
Epiphany

OPERATION CATALOG

A companion to the Core Specification

Version 0.2.0 — Phase 2 (Ko representative + broad-Ko M2 groups)

Normative for the operation kinds it defines

Contents

1	About This Companion	2
1.1	Relationship to the Core Specification	2
1.2	Conformance Profiles	3
2	The Catalog Framework	4
2.1	Value-Typed Payloads	4
2.2	Per-Primitive Schema Template	4
2.3	Reduction-Discipline Coverage	5
3	K0 — Representative Primitives	6
3.1	InsertEvent	6
3.2	DeleteEvent	7
3.3	RespellPitch	7
3.4	ModifyEvent	8
3.5	Identified-Pitch Operations	8
3.6	Transpose	9
3.7	CreateCrossCutting	9
3.8	DeleteCrossCutting	10
3.9	ModifyCrossCutting	10
3.10	ChangeRegionTimeModel	11
3.11	Structural Containers	11
3.12	SetUserSystemBreak	12
3.13	Score Settings	12
3.14	DeclareTransaction	13
3.15	ResolveConflict (meta-operation)	14
3.16	UndoTransaction (meta-operation)	14
4	v0 → v1 Payload Migration	15
5	K1 — Framework Slots (Phase 3)	16

About This Companion

The *Operation Catalog* is a companion to the Epiphany Core Specification. It fulfils the open question the core specification raises in its *Operation Catalog Conformance* section (Chapter 6, SEMANTIC OPERATIONS AND CONCURRENT REDUCTION, the `sec:semops:catalog` open question), which states that the catalog “is normative once published; this specification is non-final until the catalog is delivered.” This release delivers the catalog *framework*, the **Ko representative primitive set**, and the **M2 broad-Ko groups** (the event/pitch leaf-field, cross-cutting CRUD, structural-container, and score-settings operations the Phase 2 slice exercises) — the operation kinds the Phase 2 visible slice and binary format actually exercise, each fully specified in Chapter 3. The remaining items of the full 60–80-primitive catalog are drafted as framework slots (Chapter 5) and completed in Phase 3.

1.1 Relationship to the Core Specification

This companion does not restate the operation framework; it *references* it. The framework — operation identity and stamps, the hybrid-logical-clock monotonicity rule, the dotted-version-vector causal context, the order-independent operation-slot model and equivocation, the canonical reduction order, the four-phase lifecycle, conflict records and the conflict registry, re-anchoring, transactions, forward undo, and the LWW discipline — is the core specification’s Chapter 6. This companion defines, for each operation kind, the *payload schema* and how that kind *instantiates* the framework’s reduction, conflict, undo, and re-anchoring rules.

It also consumes, rather than re-deriving, the **ratified byte-convention baseline** (core specification Chapter 8, BINARY FORMAT COMPANION, requirement `req:format:codec-conventions`, and the CANONICAL BYTE-LAYOUT REFERENCE appendix): little-endian integers, a single discriminant byte per tagged union, `u32` length prefixes on every variable-width leaf, and raw UTF-8 free text. Operation-payload encodings are expressed in terms of that baseline; the literal wire layout of each payload is the Binary Format companion’s (Agent J’s) to pin, in coordination with this catalog.

RATIONALE

The catalog is versioned *independently* of the core specification (independent semver). Operation kinds are added over time; the catalog should evolve — adding primitives, refining conflict cases — without forcing a core specification revision. The core specification changes only when the *framework* changes.

1.2 Conformance Profiles

A **Phase-2 profile** implementation **MUST** implement every primitive in Chapter 3 — the representative set and the M2 broad-Ko groups — with the schema, reduction rule, conflict cases, undo semantics, and re-anchoring behaviour defined there. The remaining (Phase-3) framework slots of Chapter 5 are *unavailable* under the Phase-2 profile: an implementation **MUST** reject (not silently ignore) an operation whose kind is one of those slots it does not implement.

The Catalog Framework

2.1 Value-Typed Payloads

Every operation payload in this catalog is **value-typed**: it carries the real graph values its effect introduces, not identifiers that point at values in some ambient graph. An `InsertEvent` carries the whole `Event`; a `RespellPitch` carries the whole `PitchSpelling`; a `CreateCrossCutting` carries the whole tie, slur, beam, or spanner.

RATIONALE

The vo prototype carried *identifier-only projections* — an `InsertEvent` held an `EventId` plus reduction-relevant scalars; a `RespellPitch` held a content-hash *fingerprint* of the new spelling. That was sufficient to make an envelope hashable and to drive reduction, but it is **not durable**: an operation replayed in a fresh context — a backup restore, a cross-tool round-trip — needs the full value, which an identifier-only payload cannot supply. Value-typed payloads are what make an Epiphany document portable.

REQUIREMENT

A value-typed payload field **MUST** be encoded by emitting the field's value under the core specification's canonical value encoding (`req:format:codec-conventions`), framed by a `u32` little-endian length prefix. Decoding **MUST** be the exact inverse and **MUST** reject trailing bytes within the framed region. The encoding introduces no byte layout beyond the ratified baseline: a value's bytes here are byte-for-byte the bytes the whole document codec emits for that value.

2.2 Per-Primitive Schema Template

Each catalog primitive is specified under a fixed six-part template. A new primitive is a schema-fill against this template, not a fresh design:

Payload schema The value-typed fields the operation carries, with their core-specification types.

Canonical encoding The field order and framing, consuming Requirement 2.1. (The literal byte layout is the Binary Format companion's; this catalog fixes the *field set and order*.)

Reduction rule How the operation mutates canonical state when it is reached in canonical reduction order — the preconditions it checks, the objects it mints or tombstones, and the bookkeeping it records.

Conflict cases The conflict records the operation can produce, by `ConflictKind`, and which participant materialises.

Undo semantics The compensating effect of undoing a transaction that contains the operation, under each `UndoPolicy` (`StrictInverse` / `BestEffort` / `Cascade`).

Re-anchoring The behaviour when an object the operation references is tombstoned before or concurrently with it.

2.3 Reduction-Discipline Coverage

The Ko representative set is chosen so that, between them, the primitives exercise *every* reduction discipline the framework defines: position-keyed insert with system-voice promotion; delete-wins with tombstones, tuple compensation, and cross-cutting re-anchoring; field-overwrite with last-writer-wins and structural-field-collision conflicts; set-union creation; structural time-model migration; an LWW advisory; atomic transactions with descriptor precedence; and the two meta-operations (conflict resolution and forward undo). A primitive added later that reuses one of these disciplines inherits its reduction, conflict, undo, and re-anchoring treatment.

Ko — Representative Primitives

This chapter is normative under the Phase-2 profile. Each primitive’s reduction, conflict, undo, and re-anchoring behaviour is the behaviour the core specification’s Chapter 6 defines for its discipline; the description here states how the primitive instantiates it. The reference implementation is `epiphany-ops` (the `payload`, `reduce`, and `migrate` modules).

3.1 InsertEvent

Payload schema. `InsertEventOp { staff_instance: StaffInstanceId, event: Event }`. The voice, region-local position, duration, and pitch identities are read from the `Event` value; the `staff_instance` is retained alongside it so the system-voice promotion derivation is total without a containment walk.

Canonical encoding. `staff_instance`, then the length-framed canonical bytes of `event`.

Reduction rule. A position-keyed insert. Preconditions: the event’s duration is positive; the event id is neither live nor tombstoned; in graph-aware reduction the target voice exists in a metric region and the event’s pitch ids are fresh. The event and its pitches are minted live; the voice is created on first use. Concurrent inserts whose half-open duration intervals overlap in the same voice are resolved by an order-independent promotion pre-pass: the lower-`OperationId` insert is retained in the original voice, and each overlapping loser is promoted to the deterministic system voice `derive_promoted_voice_id(staff_instance, voice, winner, loser)` and tagged `VoicePromoted`.

Conflict cases. None at reduction time; promotion is a deterministic repair, not a conflict.

Undo semantics. Undoing the enclosing transaction tombstones the minted event, its pitches, and any promoted voice. `StrictInverse` conflicts if any was already tombstoned or modified; `BestEffort` tombstones the survivors; `Cascade` is `StrictInverse` over the same minted set (dependent-closure undo is a Phase-3 refinement).

Re-anchoring. Not applicable (the operation mints, it does not reference a pre-existing object that could be tombstoned).

3.2 DeleteEvent

Payload schema. `DeleteEventOp { event: EventId, tuple_compensation: TupleCompensation }`, where `TupleCompensation` is `NotInTuple`, `ReplaceWithRest { rest: Rest }` (value-typed replacement `rest`), `RewriteTuples { tuples }`, or `CascadeDeleteTuples { tuples }`.

Canonical encoding. `event`, then the tuple-compensation discriminant and its payload (a length-framed `Rest` value for `ReplaceWithRest`).

Reduction rule. Delete-wins: the event and its contained pitches are tombstoned (retaining their identifiers). Tuple compensation, when present, adds the replacement `rest` live or tombstones the cascaded tuple group. Concurrent deletes of the same event are idempotent.

Conflict cases. None for the delete itself. Graph-aware reduction refuses an ill-formed tuple compensation as a precondition failure (no-op).

Undo semantics. An insert-shaped compensation re-introduces the tombstoned content; for the prototype’s minted-object model this is the inverse of the tombstone set, with the policy treatment described under `InsertEvent`.

Re-anchoring. Tombstoning the event runs the framework’s re-anchoring rule table over every cross-cutting structure that referenced it: a tie cascade-deletes; a comment or analytical annotation orphans (user content is never silently deleted); a beam truncates while ≥ 2 members survive and otherwise cascade-deletes; a slur or spanner re-anchors to the nearest surviving endpoint while ≥ 1 survives and otherwise cascade-deletes.

3.3 RespellPitch

Payload schema. `RespellPitchOp { pitch: PitchId, spelling: PitchSpelling }` — the full spelling value (`v1`), not a fingerprint.

Canonical encoding. `pitch`, then the length-framed canonical bytes of `spelling`.

Reduction rule. A last-writer-wins field overwrite, keyed by `pitch`. Precondition: the pitch is live. The resolved spelling is the one carried by the operation latest in canonical order. Two respellings of one pitch that are causally ordered overwrite intentionally; two *concurrent* respellings with *equal* spelling reduce idempotently.

Conflict cases. Two concurrent respellings of one pitch with *differing* spellings produce a `StructuralFieldCollision` conflict recording the winner (later in canonical order), the loser, and the field `spelling`. The winner materialises and carries the `Conflicted` effect tag.

Undo semantics. Undo restores the pre-operation spelling (or removes the spelling if the operation introduced the first one), under the active policy.

Re-anchoring. If the target pitch is tombstoned, the respelling is a no-op (`TargetTombstoned`).

OPEN QUESTION

P12-K1. A `vo RespellPitch` carried only a content-hash *fingerprint* of the spelling. The fingerprint cannot be inverted to a `PitchSpelling` without a side table, so the `vo→v1` migration (Chapter 4) recovers the spelling from the score graph context — an explicit per-pitch spelling attachment whose canonical bytes hash to the fingerprint — and, when the context lacks it, declares the envelope unmigratable (the bundle opens read-only). This is the one representative payload that is not self-contained under migration; the disposition (whether a richer `vo` corpus, or a documented read-only fallback, is the long-term answer) is a Pass-12 question.

3.4 ModifyEvent

Payload schema. `ModifyEventOp { event: Event }` — the full replacement `Event` value (`v1`). The identity (and therefore the LWW key) is read from the value.

Canonical encoding. The length-framed canonical bytes of `event`.

Reduction rule. A last-writer-wins field overwrite keyed by event id. Precondition: the event is live. The resolved value is the one carried by the operation latest in canonical order; two causally ordered modifications overwrite intentionally, and two *concurrent* modifications with *equal* value reduce idempotently. Graph-aware reduction overwrites the event in place. A modification that *moves* the event (a different region-local position or duration) is recorded in the bookkeeping but its placement change is *not* applied to the graph: re-sorting a voice on a placement change is a deferred refinement, and an in-place move would break `VoiceEventsSortedNonOverlap` (Chapter 5 invariant 3). A malformed (empty pitched) replacement is likewise recorded but not materialised.

Conflict cases. Two concurrent modifications of one event with *differing* values produce a `StructuralFieldCollision` on the field `event`, recording the winner (later in canonical order) and the loser.

Undo semantics. Under the prototype’s minted-object undo (Section 3.16) a field overwrite mints nothing, so undoing the enclosing transaction does not restore the prior event value; a snapshot-and-restore inverse is a Phase-3 refinement (P11-C8).

Re-anchoring. If the target event is tombstoned, the modification is a no-op (`TargetTombstoned/TargetMissing`).

3.5 Identified-Pitch Operations

Payload schema. `InsertIdentifiedPitchOp { event: EventId, pitch: IdentifiedPitch }` mints a pitch into a live event; `DeleteIdentifiedPitchOp { pitch: PitchId }` tombstones one; `ModifyIdentifiedPitchOp { pitch: PitchId, value: Pitch }` overwrites a pitch’s acoustic / scale-position value (distinct from `RespellPitch`, which overwrites only the *spelling*).

Canonical encoding. Insert: `event`, then the length-framed `pitch` value. Delete: `pitch`. Modify: `pitch`, then the length-framed `value`.

Reduction rule. The pitch-level analogues of the event-level mint, delete, and field overwrite, inheriting their disciplines (Sections 3.1, 3.2, and this chapter’s field-overwrite treatment). **A note and a rest are the same slot under pitch add/remove** (normative): deleting the *only* pitch of a single-pitch note degrades the event to a `Rest` of the same `id/voice/position/duration` rather than leaving an empty pitched event (Chapter 5 forbids the empty chord, `ArenaError::EmptyPitchedEvent`); inserting a pitch into a rest is the dual, promoting it to a one-pitch note. This preserves the delete-wins / mint disciplines and keeps the graph consistent with the bookkeeping, which tombstones or mints the pitch object either way.

Conflict cases. Insert and delete: none (mint is set-union; delete-wins is idempotent). Modify: two concurrent differing writes of one pitch produce a `StructuralFieldCollision` on the field `pitch`.

Undo semantics. Insert is the only minting member: undoing the enclosing transaction tombstones the minted pitch, re-resting the event if it was the only one (Section 3.16). The prototype’s minted-object undo has nothing to tombstone for delete or modify, so neither is inverted under it (re-introducing a tombstoned pitch or restoring a prior value is a Phase-3 refinement, P11-C8).

Re-anchoring. An operation whose target event or pitch is tombstoned is a no-op; tombstoning a pitch runs the cross-cutting re-anchoring table over any structure that referenced it (see `DeleteEvent`).

3.6 Transpose

Payload schema. `TransposeOp { targets: Vec<PitchId>, chromatic_steps: i32 }`. Pitch identifiers are preserved; only acoustic content changes.

Canonical encoding. The canonically-ordered `targets` set, then `chromatic_steps` as a little-endian `i32`.

Reduction rule. An order-dependent content overwrite. Each live target pitch is shifted by `chromatic_steps`; reduction is order-dependent in the general case (interval composition need not commute), so the resolved value is the composition in canonical reduction order. In this prototype `chromatic_steps` is a minimal CMN alteration shift that commutes except at the alteration’s `i8` saturation bound; rich interval algebra is deferred (Chapter 4 tuning catalog; P12-K2).

Conflict cases. None — composition is deterministic in canonical order (a deterministic repair, not a conflict).

Undo semantics. Transpose mints nothing, so the prototype’s minted-object undo (Section 3.16) does not negate it; an inverse-interval undo is a Phase-3 refinement (P11-C8).

Re-anchoring. Tombstoned targets are skipped (the transpose applies only to live pitches).

3.7 CreateCrossCutting

Payload schema. `CreateCrossCuttingOp { structure: CrossCuttingValue }`, where `CrossCuttingValue` is the typed value of a `Tie`, `Slur`, `Beam`, or `Spanner`. Its identity and referenced endpoints are

read from the value.

Canonical encoding. A discriminant for the structure kind, then the length-framed canonical bytes of the structure value.

Reduction rule. Set-union creation: the structure is minted live if its id is not already live and every referenced endpoint is live; a second create of a live id is idempotent. Graph-aware reduction materialises the structure with its full fields.

Conflict cases. None (all-or-nothing creation; union is deterministic).

Undo semantics. Undo tombstones the minted structure, under the active policy.

Re-anchoring. The structure participates in the re-anchoring rule table when one of its endpoints is later tombstoned (see `DeleteEvent`).

Migration coverage. The $v_0 \rightarrow v_1$ migration (Chapter 4) reconstructs the event-anchored `Tie`, `Slur`, and `Beam` from the v_0 reference (id plus event endpoints). A `Spanner` is anchored by `TimeAnchors` rather than a fixed pair of event endpoints, so its full value is not reconstructable from the v_0 event-reference projection; a `Spanner`-create is therefore reported unmigratable (read-only), alongside the respell case of `P12-K1`, and remains so. A faithful spanner migration awaits a richer v_0 projection that carries the anchors — a Phase-3 / Pass-12 extension, not yet implemented.

3.8 DeleteCrossCutting

Payload schema. `DeleteCrossCuttingOp { structure: TypedObjectId }` — the structure named by the same key the set-union creation and the re-anchoring table use; it **MUST** be a cross-cutting kind (`Tie/Slur/Beam/Spanner`).

Canonical encoding. The canonical bytes of `structure`.

Reduction rule. Delete-wins: the structure is tombstoned (its identifier retained). A second delete of the same structure is idempotent; deleting a missing or non-cross-cutting id is a no-op precondition failure. Graph-aware reduction removes the structure from the score.

Conflict cases. None (delete-wins is idempotent).

Undo semantics. A delete mints nothing, so the prototype’s minted-object undo (Section 3.16) does not re-introduce the tombstoned structure (`P11-C8`).

Re-anchoring. The deletion is direct (the structure is the target, not a referenced endpoint); it does not itself trigger the endpoint re-anchoring table.

3.9 ModifyCrossCutting

Payload schema. `ModifyCrossCuttingOp { structure: CrossCuttingValue }` — the full replacement value (v_1). The replacement keeps the structure’s identity but may change its endpoints and per-kind fields; the LWW key is the structure’s `CrossCuttingValue::id`.

Canonical encoding. The discriminant and length-framed bytes of the `CrossCuttingValue` (as for `CreateCrossCutting`).

Reduction rule. A last-writer-wins field overwrite keyed by structure id. Precondition: the structure is live. The reduction re-derives the structure’s endpoints from the new value, so a later re-anchoring sees them. A malformed replacement is a precondition no-op — in particular a beam whose membership falls below the two-member minimum is refused rather than materialised. Graph-aware reduction overwrites the structure in place.

Conflict cases. Two concurrent differing modifications of one structure produce a `StructuralFieldCollision` on the field `cross_cutting`.

Undo semantics. A modification mints nothing, so the prototype’s minted-object undo (Section 3.16) does not restore the prior structure value (a snapshot-and-restore inverse is Phase-3, P11-C8).

Re-anchoring. If the target structure is tombstoned, the modification is a no-op; re-deriving the endpoints lets a subsequent endpoint tombstone re-anchor the structure through the standard table (see `DeleteEvent`).

3.10 `ChangeRegionTimeModel`

Payload schema. `ChangeRegionTimeModelOp { region: RegionId, new_time_model: RegionTimeModel, declared_incompatible: Vec<EventId>, remapping: PositionRemapping }` — the full target model value (`v1`).

Canonical encoding. `region`, the length-framed `new_time_model` value, the canonically-ordered `declared_incompatible` set, then `remapping`.

Reduction rule. Structural migration. The region adopts the target time model. Graph-aware reduction derives coordinate-kind incompatibilities from the region’s events (and from the remapping coverage) and refuses a migration that would violate the coordinate discipline.

Conflict cases. Concurrent same-region migrations produce a `StructuralFieldCollision` on the field `time_model`; a migration with incompatible events produces a `TimeModelMigrationFailure` naming the region and the incompatible events. A causally-later migration is re-evaluated against the first migration’s graph rather than conflicting.

Undo semantics. Undo restores the region’s prior time model under the active policy.

Re-anchoring. Not applicable.

OPEN QUESTION

P11-C6. The rich migration payload — a coordinate converter rather than a `declared_incompatible` list plus a `PositionRemapping` — remains the catalog’s to design when graph-aware migration is the only reduction path.

3.11 Structural Containers

Payload schema. Three create/delete pairs over the region hierarchy: `CreateRegionOp { region: Region } / DeleteRegionOp { region: RegionId }; CreateStaffInstanceOp { region: RegionId, instance: StaffInstance } / DeleteStaffInstanceOp { staff_instance: StaffInstanceId`

`}; CreateVoiceOp { staff_instance: StaffInstanceId, voice: Voice } / DeleteVoiceOp { voice: VoiceId }`. Each create carries the full container value (*v1*); the reduction preconditions it bears *no typed child object* — an empty container.

Canonical encoding. Create: the parent id (where the schema names one), then the length-framed canonical bytes of the container value. Delete: the container id.

Reduction rule. Set-union creation of an *empty* container, and an *empty-only* delete-wins tombstone. A create mints the container live if its id is fresh and (for staff instance and voice) its parent is live; it preconditions the carried value to bear no typed child object (a region: no staff instances, barline-alignment groups, or graphic objects; a staff instance: no voices or measures; a voice: no events), since those carry distinct `TypedObjectIds` the reducer mints separately — so contents are added by subsequent operations. A delete is a delete-wins tombstone, but a *precondition no-op* (`ContainerNotEmpty`) unless the container has no live children — the caller deletes contents first. Graph-aware reduction adds or removes the container and maintains the region’s staff extent so `RegionExtents` stays satisfied.

Conflict cases. None at reduction time: creation is set-union (a repeat create is idempotent), and the empty-only delete is a deterministic precondition gate, not a conflict.

Undo semantics. Undo of a *create* tombstones the minted container (Section 3.16); `StrictInverse` conflicts if it was concurrently mutated, with the policy treatment as for `InsertEvent`. A *delete* mints nothing, so the prototype’s minted-object undo does not re-introduce it (P11-C8).

Re-anchoring. Not applicable (the containers are minted/tombstoned by id; the empty-only precondition means a delete never strands live children).

3.12 SetUserSystemBreak

Payload schema. `SetUserSystemBreakOp { region: RegionId, anchor: TimeAnchor, present: bool }` — the full anchor value (*v1*).

Canonical encoding. `region`, the length-framed anchor value, then the boolean.

Reduction rule. A last-writer-wins advisory. The break preference is recorded for the region keyed by the anchor’s *resolved musical position*; graph-aware reduction adds or removes the anchor from the region’s user system-break list.

Conflict cases. None (LWW advisory).

Undo semantics. Undo restores the prior advisory value for the (`region`, `resolved-position`) key.

Re-anchoring. Not applicable in the prototype (the advisory is keyed by resolved position; a tombstoned anchor target degrades to the region origin).

3.13 Score Settings

Payload schema. Three score-level field overwrites: `SetMetadataOp { metadata: ScoreMetadata }` overwrites the score singleton; `SetMetricGridOp { region: RegionId, grid: Option<MetricGrid>`

`}` overwrites (or clears) a region’s default metric grid; `SetUserPageBreakOp { region: RegionId, anchor: TimeAnchor, present: bool }` is the page-break sibling of `SetUserSystemBreak`.

Canonical encoding. Metadata: the length-framed metadata value. Metric grid: region, then an `Option` discriminant and (when present) the length-framed grid value. Page break: region, the length-framed anchor value, then the boolean.

Reduction rule. Three field overwrites differing only in discipline. `SetMetadata` is an **advisory** last-writer-wins: the latest write in canonical order silently wins and the operation always applies — no working state and no conflict (the same discipline as `SetUserSystemBreak`, on the score singleton). `SetMetricGrid` is a **structural** field overwrite keyed by region: precondition the region is live and staff-based (a `FreeGraphic` region has no metric-grid slot — the op is a no-op there), and reject a grid whose meter sequence names a time signature that is not live (the Chapter 5 invariant forbids installing such a grid). `SetUserPageBreak` is a canonical LWW advisory keyed by the anchor’s resolved musical position, with the same staff-based precondition. Graph-aware reduction overwrites the metadata singleton, sets the region’s default metric grid, or adds/removes the page-break anchor under its resolved-position key (so two anchors resolving to one position occupy a single slot).

Conflict cases. `SetMetadata` and `SetUserPageBreak`: none (advisory LWW). `SetMetricGrid`: two concurrent differing grids for one region produce a `StructuralFieldCollision` on the field `metric_grid`.

Undo semantics. All three are field overwrites that mint nothing, so the prototype’s minted-object undo (Section 3.16) does not restore the prior metadata, grid, or break preference (a snapshot-and-restore inverse is a Phase-3 refinement, P11-C8).

Re-anchoring. The advisory breaks degrade as for `SetUserSystemBreak`; the metric grid and metadata are keyed by region / singleton and do not re-anchor (a deleted region’s settings are no-ops — `TargetMissing`).

3.14 DeclareTransaction

Payload schema. `TransactionDescriptor { id: TransactionId, label: String, category: Option<TransactionCategory> }`. Value-complete in vo and unchanged.

Reduction rule. Records the descriptor. Member primitives reference the transaction id and **MUST** causally depend on the descriptor; the members reduce atomically (all-or-nothing) in canonical order.

Conflict cases. A missing descriptor or a member that does not causally follow it produces a `TransactionConflict`; any member failure rolls back the whole transaction and all members read `NoOp{TransactionConflict}`.

Undo / re-anchoring. Transactions are the unit of undo (Section 3.16); re-anchoring is per member.

3.15 ResolveConflict (meta-operation)

Payload schema. `ResolveConflictPayload { target: ConflictId, action: ResolutionAction }`. Value-complete.

Reduction rule. Transitions the target conflict’s resolution state. An action of `Dismiss` reaches the `Dismissed` state; any other action reaches `Resolved`. Re-resolving with the same action is idempotent; two concurrent resolves with differing actions produce a meta-conflict.

RATIONALE

Pass 11 added `ResolutionAction::Dismiss` (item 2.5) precisely so the `Dismissed` state is reachable by an authored operation rather than merely representable. The catalog records that `Dismiss` is the action that selects it (resolving the vo ambiguity P11-C10).

3.16 UndoTransaction (meta-operation)

Payload schema. `UndoTransactionPayload { target: TransactionId, policy: UndoPolicy }`, with `UndoPolicy` one of `StrictInverse`, `BestEffort`, `Cascade`. Value-complete.

Reduction rule. A forward compensating edit computed against the materialised state at the undo’s canonical position (never literal time travel). The prototype models the compensation as tombstoning the objects the target transaction minted: `StrictInverse` conflicts (`TombstonedTarget`) if any minted object was already tombstoned; `BestEffort` tombstones the survivors; `Cascade` is `StrictInverse` over the same set (dependent-closure undo is a Phase-3 refinement, P11-C8).

vo → v1 Payload Migration

A vo envelope carries an identifier-only payload; a v1 envelope carries the value-typed payload this catalog defines. The two forms do not coexist as permanent dialects (that would double the reducer surface forever); instead the catalog ships a **one-time migration** that lifts a vo envelope to v1 using the score graph as context, applied once on read. Production code carries only v1 payloads; vo envelopes survive only as a regression corpus.

REQUIREMENT

The migration `migrate_v0_envelope(v0, context: &Score)` **MUST** be **deterministic** (two implementations migrating the same vo envelope against the same context produce byte-identical v1 envelopes) and **equivalence-preserving** (a vo envelope and its v1 migration reduce to byte-identical canonical `MaterializedState`). When a value cannot be reconstructed from the vo projection plus the context, the migration **MUST** report the envelope unmigratable rather than fabricate a value, and the bundle opens read-only.

The reference implementation (`epiphany-ops::migrate`) reconstructs the `InsertEvent` event, the `DeleteEvent` compensation, the `ChangeRegionTimeModel` model, the `SetUserSystemBreak` anchor, and the event-anchored cross-cutting structures (`Tie / Slur / Beam`) self-containedly from the vo projection; a `Spanner`, anchored by `TimeAnchors` rather than event endpoints, remains unmigratable until the projection carries them. It recovers a `RespellPitch` spelling from the context (P12-K1, Section 3.3). The migration's merge gate (`epiphany-testkit::migration`) drives the inverse direction — projecting a v1 corpus to vo and migrating it back — and asserts byte-identical reduction plus a non-vacuity guard.

K₁ — Framework Slots (Phase 3)

This chapter drafted the remaining catalogue items as framework slots. The Phase-2 **M2** expansion (the broad-Ko groups in *epiphany-ops*) implemented four groups of them; with the **M2e** catalogue expansion their full per-primitive schemas now appear in Chapter 3, so they are *normative under the Phase-2 profile* and an implementation **MUST** *not* reject them. They are cross-referenced first. The genuinely Phase-3 slots that remain **unavailable** are listed second: an implementation **MUST** reject an operation of one of *those* kinds. Each remaining slot is a schema-fill against the template of Chapter 2; adding one is not a fresh design.

Implemented since M2 (now in Chapter 3)

Modify event; identified-pitch operations; transpose M2 Group 1 — Sections 3.4, 3.5, and 3.6.

Delete / modify cross-cutting M2 Group 2 — Sections 3.8 and 3.9 (creation is Section 3.7).

Create / delete region / staff instance / voice M2 Group 3 — Section 3.11 (set-union creation and the empty-only delete).

Set metadata / metric grid / user page break M2 Group 4 — Section 3.13 (advisory metadata, structural metric grid, advisory page break).

Remaining framework slots (Phase 3 — unavailable, MUST reject)

Create score / canvas / staff The remaining structural mints (the document root, the canvas, and global staves) the Phase-2 slice does not exercise. Discipline: set-union creation.

Set time signature / tempo segment The finer-grained metric-model overwrites beneath the whole-grid *SetMetricGrid* (Section 3.13): a single meter change or tempo segment rather than the region's entire grid. Discipline: last-writer-wins structural overwrite.

Set layout The non-break layout advisories (the page/system-break advisories themselves are implemented — Sections 3.12 and 3.13). Discipline: LWW advisory.

Non-Goal

The full 60–80-primitive catalogue is not a Phase-2 deliverable. The framework (Chapter 2) and the Ko representative set (Chapter 3) are sufficient to exercise every reduction discipline; the remaining primitives are Phase-3 schema-fill.