# Creative Intelligence Framework (CIF) — Technical Whitepaper v1.2

**Status**: Draft for review (methods-first; code-free)

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**Supersedes**: v1.1.1 (+ Addendum A clarifications)

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## Abstract

We present **CIF v1.2**, an auditable framework for evaluating songs using one client-facing **Key Performance Indicator** (**KPI**), the **Hit Confidence Index (HCI)**. HCI is presently computed from a six-axis **Audio Echo Engine (AEE)** whose core model is the **Historical Echo Model (HEM)**. Lyrics are **advisory-only** in v1.2. The release formalizes parameter discipline and bounds; codifies a **Dual-Engine** future with a **Lyric Echo Engine (LEE)**; fixes governance via the **40/40 Balance Rule** (equal policy weight to audio/lyric upon LEE graduation); and adds stability-first validation (bootstrap CIs, independence checks), a Host-level **Recommendation layer**, Trend-hydrated platform lanes (Radio US canonical; Spotify advisory), fail-ledger observability, and strict provenance. **HCI math is unchanged** (audio-only KPI; lyrics advisory).

**Keywords**: Music Information Retrieval (MIR), historical echo, composite index, bootstrap CIs, independence (VIF), TTC, LUFS, governance, provenance.

## Document Control

- **Version**: v1.2 (draft)
- **Change Summary**: Integrates Addendum A; defines Radio US as canonical KPI lane; Spotify advisory; Host-only advisory invariant; Trend Snapshot advisory data; axis weight manifests; constants table; golden-run tolerance; policy switch registry; FAQ; accessibility checklist.
- **Reviewers**: [list]
- **Approvals**: [list]
- **Effective Date**: [date]
- **Superseded Docs**: CIF v1.1.1 (PDF) + Addendum A
- **Verification Thread**: see **Appendix K** (Verification Runbook Charter).

## Global Acronyms, Symbols & Terms (one-page reference)

**Engines & Models**

AEE — Audio Echo Engine (active KPI domain)

LEE — Lyric Echo Engine (advisory in v1.2; score-contributing post-graduation)

HEM — Historical Echo Model (inside AEE)

HLM — Historical Lyric Model (inside LEE)

**Audio Intelligence** — audio/acoustic layer within CIF (served by AEE)

**Language Intelligence (Lyric)** — lyric/linguistic layer (served by LEE)

**Composites & KPI**

AER — Audio Echo Resonance (AEE composite)

LER — Lyric Echo Resonance (LEE composite; future KPI input)

HCI — Hit Confidence Index (public KPI)

EACM — Equal-Axis Composite Mean (engine 6-axis mean)

> **Math reference.** For plain-language explanations, bounds, and tiny numeric examples of every equation used here (z-score, logistic map, axis construction, EACM, caps, HCI fusion, A40, DBI, $\kappa$/VIF, TTC/lift), see **Appendix N — Mathematical Gloss**.

**Variables & Ops**

Raw feature: $x$; mean/std: $\mu,\sigma$; standardization: $z=(x-\mu)/\sigma$

Logistic map: $s=\sigma(\gamma z)\in[0,1]$, $\gamma\in[0.8,1.2]$

Axis: $A_k\in[0,1]$; engine mean: $\mathrm{EACM}=\tfrac{1}{6}\sum_{k=1}^{6} A_k$

Capped engine: $\tilde{E}=\min(\mathrm{EACM},\,c)$

Fuse weight: $\beta\in[0,1]$; caps $c_{\text{audio}},\,c_{\text{lyric}}$

**Diagnostics**

Correlation matrix; VIF; condition number $\kappa$

DBI — Decadal Balance Index (normalized entropy of decadal representation; diagnostic; report-only)

A40 — Anchored-40 Prior (equal-weight decadal mixture)

A40P — “Top 40 $\approx$ Top 40$({-}40,\text{y})$, re-parameterized”

RRE — Recommendation Rules Engine (deterministic rules → lane-scoped recommendations; advisory-only)

TTC — Time-to-Chorus (s); Chorus-lift — $\Delta$ short-term LUFS (dB)

**Governance & Provenance**

Canonical KPI lane: **Radio US**; advisory lane: **Spotify**

40/40 Balance Rule: $\beta=0.5$ post-LEE graduation (v1.2 uses $\beta=1.0$)

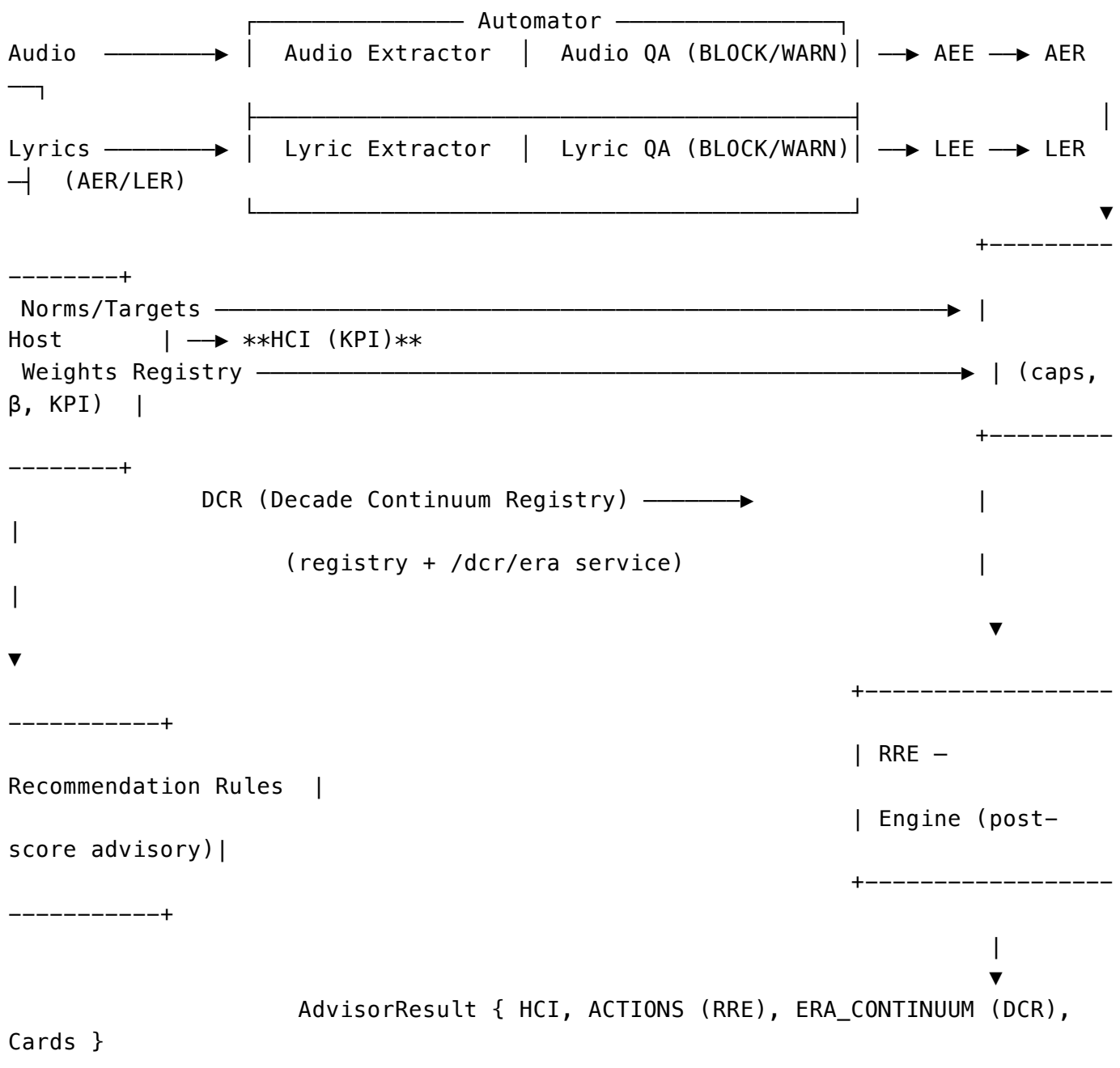
Whitening (Lenient): OFF unless $\kappa>50$ or max VIF $>7$

Seeds: $\{42,\,314,\,2718\}$; dtype: float64; BLAS threads pinned

Cards: Profile / Run / Environment; provenance footer on all figs/tables

# 3. System Overview

## Figure — Interface-Only Service Topology (v1.2, parallel extract)




### Invariants

- **Parallel extract:** Audio and Lyric extract/QA run concurrently; QA gates are independent.
- **KPI path isolation:** Engines → Host only. Advisory services (RRE, DCR, Trend) are **forbidden** from scoring.
- **v1.2 KPI:** β=1.0 ⇒ HCI uses **AER only**; LER is advisory-only until LEE graduation.
- **Non-blocking advisory:** If DCR/RRE/Trend timeout, KPI proceeds; WARN `ADVISORY_TIMEOUT` is logged on the Run Card.
- **UI-only:** GPT acts strictly as interface; all hard logic lives outside the model.

## 3.1 End-to-End Pipeline

Automator → Standardize (winsorize → z-score → logistic) → Axis construction (AEE; LEE advisory) → Engine composites (AER/LER) → Caps → **Host** consolidation (HCI; Radio lane) → **Host** Recommendation (Radio + Spotify; Trend-hydrated) → Artifacts (figs/tables/cards).

## 3.2 Music Advisor Logic — Present & Modular Future

**Present (v1.2):** AEE → AER → HCI (audio-only KPI). LEE outputs advisory analyses; lyric-like proxies in AEE are flagged and tapered post-graduation.
**Future:** Host fuses AER and LER by policy (\beta) with domain caps:

\[ \mathrm{HCI}=\beta\cdot\min(\mathrm{EACM}_{\text{audio}},c_{\text{audio}}) +(1-\beta)\cdot\min(\mathrm{EACM}_{\text{lyric}},c_{\text{lyric}}). \]

Today \(\,\beta=1.0\); post-graduation default \(\,\beta=0.5\) (**40/40**).

### 3.3 Axis Contract (engine-neutral interface)

**Input:** FeatureSet + profile ID + model ver + corpus hash + seeds.
**Output:** six axis scores, `axis_components`, EACM, `quality` flags, full `provenance`. Missing features are **excluded** with **local renormalization**; Host never multiplies axes or HCI.

### 3.4 Gates & Advisory (Host-only; post-score)

**All recommendation runs in the Host after HCI is finalized.** Advisory may read lanes/Trend/QA/preferences; **no feedback path** is allowed into features, axes, AER/LER, caps, \(\,\beta\), or HCI. **Two modes:** *Evaluation* (baseline norms) and optional *Curation* (preference re-ordering); safety items pinned; `preferences_used` recorded.

### 3.5 Governance: Lanes, \(\,\beta\), Caps, Overrides

- **Canonical KPI lane: Radio US**.
- **Advisory lanes:** Radio + Spotify; duplicates auto-hidden unless advice differs.
- **\(\,\beta\):** \(\,1.0\) today; **40/40** (\(\,\beta=0.5\)) post-LEE graduation.
- **Caps:** \(\,c_{\text{audio}} = c_{\text{lyric}} = 0.58\) defaults (sensitivity \(\,\pm 0.02\) in Appendix).
- **Overrides:** Profile-scoped; require Profile Card & Change-Log entries.

**Inline statement version (if you want it in prose):**
Today \(\,\beta=1.0\); post-graduation default \(\,\beta=0.5\) (**40/40**).

#### 3.5.1 Change-Impact Matrix & Rollback

| Knob/Policy | Change | Expected KPI effect | Guard/Gate | Rollback |
|---|---|---|---|---|
| **β** | 1.0 → 0.5 | Adds lyric sensitivity (LER) | LEE gate + KPI-purity diff | Revert β; note N/N+1 |
| **Caps** | ±0.02 | Ceiling shift on high tracks | Sensitivity run | Restore prior `cap_version` |
| **γ** | 0.8–1.2 | Local steepness of mappings | Invariant suite + goldens | Revert γ; re-hash norms |
| **Canonical lane** | Radio→Spotify | KPI drift risk | Governance vote + DBI/trend review | Rollback lane; annotate Cards |
| **A40 window** | re-anchor | Engine echo geometry shift (not KPI) | DBI≥0.85; validation figs | Restore prior A40 pack |

## 4. Methods

**Transform order:** winsorize → z-score → logistic → axis → engine mean → cap → fuse → HCI.

### 4.1 Parameter Discipline & Units

Standardization: \(z=(x-\mu)/\sigma\); winsor \(|z|>4\). Logistic mapping: \(s=\sigma(\gamma z)\), \(\gamma\in[0.8,1.2]\). Units canon: tempo (BPM), TTC (s), Chorus-lift (\(\Delta\) dB via 6s ST-LUFS), loudness (integrated LUFS).

### 4.2 Axis Construction (per engine)

\(A_k=\sum_{j\in F_k} w_{k,j}\,s_{k,j}\), with \(w_{k,j}\ge 0\), \(\sum_{j} w_{k,j}=1\), \(s_{k,j}\in[0,1]\).
Invalid features are excluded; remaining weights renormalize to 1 for that track. Axes \(\in[0,1]\).

**AEE axes (today):** Market, Sonic, Emotional, Historical/Echo, Cultural, Creative.
**LEE axes (future):** Lyric Craft, Hook Architecture, Narrative Specificity, Prosody Alignment, Thematic Resonance, Linguistic Flow.

> **Math card — Axis.** Convex blend of mapped sub-features; $A_k\in[0,1]$. Missing sub-features are dropped and remaining weights renormalize to 1. See Appendix N.

## 4.3 Engine Composites, Caps, Bounds

$\mathrm{EACM}=\tfrac{1}{6}\sum_{k=1}^{6} A_k$; capped engine $\tilde{E}=\min\!\big(\mathrm{EACM},\,c\big)$.
**Monotonicity:** increasing any $A_k$ never decreases $\tilde{E}$.
**Sensitivity:** $\partial \mathrm{EACM}/\partial A_k = 1/6$; blocked when cap is active.

## 4.4 Historical Echo Model (HEM)

Cosine geometry in standardized space; kernel width $\sigma$ via median 8-NN within the anchored 40-year corpus. **Whitening** OFF unless $\kappa>50$ or any VIF $>7$ (Lenient). If triggered, Appendix D audit prints pre/post spectra and correlation matrices.

> **Math card — Whitening.** Lenient trigger if $\kappa>50$ or any VIF $>7$; KPI math unchanged. Appendix N shows definitions and audit artifacts.

## 4.5 Segmentation Features (AEE)

**TTC:** first chorus onset with detector conf $\ge 0.60$; else NA.
**Chorus-lift:** $\Delta$ of 6s ST-LUFS windows (chorus vs verse). Validators may set NA → local axis renorm.

## 4.6 Consolidation (Host)

$$\mathrm{HCI}=\beta\cdot\min\!\big(\mathrm{EACM}_{\text{audio}},\,c_{\text{audio}}\big)+(1-\beta)\cdot\min\!\big(\mathrm{EACM}_{\text{lyric}},\,c_{\text{lyric}}\big).$$

**Today:** $\beta=1.0$ ⇒ $\mathrm{HCI}=\min\!\big(\mathrm{EACM}_{\text{audio}},\,c_{\text{audio}}\big)$.
**Example:** if $\mathrm{EACM}_{\text{audio}}=0.62$, $c_{\text{audio}}=0.58$ ⇒ HCI $=0.58$.
After LEE graduation, $\beta=0.5$, $\mathrm{EACM}_{\text{lyric}}=0.54$ ⇒ HCI $=0.5\times0.58+0.5\times0.54=0.56$.

> **Math card — HCI.** Bounds $[0,1]$; monotone in each domain; single-axis bound: a $+\Delta$ on one audio axis raises HCI by ≤ $\beta\Delta/6$ (lyric analog). See Appendix N for examples.

## 4.7 Missing-Feature Policy

Invalid features → NA; exclude and renormalize within the affected axis. Max HCI impact bounded by $\beta/6$ (audio) and $(1-\beta)/6$ (lyric), further limited by caps.

## 4.8 Anchored-40 Prior (A40) & Decadal Balance Index (DBI)

**A40 (inside engines):** equal-decade mixture within anchored window; implement via averaged decade centroids or per-decade k-NN similarities.

**DBI (diagnostic only):**

$$\mathrm{DBI}=\frac{H(p)}{\log|D|} =-\frac{1}{\log|D|}\sum_{d} p(d)\,\log p(d),\qquad 0\cdot\log 0 := 0.$$

Threshold example: report WARN for DBI $< 0.70$; target $\ge 0.85$ at validation.

> **Math card — A40 & DBI.** A40 is an equal-decade mixture prior inside engines; DBI measures decadal evenness and is diagnostic-only. See Appendix N for formulas and targets.

### 4.X Operational Envelope & OOD Triggers

Profiles: `US_Pop_2025` (anchored 1986–2025). Tempo 70–180 BPM; Runtime 120–240 s; TTC 10–35 s (NA accepted); modern stereo masters.
Lyrics focus: EN; others ⇒ `lyrics_domain=NA` (advisory labels only).

| Signal | Trigger | Action |
|---|---|---|
| **DBI** | DBI < 0.70 | WARN `LOW_DBI`; schedule corpus review |
| **Collinearity** | (\kappa>50) or any VIF>7 | Lenient whitening; attach Appendix D |
| **Segmentation** | TTC conf < 0.60 | Set TTC=NA; renorm axis; pin safety rec |
| **Lane drift** | Trend deltas > App. E thr. | WARN; human approval before promotion |
| **Language** | non-EN / low NLP conf | `lyrics_domain=NA`; advisory labels only |

## 5. Automator (Data Extract Layer)

Extractor, not a model. Produces FeatureRecord: tempo, key, TTC(+conf), structure, loudness (integrated & ST-LUFS), lyrics(+conf), provenance. **Goldilocks Safeguard** for lyrics; may set lyric domain NA (advisory may still render with low-confidence labels). QA taxonomy: BLOCK/WARN/INFO; Run Card logs acceptance.

## 6. Language Intelligence (Lyric) — LEE (status & graduation)

**Status:** advisory-only; analyses do not change HCI. Lyric-like proxies in AEE are flagged; taper to 0 on graduation to prevent double-counting.
**Six Lyric Axes:** Lyric Craft; Hook Architecture; Narrative Specificity; Prosody Alignment; Thematic Resonance; Linguistic Flow.
**Graduation Gate:** repeatability; bootstrap CI tightness; independence (corr ≤ ~0.6; VIF ≤ 5 target, ≤7 cap vs AEE); temporal stability; placebo (lyric shuffle collapses to baseline); face validity.
**Post-graduation:** LER contributes by (\beta) with caps; **40/40** default.

## 7. Validation & Uncertainty

**Fig 7.1 (Stability):** track-level bootstrap (B=100) 95% CI ribbons for HCI (Radio lane). Seeds {42,314,2718}.
**Fig 7.2 (Independence):** axis corr heatmap + VIF bars (goal ≤5; cap 7). Whitening audit in Appendix D if triggers fire.

### 7.X Assurance Case (text GSN)

**Claim C0:** HCI_v1.2 is stable, fair, reproducible for `US_Pop_2025`.
**Strategy S1:** Prove mathematical invariants under perturbations. → **Evidence E1:** Property specs + goldens (`/specs`, `/goldens`), seeds `{42,314,2718}`.
**Strategy S2:** Show advisory isolation. → **Evidence E2:** KPI-purity tests (identical HCI with advisory disabled).
**Strategy S3:** Demonstrate temporal fairness & conditioning. → **Evidence E3:** DBI $\geq 0.85$ target; Whitening Audit if $\kappa > 50$ or any VIF $> 7$ triggers.

**Assumptions:** A1 corpus represents target market; A2 Trend thresholds detect material lane shifts.
**Context:** Canonical lane = Radio US; lyrics advisory in v1.2.

## 8. Ethics, Data Governance, IP

Provenance: corpus hashes; anchored_40yr window on Profile Card. Lyric compliance: permissions, PII redaction, limited display. Advisory-not-predictive.
Methods/parameterizations proprietary; **no code** in doc.

### 8.X Security & Privacy (Lyrics)

- **Storage:** hashed track IDs, redacted snippets only (advisory).
- **Access:** role-gated; audit trail.
- **Retention:** project lifecycle or 12 months (whichever shorter).
- **Prohibited:** redistributing full texts; exporting PII.
- **Incident path:** `LYRIC.SECURITY.*` codes in Fail-Ledger + escalation contact.

## 9. Results — Canonical Profile ( US_Pop_2025 )

**KPI lane**: **Radio US** (canonical). **Advisory lanes**: Radio + Spotify; duplicates auto-hidden unless lane advice differs.

> **Advisory is post-score and Host-only.** HCI is computed first (Radio canonical), then lane-specific checklists are rendered. **Recommendations never modify HCI.**

**Table 9.1**: axis means ± sd (over seeds); **HCI** mean ± sd; 95% bootstrap CI; cap-utilization %.
**Worked Example (Track Alpha, anonymized)**: standardize → map → axes → EACM → cap → **HCI (Radio)**; then lane-specific checklists (Radio, Spotify).

## 10. Discussion & Limitations

Segmentation brittleness (TTC/lift), profile drift risk, proxy leakage risk pre-LEE graduation, compensability trade-offs (arithmetic KPI vs geometric sensitivity), interpretability governance (caps, β fixed by policy).

## 11. Conclusion & Roadmap

HCI remains stable and auditable. v1.2 prepares a dual-engine future with explicit governance and Host-only advisory. Near-term: LEE shadow mode; placebo tests; independence audits; proxy taper; Trend Snapshot cadence; Radio canonical lane review windows.

## 12. Change Log (v1.1.1 → v1.2)

Parameter discipline; bounds/monotonicity; HEM $\sigma$-rule; lenient whitening; segmentation acceptance; consolidation math; missing-feature bound; modular Axis Contract; governance ($\beta$/caps/overrides, lanes); Host-only advisory invariant; validation exhibits; DBI diagnostic; Cards & Provenance; constants table; policy switch registry; FAQ.

# Axis Weight Manifests (main text mini-tables)

> *Note:* Until weight manifests are provided, **equal per-feature weights** are used per axis (NA features are excluded and remaining weights **renormalize to 1.00**). When manifests are available, replace with declared weights; rows must still sum to 1. Proxy taper flagged where applicable.

## AEE — Market Axis

| Feature (mapped) | Weight | Units / Window | Proxy-taper note |
|---|---|---|---|
| [placeholder] | 0.00 | [e.g., BPM band] | – |
| … | … | … | … |
| **Sum** | **1.00** | | |

## AEE — Sonic Axis

| Feature (mapped) | Weight | Units / Window | Proxy-taper note |
|---|---|---|---|
| [placeholder] | 0.00 | [e.g., spectral tilt] | – |
| … | … | … | … |
| **Sum** | **1.00** | | |

## AEE — Emotional Axis

| Feature (mapped) | Weight | Units / Window | Proxy-taper note |
|---|---|---|---|
| [placeholder] | 0.00 | [e.g., valence proxy] | – |
| … | … | … | … |
| **Sum** | **1.00** | | |

## AEE — Historical/Echo Axis

| Feature (mapped) | Weight | Units / Window | Proxy-taper note |
|---|---|---|---|
| [placeholder] | 0.00 | [e.g., HEM proximity] | – |
| … | … | … | … |
| **Sum** | **1.00** | | |

## AEE — Cultural Axis

| Feature (mapped) | Weight | Units / Window | Proxy-taper note |
|---|---|---|---|
| [placeholder] | 0.00 | [e.g., rhythm archetype] | – |
| … | … | … | … |
| **Sum** | **1.00** | | |

## AEE — Creative Axis

| Feature (mapped) | Weight | Units / Window | Proxy-taper note |
|---|---|---|---|
| [placeholder] | 0.00 | [TTC, ST-LUFS lift] | – |
| … | … | … | … |
| **Sum** | **1.00** | | |

> **LEE axis tables** mirror the above (Lyric Craft, Hook Architecture, Narrative Specificity, Prosody Alignment, Thematic Resonance, Linguistic Flow). Populate once HLM components are frozen. Prosody uses alignment metadata only.

# Numerical Constants & Switches (main text)

| Constant / Policy | Value | Where used | | |
|---|---|---|---|---|
| Caps (audio, lyric) | 0.58 | §3.5, §4.3 (post-aggregation) | | |
| TTC acceptance conf | 0.60 | §4.5 validators | | |
| Winsor cutoff | | z | > 4 | §4.1 |
| Seeds | {42,314,2718} | §7, Cards | | |
| Bootstrap B | 100 | §7.1 | | |
| Whitening triggers | κ>50 or VIF>7 | §4.4, App D | | |
| Golden-run tolerance | | ΔHCI | ≤ 0.002 per track | HOWTO_REPRODUCE |

# Policy Switch Registry (one-pager)

| Switch | Default | Owner | Change path | Evidence required |
|---|---|---|---|---|
| Canonical lane | Radio US | Governance | Profile override + Change-Log | DBI ≥ 0.85; decade stability |
| β policy | 1.0 (today) | Governance | Graduation decision | LEE gate: repeatability, CIs, independence, placebo |
| Caps | 0.58 | Governance | Profile override | Sensitivity ±0.02 review |
| Whitening | OFF | Methods | Triggered by κ/VIF | Appendix D audit |
| Trend cadence | periodic | Data | Snapshot approval | Delta thresholds met |

# Trend Layer (Host advisory data)

Advisory-only; hydrates lane targets for the Recommendation layer. Precedence: Manual curated snapshot → Datahub export → fallback. Stamped with `norms_timestamp`, `source_name`, `source_version`, `commit`. Guards: delta thresholds; conflict bounds; provenance; no auto-flip of canonical lane.

# Host Recommendation Layer (RRE + playbooks)

Deterministic rule graph: **Axis deficit → Intent → Playbook → Actions**. Inputs: final axes, QA/validators, Trend Snapshot, platform lane, **DCR era_analogs**. Outputs: top-K (default 5) actions per lane, evidence links (measurement → target), counterfactual nudge bands with confidence tags. **Baseline vs Curation** views; safety items pinned; `preferences_used` recorded. **Duplicates hidden** between Radio & Spotify unless advice differs.

# Fail-Ledger & RAG

Failure taxonomy ( `AUDIO.INTEGRITY.*`, `EXTRACT.TTC.*`, `EXTRACT.LYRICS.*`, `ENGINE.*.OWNERSHIP`, `NORMS.*`, `SUGGEST.ROUTER.*`, etc.) with severity (BLOCK/WARN/INFO), reason, recovery, exposure. RAG banner on Run Card; SLI/SLO observability for TTC accepted %, lyric accepted %, independence OK %, CI width.

# Ethics & Compliance (lyric handling box)

Permissible ingestion; storage redaction; display limits (advisory snippets only); no redistribution of full texts; access controls; audit trails.

## HOWTO_REPRODUCE

Seeds/dtype/threads; commands to render Cards, figs, tables; golden-run diff with **|ΔHCI| ≤ 0.002** acceptance; expected hashes.
**KPI Purity test:** HCI identical with advisory disabled.
**No NaNs/Inf/out-of-range** allowed in KPI path.

## FAQ

**Why Radio as canonical?** Slower drift, decadal continuity—closest to 40-year archetypes.
**Do preferences affect HCI?** No—preferences re-rank advisory only.
**What if lyrics are missing?** Lyric domain NA; HCI uses audio only; advisory may still render with low-confidence labels.
**Why caps=0.58?** Fairness guardrail; sensitivity ±0.02 reported in Appendix.
**What's Trend vs Corpus?** Trend hydrates advisory lane targets; engines remain anchored to historical corpus.
**Can advice change the score?** No—Host-only, post-score, read-only.

> *Side note (margin callout, optional):* 🔒 **Host-Only Advisory (Do Not Bypass)** — Engines: measure only → AER/LER; Host: caps→HCI→advisory; advisory reads lanes+Trend+QA; **never writes to scoring**; no feedback into HCI.

## FAQ

**Why Radio as canonical?** Slower drift, decadal continuity—closest to 40-year archetypes.
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**What's Trend vs Corpus?** Trend hydrates advisory lane targets; engines remain anchored to historical corpus.
**Can advice change the score?** No—Host-only, post-score, read-only.

## Appendix E — Trend Snapshot Deltas (template)

**Scope:** Lane-scoped targets **do not** change HCI; they **hydrate advisory only**. Show previous vs current snapshot with thresholds.

| Lane | Metric | Prev | Current | Δ | Threshold | Status |
|---|---|---|---|---|---|---|
| Radio US | ttc_sec (range) | 12–25 | 12–25 | 0 | ≥3 sec | OK |
| Radio US | runtime_sec (range) | 165–210 | 165–210 | 0 | ≥20 sec | OK |
| Spotify | intro_cap_sec | 9 | 9 | 0 | ≥3 sec | OK |

> **Note:** Populate from `trend_snapshot` on the Profile Card. Any Δ exceeding thresholds sets **WARN** and requires human approval before promotion.

# Cards — Copy/Paste Templates

## Profile Card (JSON)

```
{
  "profile_id": "US_Pop_2025",
  "anchored_40yr": true,
  "window": "1986–2025",
  "canonical_lane": "radio_us",
  "advisory_lanes": ["radio_us", "spotify"],
  "norms_timestamp": "2025-10-15T00:00:00Z",
  "trend_snapshot": {
    "source_name": "market_norms_datahub",
    "source_version": "2025.Q4",
    "window_start": "2025-09-15",
    "window_end": "2025-10-15",
    "timezone": "UTC"
  },
  "weights_source": "spec_default_equal",
  "weights_manifest_id": null,
  "features_decl_source": "axis_contract_v1",
  "advisory_host_only": true,
  "advisory_feedback_into_scoring": false,
  "beta_policy_source": "fixed:1.0",
  "caps_source": "default:0.58",
  "canonical_lane_source": "policy",
  "dcr_id": "DCR-US_Pop_2025-v1.1",
  "dcr_sha256": "<hash>",
  "norms_hash": "<norms-hash>",
  "dcr_service_version": "1.0.0",
  "rre_service_version": "1.0.0",
  "rre_ruleset_version": "v1.0",
  "rre_ruleset_hash": "<hash>",
  "ood_flag": false,
  "effective_policy_hash": "<hash>"
}
```

## Run Card (JSON)

```
{
  "run_id": "RUN-20251103-XXXX",
  "profile_id": "US_Pop_2025",
  "canonical_lane": "radio_us",
  "advisory_lanes_rendered": ["radio_us", "spotify"],
  "preferences_used": false,
  "fail_ledger": [],
  "rag_status": "GREEN",
  "advisory_host_only": true,
  "advisory_feedback_into_scoring": false,
  "weights_source": "spec_default_equal",
  "dcr_id": "DCR-US_Pop_2025-v1.1",
  "dcr_sha256": "<hash>",
  "dcr_projection_year": 2030,
  "dcr_status": "OK",
  "rre_service_version": "1.0.0",
  "rre_ruleset_version": "v1.0",
  "rre_ruleset_hash": "<hash>",
  "env_hash": { "os": "macOS-12.x", "blas": "OpenBLAS", "cpu": "Apple-M2" }
}
```

### Environment Card (JSON)

```
{
  "os_build": "macOS 12.x",
  "python_version": "3.11.x",
  "numpy_blas_vendor": "OpenBLAS",
  "cpu_family": "Apple-M2",
  "float_dtype": "float64",
  "blas_threads_pinned": true,
  "seeds": [42, 314, 2718]
}
```

# Appendix F — Failure Modes & Alternatives Considered

**Purpose.** Document concrete failure cases and rejected alternatives so readers see the tradeoffs behind v1.2. This appendix complements the Fail-Ledger taxonomy and SLOs and gives reproducible acceptance tests without changing HCI math.

## F.1 Layered failure cases (examples → mitigation)

### Automator (extractor)

- **TTC misdetection on long/introspective openings**
  *Symptom:* high TTC variance; conf<0.60.
  *Mitigation:* accept NA; pin safety suggestion (Structure Tightening); axis renorm; ledger `EXTRACT.TTC.CONF_LOW`.
- **Lyric capture fails / language mismatch**
  *Symptom:* low OCR/NLP conf; unsupported language.
  *Mitigation:* `lyrics_domain=NA`; advisory flagged "Low-Confidence"; ledger `EXTRACT.LYRICS.CONF_LOW`.
- **Unusual program material (medleys, live crowd, skits)**
  *Symptom:* segmentation unstable; loudness windows erratic.
  *Mitigation:* winsorization; NA windows; Host reduced-axis mode; RAG=AMBER.

### Engines (AEE/LEE)

- **Proxy leakage (lyric-like features inside AEE)**
  *Risk:* double-counting once LEE graduates.
  *Mitigation:* ownership guard; taper plan to 0 at LEE graduation; ledger `ENGINE.AEE.OWNERSHIP` on violations.
- **Independence breach (VIF>7)**
  *Symptom:* unstable axis contributions.
  *Mitigation:* Lenient whitening trigger; Appendix D audit; no KPI change.
- **Out-of-distribution tempo/range**
  *Symptom:* mapped features saturate at bounds.
  *Mitigation:* bounds check; report saturation; advice focuses on structure/hooks rather than spectral loudness.

### Host (consolidation + advisory)

- **Lane conflicts (Radio vs Spotify targets disagree)**
  *Symptom:* duplicated advice with minor wording changes.
  *Mitigation:* auto-dedupe identical advice; where conflicts remain, RRE emits two minimal plans with provenance; ledger `SUGGEST.ROUTER.CONFLICT`.

- **Preferences drift** (if enabled later)
  *Risk:* appearance of bias.
  *Mitigation:* Evaluation vs Curation separation; immutable baseline first; `preferences_used` footer.

### Governance / Data

- **Trend deltas too large**
  *Symptom:* sudden TTC/runtime jumps.
  *Mitigation:* thresholds → WARN; require human approval; ledger `NORMS.DELTA.OUTLIER`.
- **Snapshot provenance missing**
  *Mitigation:* BLOCK; `NORMS.OVERRIDE.NO_PROVENANCE`.

### Artifacts / Reporting

- **Figure build failures / PDF issues**
  *Mitigation:* artifacts `ARTIFACTS.*` codes; rerender policy; tagged-PDF checks for accessibility.

## F.2 Edge cases (policy notes)

- **Instrumentals / karaoke:** lyric domain NA; HCI uses audio only; advisory reflects audio-first playbooks.
- **Very short tracks (<60s):** runtime windows flagged; advice guards against over-shortening intros.
- **Extreme BPM (<70/>180):** treat TTC and lift as primary levers; avoid misleading spectral pushes.

## F.3 Alternatives considered (rejected or deferred)

| Alternative | Rationale for rejection/defer | Risk avoided | Outcome |
|---|---|---|---|
| Spotify as canonical KPI lane | Higher volatility; playlist churn | KPI drift vs 40-year thesis | **Keep Radio US canonical** |
| Geometric mean as KPI | Harsh non-compensability; user-unfriendly | Over-penalizing single deficits | Use arithmetic KPI; show geometric in sensitivity |
| Default whitening ON | Can distort semantics; fragile | Instability, over-correction | **Lenient trigger** only (κ>50 or VIF>7) |
| Preferences in scoring | Subjectivity contaminates KPI | Loss of trust/repeatability | **Advisory only** (Curation view) |
| Penalize missing features | Unfair to certain genres/material | Hidden bias | **NA + renorm** within axis |
| Merge lyric features into AEE | Ownership confusion; double-count risk | Leakage | Separate LEE; taper proxies at graduation |
| Auto-flip canonical lane via Trend | Overreacting to noise | KPI instability | **Governance decision** only |

## F.4 Proof obligations (acceptance tests)

- **Golden-run guard:** With no policy change, per-track **|ΔHCI| ≤ 0.002**.
- **Monotonicity:** increasing any axis cannot reduce EACM* or HCI after caps.
- **Independence:** corr≤~0.6; VIF≤5 target (cap 7).
- **Placebo (LEE):** lyric shuffle collapses LER toward baseline (advisory today).
- **Lane discipline:** HCI computed in **Radio US**; Spotify advisory only.

## F.5 Quick audit checklist (reader)

1. Confirm `canonical_lane==radio_us` and `preferences_used=false` on the HCI row.
2. Check Fail-Ledger for extractor NA decisions (TTC, lyrics).

3. Verify axis tables sum to **1.00** (NA renorm noted).
4. Inspect CI bands width; compare to seeds and profile window.
5. If Trend changed, see Appendix E for deltas and approvals.

# Appendix G — Conformance Checklist (final 5)

- **KPI lane discipline:** HCI computed in **Radio US** (canonical lane).
- **Advisory isolation:** `preferences_used=false` for HCI; `advisory_host_only==true` and `advisory_feedback_into_scoring==false`.
- **Lane rendering:** Radio + Spotify checklists generated; **duplicates auto-hidden** unless lane advice differs.
- **Weights provenance:** `weights_source` present; per-axis weights **sum to 1.00** after NA renormalization.
- **Golden-run bound:** with no policy changes, **|ΔHCI| ≤ 0.002 per track**.

### Sidebar — DCR vs. Track Analysis Pack (TAP)

**Purpose:** Remove confusion between the advisory **DCR** and the per-track analysis artifact historically called **DATA_PACK**.
**TAP (Track Analysis Pack)** is the preferred name going forward; **DATA_PACK** remains an alias for backward compatibility.

**DCR — Decade Continuum Registry (formerly DCP; reference/advisory)**
• Role: era-analog context and a soft 2030 projection.
• Affects HCI: **No** (advisory-only).
• Provenance: `dcr_id`, `dcr_sha256`, `dcr_service_version`, `dcr_projection_year`.
• Owner: Methods/Musicology. \

**TAP — Track Analysis Pack (per-track analysis)**
• Role: the track's mapped features under a profile (tempo band, TTC, runtime, loudness windows, structure marks, etc.) used by engines.
• Affects HCI: **Yes (indirectly)** by feeding AEE/LEE which the Host fuses.
• Provenance: `profile_id`, seeds, env hash, norms timestamp.
• Owner: Data/Methods. \

**Policy:** DCR **must never** enter the KPI path (lint rule). TAP/engines feed KPI; DCR/Recommendation Rules Engine (RRE) feed **Host Recommendation** only.
**Testing:** KPI golden runs cover TAP/engines; snapshot tests cover DCR registries/services.
**Naming:** Prefer **TAP** in documentation; keep **DATA_PACK** as a documented alias.

# Appendix D — Collinearity & Whitening

When whitening is active, a **Whitening Report** artifact (κ, VIFs, eigen spectrum) is attached to the run. Interpretability labels for impacted axes are suppressed during whitening. Inequalities are pinned: **lenient** trigger at $\kappa > 50$ or $VIF > 7$.

# Appendix H — Decade Continuum Registry (DCR) — Deterministic Era Mapping for Advisory Context (formerly DCP)

**Intent.** Externalize era-analog logic into a **versioned, deterministic** JSON registry and **stateless microservice**, with GPT acting strictly as UI. **Advisory-only**: DCR never alters HCI; it informs historical/cultural narratives and post-analysis recommendations.

> **Deprecation note:** `/dcp/era` is supported as an alias for one release (SUNSETS **2026-03-31**). Prefer `/dcr/era`. Calls to the alias should emit WARN code `DEPRECATED_ROUTE`.

## H.1 Placement & Invariants

DCR lives **outside engines** and feeds the **Host Recommendation layer**. Advisory-only; deterministic under fixed norms.

## H.2 Registry (spec)

Path: `era_continuum/<region>/<profile>/v1.1.json`


```
{
  "dcr_id": "DCR-US_Pop_2025-v1.1",
  "dcr_sha256": "<hash>",
  "profile_id": "US_Pop_2025",
  "window": "1986-2025",
  "clusters": [
    {
      "anchor": 1985,
      "centroid": { "tempo_band": 100, "ttc_sec": 22 },
      "tolerances": { "tempo_band": 8, "ttc_sec": 6 },
      "analogs": ["Artist-Track-A", "Artist-Track-B"],
      "notes": "verse-first, gated drums"
    },
    {
      "anchor": 1995,
      "centroid": { "tempo_band": 95, "ttc_sec": 18 },
      "tolerances": { "tempo_band": 8, "ttc_sec": 5 },
      "analogs": ["..."],
      "notes": "..."
    },
    {
      "anchor": 2005,
      "centroid": { "tempo_band": 98, "ttc_sec": 16 },
      "tolerances": { "tempo_band": 8, "ttc_sec": 5 },
      "analogs": ["..."],
      "notes": "..."
    },
    {
      "anchor": 2015,
      "centroid": { "tempo_band": 102, "ttc_sec": 14 },
      "tolerances": { "tempo_band": 8, "ttc_sec": 4 },
      "analogs": ["..."],
      "notes": "..."
    }
  ],
  "projection": {
    "year": 2030,
    "label": "soft projection",
    "traits": ["shorter intros", "lift clarity"],
    "confidence": 0.6
  },
  "known_gaps": ["non-English corpora thin pre-2000"]
}
```

Anchors & Rollover Policy. Packs are static & versioned. Annual rollover publishes a new DCR version with an effective date and a 30-day parallel N/N+1 run. No runtime auto-roll in KPI.

## H.3 Microservice (stateless)

`/dcr/era` (POST; **deprecated alias**: `/dcp/era` for one release) ⇒ deterministic nearest-era analogs + projection under fixed norms.

```
{
  "input": {
    "tempo_band": 100,
    "ttc_sec": 18,
    "runtime_sec": 176,
    "exposures": 0,
    "key_mode": "D major",
    "groove": "dembo_half_time"
  },
  "dcr_id": "DCR-US_Pop_2025-v1.1"
}
```

**Response**

```json
{
  "dcr_id": "DCR-US_Pop_2025-v1.1",
  "dcr_sha256": "<hash>",
  "norms_hash": "<norms-hash>",
  "analogs": [
    {"anchor": 1995, "distance": 0.12, "within_tol": true, "why": ["TTC in-
range","tempo band match"]},
    {"anchor": 2005, "distance": 0.15, "within_tol": true, "why": ["runtime
within window"]}
  ],
  "projection": {"year": 2030, "label": "soft projection", "traits": ["14–22s
TTC","1–2 dB chorus lift"], "confidence": 0.6},
  "known_gaps": ["lyric-only signals excluded"],
  "dcr_service_version": "1.0.0"
}
```

**AdvisorResult injection** (new block):

```json
{
  "ERA_CONTINUUM": {
    "dcr_id": "DCR-US_Pop_2025-v1.1",
    "dcr_sha256": "<hash>",
    "analogs": [{ "anchor": 1995, "distance": 0.12, "within_tol": true }],
    "projection": { "year": 2030, "label": "soft projection", "traits": ["14–22s
TTC","1–2 dB chorus lift"] }
  }
}
```

## H.4 Quality & Tests

- **Golden vectors** per profile; snapshot tests per pack.
- **Pack integrity**: schema + hash; anchors monotone; tolerances non-negative.
- **Deterministic matching** under fixed norms; CI pipeline on every pack change.
- **Dual-version rollout (N/N+1)** to reduce drift risk; shared changelog with Trend Snapshot.

## H.5 Risks & Mitigations

- **Overfitting to narrow analogs** → provide multiple analogs + rationale + tolerance windows; mark **known_gaps**.
- **Drift vs norms** → pack/profile coupling; block if profile mismatch; show WARN if norms window changes.
- **Confusion with A40** → explicitly **advisory-only**; A40 remains inside engines.

## H.6 Success Criteria

- Deterministic outputs for fixed inputs.
- Reduced GPT prompt surface (UI-only).
- Faster iteration via pack updates without UI changes; provenance stamped on Cards.

## H.7 Governance

- **Owner:** Data & Methods. **Change path:** versioned pack + service semver + Change-Log entry. **Evidence:** snapshot diffs, golden vectors; RAG status on Run Card.

# Policy Switch Registry (excerpt)

- **canonical_lane** = `radio_us` (Owner: Methods; Evidence: Profile Card)
- **advisory_host_only** = `true` ; **advisory_feedback_into_scoring** = `false` (Owner: Methods; Evidence: Run Card)
- **rre_enabled** = `true` ; **rre_in_kpi_path** = `false` (FORBIDDEN) (Owner: Product/Methods; Evidence: `rre_ruleset_hash` )
- **dcr_enabled** = `true` (alias `/dcp/era` supported for one release); **dcr_in_kpi_path** = `false` (FORBIDDEN)
- **beta** = `1.0` (flip to `0.5` post-LEE graduation via governance)
- **whitening_trigger** = `lenient` (κ > 50 or VIF > 7; audit in Appendix D)
- **effective_policy_hash** = `hash(caps, beta, whitening, lanes, dcr_id, rre_ruleset)` (Owner: Methods; Evidence: Run Card)

# Appendix I — Recommendation Rules Engine (RRE) — ACTIONS Block (example)

**Grammar (mini-spec).**
IF condition(feature, op, value, lane?) THEN action(target, range|value) WITH severity∈{info,low,medium,high}.

```
{
  "ACTIONS": [
    {
      "rule_id": "RRE.TTC.SHORTEN_≤20.v1",
      "lane": "radio_us",
      "severity": "high",
      "evidence": { "ttc_sec": 26, "target_range": "12–25" },
      "text": "Bring the first chorus to ≤20s to meet Radio US norms.",
      "playbook_id": "radio_ttc_v1",
      "playbook_sha256": "<sha256>"
    },
    {
      "rule_id": "RRE.LIFT.ADD_+1_TO_+2_DB.v2",
      "lane": "spotify",
      "severity": "medium",
      "evidence": { "chorus_lift_db": 0.6, "target_range": "1.0–2.0" },
      "text": "+1–2 dB chorus lift to improve contrast for skip-prone feeds.",
      "playbook_id": "chorus_lift_v2",
      "playbook_sha256": "<sha256>"
    }
  ],
  "playbooks": ["radio_ttc_v1", "chorus_lift_v2"]
}
```


# Appendix J — Data & Model Cards (one-pagers)

## J.1 Data Card — Anchored Corpus (US_Pop_2025)

Scope & window: 1986–2025; US Pop. Selection: charted/top-rotation; mastered releases.
Decadal coverage: DBI reported on Profile Card (target ≥0.85).
Known gaps: non-EN lyric scarcity pre-2000.
Hashes: `norms_hash` , corpus manifest hash.

## J.2 Trend Snapshot Card — Radio/Spotify

Source: market_norms_datahub. Window: rolling 30 d.
Thresholds: per Appendix E. Reviewer: [name].
Hashes: `source_version` , `commit` , `norms_timestamp` . Effective: [date].

## J.3 Model Card — AEE v1.2 / LEE (shadow)

Inputs: standardized feature set per Axis Contract.
Axes: six per engine (§4.2). Caps & γ: caps=0.58; γ∈[0.8,1.2].
Seeds/dtype: {42,314,2718}, float64; BLAS pinned.
Intended use: KPI (AEE), advisory (LEE until graduation).
OOD limits: see §4.X Operational Envelope.

# Appendix K — Verification Runbook Charter (separate thread)

Purpose: keep rigorous, fast-moving verification workstreams **separate from authoring**.
Thread label: “CIF v1.2 — Verification Runbook” (test-only; no doc edits).

**Scope (In):** winsorize→z-score→logistic stability; axis convexity & NA renorm; engine caps; HCI fusion bounds; A40/DBI; whitening triggers; bootstrap CIs; KPI purity; Trend/RRE/DCR isolation; DCR determinism.
Seeds {42,314,2718}; dtype float64; BLAS pinned.

**CI gates (must pass):** KPI Purity; golden-run $|\Delta \mathrm{HCI}| \leq 0.002$; no `NaN` / `Inf` /out-of-range; adversarial coverage $\geq 1\times$ per class.
**Artifacts:** pass/fail table; Fail-Ledger (codes + minimal repro JSON); seeds and pack/model/ruleset hashes; **Doc Deltas** list.

# Appendix L — Risk Register (top 8)

| ID | Risk | Likelihood | Impact | Mitigation (in doc) | Residual |
|---|---|---|---|---|---|
| R1 | Over-reliance on Trend targets | M | M | Advisory-only; thresholds + approvals | Low |
| R2 | Proxy leakage pre-LEE graduation | M | M | Ownership guard + taper plan | Low |
| R3 | OOD material (very short/long) | M | M | OOD flags; reduced-axis mode | Low–M |
| R4 | Collinearity shocks | L–M | M | Lenient whitening + audit | Low |
| R5 | Corpus drift lowers DBI | M | M | DBI monitoring; rebalance | Low–M |
| R6 | Lyrics privacy compliance | L | H | Redaction, access control, audit | Low |
| R7 | Lane change whiplash | L | H | Governance vote; N/N+1 rollout | Low |
| R8 | CI misread as prediction | M | M | Clear CI meaning; seeds on Cards | Low |

# Appendix M — Interop & Artifacts (schema stubs)

## M.1 TAP (Track Analysis Pack)

```
{
  "type":"object",
  "required":["profile_id","features","seeds","env_hash","norms_timestamp"],
  "properties":{
    "profile_id":{"type":"string"},
    "features":{"type":"object"},
    "seeds":{"type":"array","items":{"type":"integer"}},
    "env_hash":{"type":"object"},
    "norms_timestamp":{"type":"string"}
  }
}

M.2 AdvisorResult (excerpt)

{
  "HCI":{"type":"number"},
  "ACTIONS":{"type":"array"},
  "ERA_CONTINUUM":{"type":"object"},
  "cards":{"type":"object"}
}

M.3 ERA_CONTINUUM block

{
  "dcr_id":{"type":"string"},
  "dcr_sha256":{"type":"string"},
  "analogs":{"type":"array"},
  "projection":{"type":"object"}
}
```

# Appendix N — Mathematical Gloss (plain-language)

> Purpose: explain each equation used in CIF v1.2 with units, bounds, and mini examples. Link here from the first use of each symbol.

## Core transforms

**Winsorization (outlier clamp)**

Clamp standardized values to a safe band, typically $|z| \le 4$.

*Why:* prevents extremes from dominating.

*Example:* $z = 6.2 \to 4$; $z = -5.1 \to -4$.

**Standardization (z-score)**

$z = (x - \mu)/\sigma$

*Meaning:* express raw $x$ in std-dev units vs profile mean $\mu$ and std $\sigma$.

*Domain:* $x$ in native units (BPM, LUFS, s); $z$ unitless; $\sigma > 0$.

*Example:* $x = 105$, $\mu = 100$, $\sigma = 10$ ⇒ $z = 0.5$.

**Logistic map (bounded score)**

$s = \dfrac{1}{1 + e^{-\gamma z}} = \sigma(\gamma z)$, $\gamma \in [0.8, 1.2]$

*Meaning:* squash $z$ smoothly into $[0, 1]$ so features blend cleanly.

*Props:* $s \in [0, 1]$; monotone; $\left|\frac{ds}{dz}\right| \le |\gamma|/4$.

*Example:* $z = 0.5$, $\gamma = 1.0$ ⇒ $s \approx 0.622$.

**Transform order**

Winsorize → z-score → logistic. (Preserves shape & stability.)

## Axis construction (engine-local)

**Convex axis**

$A_k = \sum_{j \in F_k} w_{k,j}\, s_{k,j}$ with $w_{k,j} \ge 0$, $\sum_j w_{k,j} = 1$, $s_{k,j} \in [0, 1]$.

*Meaning:* axis is a weighted blend of mapped sub-features.

*Props:* $A_k \in [0, 1]$; monotone in each $s_{k,j}$.

*Missing:* drop NA features and renormalize remaining weights to 1.

*Example:* $s = (0.7, 0.5)$, $w = (0.6, 0.4)$ ⇒ $A_k = 0.62$.

## Engine composite & cap

**Engine mean (EACM)**

$\mathrm{EACM} = \frac{1}{6} \sum_{k=1}^{6} A_k$

*Meaning:* interpretable average of a domain's six axes.

*Props:* monotone; sensitivity $\partial \mathrm{EACM}/\partial A_k = 1/6$.

*Example:* $(0.60, 0.52, 0.55, 0.58, 0.50, 0.62)$ ⇒ $0.5617$.

**Cap (fairness guardrail)**

$\tilde{E} = \min\big(\mathrm{EACM},\, c\big)$

*Meaning:* caps domain influence at calibrated high-percentile $c$.

*Props:* $\tilde{E} \in [0, c]$; flat gradient when capped.

*Example:* $\mathrm{EACM} = 0.62$, $c = 0.58$ ⇒ $\tilde{E} = 0.58$.

## KPI fusion (Host)

**Hit Confidence Index (HCI)**

$\mathrm{HCI} = \beta \cdot \min\big(\mathrm{EACM}_{\text{audio}},\, c_{\text{audio}}\big) \;+\; (1 - \beta) \cdot \min\big(\mathrm{EACM}_{\text{lyric}},\, c_{\text{lyric}}\big)$

*Meaning:* combines audio and lyric composites with policy weight $\beta$ and per-domain caps.

*Policy:* today $\beta = 1.0$ (audio-only KPI); post-graduation default $\beta = 0.5$ (**40/40**).

*Bounds:* $\mathrm{HCI} \in [0, 1]$; monotone in each domain; convex in $\mathrm{EACM}_*$.

*Single-axis bound:* a $+\Delta$ on one audio axis raises HCI by at most $\beta\,\Delta/6$ (lyric analog).

*Examples:* today $\mathrm{EACM}_{\text{audio}} = 0.62$, $c_{\text{audio}} = 0.58$ ⇒ $\mathrm{HCI} = 0.58$.

Post-grad with $\mathrm{EACM}_{\text{lyric}} = 0.54$, $c_{\text{lyric}} = 0.58$, $\beta = 0.5$ ⇒ $0.56$.

## Temporal priors & diagnostics

**Anchored-40 Prior (A40)**

$p_{\mathrm{A40}}(x) = \frac{1}{|D|} \sum_{d \in D} p(x \mid d)$ over decades in the anchored window.

*Impl:* decade centroids (cosine) or per-decade k-NN averages; normalized.

*Role:* prior only; KPI math unchanged.

**Decadal Balance Index (DBI)**

$\mathrm{DBI} = \dfrac{H(p)}{\log |D|} = -\dfrac{1}{\log |D|} \sum_{d \in D} p(d) \log p(d)$, with $0 \log 0 := 0$.

*Meaning:* evenness of decade representation ($0$ one-decade, $1$ uniform).

*Targets:* WARN if DBI $< 0.70$; healthy $\geq 0.85$.

*Examples:* uniform over 4 decades ⇒ $1.0$; $(0.90, 0.10, 0, 0) \approx 0.19$.

## Geometry & conditioning

**Cosine similarity (HEM space)**

$\cos\theta = \dfrac{\mathbf{u} \cdot \mathbf{v}}{\|\mathbf{u}\| \, \|\mathbf{v}\|}$ (scale-invariant).

**Kernel width via median 8-NN**

$\sigma = \mathrm{median}\{\text{distance to 8 nearest neighbors}\}$ in the anchored corpus.

*Why:* robust local scale for kernels.

**Condition number ($\kappa$)**

Largest/smallest singular value ratio of feature covariance/design matrix.

*Policy:* **Lenient whitening** triggers if $\kappa > 50$ or any VIF $> 7$.

**Variance Inflation Factor (VIF)**

$\mathrm{VIF}_j = \dfrac{1}{1 - R_j^2}$ where $R_j^2$ regresses feature $j$ on the others.

*Targets:* $\leq 5$ goal; 7 cap (audit in Appendix D if exceeded).

**Whitening (if triggered)**

Decorrelates features to improve conditioning; **KPI math unchanged**. Report pre/post spectra and corr matrices.

## Segmentation & loudness (AEE)

**Time-to-Chorus (TTC)**

First chorus onset with detector confidence $\geq 0.60$; else NA (axis renorm).

**Chorus lift**

$\Delta$ in short-term LUFS (e.g., 6s windows) between chorus and verse; typical 1–2 dB.

## Stability & uncertainty

**Bootstrap CI (track-level)**

$B = 100$ on fixed seeds; report mean±sd and 95% CI bands (stability), not prediction intervals.

## Policy knobs (math touchpoints)

**Caps (per domain)** — calibrate near the 95th percentile per profile; recorded as `cap_profile_version`.

**Beta (fusion weight)** — today $\beta = 1.0$; post-LEE default $\beta = 0.5$ (**40/40**).

**Missing-feature bound** — each missing axis affects HCI by at most $\beta/6$ (audio) or $(1-\beta)/6$ (lyric) before caps.

## Quick symbol map

$x$ raw; $\mu, \sigma$ mean/std; $z$ standardized; $s$ mapped; $A_k$ axis; $\mathrm{EACM}$ engine mean; $\tilde{E}$ capped engine; $c$ cap; $\beta$ fuse; $\kappa$ condition number; VIF variance inflation; DBI decadal balance.

**Appendix order (canonical):**
D — Collinearity & Whitening (Audit)
E — Trend Snapshot Deltas
F — Failure Modes & Alternatives
G — Conformance Checklist
H — Decade Continuum Registry (DCR)
I — RRE ACTIONS Example
J — Data & Model Cards
K — Verification Runbook Charter
L — Risk Register
M — Interop & Artifacts (schema stubs)
N — Mathematical Gloss (plain-language)

*Policy:* **ACTIONS** never alter HCI; they are advisory outputs produced by **RRE** after scoring.