical substrate configurations here. Operator-valued promotion belongs to the quantum-completion stage, where loop pair creation and annihilation (in topologically trivial pairs preserving total Q) become operative.

This paper therefore addresses item (1) substantially — operationally via §§5–8 and ontologically via §10 — and prepares the structural framework for item (2). Items (3) and (4) remain open.

Source-carrier vs. matter. The present paper does not yet derive matter in the particle-physics sense. It derives a candidate source-carrier ontology: persistent, topologically protected substrate excitations capable of carrying conserved current. Calling these structures "matter" is justified only provisionally, pending the species decomposition (§16 item 1), spinorial extension (§16 item 2), and quantum-field promotion (§16 item 3). The "matter-sector" terminology used throughout this paper and *Matter Coupling* §15 should be read as "proto-matter source-carrier sector" until those deliverables close. The §10 ontological integration does not change this scope: it grounds the source-carrier ontology in the Fold programme but does not by itself promote source-carriers to matter.

13.3 The right framing

The right reading is not "the substrate carrier of J^μ is established" but: given the framework of *Matter Coupling*, primitive commitment loops are the unique substrate structures satisfying source-admissibility within the current catalogue, they are the transport-stable manifestation of fold commitment under the §10 integration, and they supply integer-valued conserved topological charge of the structural form required for matter-sector coupling. That is a strong claim, but a clearly delimited one. The species-decomposition stage must establish which loop topologies correspond to which physical particle species, and the spinorial-structure stage must establish the fermionic content; both are now next-stage priorities with a clean structural and ontological framework to build on.

What the paper most certainly does not claim: that the loop ontology constitutes a derivation of charged matter, or of the Standard Model spectrum, or of QED. None of these follows from the present construction alone. What it does claim is that any future matter-sector construction within VERSF must operate within the loop-ontology framework (or supply an explicit extension of the substrate catalogue with corresponding revision of *Matter Coupling* Lemma 7.0.1). The Fold-theoretic grounding of §10 is a further constraint that aligned future work should respect if the §10 integration is to be preserved, but alternative ontological groundings of the loop ontology are not excluded: future work that honours §§5–8 but reads the substrate ontology differently from §10 is not ruled out, and the technical coincidence check of §16 item 6 (still pending) is the eventual arbiter of whether the §10 ontological reading is the correct one or whether an alternative is required.

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14. Relation to Earlier VERSF Papers, and the Dependency Graph

This paper sits at the intersection of seven earlier strands:

- The refinement persistence and cohomology papers, which established $H^1(\mathcal{G}(\Lambda))$ as the refinement-stable observable sector and the Wilson-loop identification used in Theorem 5.
- The Maxwell admissibility paper, which derived U(1) gauge transport from the foundational bound axioms (BCB/TPB), established the sign and normalisation of the kinetic term, and constructed the Wilson loops whose holonomy pairing gives Theorem 5 its cohomological content.
- The Hamiltonian admissibility paper, which proved unitary reversible evolution on the persistent sector pre-coupling.
- The topological threshold paper, which established $\beta_1 \geq 1$ for irreversible commitment.
- The primitive occupancy paper, which established commitment-capacity density and the scaling relation $\rho \sim 1/\xi^3$.
- The Fold programme, especially *The Fold and the Record*, which supplies the ontological foundation grounded operationally in §10 and the record-current uniqueness result targeted by the technical coincidence check of §16 item 6.
- The *Matter Coupling* paper (the immediately preceding paper in this strand), which established the coupling theorem and identified the matter question this paper addresses.

The present paper is the first to combine all seven into a substrate-ontology construction for the source current with explicit Fold-theoretic grounding. It also draws structural guidance from the Single-Source Theorem (via *Matter Coupling* §7.0 and §5.4 above). (The bound axioms BCB and TPB are inherited foundational results of the Maxwell-admissibility strand and are not re-derived here; BCB's operative content is the prohibition of spontaneous uncommitment used in §3.2 and §6.4.)

Fold coincidence check (held provisionally; technical check distinct from §10's ontological integration). The relation between this paper's record current J^μ and the record current of *The Fold and the Record*, particularly its record-current uniqueness result, has the two layers set out at the head of §10: ontological alignment (supplied here) and technical coincidence (the claim that J^μ = Π_pers C^μ here coincides, up to overall normalisation, with the Π_pers projection of the unique Fold record current — §16 item 6, the immediate next deliverable). Until the technical check is completed, the structural-integration claim with the Fold programme is held provisionally — supported ontologically but unverified technically.

Dependency graph. The construction rests on the following structural graph:

Result	Depends on
Persistent U(1) sector on $H^1(\mathcal{G}(\Lambda))$	Refinement persistence + Wilson identification
Wilson-loop construction and integer-valued holonomy	Maxwell admissibility paper
Commitment continuity $\partial_\mu C^\mu = 0$	BCB axiom + finite distinguishability + irreversibility
Topological threshold $\beta_1 \geq 1$	Refinement-erosion argument applied to simply-connected commitment
Primitive occupancy and $\rho \sim 1/\xi^3$ scaling	Primitive occupancy theorem
Fold ontology and persistence-via-topological-trapping	Fold programme
(P1)–(P5) admissibility principles	*Matter Coupling* §6
Catalogue Closure Theorem	*Matter Coupling* §7.0 (from SST + admissibility)
Coupling $\mathscr{L}_{int} = -J^\mu A_\mu$	*Matter Coupling* Theorem 1
Gauge invariance ⇔ conservation	*Matter Coupling* Theorem 2
Maxwell-form dynamics $\partial_\mu F^{\mu\nu} = J^\nu$	*Matter Coupling* Theorem 3
Source admissibility (SA1–SA5)	(P1)–(P5) + Lemma 1 of this paper
Primitive commitment loops (Definition 1)	$\beta_1 \geq 1$ + commitment continuity + refinement persistence + primitive occupancy
Loops satisfy SA1–SA5 (Proposition 2)	Definition 1 + Lemma 1
Hydrodynamic $J^\mu = \rho_{pers} u^\mu$ (Theorem 3)	Loop ontology + (H1), (H2) separation-of-scales + single-species regime + Derivative Suppression Lemma + relativistic dust-fluid identification
Projection–transport intertwining (Lemma 2)	Π_{pers} a graded chain map (closure of persistent sub-complex at every grade) + continuum identification of ∂_μ as generator
Conservation $\partial_\mu J^\mu = 0$ (Theorem 4)	Lemma 2 + commitment continuity

Result	Depends on
Integer cohomology $Q \in H^1(\mathcal{G}(\Lambda); \mathbb{Z})$ (Theorem 5)	Loop ontology + holonomy pairing + Wilson-loop construction of Maxwell admissibility paper
Fold-theoretic grounding of loops (§10)	Fold programme + operational results of §§5–8

No row in this table is supplied by this paper alone; every result is either inherited or derived by combining inherited results under the admissibility framework introduced by *Matter Coupling* and the Fold-theoretic grounding of §10.

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15. Epistemic Status

The results of this paper are labelled by status, in the three-tier framework of *Matter Coupling* §16.

Proven within the framework.

- **Proposition 1 (Source admissibility)** is the dual restatement of the coupling-admissibility constraints on the current, used as the target of Lemma 1.
- **Lemma 1 (Equivalence of admissibility frameworks)** is a mathematical consequence of *Matter Coupling*'s (P1)–(P5) and the definition of $-J^\mu A_\mu$, established by direct propagation in §4.2. The P4 → SA4 arrow is the loosest of the five and is supported by the refinement-limit-matching argument made explicit there.
- **Lemma 2 (Projection–transport intertwining)** follows from (i) Π_{pers} being a graded chain map — equivalently, closure of the persistent sub-complex under the transport differential at every grade, with demotion supplied by refinement-persistence closure and promotion forbidden by BCB — and (ii) the continuum-limit identification of ∂_μ with the generator of admissible transport. The two claims are structurally distinct and separately verifiable. The chain-map formulation is what makes the statement typecheck, since the grade-1 and grade-0 actions of Π_{pers} are distinct maps.
- **Theorem 3 (Hydrodynamic limit)** is proven as a coarse-grained limit conditional on (H1), (H2), the dust-fluid normalisation $u^\mu u_\mu = 1$, and the single-species (comoving) regime. The Derivative Suppression Lemma of *Matter Coupling* §7 supplies the leading-order character. The conditional clauses match standard hydrodynamic input; the single-species clause is load-bearing and is the point at which the species programme will generalise the result to a multi-fluid current (§6.2).
- **Theorem 4 (Conservation)** is a one-line consequence of Lemma 2 and commitment continuity.
- **Theorem 5 (Integer cohomology identification via holonomy), core clause.** That loop winding furnishes a $\mathbb{Z}$-valued class in $H^1(\mathcal{G}(\Lambda); \mathbb{Z})$ via the holonomy pairing, and that Q is conserved under admissible transport, follows from the topological non-recombinability of loops (L1, L2) and the Wilson-loop construction of the Maxwell admissibility paper. It

is not via Poincaré duality, which on the four-dimensional substrate complex would give $H_1 \leftrightarrow H^3$ rather than $H_1 \leftrightarrow H^1$.

Conditional on framework assumptions.

- **Theorem 5, intrinsic-winding ⇔ holonomy clause.** The identification of the intrinsic H_1 winding with the gauge holonomy is conditional on the on-shell coupled configurations of §7, where J^μ sources A_μ; it is not a kinematic identity for generic A_μ (§8.2).
- **Proposition 2 (uniqueness clause)** holds within the currently identified VERSF substrate catalogue. Catalogue extension — identification of irreducibly non-topological persistent commitment structures, or alternative transport-stable manifestations of fold commitment outside the loop ontology — would weaken the uniqueness to "loops are among the source-admissible substrate structures" rather than "loops are the unique such structure."
- **The substrate-level definition of u^μ** via Eckart-frame loop transport is conditional on the loop ontology supplying a characterisation independent of the loop construct itself. As discussed in §5.4, the present construction narrows but does not fully close *Matter Coupling* Lemma 7.0.1's conditional clause on u^μ. The closure direction (loops as solitons of commitment-continuity dynamics, equivalently the Fold-theoretic characterisation of §10.4) is sketched in §5.4 and §10.4 and recorded as §16 item 4.
- **The dust-fluid normalisation $u^\mu u_\mu = 1$** is committed as a convention in §2 and used firmly throughout; it is listed here as conditional only in the sense that alternative normalisations are structurally available for downstream papers, not that the commitment is provisional within the present construction. Alternative normalisations would not give the conventional relativistic dust-current reading that *Matter Coupling* §5's $J^\mu = \rho u^\mu$ form was trading on; should a downstream paper adopt one, the hydrodynamic identification of Theorem 3 would need to be restated.
- **The Derivative Suppression Lemma** relied upon in §6.5 requires the smooth-form-factor regularity assumption of *Matter Coupling* §7. If the refinement functor is sharp-cutoff rather than smooth, the suppression scaling weakens and the leading-order character of Theorem 3 needs to be restated.
- **The Π_{pers} projector** is well-defined whenever the refinement functor of the persistence papers is well-defined, and is adopted here as a provisional working construction (idempotent, positivity-preserving, contractive on the density grade) pending the persistence-paper completion. Full rigorous explicit construction is §16 item 5.

Interpretive (Fold integration).

- The Fold integration of §10 is interpretive, not derivational. The operational results of §§5–8 are unchanged. §10 supplies an ontological identification of loops as transported persistent fold structures, grounding the (L1)–(L4) conditions and the integer-winding structure in the Fold programme. The interpretation is consistent with the Fold programme as it stands (in particular with the §3.5 inherited results and the record-current uniqueness result), but its technical validation — the coincidence check of §16 item 6 — has not yet been carried out. The structural-integration claim is therefore supported ontologically and held provisionally pending the technical check.

Conjectural / open.

- The connection between loop winding and observed elementary electromagnetic charge. Theorem 5 establishes integer-quantised conserved charge in $H^1(\mathcal{G}(\Lambda); \mathbb{Z})$, and §10.5 identifies the integer character with conserved fold closure classes, but the numerical correspondence between elementary winding and observed elementary charge requires the species-decomposition stage.
- Species decomposition of J^μ into matter-resolved currents $J^\mu = \Sigma_a q_a J^\mu_a$.
- Spinorial structure connecting loops to the spin-as-double-cover programme.
- Quantum field structure promoting the loop ontology to operator-valued matter sectors and full coupled QED, including the loop pair creation/annihilation processes implicit in §8.1.
- Non-abelian generalisation of the loop ontology, which requires extension beyond the present U(1) framework.

This labelling is conservative. Nothing in the "proven" category extends beyond what the proofs strictly establish; nothing in the "interpretive" or "conditional" categories is treated as derived; nothing in the "conjectural" category is assumed for the present results.

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16. Open Problems

The construction opens, rather than closes, several lines of work. **Numbering reconciliation:** items 1–3 correspond to deliverables (2)–(4) of *Matter Coupling* §15 — item 1 here is *Matter Coupling*'s deliverable (2), item 2 is deliverable (3), item 3 is deliverable (4). The off-by-one arises because *Matter Coupling*'s deliverable (1) (charged excitations as identifiable substrate structures) is substantially addressed by the present paper rather than left open. Items 4–9 are subsidiary structural completions specific to the present construction and have no *Matter Coupling* correspondents.

1. Species decomposition of the loop ensemble (dominant gap). The loop ontology classifies loops by integer winding (equivalently, by fold closure class under §10.5) but does not yet supply a canonical species classification of loop topology classes mapping to observed charged particles. This is item (2) of *Matter Coupling* §15 and the natural next phase. It is also the stage at which the single-species form of Theorem 3 generalises to the multi-fluid current $J^\mu = \Sigma_a \rho_a u_a^\mu$ of §6.2.

Not every loop is a particle. The loop ontology does not imply that every mathematically possible loop class corresponds to a physical particle species. Physical species should be identified only with loop classes satisfying additional admissibility filters beyond mere existence of the topology. A candidate definition:

Candidate definition (physical source-carrier species). A physical source-carrier species is a primitive loop class $[\mathcal{C}_a]$ satisfying: (1) persistence under δ^* (refinement stability); (2) finite primitive support; (3) stable winding/closure class (topological-spectral discreteness); (4)

compatibility with spinorial double-cover transport (item 2 below); (5) admissible coupling to A_μ through a species-resolved current J_a^μ.

Species decomposition is therefore not arbitrary loop enumeration but an admissibility-selected spectrum of stable loop classes. Applying the closure-geometry machinery of the CKM/PMNS derivation to this filtered spectrum is the suggested route.

2. Spinorial extension of the loop ontology. The loops of §5.1 are scalar carriers. Extending to spinorial loops — substrate configurations carrying double-cover representations — is required to recover fermionic matter. This is item (3) of *Matter Coupling* §15 and is structurally tied to the spin-as-double-cover programme.

3. Quantum-field promotion. Operator-valued promotion of loops to a Fock-like structure on the persistent sector, with the gauge sector quantised in parallel, is item (4) of *Matter Coupling* §15 — the natural completion to QED. Loop pair creation and annihilation in topologically trivial pairs ($w_+ + w_- = 0$) becomes operative at this stage, replacing the strict classical stability of §8.1 with a quantum process structure preserving total Q.

4. Substrate-level definition of u^μ as soliton/fold four-velocity. As noted in §5.4 and §10.4, the loop ontology narrows but does not fully close *Matter Coupling* Lemma 7.0.1's conditional on u^μ. The concrete target is to characterise u^μ as the soliton four-velocity field of an SST-admissible field theory whose continuity equation is $\partial_\mu C^\mu = 0$, with loops emerging as the topologically protected soliton sector — equivalently, under §10.4, as the transport four-velocity of fold-supported closure structures. This converts u^μ from a loop-construct definition to an independent SST-functional/Fold-theoretic definition.

5. Rigorous construction of Π_{pers} from the refinement functor. The projector Π_{pers} of §6.3 is adopted as a provisional working construction. A rigorous explicit construction from the refinement functor of the persistence papers — establishing the graded chain-map, positivity, and contractivity properties from first principles — would discharge the §15 conditional on this point and could be carried out within the persistence papers themselves.

6. Fold coincidence check (technical). The companion check that J^μ here coincides with the Π_{pers} projection of the Fold programme's record-current uniqueness result (§14). This is the technical verification distinct from the ontological alignment of §10. Short calculation, immediate next deliverable.

7. κ-field commutativity check. A formal commutativity result connecting the κ-field's retarded continuity dynamics to Theorem 4's chain-map intertwining argument (Lemma 2), as flagged at the end of §9.

8. Non-abelian generalisation. Extending the loop ontology to non-abelian gauge structure is tied to the catalogue-scope question of *Matter Coupling* §7.1 and would require introducing additional substrate primitives. Structurally downstream of items 1–3.

9. Target theorem for the loop-dynamics paper. A concrete statement that would close the dynamical-derivation gap noted in §5.1 and §10.7:

Target theorem. Under an admissible commitment-continuity dynamics for ρ (with continuity equation $\partial_\mu C^\mu = 0$ and stability functional of the form $E_{loop}[\rho]$ sketched in §5.4), the only stable finite-support transport excitations satisfying $\beta_1 \geq 1$ are topological loop solitons whose hydrodynamic limit is $J^\mu = \rho_{pers} u^\mu$.

Discharging this would: (i) close item 4 by supplying u^μ as the soliton four-velocity field; (ii) render the loop ontology of Definition 1 a derived rather than postulated structure, addressing the dynamical-derivation weakness identified in §5.1 and §10.7; and (iii) supply concrete content for the candidate stability functional $E_{loop}[\rho]$. The target theorem turns the dominant dynamical-derivation gap of the present paper into a concrete next-paper deliverable.

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17. Conclusion

The *Matter Coupling* paper established that the persistent cohomological sector of VERSF couples to a substrate-level record current J^μ via the unique admissible interaction $-J^\mu A_\mu$, with the Catalogue Closure Theorem fixing $J^\mu = \rho u^\mu$ as the unique admissible substrate Lorentz-covariant primitive vector of mass dimension 3. The microscopic substrate origin of J^μ was identified in §15 of that paper as the dominant remaining gap.

The present paper proposes a substrate ontology for J^μ. The proposal is that J^μ is the coarse-grained transport of refinement-persistent, topologically protected commitment structure — primitive commitment loops in the sense of Definition 1 — and that loops are, within the currently identified substrate catalogue, the unique class of substrate structures satisfying source-admissibility. The hydrodynamic limit of loop transport, under the dust-fluid normalisation $u^\mu u_\mu = 1$ committed in §2 and in the single-species regime, yields

$$J^\mu = \rho_{pers} u^\mu = \Pi_{pers}^{(1)} C^\mu,$$

with ρ_{pers} the Lorentz-invariant rest-frame density of the loop ensemble; the generic multi-species ensemble carries the multi-fluid current $J^\mu = \Sigma_a \rho_a u_a^\mu$ of §6.2. Conservation $\partial_\mu J^\mu = 0$ follows from commitment continuity and Lemma 2's projection–transport intertwining. Integer-valued loop winding supplies a structural route toward charge quantisation via the integer cohomology $H^1(\mathcal{G}(\Lambda); \mathbb{Z})$, through the holonomy pairing with H_1 used in the Wilson-loop construction of the Maxwell admissibility paper.

The Fold integration of §10 supplies the ontological grounding: loops are reinterpreted as transported persistent fold structures, the (L1)–(L4) conditions of Definition 1 are identified as closure-trapping conditions for transported fold commitment, and the construction is unified in the ontological chain Void → Fold → Irreversible commitment → Closure topology → Persistent loops → J^μ → Gauge transport. The gauge sector, the record current, the loop ontology, and the topological charge structure are therefore not independent ingredients but successive large-scale manifestations of the same underlying fold architecture.

Within the matter-sector programme of *Matter Coupling* §15, this construction discharges item (1) — charged excitations as identifiable substrate structures, operationally via §§5–8 and ontologically via §10 — and prepares the structural framework for item (2), species decomposition. Items (3) and (4) — spinorial structure and quantum-field promotion — remain open. The paper is a structural waypoint in the matter-sector programme rather than its completion.

The Maxwell equations now have an explicit substrate-level architecture across both halves of their structure. The homogeneous side $\partial_{[\alpha} F_{\beta\gamma]} = 0$ arises from the cohomological exactness of $F = dA$ on the persistent sector. The inhomogeneous side $\partial_\mu F^{\mu\nu} = J^\nu$ arises from the coupling of the persistent sector to coarse-grained topological commitment loop transport, with the coupling structure forced by *Matter Coupling* Theorem 1, the loop ontology supplying the microscopic substrate carrier of J^ν, and the Fold integration supplying the ontological ground for that carrier as transported persistent fold structure.

The construction is conditional in exactly the senses *Matter Coupling* itself was conditional, open in exactly the directions *Matter Coupling* §15 identified as next-stage priorities, and ontologically grounded in the Fold programme via §10 in a way that substantially reduces the ontological fragmentation of the framework. What it adds is a substrate ontology that converts the matter-sector next-stage priorities from open-ended "what carries J^μ?" to structurally constrained "which loop topologies (equivalently, which fold closure classes) correspond to which observed charged species, how do spinorial loop extensions recover fermionic matter, and what is the soliton/fold characterisation of u^μ that closes *Matter Coupling* Lemma 7.0.1?" These are tractable questions with a clean operational and ontological framework to build on, and they constitute the next phase of the VERSF electromagnetic and matter-sector programme.