

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

<b>Status:</b> Draft for review (methods-first; code-free)
<b>Date:</b> 2025-11-03 (America/Chicago)
<b>Supersedes:</b> v1.1.1 (+ Addendum A clarifications)
<b>Primary Author:</b> <b>Keith Hetrick</b> (Architecture, Methods, Governance)
<b>Contributors:</b> Keith Hetrick — Maintainer
<b>Affiliation:</b> Bellweather Studios
<b>Contact:</b> <a href="mailto:keith@bellweatherstudios.com">keith@bellweatherstudios.com</a> ( <a href="mailto:keith@bellweatherstudios.com">mailto:keith@bellweatherstudios.com</a> )
<b>Doc ID:</b> CIF-TW-v1.2
<b>Confidentiality:</b> Internal draft; redistribution only with approval.

## ⇌ 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- **Superseded Docs:** CIF v1.1.1 (PDF) + Addendum A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:  $\text{EACM} = \frac{1}{6} \sum_{k=1}^6 A_k$   
Capped engine:  $\tilde{E} = \min(\text{EACM}, c)$   
Fuse weight:  $\beta \in [0, 1]$ ; caps  $c_{\text{audio}}, c_{\text{lyric}}$

**Diagnostics**

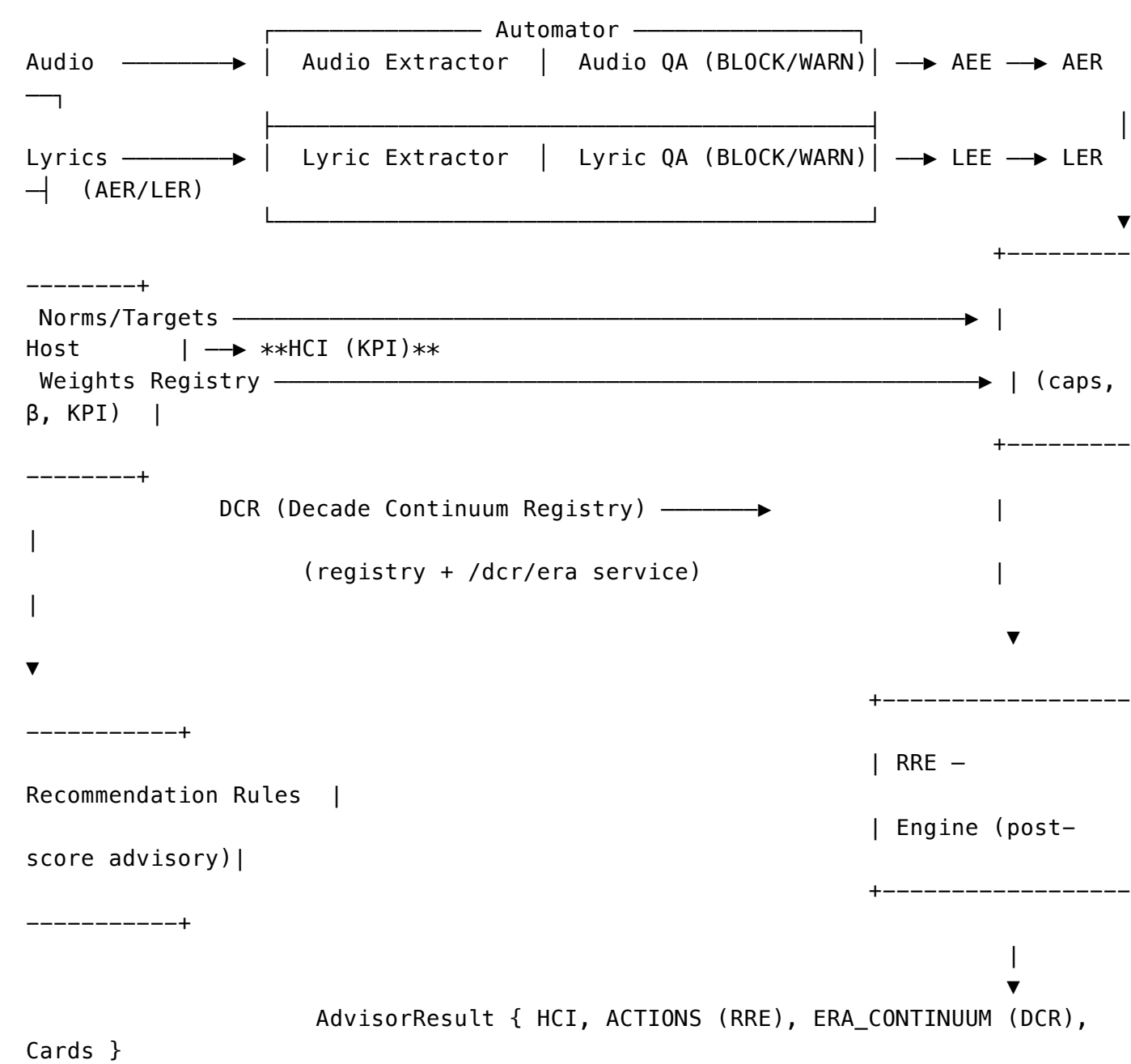
Correlation matrix; VIF; condition number  $\kappa$   
DBI — Decadal Balance Index (normalized entropy of decadal representation; diagnostic; report-only)  
A40 — Anchored-40 Prior (equal-weight decadal mixture)  
A40P — “Top 40  $\approx$  Top 40(−40 y), re-parameterized”  
RRE — Recommendation Rules Engine (deterministic rules  $\rightarrow$  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:**  $\beta=1.0 \Rightarrow$  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 ( $\backslash\beta$ ) with domain caps:

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

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
$\beta$	1.0 $\rightarrow$ 0.5	Adds lyric sensitivity (LER)	LEE gate + KPI-purity diff	Revert $\beta$ ; note N/N+1
Caps	$\pm 0.02$	Ceiling shift on high tracks	Sensitivity run	Restore prior <code>cap_version</code>
$\gamma$	0.8–1.2	Local steepness of mappings	Invariant suite + goldens	Revert $\gamma$ ; re-hash norms
Canonical lane	Radio $\rightarrow$ Spotify	KPI drift risk	Governance vote + DBI/trend review	Rollback lane; annotate Cards
A40 window	re-anchor	Engine echo geometry shift (not KPI)	DBI $\geq 0.85$ ; validation figs	Restore prior A40 pack

## 4. Methods

**Transform order:** winsorize  $\rightarrow$  z-score  $\rightarrow$  logistic  $\rightarrow$  axis  $\rightarrow$  engine mean  $\rightarrow$  cap  $\rightarrow$  fuse  $\rightarrow$  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)

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

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

$EACM = \frac{1}{6} \sum_{k=1}^6 A_k$ ; capped engine  $\tilde{E} = \min(EACM, c)$ .

**Monotonicity:** increasing any  $A_k$  never decreases  $\tilde{E}$ .

**Sensitivity:**  $\partial EACM / \partial A_k = 1/6$ ; 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  $\geq 0.60$ ; else NA.

**Chorus-lift:**  $\Delta$  of 6s ST-LUFS windows (chorus vs verse). Validators may set NA  $\rightarrow$  local axis renorm.

### 4.6 Consolidation (Host)

$$HCI = \beta \cdot \min(\max(EACM_{\text{audio}}, c_{\text{audio}}), \max(EACM_{\text{lyric}}, c_{\text{lyric}})) + (1 - \beta) \cdot \min(\max(EACM_{\text{audio}}, c_{\text{audio}}), \max(EACM_{\text{lyric}}, c_{\text{lyric}}))$$

**Today:**  $\beta = 1.0 \Rightarrow$

$HCI = \min(\max(EACM_{\text{audio}}, c_{\text{audio}}), \max(EACM_{\text{lyric}}, c_{\text{lyric}}))$ .

**Example:** if  $EACM_{\text{audio}} = 0.62$ ,  $c_{\text{audio}} = 0.58 \Rightarrow HCI = 0.58$ .

After LEE graduation,  $\beta = 0.5$ ,  $EACM_{\text{lyric}} = 0.54 \Rightarrow HCI = 0.5 \times 0.58 + 0.5 \times 0.54 = 0.56$ .

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

### 4.7 Missing-Feature Policy

Invalid features  $\rightarrow$  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):**

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

Threshold example: report WARN for DBI  $< 0.70$ ; target  $\geq 0.85$  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  $\Rightarrow$  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  $\leq$  ~0.6; VIF  $\leq$  5 target,  $\leq$ 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  $\leq$ 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.  $\rightarrow$  **Evidence E1:** Property specs + goldens ( /specs , /goldens ), seeds {42,314,2718} .

**Strategy S2:** Show advisory isolation.  $\rightarrow$  **Evidence E2:** KPI-purity tests (identical HCI with advisory disabled).

**Strategy S3:** Demonstrate temporal fairness & conditioning.  $\rightarrow$  **Evidence E3:** DBI  $\backslash(\geq 0.85\backslash)$  target; Whitening Audit if  $\backslash(\backslash\kappa>50\backslash)$  or any VIF  $\backslash(>7\backslash)$  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  $\pm$  sd (over seeds); **HCI** mean  $\pm$  sd; 95% bootstrap CI; cap-utilization %.

**Worked Example (Track Alpha, anonymized):** standardize  $\rightarrow$  map  $\rightarrow$  axes  $\rightarrow$  EACM  $\rightarrow$  cap  $\rightarrow$  **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,  $\beta$  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 $\rightarrow$ v1.2)

Parameter discipline; bounds/monotonicity; HEM  $\backslash(\backslash\sigma\backslash)$ -rule; lenient whitening; segmentation acceptance; consolidation math; missing-feature bound; modular Axis Contract; governance  $(\backslash(\backslash\beta\backslash)/\text{caps}/\text{overrides}, \text{lanes})$ ; 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	$\kappa > 50$ or VIF>7	§4.4, App D		
Golden-run tolerance		$\Delta$ HCI	$\leq 0.002$ 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 $\geq 0.85$ ; decade stability
$\beta$ policy	1.0 (today)	Governance	Graduation decision	LEE gate: repeatability, CIs, independence, placebo
Caps	0.58	Governance	Profile override	Sensitivity $\pm 0.02$ review
Whitening	OFF	Methods	Triggered by $\kappa$ /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  $\rightarrow$  Datahub export  $\rightarrow$  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  $\rightarrow$  Intent  $\rightarrow$  Playbook  $\rightarrow$  Actions**. Inputs: final axes, QA/validators, Trend Snapshot, platform lane, **DCR era\_analogs**. Outputs: top-K (default 5) actions per lane, evidence links (measurement  $\rightarrow$  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 ( `AUDIO0.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.

**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.

## 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	<b>Keep Radio US canonical</b>
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	<b>Lenient trigger</b> only ( $\kappa > 50$ or $VIF > 7$ )
Preferences in scoring	Subjectivity contaminates KPI	Loss of trust/repeatability	<b>Advisory only</b> (Curation view)
Penalize missing features	Unfair to certain genres/material	Hidden bias	<b>NA + renorm</b> 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	<b>Governance decision</b> only

F.4 Proof obligations (acceptance tests)

- **Golden-run guard:** With no policy change, per-track  $|\Delta HCI| \leq 0.002$ .
- **Monotonicity:** increasing any axis cannot reduce EACM\* or HCI after caps.
- **Independence:**  $\text{corr} \leq \sim 0.6$ ;  $VIF \leq 5$  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,  $|\Delta \text{HCI}| \leq 0.002$  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 ( $\kappa$ , 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  $\text{VIF} > 7$ .

## 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_T0_+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  $\geq 0.85$ ).  
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 &  $\gamma$ : `caps=0.58`;  $\gamma \in [0.8, 1.2]$ .  
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  $\left(|\Delta \mathrm{HCI}| \leq 0.002\right)$ ; no NaN / Inf /out-of-range; adversarial coverage  $\left(\geq 1\times\right)$  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  $(|z| \leq 4)$ .

*Why:* prevents extremes from dominating.

*Example:*  $(z = 6.2 \text{ to } 4)$ ;  $(z = -5.1 \text{ to } -4)$ .

### 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:*  $(x = 105)$ ,  $(\mu = 100)$ ,  $(\sigma = 10) \Rightarrow (z = 0.5)$ .

### Logistic map (bounded score)

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

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

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

*Example:*  $(z = 0.5)$ ,  $(\gamma = 1.0) \Rightarrow (s \approx 0.622)$ .

### Transform order

Winsorize  $\rightarrow$  z-score  $\rightarrow$  logistic. (Preserves shape & stability.)

## Axis construction (engine-local)

### Convex axis

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

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

## 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:*  $((0.60, 0.52, 0.55, 0.58, 0.50, 0.62)) \Rightarrow (0.5617)$ .

### Cap (fairness guardrail)

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

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

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

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

## KPI fusion (Host)

### Hit Confidence Index (HCI)

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

*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  $(\mathrm{EACM}_{\text{audio}} = 0.62), (c_{\text{audio}} = 0.58) \Rightarrow (\mathrm{HCI} = 0.58)$ .

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

## Temporal priors & diagnostics

### Anchored-40 Prior (A40)

$(p_{\text{A40}}(x) = \frac{1}{|D|} \sum_{d \in D} p(x \mid d))$  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)

$(\mathrm{DBI} = \frac{H(p)}{\log |D|} = -\frac{1}{\log |D|} \sum_{d \in D} p(d) \log p(d))$ , 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  $\Rightarrow 1.0$ ;  $((0.90, 0.10, 0, 0) \approx 0.19$ ).

## Geometry & conditioning

### Cosine similarity (HEM space)

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

### Kernel width via median 8-NN

$\sigma = \text{median}\{\text{distance to 8 nearest neighbors}\}$  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)

$\text{VIF}_j = \frac{1}{1 - R_j^2}$  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  $\text{mean} \pm \text{sd}$  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;  $\text{EACM}$  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.