
Epiphany

BINARY FORMAT

A companion to the Core Specification

Version 0.2.0 — Phase 2/3 (canonical wire format: primitives through bundle physical layout
+ Ko and Phase-3-tranche payload framing)

Normative for the byte layouts it defines

Contents

1	About This Companion	3
1.1	Relationship to the Core Specification and the Operation Catalog	3
1.2	Conformance	4
2	Encoding Conventions	6
2.1	The Three Encoding Regimes	6
2.2	Primitive Composition Rules	7
3	Identifiers and Derivations	9
3.1	The 128-Bit Identifier Family	9
3.2	TypedObjectId	9
3.3	System-Derived Counters and Digest Truncations	10
3.4	The Domain-Tag Registry	11
3.5	SnapshotId	11
4	Primitive Value Encodings	13
4.1	RationalTime	14
5	Graph Value Layouts	15
5.1	The Score Envelope	15
5.2	Composition Rules as Normative Encoding Facts	16
5.3	Discriminant Tables	17
5.3.1	C-style enums (one byte, no payload)	17
5.3.2	Tagged unions (one byte, then the variant payload)	17
5.4	Representative Complete Layouts	18
5.4.1	RationalTime	18
5.4.2	TimeAnchor	18
5.4.3	Pitch	19
5.4.4	Event	19
5.4.5	Slur	19
5.5	The CanonicalValue Seam	19
5.6	The Frozen-Layout Rule	20
6	Operation Wire Forms	21
6.1	The Operation Envelope	21
6.2	OperationPayload and the Meta-Operations	22
6.3	OperationKind: the Primitive Wire Discriminants	22
6.4	OperationKindTag: a Separate Discriminant Space	24

6.5	Stamps and Causal Contexts	24
6.6	Effects, Conflicts, Anomalies, and Materialized State	25
6.6.1	MaterializedState	26
6.7	vo Payloads Have No Wire Form	26
7	Bundle Physical Layout	28
7.1	The Fixed Header (64 bytes)	28
7.2	The Superblock Slots (256 bytes each)	28
7.3	Chunks	29
7.3.1	ChunkRef (95 bytes)	30
7.4	Operation-Envelope Block Payloads	30
7.5	The Manifest	30
7.6	The Operation Index	32
8	Extension Declaration Blobs and Edit Barriers	34
8.1	Framing	34
8.2	EditBarrier	35
9	Schema Evolution	36
9.1	The Chunk-Level Gate	36
9.2	What “Additive” Means Here	36
9.3	Migration Discipline	37
10	Non-Canonical Pinned Encodings	38
10.1	LayoutObjectId (MUSCLOID)	38
10.2	ResolvedLayoutIR Canonical Output	38
10.3	Layout Caches and Font Metrics	39
11	Golden Anchor Registry	40
12	Revision History	43

About This Companion

The *Binary Format* document is a companion to the Epiphany Core Specification. It fulfils the core specification’s delegation in Chapter 8, BINARY FORMAT COMPANION (the `sec:format:binary` section): the byte-level encoding — integer conventions, exact field widths, record alignment, endianness, string encoding details, struct layouts — is delivered here. In the core specification’s words: “*The Binary Format document is normative; an implementation cannot conform to the file format specification without conforming to the Binary Format specification.*”

This release (v0.1.0) delivers the full **K-independent** encoding surface — identifier and derivation layouts, primitive value encodings, the whole-SCORE composite value codec, the operation-layer wire forms, the bundle physical layout, and the extension-declaration blob forms — *plus* the **Ko/M2 operation-payload wire framing**. The Operation Catalog’s Ko set (the representative primitives and the M2 broad-Ko groups, catalog version 0.4.0) now exists in ratified form, so the historical “waits for Agent K” clause in the Phase-2 charter is discharged: every operation kind the catalog defines has its literal wire form pinned in Chapter 6.

This document does *not* cover:

- the canonical s-expression form — that is the *Text Projection* companion’s;
- per-profile feature lists — the *Profile Conformance* companion’s;
- the Chapter-4 tuning-catalog values (pitch-space and tuning-system registries), which are undelivered Track-C work and have no wire form yet;
- the required conformance harnesses (the cross-implementation decoder test and the wire-format fuzzer). Those are *implementation* deliverables tracked in the Phase-2 process documents, not part of this document’s normative text; Chapter 11 records the golden anchors that any such harness must reproduce.

1.1 Relationship to the Core Specification and the Operation Catalog

This companion *inherits* — it never re-derives — the core specification’s ratified convention baseline: core specification Chapter 8, BINARY FORMAT COMPANION, requirement `req:format:codec-conventions`, together with the CANONICAL BYTE-LAYOUT REFERENCE appendix (`app:bytes`). That appendix consolidates every discriminant table, derivation preimage, and primitive encoding Pass 11 and Pass 12 ratified, precisely so that this document

could import it as a starting point rather than recovering the layouts from the crates. Chapter 3 therefore reproduces only *compact* normative tables, each with a citation back to the appendix row and requirement that governs it; where this document and a ratified core requirement disagree, **the core requirement governs** and the discrepancy is a defect in this document.

What this document adds is the completion of the appendix’s deferred list (core specification, LAYOUTS DEFERRED TO THE COMPANIONS, `sec:bytes:deferred`): the `OperationKind` and `OperationKindTag` discriminants and full per-operation payload encodings; the full composite struct layouts (whole-`Score`, operation envelopes, the manifest body’s field order); schema-version wire evolution; and the varint question, which Chapter 2 settles.

The division of labour with the *Operation Catalog* is exact: the catalog fixes each operation’s **field set and order** (Operation Catalog, `PER-PRIMITIVE SCHEMA TEMPLATE`) and its semantics; this document pins the **bytes** of those fields. Chapter 6 cites the catalog section for every payload rather than restating what the fields mean. Likewise, graph *types* are the core specification’s Chapters 2–5, and the structural layer of the bundle — what a header, superblock, chunk graph, or manifest *is* and how it behaves — is core Chapter 8; this document specifies only how those structures’ bits are laid out.

RATIONALE

Versioning. This companion is versioned independently of the core specification (independent semver), like the Operation Catalog — but tied tighter to it: the binary-format MAJOR version tracks the core specification’s major version (both are pre-1.0 working drafts today, hence v0.1.0), while MINOR versions diverge freely. Byte layouts change on a slower, more deliberate cadence than prose; a core-spec minor revision that touches no wire fact requires no revision here, and an additive discriminant append here (Chapter 9) requires no core-spec revision.

1.2 Conformance

The byte layouts in this document are **normative**. An implementation conforms to the Epiphany binary format if and only if, for every layout this document defines, it produces exactly the specified bytes when encoding and accepts exactly the specified language of byte strings when decoding.

Decode discipline is **reject, never normalize** — the workspace-wide convention the core specification establishes in Appendix D (canonical serialization determinism and ordered iteration). Concretely, each of the following is a *decode error*, never an input to be repaired:

- an unknown discriminant in any tagged union;
- a set- or map-valued field whose elements are not in strictly ascending canonical order, or which contains duplicates;
- text that is not in Unicode NFC where NFC is required (catalog identifiers, barrier pitch-space names, operation labels);
- trailing bytes after a complete top-level value (Requirement 2.2);
- recursion beyond a normative depth bound (Requirement 8.2).

A decoder **MUST NOT** silently sort, deduplicate, NFC-fold, truncate, or otherwise canonicalize non-canonical input: two implementations that disagree on repair would disagree on canonical state.

The **golden anchor registry** (Chapter 11) is the conformance contract binding this text to the reference implementation: every layout in this document is anchored by at least one named test in the reference crates, and a change that breaks an anchor is either a defect or a deliberate, versioned format revision (Chapter 9).

Encoding Conventions

This chapter restates the ratified convention baseline (core specification, requirement `req:format:codec-conventions`) as normative fact and completes it: the three prefix/endianness regimes, the primitive composition rules, the varint disposition, and the trailing-bytes rule.

2.1 The Three Encoding Regimes

Three internally consistent regimes coexist in the format. Every layout in this document belongs to exactly one of them, and each layout's chapter says which.

Regime	Surfaces	Rules
(a)	Canonical document encodings: the core value codec (Chapter 5), the operation layer (Chapter 6), the bundle codec (Chapter 7).	Little-endian fixed-width integers; <code>u32</code> little-endian counts and length prefixes on every variable-width field.
(b)	Layout-side pinned encodings: the extension-declaration blobs and edit-barrier trees (Chapter 8) and the <code>ResolvedLayoutIR</code> canonical output (Chapter 10).	Little-endian integers; <code>u64</code> little-endian counts and length prefixes. Deliberate, golden-locked divergence from regime (a).
(c)	Identifiers and hash-derived forms: the 128-bit identifier family, <code>ReplicaId</code> , <code>OperationId</code> , <code>ConflictId</code> , the <code>TypedObjectId</code> discriminant, digest truncations (Chapter 3).	Big-endian fixed width. Numeric order equals canonical byte order, which is what Appendix D's ordered iteration requires.

RATIONALE

Regimes (a) and (b) differ only in prefix width, and the divergence is *tolerated rather than repaired*: the two surfaces were golden-locked independently (the barrier blobs and the resolved-layout output carry their own literal-byte anchors), they never embed one another's framing, and unifying the prefix width now would break locked bytes for zero

benefit. The divergence is recorded as an open question for the next schema-major revision (Chapter 9). Regime (c) is not a divergence at all: an identifier’s byte form *is* its sort key, so big-endian is load-bearing.

2.2 Primitive Composition Rules

The following rules apply throughout regime (a); regimes (b) and (c) state their deltas in their own chapters.

Booleans. A single byte: 0 = false, 1 = true. Any other value is a decode error.

Integers. Fixed-width little-endian two’s complement (u8/i8 through u128), except within regime (c).

Option<T>. A presence byte: 0 = absent (no further bytes), 1 = present, followed by T’s encoding. A presence byte greater than 1 is a decode error.

Sequences, sets, maps. A u32 little-endian element count, then each element (for maps: key then value). Set- and map-valued fields are emitted in canonical iteration order — ascending by the key’s canonical byte form — and decoders reject out-of-order or duplicated elements wherever the field is a set or map (as opposed to an order-significant list).

Free text. A u32 little-endian byte length, then the raw UTF-8 bytes. Free-text fields (e.g. a score title) are **never** NFC-folded by the codec: $\text{decode}(\text{encode}(x)) = x$ is the round-trip identity, and folding would break it. By contrast, *catalog identifiers* (pitch-space ids, tuning-system ids, and the other `catalog_id` newtypes) are NFC-normalized *at construction*, so their stored form is already NFC; the codec encodes the stored string verbatim. Operation-layer text fields (the transaction label, conflict field paths) are NFC-normalized at encode time (Chapter 6).

Structs. Positional, unframed concatenation of the fields’ encodings in declaration order. No field tags, no per-field lengths, no padding, no alignment. (This is the layout the frozen-layout rule, Requirement 5.6, freezes.)

Tagged unions. A single discriminant byte, then the selected variant’s payload encoded positionally. Two documented exceptions: `TypedObjectId` uses a 16-bit *big-endian* discriminant (core requirement `req:graph:typed-object-id-discriminants`; Chapter 3), and the bundle’s `ProfileId` uses a u32 little-endian discriminant (core requirement `req:format:profileid-discriminants`; Chapter 7).

Determinism-canonical leaves. Where a composite codec embeds a value whose canonical byte form is owned by the determinism layer or the identifier layer (a graph identifier, `ContentHash`, `CanonicalF64`, `RationalTime`, a wall-clock integer), the core value codec frames it as a u32 little-endian length prefix followed by the leaf’s own canonical bytes — even when the leaf is fixed-width. The leaf’s bytes are then self-describing under its own decoder. (The operation layer instead embeds fixed-width leaves *raw*, unprefixed; Chapter 6 states this explicitly.)

REQUIREMENT

No varint. Schema major 0 defines *no* variable-length integer encoding. Every integer field in every layout in this document is fixed-width. The core specification’s “varint conventions” language (Chapter 8, BINARY FORMAT COMPANION) is hereby discharged as *none*: an encoder **MUST NOT** emit, and a decoder **MUST NOT** accept, any LEB128-style or otherwise variable-width integer under schema major 0. Variable width in this format comes only from explicit `u32/u64` length prefixes and from `RationalTime`’s length-prefixed big-integer magnitudes (Chapter 4).

REQUIREMENT

Trailing bytes. Every top-level decode entry point — a `whole-Score` value, a `per-value CanonicalValue` decode, an `OperationKindTag`, a `MaterializedState`, a manifest payload, an operation-index payload, a block payload, an extension-declaration blob, a fixed-width primitive — **MUST** reject input with bytes remaining after the complete value has been decoded. Trailing bytes are a decode error, never ignored padding.

Identifiers and Derivations

This chapter is an *import-by-citation* of the core specification’s CANONICAL BYTE-LAYOUT REFERENCE appendix (`app:bytes`): that appendix and its golden anchors govern every table in this chapter, and the tables here are compact restatements for self-containedness, not a second source of truth. All layouts in this chapter are regime (c): big-endian, fixed width.

3.1 The 128-Bit Identifier Family

ReplicaId. 8 bytes, big-endian u64. The reserved system namespace is `ReplicaId::SYSTEM_DERIVED = 0xFFFF_FFFF_FFFF_FFFF`; user-authored replicas **MUST NOT** use it.

Typed graph identifiers. Every typed 128-bit graph identifier (`EventId`, `PitchId`, `VoiceId`, `RegionId`, `StaffInstanceId`, `TransactionId`, ... — the `graph_id` family) packs the 64-bit replica into the high half and the counter into the low half, and encodes as exactly 16 bytes: replica big-endian (8) || counter big-endian (8). Numeric order, canonical byte order, and Appendix-D iteration order coincide.

OperationId. The same 16-byte form: replica big-endian (8) || counter big-endian (8). Ordering is (*replica, counter*) lexicographic, which equals byte order.

Registry and author identifiers (operation layer). The opaque 128-bit registry newtypes (`OperationKindRegistryId`, `ConflictKindRegistryId`, `ResolutionRegistryId`, `RepairKindRegistryId`, `ReanchorReasonRegistryId`, `ReplicaAnomalyRegistryId`, `IntegrityAnomalyRegistryId`, `ExtensionPreconditionId`, `PreconditionFailureRegistryId`) and `AuthorId` all encode as 16 big-endian bytes.

3.2 TypedObjectId

Canonical form: a **16-bit big-endian discriminant** || the variant payload (core requirement `req:graph:typed-object-id-discriminants`). Non-Registered variants carry one 16-byte identifier, for a total of **18 bytes**; Registered carries the `ObjectKindRegistryId` (16 big-endian bytes) || the extension’s own raw u128 (16 big-endian bytes), for a total of **34 bytes**. An unknown discriminant is a decode error.

Disc	Variant	Disc	Variant
0	Event	14	Spanner
1	Pitch	15	Marker

Disc	Variant	Disc	Variant
2	Voice	16	AnalyticalAnnotation
3	Staff	17	Comment
4	StaffInstance	18	GraphicObject
5	StaffGroup	19	GraphicGesture
6	Region	20	TimeSignature
7	Instrument	21	AnalysisLayer
8	PartDefinition	22	Tuplet
9	Measure	23	RepeatStructure
10	BarlineAlignmentGroup	24	LyricLine
11	Slur	25	ChordSymbol
12	Tie	26	View
13	Beam	27	Registered

3.3 System-Derived Counters and Digest Truncations

All content derivation uses BLAKE3-256 over a domain-separated preimage: the 8-byte domain tag is always the first bytes hashed. Two truncations recur, both taking the digest’s *leading* bytes big-endian:

- $\text{trunc64}(d) = \text{u64} :: \text{from_be_bytes}(d[0..8])$ — the counter of a system-derived identifier;
- $\text{trunc128}(d) = \text{u128} :: \text{from_be_bytes}(d[0..16])$ — content-derived 128-bit identifiers.

The system-derived counter function is $\text{trunc64}(\text{BLAKE3}(\text{tag} \parallel \text{inputs}))$; the resulting identifier is $\text{from_parts}(\text{ReplicaId}::\text{SYSTEM_DERIVED}, \text{counter})$. Only a system domain tag (prefix MUSCS) may seed it. The ratified instances (governed by `app:bytes` and the cited requirements):

Identifier	Tag	Canonical inputs
Promoted VoiceId	MUSCSVCE	64-byte preimage: <code>staff_instance (16 BE) original_voice (16 BE) winning_op (16 BE) losing_op (16 BE)</code> . Core SYSTEM-PROMOTED VOICES.
System PitchId	MUSCSPCH	The pitch’s intrinsic canonical bytes (core requirement <code>req:graph:system-derived-pitch-id</code>).
IntegrityAnomalyId	MUSCSANM	The anomaly kind’s canonical bytes (Chapter 6; core requirement <code>req:graph:integrity-anomaly-id</code>).

The 128-bit content-derived identifiers:

Identifier	Tag	Preimage after the tag
ConflictId	MUSCCONF	<code>kind.canonical_bytes()</code> causing operations (each 16 BE, sorted by canonical bytes) affected objects (each <code>TypedObjectId</code> canonical bytes, sorted); <code>trunc128</code> . Wire form of the id itself: 16 big-endian bytes.

Identifier	Tag	Preimage after the tag
ManifestId	MUSCMNIF	document_id (16) generation (u64 LE) manifest body bytes (body excludes the manifest_id field); trunc128. Restated normatively in Chapter 7 (core requirement req:format:manifest-id). Note the <i>on-disk</i> field encodes little-endian (Chapter 7).
EnvelopeHash	MUSCENVH	The envelope’s complete canonical bytes; the full 32-byte digest (no truncation). Chapter 6.
LayoutObjectId	MUSCLOID	Non-canonical; three preimage shapes, Chapter 10 (core requirement req:layoutir:object-id-derivation).
BlobId	MUSCBLOB	The blob payload, bare (req:format:blob-hash-shape); full 32-byte digest. Chapter 4.

3.4 The Domain-Tag Registry

Every domain tag is exactly 8 printable-ASCII bytes beginning `MUSC`; the vocabulary is closed (governed by `app:bytes`, `DOMAIN-TAG REGISTRY`). Extension system tags **MUST** begin `MUSCS`, be exactly 8 bytes, and collide with neither the built-ins nor the file magics.

Tag	Name	Use
MUSCCHNK	chunk	non-manifest chunk hash preimages
MUSCMANI	manifest	manifest chunk hash preimages
MUSCBLOB	blob	BlobId (bare <i>tag</i> <i>payload</i>)
MUSCCONF	conflict	ConflictId derivation
MUSCENVH	envelope	EnvelopeHash
MUSCFNTM	font metrics	glyph-catalog metrics hash (non-canonical)
MUSCMNIF	manifest id	ManifestId derivation
MUSCSVCE	system voice	promoted-voice counters
MUSCSPCH	system pitch	system-derived pitch counters
MUSCSANM	system anomaly	IntegrityAnomalyId
MUSCLOID	layout object id	LayoutObjectId (non-canonical)
MUSCBND\0	bundle magic	file magic, <i>not</i> a hash tag (note the trailing NUL)
MUSCSUPR	superblock magic	slot magic, <i>not</i> a hash tag

3.5 SnapshotId

The core specification’s support-type identity table says “*the Binary Format companion defines the exact derivation*” of `SnapshotId`. `vo` has no snapshot producer — pruning and canonical-base creation are deferred — so there is nothing to derive *from* yet.

REQUIREMENT

In schema major 0, `SnapshotId` is an **opaque 16-byte identifier**: 16 raw bytes on the wire (Chapter 4), with no normative derivation function. Readers **MUST** treat two `SnapshotIds` as equal iff their 16 bytes are equal and **MUST NOT** attempt to derive or verify a snapshot id from snapshot content.

OPEN QUESTION

The `SnapshotId` derivation (presumably a content derivation in the `trunc128` family, over the snapshot's canonical payload and its covering frontier) is deferred together with the pruning/garbage-collection track that will produce the first snapshots. It must be pinned before any writer emits a `canonical_base`; until then the opaque reading above is complete.

Primitive Value Encodings

The leaf encodings owned by the determinism layer and the small fixed identifier types. These byte forms are what the framings of Chapters 5–7 embed.

Type	Width	Encoding
CanonicalF64	8	IEEE-754 binary64, little-endian. -0.0 is canonicalized to $+0.0$ at construction, so the negative-zero bit pattern never appears in canonical bytes. Decode rejects NaN and $\pm\infty$ (non-finite floats are corruption).
QuantizedCoord	8	i64 little-endian, in units of $1/1024$ staff space (<code>STAFF_SPACE_GRID = 1024</code>). Construction from a float rounds ties-to-even and rejects non-finite or out-of-range input.
ContentHash	32	Raw BLAKE3-256 digest bytes.
ChunkId	32	Raw digest bytes (a <code>ContentHash</code> newtype).
DomainTag	8	The raw ASCII tag bytes. Decode validates against the closed vocabulary of Section 3.4; foreign bytes are a decode error.
WallClockTime	8	i64 little-endian, nanoseconds. Floating-point wall-clock time is forbidden in stored data.
WallClockDuration	8	i64 little-endian, nanoseconds.
SchemaVersion	4	major u16 LE minor u16 LE.
SemVer	12	major u32 LE minor u32 LE patch u32 LE. Canonical ordering of <code>SemVer</code> -keyed collections is numeric on (<i>major, minor, patch</i>), never byte-lexicographic on the little-endian encoding (which would order <code>256.0.0</code> before <code>1.0.0</code>).
Reduction	4	u32 little-endian.
AlgorithmVersion	4	u32 little-endian.
FileUuid, DocumentId, LineageId, SnapshotId, ExtensionId, ProfileRegistryId	16	16 raw opaque bytes each. No internal structure is interpreted; equality is byte equality.
BlobId	32	Raw digest bytes: <code>BLAKE3(MUSCBLOB payload)</code> , the only bare <i>tag payload</i> content hash in the format (core requirement <code>req:format:blob-hash-shape</code>).
FrontierBytes	var	u32 LE length opaque bytes (an ops-computed causal frontier the bundle carries verbatim).

4.1 RationalTime

Restating core requirement `req:format:rationaltime-encoding`, which governs. `RationalTime` is an arbitrary-precision rational, always stored *reduced* (equal rationals encode identically; the sign lives on the numerator; the denominator is strictly positive). Its canonical byte form:

Field	Encoding
sign	1 byte: 0 = zero, 1 = positive, 2 = negative
numerator	u32 LE magnitude byte length big-endian magnitude bytes
denominator	u32 LE magnitude byte length big-endian magnitude bytes

`Decode` rejects a sign byte greater than 2, a zero denominator, and trailing bytes. `MusicalPosition` and `MusicalDuration` are newtypes whose canonical bytes are exactly their inner `RationalTime`'s. Wall-clock integers deliberately do *not* use this form: they are the fixed-width little-endian integers of the table above, matching `QuantizedCoord`'s convention.

Graph Value Layouts

This chapter defines the schema-major-0 wire form of every value reachable from a `Score` — the whole-document composite codec. The core specification’s `DECISIONS` record (P11-4) held this codec *provisional* pending this companion; Requirement 5.1 and Requirement 5.6 **ratify** it: the reference implementation’s layout, as specified here, *is* the schema-major-0 wire form, and P11-4’s provisional status is discharged.

All layouts in this chapter are regime (a): little-endian, `u32` prefixes.

5.1 The Score Envelope

REQUIREMENT

The canonical bytes of a `Score` are the bare positional concatenation of its nineteen fields’ encodings, in exactly this order:

1. `metadata`
2. `canvas`
3. `instruments`
4. `staves`
5. `staff_groups`
6. `parts`
7. `cross_cutting`
8. `time_signatures`
9. `tuning_context`
10. `tempo_map`
11. `events`
12. `spelling_attachments`
13. `decomposition_attachments`
14. `spelling_precedence`
15. `analysis_layers`
16. `views`

- 17. identity
- 18. tombstoned_pitches
- 19. tombstoned_events

There is **no magic** and **no version prefix** at the value level: format identification lives in the bundle’s fixed header (Chapter 7) and versioning lives at the chunk layer (SchemaVersion in every ChunkRef and superbloc; Chapter 9). Decoders **MUST** reject trailing bytes after the nineteenth field.

5.2 Composition Rules as Normative Encoding Facts

The reference codec is built from a small set of conventions; each is a normative statement about the bytes, not an implementation detail:

Positional structs. Every struct in this chapter encodes as its fields in declaration order, unframed (Section 2.2). Zero-field structs encode as zero bytes.

C-style enums. A fieldless enum is a single discriminant byte (tables in Section 5.3).

Tagged unions. A discriminant byte, then the variant’s fields positionally.

Leaf framing. The determinism-canonical leaf types — ReplicaId, OperationId, every embedded typed graph identifier (EventId, PitchId, VoiceId, StaffId, StaffInstanceId, StaffGroupId, RegionId, InstrumentId, PartDefinitionId, MeasureId, BarlineAlignmentGroupId, SlurId, TieId, BeamId, SpannerId, TupletId, MarkerId, AnalyticalAnnotationId, CommentId, RepeatStructureId, LyricLineId, ChordSymbolId, GraphicObjectId, GraphicGestureId, TimeSignatureId, AnalysisLayerId, ViewId) — plus ContentHash, CanonicalF64, RationalTime, MusicalPosition, MusicalDuration, WallClockTime, and WallClockDuration, are each emitted as u32 LE length || the leaf’s canonical bytes (Chapters 3 and 4). An embedded 16-byte identifier therefore occupies 20 bytes inside a Score. Decode runs the leaf’s own validating decoder over the framed region.

Catalog identifiers. The catalog_id newtypes (PitchSpaceId, TuningSystemId, AccidentalId, registry-name ids, ...) encode as their stored NFC string under the String rule (u32 LE length || UTF-8).

EventArena. u32 LE event count, then each Event in ascending-EventId order (identity travels inside each event; the arena adds no per-event framing).

Validated reconstruction. Types with checked constructors decode through them: TupletRatio rejects degenerate ratios, KeySignature encodes its fifths() as i8 and rejects out-of-range values, TimeSignature re-validates that beat groups sum to the measure duration, NonZeroU16 rejects zero, EventOrderingDAG rejects cyclic edge maps, ReferencePitch, Tempo, and SpellingPrecedence re-validate their invariants. Structurally well-formed bytes that fail a type invariant are a decode error (reject-never-normalize).

5.3 Discriminant Tables

The complete discriminant assignment for schema major 0. Every table is governed by Requirement 5.6: an unknown discriminant is a decode error; changes are gated by Chapter 9.

5.3.1 C-style enums (one byte, no payload)

Type	Discriminants
MeasurePosition	0 Start, 1 End
RegionEdge	0 Start, 1 End
CmnNominal	0 C, 1 D, 2 E, 3 F, 4 G, 5 A, 6 B
SpellingSourceKind	0 UserChosen, 1 Imported, 2 Propagated, 3 Inferred, 4 Analytical
TempoShape	0 Constant, 1 Linear, 2 Exponential, 3 Curve
StemDirection	0 Up, 1 Down
MeasureNumberVisibility	0 Auto, 1 Always, 2 Never
Aleatoric	0 Musical, 1 WallClock, 2 EitherPerEvent, 3 FreelyMixed
AnchoringDiscipline	
NoteValue	0 Whole, 1 Half, 2 Quarter, 3 Eighth, 4 Sixteenth, 5 ThirtySecond, 6 SixtyFourth
ClefShape	0 G, 1 F, 2 C, 3 Percussion

5.3.2 Tagged unions (one byte, then the variant payload)

Type	Discriminants
AnchorOffset	0 Musical, 1 WallClock, 2 Zero
TimeAnchor	0 Event, 1 Measure, 2 Region, 3 WallClock (Section 5.4)
EventPosition	0 Musical, 1 WallClock
ConcreteDuration	0 Musical, 1 WallClock
EventDuration	0 Musical, 1 WallClock, 2 Indeterminate
TimeBounds	0 MusicalRange, 1 WallClockRange, 2 Unbounded
PitchSpacePosition	0 Cmn, 1 Integer, 2 JiVector, 3 Registered
TuningReference	0 Inherit, 1 Explicit
AcousticRealization	0 Implicit, 1 CentsOffset, 2 AbsoluteHz
SpellingNominal	0 Cmn, 1 Integer, 2 Registered
SpellingSource	0 UserChosen, 1 Inferred, 2 Imported, 3 Propagated, 4 Analytical
SpellingScope	0 Pitch, 1 Range
SpellingDirective	0 Explicit, 1 Rule
VoiceSelector	0 All, 1 Voices
GraceKind	0 Acciaccatura, 1 Appoggiatura, 2 Unmeasured, 3 Measured-Fraction
IndeterminacyKind	0 Pitch, 1 Duration, 2 Choice, 3 Compound
TrajectoryEndpoint	0 EventPitch, 1 ExplicitPitch
TrajectoryShape	0 Linear, 1 Exponential, 2 Curve, 3 Stepwise
Event	0 Pitched, 1 Unpitched, 2 Rest, 3 Indeterminate, 4 Trajectory, 5 Graphic, 6 Cue (Section 5.4)
RegionTimeModel	0 Metric, 1 Proportional, 2 Aleatoric
RegionContent	0 StaffBased, 1 FreeGraphic, 2 Hybrid

Type	Discriminants
VoiceOrigin	0 UserDeclared, 1 Imported, 2 SystemPromoted
StaffGroupKind	0 GrandStaff, 1 Bracket, 2 SubBracket, 3 Choral, 4 Registered
TieClass	0 Standard, 1 Editorial, 2 CrossVoice, 3 LaissezVibrer, 4 Registered
AnnotationAnchor	0 Event, 1 Range, 2 Region
GestureAnchoring	0 Events, 1 Range, 2 Free
DecompositionSource	0 UserChosen, 1 Inferred, 2 Imported, 3 Propagated
TimeSignatureDisplay	0 Standard, 1 Compound, 2 Irrational, 3 MixedDenominators, 4 None, 5 Symbolic

REQUIREMENT

The `SpellingSource` / `SpellingSourceKind` trap. These two vocabularies name the same five provenance concepts but assign them *different* discriminants: `SpellingSourceKind` (the C-style precedence-list element) is 0 UserChosen, 1 Imported, 2 Propagated, 3 Inferred, 4 Analytical, while `SpellingSource` (the payload-carrying attachment provenance) is 0 UserChosen, 1 Inferred, 2 Imported, 3 Propagated, 4 Analytical. The orders differ (`Inferred` is 3 in one and 1 in the other), both are golden-locked, and an implementation **MUST NOT** share one discriminant function between them.

5.4 Representative Complete Layouts

The following layouts are spelled byte-by-byte both as worked examples of the composition rules and as normative fact. Recall that inside this chapter’s codec every leaf is framed (`u32 LE length || bytes`), so an embedded 16-byte identifier occupies $4 + 16 = 20$ bytes.

5.4.1 RationalTime

As a leaf inside a composite: `u32 LE length || the canonical form of Section 4.1 (sign || length-prefixed big-endian numerator magnitude || length-prefixed big-endian denominator magnitude)`.

5.4.2 TimeAnchor

One discriminant byte, then:

0 Event `id (EventId leaf, 20) || offset (AnchorOffset: tag byte, then for Musical a MusicalDuration leaf, for WallClock a WallClockDuration leaf ( $4 + 8 = 12$ ), for Zero nothing)`.

1 Measure `id (MeasureId leaf, 20) || position (MeasurePosition, 1) || offset (AnchorOffset)`.

2 Region `id (RegionId leaf, 20) || edge (RegionEdge, 1) || offset (AnchorOffset)`.

3 WallClock `time (WallClockTime leaf, 12)`.

5.4.3 Pitch

Positional struct: `scale_position` || `acoustic`.

- `ScalePosition` = `space` (`PitchSpaceId`: NFC string, u32 LE length || UTF-8) || `position` (`PitchSpacePosition`: tag byte, then `Cmn` = nominal (`CmnNominal`, 1) || `alteration` (i8, 1) || `octave` (i8, 1); `Integer` = `space_size` (u16 LE, 2) || `index` (i32 LE, 4); `JiVector` = u32 LE count || that many i32 LE components; `Registered` = a catalog-id string).
- `AcousticPitch` = `tuning` (`TuningReference`: tag byte; Explicit carries a `TuningSystemId` catalog-id string) || `realization` (`AcousticRealization`: tag byte; `CentsOffset` and `AbsoluteHz` each carry a `CanonicalF64` leaf, $4 + 8 = 12$).

5.4.4 Event

One discriminant byte (0–6), then the variant struct positionally. All seven variants share the prefix `id` (`EventId` leaf) || `voice` (`VoiceId` leaf) || `position` (`EventPosition`) || `duration` (`EventDuration`); the remaining fields, in order:

Disc	Variant	Fields after the common prefix
0	Pitched	<code>pitches</code> <code>articulations</code> <code>dynamic</code> <code>ornaments</code> <code>stem</code> <code>grace</code>
1	Unpitched	<code>staff_position</code> <code>instrument_member</code> <code>articulations</code> <code>dynamic</code> <code>stem</code> <code>grace</code>
2	Rest	<code>vertical_position</code> <code>visible</code>
3	Indeterminate	<code>indeterminacy</code> <code>hints</code>
4	Trajectory	<code>start</code> <code>end</code> <code>shape</code> <code>display</code>
5	Graphic	<code>graphics</code> <code>playback_bindings</code>
6	Cue	<code>source</code> <code>rendering</code>

Each field encodes under this chapter’s rules for its type (vectors are u32-counted, options carry a presence byte, embedded identifiers are leaves, unions carry their tag byte).

5.4.5 Slur

Positional struct of three leaves: `id` (`SlurId` leaf, 20) || `start_event` (`EventId` leaf, 20) || `end_event` (`EventId` leaf, 20) — 60 bytes total.

5.5 The CanonicalValue Seam

The public per-value codec — the seam between this document and the Operation Catalog’s value-typed payloads (Operation Catalog, VALUE-TYPED PAYLOADS, requirement `req:catalog:value-encoding`) — is defined for exactly these eighteen types:

`Event`, `Rest`, `Pitch`, `IdentifiedPitch`, `PitchSpelling`, `Tie`, `Slur`, `Beam`, `Spanner`, `RegionTimeModel`, `TimeAnchor`, `Region`, `StaffInstance`, `Voice`, `DecompositionAttachment`, `SpellingSourceKind`, `ScoreMetadata`, `MetricGrid`.

The seam introduces **no new bytes**: a value’s stand-alone canonical bytes are byte-for-byte the bytes the whole-Score codec embeds for that value. Stand-alone decode applies the same validation and rejects trailing bytes.

5.6 The Frozen-Layout Rule

REQUIREMENT

Frozen positional layouts (the schema-evolution keystone). Within schema major 0, every positional struct layout in this chapter is **frozen**: there is no field-addition mechanism at the value level — no per-field framing, no optional-field encoding, no trailing-field tolerance. Any change to any struct’s field *set* or field *order* is a schema-MAJOR change and requires a documented migration in this document’s revision history (Chapter 9). Appending a *new variant* to an **open** discriminant vocabulary is a schema-MINOR change under the rules of Chapter 9. At the value layer, the open vocabularies are those with a Registered **escape variant** — `PitchSpacePosition`, `SpellingNominal`, `StaffGroupKind`, `TieClass` — through which extensions attach without any wire change at all; every *other* union in Section 5.3 (including `Event`, `TimeAnchor`, `TimeSignatureDisplay`) is closed in vo and may grow only by an append ratified in a revision of this document. This rule ratifies the project’s staging decision that data-model payload expansion — `SlurKind`, beam geometry, voltas, instrument bodies, score-metadata growth, and their kin — lands as a coordinated schema-MAJOR revision of this document, not as ad-hoc field insertion.

Operation Wire Forms

This chapter pins the operation layer: envelopes, payloads, stamps, causal contexts, effects, and materialized state. It **ratifies** the encodings the ops crate’s `DECISIONS` record held as “provisional canonical encoding” (mirroring core P11-4); that provisional status is discharged.

Regime (a) applies, with one composition difference from Chapter 5: the operation layer embeds *fixed-width* canonical leaves (identifiers, hashes, `ConflictId`) **raw**, without a length prefix (`push_canon`); only variable-width parts carry `u32` LE length prefixes (`push_lp_bytes`). Sequences (`push_seq`) are a `u32` LE count, then each element individually length-prefixed (`u32` LE), regardless of element width. Text (`push_str`) is NFC-normalized at encode time, then length-prefixed UTF-8. Embedded graph values are the `CanonicalValue` bytes of Section 5.5, framed by a `u32` LE length prefix (Operation Catalog requirement `req:catalog:value-encoding`).

6.1 The Operation Envelope

REQUIREMENT

An `OperationEnvelope`’s canonical bytes are, in order:

Field	Encoding
<code>id</code>	<code>OperationId</code> , 16 big-endian bytes, raw
<code>author</code>	<code>AuthorId</code> , 16 big-endian bytes, raw
<code>stamp</code>	<code>OperationStamp</code> , 28 bytes (Section 6.5)
<code>causal_context</code>	<code>CausalContext</code> (Section 6.5)
<code>transaction</code>	option tag byte (0 absent / 1 present), then <code>TransactionId</code> 16 BE if present
<code>payload</code>	<code>OperationPayload</code> (Section 6.2)

Id-leads property. The envelope’s first 16 bytes *are* the `OperationId`’s canonical bytes. This is load-bearing: the operation index (Chapter 7, Section 7.6) keys its entries on those leading 16 bytes without decoding envelopes, and the sanctioned partial read (*peek*) of an envelope is exactly its leading 16 bytes. Any future envelope revision **MUST** preserve id-leads or revise the operation index in the same schema-major step.

`EnvelopeHash` = `BLAKE3`(`MUSCENVH` || *envelope canonical bytes*) — the full 32-byte digest.

Envelopes are **encode-only** at this layer, deliberately: once committed, an envelope is stored and transported as opaque bytes and is never reconstructed into typed form by the storage layer; the peek above is the only sanctioned partial read. (Reducers decode payloads they authored or received through the ops layer’s own typed surface; the wire contract is that stored envelope bytes are preserved verbatim, since `EnvelopeHash` commits to them.)

6.2 OperationPayload and the Meta-Operations

`OperationPayload`: one discriminant byte, then the variant.

Disc	Variant	Payload
0	Primitive	an <code>OperationKind</code> (Section 6.3)
1	ResolveConflict	target (ConflictId, 16 BE) action (ResolutionAction)
2	UndoTransaction	target (TransactionId, 16 BE) policy (UndoPolicy, 1 byte)
3	ResolveEquivocation	target (OperationId, 16 BE) chosen (EnvelopeHash, 32)

Discriminants 0–2 are the ratified v1 values; 3 was appended by the catalog’s `RESOLVEEQUIVOCATION` (META-OPERATION) entry. The vocabulary is append-only: new meta-operations take ≥ 4 .

`UndoPolicy` is one byte: 0 `StrictInverse`, 1 `BestEffort`, 2 `Cascade`. `ResolutionAction` is one byte then an optional payload (app:bytes, core requirement req:semops:resolution-action-discriminants): 0 `AcceptLoser`, 1 `KeepWinner`, 2 `Override` (|| `OperationId` 16 BE), 3 `Reanchor` (|| `TypedObjectId`), 4 `Dismiss`, 5 `Registered` (|| `ResolutionRegistryId` 16 BE).

6.3 OperationKind: the Primitive Wire Discriminants

REQUIREMENT

The `OperationKind` wire discriminant is one byte, golden-locked to the table below. The vocabulary is **append-only**: new primitive kinds take discriminants past 27; the assignments below never change.

Each row also pins the payload’s byte layout; the field *set and order* is the Operation Catalog’s (the cited section governs semantics). “lp(*T*)” means the `u32`-LE-length-prefixed `CanonicalValue` bytes of a `T` (Section 5.5); bare identifiers are raw 16 big-endian bytes; “seq[↑]” is a `push_seq` sequence sorted ascending by canonical bytes.

Disc	Kind	Payload layout	Catalog section
0	InsertEvent	staff_instance (16) lp(Event)	INSERTEVENT
1	DeleteEvent	event (16) TupleCompensation	DELETEEVENT
2	RespellPitch	pitch (16) lp(PitchSpelling)	RESPELLPITCH
3	CreateCrossCutting	CrossCuttingValue	CREATECROSSCUTTING

Disc	Kind	Payload layout	Catalog section
4	ChangeRegionTimeModel	region (16) lp(RegionTimeModel) seq [↑] (EventId) PositionRemapping	CHANGEREGION TIMEMODEL
5	SetUserSystemBreak	region (16) lp(TimeAnchor) present (bool, 1)	SETUSERSYSTEMBREAK
6	DeclareTransaction	id (16) label (NFC string) option tag TransactionCategory if present	DECLARETRANSACTION
7	Registered	OperationKindRegistryId (16) lp(opaque bytes)	K1 — FRAMEWORK SLOTS
8	ModifyEvent	lp(Event)	MODIFYEVENT
9	Transpose	seq [↑] (PitchId) chromatic_steps (i32 LE, 4)	TRANPOSE
10	InsertIdentifiedPitch	event (16) lp(IdentifiedPitch)	IDENTIFIED-PITCH OPERATIONS
11	DeleteIdentifiedPitch	pitch (16)	IDENTIFIED-PITCH OPERATIONS
12	ModifyIdentifiedPitch	pitch (16) lp(Pitch)	IDENTIFIED-PITCH OPERATIONS
13	DeleteCrossCutting	structure (TypedObjectId, 18/34)	DELETECROSSCUTTING
14	ModifyCrossCutting	CrossCuttingValue	MODIFYCROSSCUTTING
15	CreateRegion	lp(Region)	STRUCTURAL CONTAINERS
16	DeleteRegion	region (16)	STRUCTURAL CONTAINERS
17	CreateStaffInstance	region (16) lp(StaffInstance)	STRUCTURAL CONTAINERS
18	DeleteStaffInstance	staff_instance (16)	STRUCTURAL CONTAINERS
19	CreateVoice	staff_instance (16) lp(Voice)	STRUCTURAL CONTAINERS
20	DeleteVoice	voice (16)	STRUCTURAL CONTAINERS
21	SetMetadata	lp(ScoreMetadata)	SCORE SETTINGS
22	SetMetricGrid	region (16) option tag (0/1) lp(MetricGrid) if present	SCORE SETTINGS
23	SetUserPageBreak	region (16) lp(TimeAnchor) present (bool, 1)	SCORE SETTINGS
24	CreateStaff	lp(Staff)	CREATESTAFF
25	SetTimeSignature	region (16) lp(TimeAnchor) option tag (0/1) lp(TimeSignature) if present	METER AND TEMPO OVERWRITES
26	SetTempoSegment	option tag region (16) if present lp(TimeAnchor) option tag lp(TempoSegment) if present	METER AND TEMPO OVERWRITES
27	SetStaffLayout	staff_instance (16) option tag instrument_override (16) if present option tag lp(StaffLineConfiguration) if present visible (bool, 1)	SETSTAFFLAYOUT

Sub-vocabularies used above (one discriminant byte, then the listed payload):

TupletCompensation. 0 NotInTuplet (empty); 1 ReplaceWithRest || lp(Rest); 2 RewriteTuplets || seq[↑](TupletId); 3 CascadeDeleteTuplets || seq[↑](TupletId).

CrossCuttingValue. 0 Tie, 1 Slur, 2 Beam, 3 Spanner; in every case the tag is followed by lp(the typed structure’s CanonicalValue bytes).

PositionRemapping. 0 PreserveTime (empty); 1 Reassign || u32 LE entry count || entries, each EventId (16, raw) || lp(MusicalPosition), ascending by EventId.

TransactionCategory. 0 NoteEntry, 1 Structural, 2 Layout, 3 Import, 4 Registered || OperationKindRegistryId (16 BE) — governed by app:bytes (core requirement req:semops:transaction-category).

OperationKind is encode-only at the storage boundary, like the envelope that carries it.

6.4 OperationKindTag: a Separate Discriminant Space

REQUIREMENT

OperationKindTag — the payload-free projection of an operation kind, stored by edit barriers (Chapter 8) — has its **own** discriminant space, assigned independently of Section 6.3, with both encode and validating decode. One byte; only Registered carries a payload (its OperationKindRegistryId, 16 big-endian bytes, total 17). Unknown discriminants and wrong lengths are decode errors. Append-only past 27.

Disc	Tag	Disc	Tag
0	InsertEvent	12	DeleteStaffInstance
1	DeleteEvent	13	SetUserSystemBreak
2	ModifyEvent	14	SetUserPageBreak
3	RespellPitch	15	DeclareTransaction
4	Transpose	16	Registered
5	CreateCrossCutting	17	InsertIdentifiedPitch
6	DeleteCrossCutting	18	DeleteIdentifiedPitch
7	ModifyCrossCutting	19	ModifyIdentifiedPitch
8	ChangeRegionTimeModel	20	CreateVoice
9	InsertRegion	21	DeleteVoice
10	DeleteRegion	22	SetMetadata
11	InsertStaffInstance	23	SetMetricGrid
24	InsertStaff	25	SetTimeSignature
26	SetTempoSegment	27	SetStaffLayout

Naming mapping. The kind-to-tag projection renames three pairs: OperationKind::CreateRegion projects to OperationKindTag::InsertRegion, and OperationKind::CreateStaffInstance projects to OperationKindTag::InsertStaffInstance, and OperationKind::CreateStaff projects to OperationKindTag::InsertStaff. The mismatch is intentional (the tag space predates the M2c naming) and is pinned here so barrier authors target the right tag.

6.5 Stamps and Causal Contexts

HybridLogicalClock: physical_time (WallClockTime, i64 LE, 8) || logical_counter (u32 LE, 4). OperationStamp: hlc (12) || id (OperationId, 16 BE) — **28 bytes total, fixed width**. The canonical reduction tuple orders stamps as (physical_time, logical_counter, replica, counter), ascending; the replica comparison equals big-endian byte order.

CausalContext (dotted version vector):

Field	Encoding
vector	u32 LE entry count entries, each replica (8 BE) counter (u64 LE, 8), ascending by replica
dots	u32 LE count OperationIds (16 BE each), ascending

The vector is *zero-based-floor* (P11-C7): an entry (r, c) covers counters $0.. = c$ of replica r ; absence of a replica covers nothing.

6.6 Effects, Conflicts, Anomalies, and Materialized State

These types are canonical *materialized* facts: they appear in `MaterializedState`’s canonical bytes, so their discriminants and layouts are normative wire facts even though they are never stored inside envelopes. All decode validation is performed by the ops layer’s validating decoder; unknown discriminants, bad lengths, non-canonical orders, and trailing bytes are decode errors.

Type	Layout (tag byte, then payload)
OperationEffect	0 Applied (empty); 1 AppliedWithRepair seq(RepairRecord); 2 Conflicted ConflictId (16 BE); 3 TombstonedTarget TypedObjectId; 4 NoOp NoOpReason.
NoOpReason	0 TargetTombstoned; 1 AlreadyApplied; 2 SupersededByLaterOperation OperationId (16 BE); 3 PreconditionFailedUnderReduction PreconditionFailureReason; 4 TransactionConflict.
PreconditionFailureReason	0 TargetMissing; 1 TargetTombstoned; 2 WrongRegionTimeModel; 3 TupletCompensationInvalid; 4 EventDurationInvalid; 5 PositionOutsideRegion; 6 PitchSpaceMismatch; 7 VoiceMissing; 8 ExtensionPrecondition id (16 BE); 9 Registered id (16 BE); 10 ContainerNotEmpty; 11 TempoMapMalformed.
RepairRecord	(struct) kind (RepairKind) target (TypedObjectId).
RepairKind	0 Reanchored from (TypedObjectId) to (TypedObjectId) ReanchorReason; 1 SpannerTruncated seq(TypedObjectId); 2 Orphaned; 3 CascadeDeleted; 4 AttachmentTombstoned; 5 VoicePromoted from (VoiceId, 16 BE) to (VoiceId, 16 BE); 6 TupletCompensated TupletCompensationKind; 7 Registered id (16 BE).
ReanchorReason	0 SameVoiceNearer; 1 SameStaffInstanceNearer; 2 SameStaffNearer; 3 SameRegionNearer; 4 ExplicitFallback; 5 DeclaredByExtension id (16 BE).
TupletCompensationKind	0 ReplaceWithRest; 1 RewriteTuplets; 2 CascadeDeleteTuplets. (No payload; distinct from the payload-carrying <code>TupletCompensation</code> of Section 6.3.)
PendingReason	tag blocker (OperationId, 16 BE) in every variant: 0 MissingCausalPredecessor; 1 DependsOnEquivocated; 2 DependsOnExcluded; 3 DependsOnPending; 4 HaltedBySystemCollision.
ConflictKind	0 StructuralFieldCollision winner (16 BE) loser (16 BE) FieldPath (NFC string); 1 TransactionConflict transaction (16 BE) seq [†] (OperationId); 2 TombstonedTarget TypedObjectId OperationId (16 BE); 3 ReanchorFailure original_referent (TypedObjectId) referencing_object (TypedObjectId); 4 TimeModelMigrationFailure region (16 BE) seq [†] (TypedObjectId); 5 ExtensionConflict kind_id (16 BE) lp(opaque details).
ConflictResolutionState	0 Unresolved; 1 Resolved by (16 BE) ResolutionAction; 2 Dismissed by (16 BE).

Type	Layout (tag byte, then payload)
ConflictRecord	(struct) id (ConflictId, 16 BE) seq(caused_by: OperationId, stored sorted) kind seq(affected_objects: TypedObjectId, stored sorted) resolution_state.
IntegrityAnomaly	(struct) id (IntegrityAnomalyId, 16 BE) kind.
IntegrityAnomalyKind	0 SystemIdentifierCollision ObjectKind colliding_counter (u64 LE) the two input-set blobs, each lp(bytes), emitted lo ≤ hi by byte comparison; 1 OperationSlotEquivocated OperationId (16 BE); 2 ReplicaStreamQuarantined replica (8 BE) first_bad_counter (u64 LE); 3 Registered id (16 BE).
AnomalousReplicaSegment	(struct) replica (8 BE) first_bad_counter (u64 LE) ReplicaAnomalyReason (0 HlcMonotonicityViolation two OperationIds; 1 Registered id 16 BE) seq(excluded: OperationId, ascending counter).
FieldPath	an NFC string (u32 LE length UTF-8).
ObjectState	0 Live (empty); 1 Tombstoned deleted_by (OperationId, 16 BE) minted_by (OperationId, 16 BE).
ObjectKind (ops)	0 Voice; 1 Pitch; 2 Registered OperationKindRegistryId (16 BE) — governed by app:bytes (core requirement req:graph:object-kind-vocab). Distinct from the barrier layer’s 2-byte ObjectKind (Chapter 8).

6.6.1 MaterializedState

The canonical bytes of a reduction’s materialized state are eight sections, concatenated; every section is u32-LE-counted (the conflict registry carries its own count) and in the stated normative order, so the bytes are identical across any permutation of the input operation set:

1. **effects** — count, then per entry OperationId (16 BE, raw) || lp(OperationEffect); in canonical reduction order;
2. **conflict registry** — a seq of lp(ConflictRecord), ascending ConflictId;
3. **anomalies** — count, then each lp(IntegrityAnomaly), ascending IntegrityAnomalyId;
4. **objects** — count, then per entry TypedObjectId (raw) || ObjectState, ascending TypedObjectId;
5. **spellings** — count, then per entry PitchId (16 BE, raw) || lp(PitchSpelling), ascending PitchId;
6. **breaks** — count, then per entry RegionId (16 BE, raw) || MusicalPosition (raw RationalTime form, self-describing, *not* leaf-framed) || present (bool, 1); ascending (region, position);
7. **page breaks** — same shape and order as breaks;
8. **pending** — count, then per entry OperationId (16 BE, raw) || PendingReason, ascending OperationId.

Decode is fully validating (orders, tags, lengths, trailing bytes) and rejects non-canonical input.

6.7 vo Payloads Have No Wire Form

The prototype’s vo identifier-projection payload types are an **in-memory migration guard only**: they carry no canonical encoding, and no vo wire form was ever shipped. The vo→v1

migration is *semantic* — typed value reconstruction, specified in the Operation Catalog’s `vo → v1` `PAYLOAD MIGRATION` chapter — not a byte-level translation, and nothing in this document defines bytes for a `vo` payload.

Bundle Physical Layout

The physical file: the fixed prelude, chunks, blocks, the manifest, and the operation index. This chapter **ratifies** the bundle crate’s provisional encodings (its `DECISIONS` entries `P11-D2`, `P11-D4`, and `P11-D5` pending-companion status is discharged) and the operation-index byte form (`P12-D1`). Structural *semantics* — superblock selection, commit protocol, recovery, retention — are core specification Chapter 8; this chapter pins bytes only. Regime (a) applies except where a table says otherwise.

7.1 The Fixed Header (64 bytes)

Offset 0 of every bundle. Written at creation, never rewritten within a format major version. All integers little-endian.

Range	Field	Value / rule
0..8	magic	MUSCBND\0 (8 bytes, ASCII, trailing NUL)
8..10	format_major (u16)	0 in this version; readers reject other values
10..12	format_minor (u16)	1 written in this version
12..16	header_length (u32)	64; readers reject other values
16..24	superblock_a_offset (u64)	64; readers reject other values
24..32	superblock_b_offset (u64)	320; readers reject other values
32..48	file_uuid	16 opaque bytes
48..60	reserved	written zero; ignored on read
60..64	header_crc	CRC-32C of bytes 0..60, u32 LE

Readers **MUST** verify the magic and the CRC before consulting any other part of the file.

7.2 The Superblock Slots (256 bytes each)

Two slots, at offsets 64 (A) and 320 (B); the only mutable on-disk objects. Selection *semantics* (highest valid committed generation, the equal-generation rule, torn-write fallback) are core Chapter 8, `SUPERBLOCK SELECTION`; the bytes:

Range	Field	Encoding
0..8	magic	MUSCSUPR (8 ASCII bytes)
8..16	generation	u64 LE

Range	Field	Encoding
16..24	manifest_offset	u64 LE
24..32	manifest_length	u64 LE (also the uncompressed length; the manifest is mandatorily uncompressed)
32..64	manifest_hash	32 raw digest bytes
64..68	manifest_schema_version	SchemaVersion (u16 LE u16 LE)
68..72	reduction_algorithm_version	u32 LE
72..92	profile_id	20 bytes: u32 LE discriminant (0 Full, 1 ReadOnly, 2 Lite, 3 Custom) ProfileRegistryId (16 raw bytes; writers MUST emit zero unless Custom, readers ignore it unless Custom). Core requirement req:format:profileid-discriminants.
92..100	commit_state	two u32 LE words: Committed = (0,0); any tag $\neq 0$ decodes as Reserved(value) and the slot is invalid for ordinary selection. Writers in this version MUST produce only Committed.
100..108	commit_timestamp	i64 LE nanoseconds; advisory — selection never consults it
108..252	reserved	written zero; ignored on read
252..256	superblock_crc	CRC-32C of bytes 0..252, u32 LE

7.3 Chunks

The bundle body begins at `BODY_START = 320 + 256 = 576`. A chunk’s on-disk form is its raw (possibly compressed) payload bytes at a byte offset — **no per-chunk length prefix, magic, or trailer on disk**; the offset, lengths, compression, and hash live in the referencing `ChunkRef`. A chunk reference whose offset is below `BODY_START` is malformed.

Content hash preimage (core Chapter 8, DOMAIN-SEPARATED PREIMAGES; governs identity):

$\text{BLAKE3}(\text{domain} \parallel \text{kind}(1) \parallel \text{schema}(4) \parallel \text{uncompressed_length}(\text{u64 LE}) \parallel \text{payload})$

where *domain* is `MUSCMANI` for Manifest chunks and `MUSCCHNK` otherwise. Compression is *not* in the preimage. Blob chunks are addressed by the bare `BlobId` form instead (Chapter 4).

ChunkKind is a single byte, a **closed** vocabulary (no Registered variant; core requirement req:format:chunkkind-discriminants): 0 OperationEnvelopeBlock, 1 OperationIndex, 2 Snapshot, 3 Blob, 4 ExtensionData, 5 TextProjection, 6 LayoutCache, 7 IntegrityIndex, 8 Manifest.

CompressionAlgorithm is a fixed two bytes, discriminant || parameter: None = (0,0); Zstd{level} = (1,level); Reserved(*v*) = (2,*v*). None is *not* a bare tag — its zero parameter byte is always present.

Read rules. Writers in this format version emit None only; *reading* zstd at any level is a conformance **MUST**. A zstd payload is decompressed into a buffer sized *exactly* by the declared `uncompressed_length` (checked against the reader’s resource policy before allocation): a

stream that would exceed the declaration, ends short of it, or carries trailing garbage is corruption. After decompression the content hash is verified over the uncompressed bytes, and $id = hash$ is checked. A chunk whose declared schema major differs from the reader’s supported major is rejected (Chapter 9). Reserved compression is rejected. The **manifest chunk is mandatorily uncompressed**: a compressed manifest reference is rejected before any bytes are read. The reference reader bounds any single chunk at 256 MiB (`MAX_CHUNK_BYTES`); the bound is reader policy, not a wire fact.

7.3.1 ChunkRef (95 bytes)

Range	Field	Encoding
0..32	<code>id</code>	32 raw digest bytes
32..33	<code>kind</code>	ChunkKind byte
33..37	<code>schema_version</code>	u16 LE u16 LE
37..45	<code>offset</code>	u64 LE
45..53	<code>compressed_length</code>	u64 LE
53..61	<code>uncompressed_length</code>	u64 LE
61..63	<code>compression</code>	2 bytes
63..95	<code>hash</code>	32 raw digest bytes (restates <code>id</code>)

The canonical sort key for chunk-reference collections is (*kind discriminant*, *hash*, *offset*), ascending — the Appendix-D chunk-reference order. Every set-valued `ChunkRef` field in this chapter is sorted by it and deduplicated before encoding.

7.4 Operation-Envelope Block Payloads

The uncompressed payload of an `OperationEnvelopeBlock` chunk:

u32 LE envelope count || per envelope {u32 LE byte length || envelope bytes}

Envelope bytes are opaque to the bundle (their internal form is Chapter 6). Each envelope’s offset — the byte offset of its *first content byte* within the uncompressed block payload, with its length prefix at *offset* − 4 — is deterministically recoverable from this framing alone; it is the coordinate the operation index records. Writers **SHOULD** begin a new block rather than let an uncompressed payload exceed 1 MiB (an individual envelope larger than that occupies its own block); readers **MUST** accept blocks up to the active profile’s bound (default 64 MiB). Block boundaries are storage artifacts: the envelope set is the union across blocks.

7.5 The Manifest

On-disk manifest chunk payload:

`manifest_id` (16 bytes, u128 *little-endian*) || *body*

(The little-endian on-disk field is a deliberate, golden-locked quirk: the *derivation* truncates big-endian like every content-derived id, but the bundle codec serializes the resulting u128 under its little-endian integer rule.)

REQUIREMENT

Restating core requirement `req:format:manifest-id`, which governs:

`ManifestId = trunc128(BLAKE3(MUSCMNIF || document_id || generation || body))`

with *document_id* as its 16 raw bytes, *generation* as u64 little-endian, and *body* the complete manifest body below (which itself opens with *document_id* and *generation* — the double commitment is intentional and locked). Writers re-derive the id from the body at encode time; decoders verify it.

The *body* is a positional struct of thirteen fields:

#	Field	Encoding and canonical order
1	<code>document_id</code>	16 raw bytes
2	<code>lineage_id</code>	option tag 16 raw bytes if present
3	<code>generation</code>	u64 LE
4	<code>operation_roots</code>	u32 LE count <code>ChunkRefs</code> , sorted by the canonical chunk-reference key, deduplicated
5	<code>operation_block_summaries</code>	u32 LE count entries { <code>chunk_id</code> (32) <code>OperationBlockSummary</code> }, ascending <code>chunk_id</code>
6	<code>operation_index_root</code>	option tag <code>ChunkRef</code>
7	<code>canonical_base</code>	option tag <code>SnapshotRef</code>
8	<code>acceleration_snapshots</code>	u32 LE count <code>SnapshotRefs</code> , sorted ascending by their full encoded bytes, deduplicated
9	<code>blob_roots</code>	u32 LE count <code>BlobRefs</code> , sorted ascending by encoded bytes, deduplicated
10	<code>profile_declarations</code>	u32 LE count <code>ProfileDeclarations</code> , sorted by the key (<code>profile_id</code> , <code>version</code>) with <code>SemVer</code> compared <i>numerically</i> , deduplicated
11	<code>extension_declarations</code>	u32 LE count <code>ExtensionDeclarations</code> , sorted by (<code>extension_id</code> , <code>version</code>), <code>SemVer</code> numeric, deduplicated
12	<code>text_projection_root</code>	option tag <code>ChunkRef</code>
13	<code>integrity_root</code>	option tag <code>ChunkRef</code>

Sub-records, positionally:

OperationBlockSummary = `dvv_summary` (`FrontierBytes`: u32-LE-prefixed opaque bytes) || `min_stamp` (u32-LE-prefixed opaque stamp bytes) || `max_stamp` (same). The contents are ops-computed (Chapter 6); the bundle carries them verbatim.

SnapshotRef = `snapshot_id` (16 raw) || `covers_causal_frontier` (`FrontierBytes`) || `reduction_algorithm_version` (u32 LE) || `profile_id` (20 bytes, as in the superblock) || `root` (`ChunkRef`, 95) || `hash` (32 raw).

BlobRef = `blob_id` (32 raw) || `media_type` (u32-LE-prefixed ASCII; decode validates a well-formed RFC 6838 type/subtype restricted name) || `offset` (u64 LE) || `compressed_length` (u64 LE) || `uncompressed_length` (u64 LE) || `compression` (2) || `hash` (32 raw) || `option tag` || `declared_max_uncompressed_length` (u64 LE) if present.

ProfileDeclaration = profile_id (20) || version (SemVer, 12) || constraints (ProfileConstraints = max_uncompressed_block_size (u64 LE) || RetentionPolicy). RetentionPolicy = retain_previous_manifests (u32 LE) || option tag || retain_duration (i64 LE) if present || retain_named_checkpoints (bool, 1).

ExtensionDeclaration = extension_id (16 raw) || version (SemVer, 12) || required (bool, 1) || u32 LE count || preserved_chunk_roots (ChunkRefs, canonical order, deduplicated) || affected_object_kinds (u32-LE-prefixed opaque blob) || edit_barriers (u32-LE-prefixed opaque blob). The two blobs' internal form is Chapter 8; the bundle preserves them verbatim.

REQUIREMENT

Reject non-canonical manifests. A decoder **MUST** accept a manifest payload only if re-encoding the decoded manifest reproduces the input byte-for-byte. This single check subsumes: the stored manifest_id matching the body-derived id, every set-valued vector being in its canonical order with no duplicates, and every optional field using presence byte 0/1. Unsorted, duplicated, or wrongly-identified manifest bytes are malformed — never re-sorted or repaired.

7.6 The Operation Index

REQUIREMENT

Operation-index payload (ratifies P12-D1). The uncompressed payload of an OperationIndex chunk is:

u32 LE block_count || that many ChunkRefs (95 bytes each, strictly ascending canonical order) || u32 LE entry_count || that many entries, each {id (16 raw operation-id bytes) || block (u32 LE ordinal into the block vector) || offset (u32 LE)}, strictly ascending by id bytes.

The empty index is exactly 8 zero bytes. offset is the byte offset of the envelope's *first content byte* within the uncompressed payload of the named block (the envelope's u32 length prefix sits at offset - 4) — well-defined by the id-leads property (Requirement 6.1) and the block framing (Section 7.4).

One slot per id. Strict ascent makes duplicate ids unrepresentable: an index payload containing two entries with equal id bytes is malformed. Equivocation candidates (multiple envelopes claiming one OperationId) live *inside* the operation set's slot model (core Chapter 6), never as duplicate index rows.

Staleness. An index *covers* a manifest iff its block vector equals the manifest's deduplicated, canonically sorted operation_roots under **full ChunkRef equality** — every field, not just the content hash, since the index hands out its stored references for reading. A reader that finds the index stale **MUST** reject it and rebuild from the blocks.

A rejected or stale index is **never bundle corruption**: the index is a non-canonical accelerator, and rebuild-from-blocks is always sound.

Decoders **MUST** reject: unsorted or duplicated blocks or entry ids, a block reference whose kind is not OperationEnvelopeBlock, an entry whose block ordinal is out of

range, and trailing bytes.

The core specification’s commit-time **SHOULD** — refresh the index when the operation log has “grown significantly” since it was built — has an **implementation-defined** threshold in vo: this document deliberately does not pin a number, and conforming writers may use any policy (including always or never refreshing at commit), because the index is non-canonical.

OPEN QUESTION

Whether to pin a normative refresh threshold (e.g. a block-count or byte-size ratio) or leave it permanently implementation-defined. Leaving it open costs only lookup performance on stale-index bundles; pinning it too early would constrain writers for no interoperability gain. Revisit when a second writer implementation exists.

Extension Declaration Blobs and Edit Barriers

The two opaque blobs a manifest `ExtensionDeclaration` carries — `affected_object_kinds` and `edit_barriers` — have their internal byte form pinned here. This chapter **ratifies** P12-E1 (the blob and barrier-tree byte form), P12-E2 (the recursion bound), and P12-E3 (the barrier `ObjectKind` representation). Barrier *semantics* — scope matching, prohibited-edit evaluation, conservative treatment of unknown extensions — are core Chapter 8 (FORWARD COMPATIBILITY AND EDIT BARRIERS); this chapter pins bytes only.

These layouts are **regime (b)**: all counts and length prefixes are `u64` little-endian — a deliberate, golden-locked divergence from the `u32` regime (Section 2.1).

8.1 Framing

element $\text{elem}(x) = \text{u64 LE byte length} \parallel x\text{'s canonical bytes}$.

set $\text{set}(xs) = \text{elements' canonical byte strings, sorted ascending byte-lexicographic and deduplicated; then u64 LE element count} \parallel \text{each element as elem}$. Order and repetition in the source collection cannot affect the bytes; decoders reject unsorted or duplicated elements.

list $\text{list}(xs) = \text{u64 LE count} \parallel \text{each element as elem, order-significant (used only for condition subtrees)}$.

REQUIREMENT

The two blobs (ratifies P12-E1). The `affected_object_kinds` blob is set of barrier `ObjectKind` elements; the `edit_barriers` blob is set of `EditBarrier` elements. Both decode under reject-never-normalize with trailing bytes forbidden.

REQUIREMENT

Barrier `ObjectKind` (ratifies P12-E3). A barrier `ObjectKind` is the `TypedObjectId` discriminant of Section 3.2, encoded as **2 little-endian bytes**. Decode is **open-value**: every `u16` decodes successfully — an unknown kind (a future core kind or an extension-

registered kind) is a *value*, not a decode branch, and simply never matches any object the reader knows. This is the format’s forward-compatibility stance for barrier kinds: unknown kinds are preserved and re-emitted verbatim, never dropped or rejected.

8.2 EditBarrier

An `EditBarrier`’s canonical bytes, positionally:

```
scope || set(affected_object_kinds: ObjectKind) || set(prohibited_operation_kinds:
              OperationKindTag, Section 6.4) || condition
```

`BarrierScope`: one discriminant byte, then the payload:

Disc	Variant	Payload
0	WholeScore	(none)
1	Region	RegionId, 16 big-endian bytes
2	StaffInstance	StaffInstanceId, 16 BE
3	AnalysisLayer	AnalysisLayerId, 16 BE
4	ObjectSet	set of TypedObjectId canonical bytes (18/34 each)
5	PitchSpace	u64 LE byte length the pitch-space id’s NFC UTF-8 bytes; decoders reject non-NFC input
6	TuningContext	(none)
7	Registered	BarrierScopeRegistryId, u128 <i>little-endian</i> (16 bytes)

`BarrierCondition`: one discriminant byte, then the payload; the tree is recursive:

Disc	Variant	Payload
0	Always	(none)
1	ObjectExists	TypedObjectId
2	ObjectHasExtensionData	object (TypedObjectId) extension (ExtensionRef, u128 LE, 16)
3	All	list of conditions
4	Any	list of conditions
5	Not	one elem-framed condition
6	Registered	BarrierConditionRegistryId, u128 LE (16)

Note the endianness: the barrier layer’s registry identifiers (`BarrierScopeRegistryId`, `BarrierConditionRegistryId`, `ExtensionRef`) encode u128 *little-endian*, unlike the big-endian identifier family of Chapter 3. This is part of the golden-locked regime-(b) surface.

REQUIREMENT

Recursion bound (ratifies P12-E2). `MAX_CONDITION_DEPTH = 64` is the normative bound on `BarrierCondition` nesting. Decoders **MUST** reject a condition tree nested deeper than 64 levels of All/Any/Not; writers **MUST NOT** emit one. The bound exists so adversarial bytes cannot drive unbounded recursion; real barriers are depth 1–2.

Schema Evolution

The core specification delegates schema evolution to this document (core Chapter 8, `SCHEMA VERSIONING`: “*Schema evolution is governed by the Binary Format companion specification, which defines the wire encoding for each schema version*”). This chapter defines the wire rules for schema major 0.

9.1 The Chunk-Level Gate

Every chunk declares a `SchemaVersion` (major, minor) in its `ChunkRef` and the superblock declares the manifest’s. The gate:

- **Major** = incompatible. A reader **MUST** reject a chunk whose schema major it does not support. The current major is 0.
- **Minor** = additive. `vo` readers verify the major only; the minor is a *record*, not a gate — but it is a mandatory record: a writer **MUST** raise the chunk schema minor when it emits any discriminant appended after the minor it otherwise declares, so that a decode failure on an unknown appended discriminant is attributable to a version skew rather than corruption.

9.2 What “Additive” Means Here

Under the frozen-layout rule (Requirement 5.6), positional struct layouts admit *no* additive change: there is no optional-field or trailing-field mechanism at the value level. In particular, and stated honestly: **the manifest body cannot grow a fourteenth field within major 0**. The manifest is a positional struct whose decoder rejects trailing bytes, so manifest-body extension is major-gated in `vo` exactly like every other struct.

The *only* minor-additive mechanism in schema major 0 is **appending discriminants to open vocabularies**:

- `OperationKind`: append at ≥ 24 (Requirement 6.3);
- `OperationKindTag`: append at ≥ 24 (Requirement 6.4);
- `OperationPayload`: append at ≥ 4 (Section 6.2);
- the value-layer unions enumerated as closed in Requirement 5.6 may gain appended variants only through a ratified revision of this document, also minor-additive.

ChunkKind is **closed** — it has no Registered variant and no append story inside major o, because its discriminant enters every chunk’s hash preimage; a new chunk kind is a format-major event.

Separately, many vocabularies carry a Registered *escape variant* (RepairKind, ReanchorReason, PreconditionFailureReason, IntegrityAnomalyKind, ReplicaAnomalyReason, TransactionCategory, ResolutionAction, ConflictKind via ExtensionConflict, BarrierScope/BarrierCondition, TieClass, StaffGroupKind, PitchSpacePosition, SpellingNominal, TypedObjectId, and the barrier ObjectKind’s open value space). Extension through an escape variant is **not** a schema change at all: the wire form is already defined.

9.3 Migration Discipline

A schema-MAJOR bump **MUST** ship with a migration documented in this document’s revision history (Chapter 12): what changed, byte-for-byte, and the deterministic translation from the old form. The precedent is the $v_0 \rightarrow v_1$ operation-payload migration, which lives in the Operation Catalog ($v_0 \rightarrow v_1$ PAYLOAD MIGRATION) because it was semantic rather than byte-level (Section 6.7); byte-level migrations belong here.

OPEN QUESTION

Whether the u_{64}/u_{32} length-prefix divergence between regimes (a) and (b) (Section 2.1) gets unified at the next schema major. Unification would simplify decoders and cost one coordinated re-lock of the barrier-blob and resolved-layout goldens; leaving it is free but permanent. Decide when the first major bump is scheduled for other reasons — the divergence alone does not justify one.

Non-Canonical Pinned Encodings

Non-canonical means: never part of document identity. Nothing in this chapter enters a content hash that canonical state depends on, and all of it can be discarded and rebuilt without changing the document. The encodings are pinned for *reproducibility* — byte-equal conformance claims and cache correctness — not for durability.

10.1 LayoutObjectId (MUSCLOID)

Governed by core requirement `req:layoutir:object-id-derivation`. `LayoutObjectId = trunc128(BLAKE3(MUSCLOID || inputs))`, with three preimage shapes:

stable *inputs* = the source `TypedObjectId`'s canonical bytes.

manifestation *inputs* = source canonical bytes || `RegionId` canonical bytes (16 BE) — distinct regions give one source distinct manifestation ids.

synthesized *inputs* = source canonical bytes || five u64 LE words: the `SynthesisKind` discriminant, the registry id's high and low 64 bits (zero unless `Registered`), and the instance key's high and low 64 bits.

`SynthesisKind` discriminants: 0 CancellationAccidental, 1 KeySignatureNatural, 2 GeneratedRest, 3 EngravedBreak, 4 MultimeasureRest, 5 Cautionary, 6 Registered.

10.2 ResolvedLayoutIR Canonical Output

The resolved layout's canonical bytes are the **byte-equal conformance surface** of core Chapter 7: two conforming engravers given the same score, profile, and glyph catalog must produce identical bytes. The encoding is regime (b) — u64 LE counts and length prefixes — with every geometric coordinate quantized to the 1/1024 staff-space grid as a `QuantizedCoord` (8 LE bytes; Chapter 4); a non-finite or out-of-range coordinate is a determinism violation and **MUST** be rejected, never normalized. The top-level section order is: source score version || pages || glyphs || strokes || engraving decisions || glyph-catalog identity; within each section, elements carry their provenance (built on `MUSCLOID` ids) and their quantized geometry. The full leaf grammar is pinned by the reference implementation's golden and round-trip anchors

(Chapter 11) rather than restated field-by-field here, because the surface is non-canonical and evolves with the engraving feature set.

10.3 Layout Caches and Font Metrics

LayoutCache chunks (ChunkKind 6) hold cached layout artifacts; they are **always discardable**, and a reader **MUST NOT** treat a missing, stale, or undecodable layout cache as bundle corruption. The glyph-metrics identity hash is domain-separated under MUSCFNTM (a reserved built-in, non-canonical tag): it names the metrics a layout was computed against, so caches and conformance runs can detect font drift; it never enters canonical state.

Golden Anchor Registry

The conformance contract binding this document to the reference implementation. Three lock classes:

literal-byte the test asserts exact expected bytes or exact discriminant literals — the strongest lock;

round-trip the test asserts `decode ◦ encode = id` and re-encode byte-stability over a corpus;

canonical-equality the test asserts that semantically equal values encode identically (order-independence, reduction identities).

The first block restates the anchors already recorded in the core specification’s `app:bytes` REFERENCE-IMPLEMENTATION LOCKS table (which governs them); the second block adds the anchors this document introduces, which `app:bytes` predates.

Each anchor names its crate file, then the test on a second line.

Layout	Anchor	Class
<i>Imported from <code>app:bytes</code>:</i>		
<code>TypedObjectId</code>	<code>epiphany-core/src/ids.rs</code> <code>::typed_object_id_byte_form_is_locked</code>	literal-byte
<code>Promoted VoiceId</code>	<code>epiphany-core/src/graph.rs</code> <code>::promoted_voice_id_byte_form_is_locked</code>	literal-byte
<code>System PitchId</code>	<code>epiphany-core/src/pitch.rs</code> <code>::system_pitch_id_byte_form_is_locked</code>	literal-byte
<code>IntegrityAnomalyId</code>	<code>epiphany-ops/src/anomaly.rs</code> <code>::integrity_anomaly_id_byte_form_is_locked</code>	literal-byte
<code>ObjectKind (ops)</code>	<code>epiphany-ops/src/support.rs</code> <code>::object_kind_discriminants_are_golden</code>	literal-byte
<code>ChunkKind</code>	<code>epiphany-bundle/src/chunk.rs</code> <code>::chunk_kind_discriminants_are_golden</code>	literal-byte
<code>CompressionAlgorithm</code>	<code>epiphany-bundle/src/chunk.rs</code> <code>::compression_algorithm_encoding_is_golden</code>	literal-byte
<code>ProfileId</code>	<code>epiphany-bundle/src/superblock.rs</code> <code>::profile_id_discriminants_are_golden</code>	literal-byte
<code>ManifestId</code>	<code>epiphany-bundle/src/ids.rs</code> <code>::manifest_id_is_content_derived_and_deterministic</code>	canonical-equality
<code>TransactionCategory</code>	<code>epiphany-ops/src/payload.rs</code> <code>::transaction_category_discriminants_are_golden</code>	literal-byte

Layout	Anchor	Class
ResolutionAction	epiphany-ops/src/conflict.rs ::resolution_action_discriminants_are_golden	literal-byte
BlobId	epiphany-determinism/src/hash.rs ContentHash::of_blob tests	round-trip
RationalTime	epiphany-core/src/time.rs ::equal_rationals_encode_identically	canonical-equality
MUSCLOUD derivation	epiphany-layout-ir/src/provenance.rs ::stable_id_uses_the_ratified_muscloid_derivation	literal-byte
Domain-tag spellings	epiphany-determinism/src/domain.rs ::exact_tag_spellings_match_spec	literal-byte
<i>Added by this document:</i>		
OperationKind discriminants (§6.3)	epiphany-ops/src/payload.rs ::operation_kind_wire_discriminants_are_golden	literal-byte
OperationPayload discriminants (§6.2)	epiphany-ops/src/payload.rs ::operation_payload_discriminants_are_golden	literal-byte
OperationKindTag (§6.4)	epiphany-ops/src/payload.rs ::operation_kind_tag_decode_mirrors_encode_exactly	round-trip
ResolveEquivocation payload (§6.2)	epiphany-ops/src/payload.rs ::resolve_equivocation_payload_encodes_target_then_hash	literal-byte
OperationStamp (§6.5)	epiphany-ops/src/stamp.rs ::stamp_encode_is_stable	literal-byte
CausalContext (§6.5)	epiphany-ops/src/causal.rs ::canonical_encoding_is_build_order_independent	canonical-equality
MaterializedState (§6.6.1)	epiphany-ops/src/decode.rs ::reduced_states_decode_and_reencode	round-trip
Operation-index payload (§7.6)	epiphany-bundle/src/opindex.rs ::payload_encoding_is_golden	literal-byte
Fixed header (§7.1)	epiphany-bundle/src/header.rs ::header_round_trips	round-trip
Superblock (§7.2)	epiphany-bundle/src/superblock.rs ::superblock_round_trips_through_256_bytes	round-trip
Chunk hash preimage (§7.3)	epiphany-bundle/src/chunk.rs ::hash_preimage_matches_the_spec_layout	literal-byte
ChunkRef (§7.3.1)	epiphany-bundle/src/chunk.rs ::chunk_ref_round_trips	round-trip
Manifest body (§7.5)	epiphany-bundle/src/manifest.rs ::re_encode_is_byte_identical, ::manifest_round_trips, ::duplicate_roots_collapse_on_encode, ::semver_orders_numerically_not_byte_wise	round-trip + canonical-equality
Barrier kinds blob (§8.1)	epiphany-layout-ir/src/barrier.rs ::affected_object_kinds_blob_bytes_are_golden	literal-byte
Barriers blob (§8.2)	epiphany-layout-ir/src/barrier.rs ::edit_barriers_blob_bytes_are_golden	literal-byte
Barrier variants (§8.2)	epiphany-layout-ir/src/barrier.rs ::every_scope_and_condition_variant_round_trips_byte_identically	round-trip
Whole-Score codec (§5.1)	epiphany-core/src/codec.rs ::generator_scores_round_trip, ::trailing_and_truncated_bytes_are_rejected	round-trip

Layout	Anchor	Class
CanonicalValue seam (§5.5)	epiphany-core/src/codec.rs ::value_types_round_trip_over_generator_ corpus	round-trip

Struct *bodies* in Chapter 5 are round-trip-locked rather than literal-byte-locked: their byte identity follows from the frozen positional rule plus the literal-byte locks on every discriminant and leaf they embed. A future cross-implementation decoder test (the deferred conformance harness) should add literal-byte vectors for the representative layouts of Section 5.4.

Revision History

Date	Section	Change
July 2, 2026	All	0.1.0 — Initial companion: ratifies the previously provisional whole-Score value codec (core P11-4), operation-layer wire forms (ops), bundle physical layout (bundle P11-D2/D4/D5), operation-index payload (P12-D1), and extension-blob/edit-barrier byte forms (P12-E1/E2/E3); pins the no-varint rule, the frozen-positional schema-evolution keystone, and the id-leads envelope property; SnapshotId derivation deferred (open question).
July 2, 2026	Operation wire forms	0.2.0 — Phase-3 first tranche: appended OperationKind wire discriminants 24–27 (CreateStaff, SetTimeSignature, SetTempoSegment, SetStaffLayout) with their payload layouts, the matching OperationKindTag discriminants 24–27 (kind-to-tag naming gains CreateStaff → InsertStaff), and PreconditionFailureReason 11 (TempoMapMalformed) — a schema- <i>minor</i> evolution under this document’s own append-only rules (Chapter 9); no existing assignment changed. Semantics: Operation Catalog 0.5.0 (CREATESTAFF, METER AND TEMPO OVERWRITES, SETSTAFFLAYOUT, and the value-restoring UNDOTRANSACTION revision).