

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

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

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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- **Superseded Docs:** CIF v1.1.1 (PDF) + Addendum A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, κ /VIF, TTC/lift), see **Appendix N — Mathematical Gloss**.

Variables & Ops

Raw feature: x ; mean/std: μ, σ ; 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 κ

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 — Δ 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 $\beta = 1.0$)

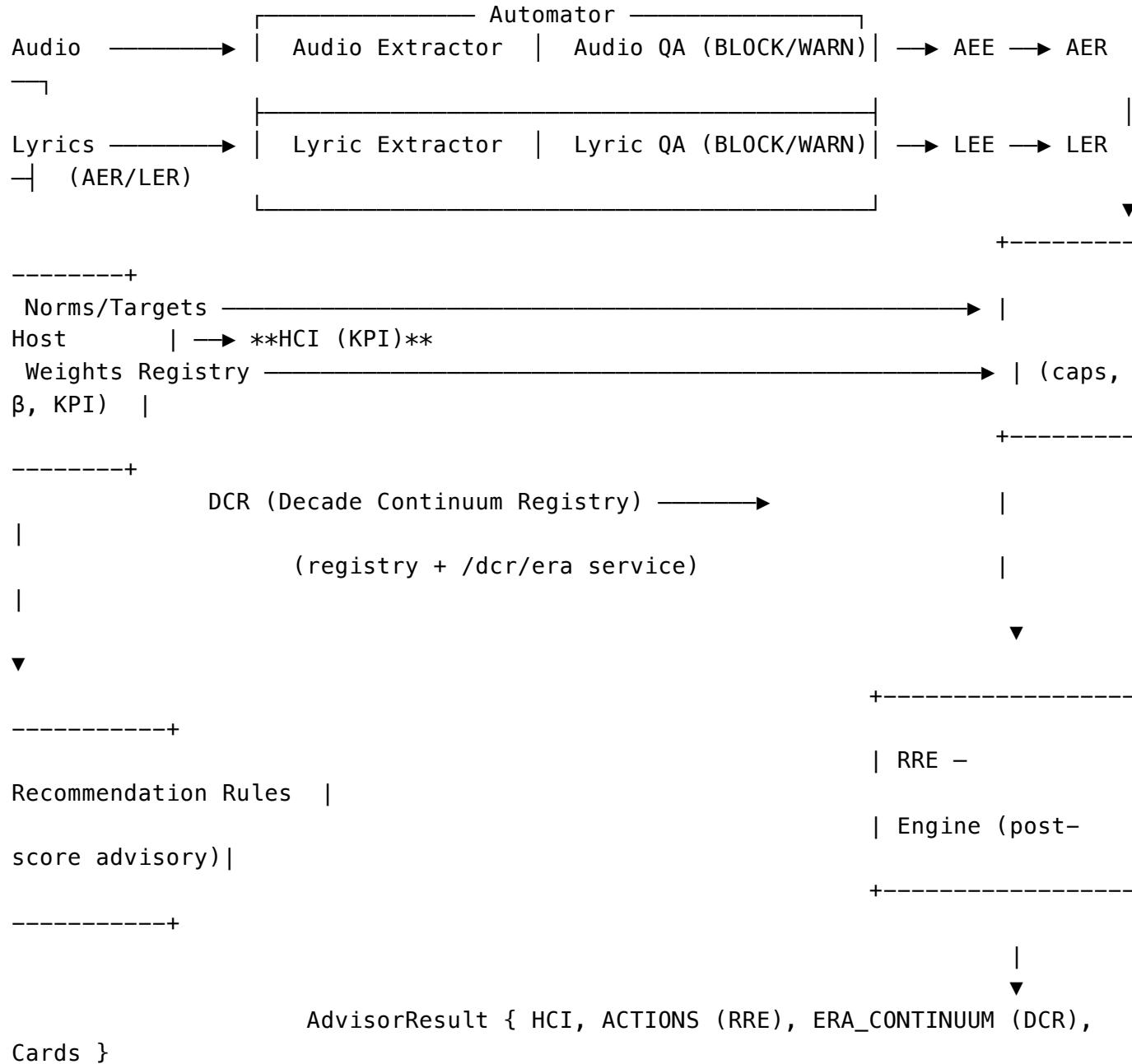
Whitening (Lenient): OFF unless $\kappa > 50$ or max VIF > 7

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:** $\beta=1.0 \Rightarrow \text{HCI}$ 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 (HCl; 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:

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

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, β , or HCI. **Two modes:** Evaluation (baseline norms) and optional Curation (preference re-ordering); safety items pinned; preferences_used recorded.

3.5 Governance: Lanes, β , Caps, Overrides

- **Canonical KPI lane: Radio US.**
- **Advisory lanes:** Radio + Spotify; duplicates auto-hidden unless advice differs.
- β : 1.0 today; **40/40** ($\beta = 0.5$) post-LEE graduation.
- **Caps:** $c_{\text{audio}} = c_{\text{lyric}} = 0.58$ defaults (sensitivity ± 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 (Δ 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 σ 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 ≥ 0.60 ; else NA.

Chorus-lift: Δ of 6s ST-LUFS windows (chorus vs verse). Validators may set NA → local axis renorm.

4.6 Consolidation (Host)

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

Today: $\beta = 1.0 \Rightarrow$

$$(HCI) = \min(\text{EACM}_{\text{audio}}, c_{\text{audio}}).$$

Example: if $(\text{EACM}_{\text{audio}} = 0.62)$, $(c_{\text{audio}} = 0.58) \Rightarrow HCI = 0.58$.

After LEE graduation, $(\beta = 0.5)$, $(HCI) = \min(\text{EACM}_{\text{lyric}}, c_{\text{lyric}}) = 0.54 \Rightarrow HCI = 0.5 \times 0.58 + 0.5 \times 0.54 = 0.56$.

Math card — HCI. Bounds $[0, 1]$; monotone in each domain; single-axis bound: a Δ 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 → 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):

$$DBI = \frac{\log |D|}{\sum_d p(d)} = -\frac{1}{\log |D|} \sum_d p(d) \log p(d)$$

Threshold example: report WARN for DBI < 0.70 ; target ≥ 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_DBM ; 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 \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, 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 \rightarrow v1.2)

Parameter discipline; bounds/monotonicity; HEM $\backslash(\sigma)$ -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	$\kappa > 50$ or $VIF > 7$	§4.4, App D		
Golden-run tolerance		ΔHCl	≤ 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 if lyrics are missing? Lyric domain NA; HCI uses audio only; advisory may still render with low-confidence labels.

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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 ($\kappa > 50$ 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 $|\Delta\text{HCI}| \leq 0.002$.
- **Monotonicity:** increasing any axis cannot reduce EACM* or HCI after caps.
- **Independence:** $\text{corr} \leq \sim 0.6$; $\text{VIF} \leq 5$ 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 (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 $\text{VIF} > 7$.

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>",
  "analog": [
    {"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>",
 "analog": [{"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 ( $\kappa > 50$  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  $\rightarrow$  z-score  $\rightarrow$  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  $(|\Delta \text{mathrm{HCI}}| \leq 0.002)$ ; no NaN / Inf /out-of-range; adversarial coverage  $(\geq 1\text{times})$  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"},
 "analog": {"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)

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

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

*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)

$\{(\text{EACM}) = \frac{1}{6} \sum_{k=1}^6 A_k\}$

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

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

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

### Cap (fairness guardrail)

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

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

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

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

## KPI fusion (Host)

---

### Hit Confidence Index (HCI)

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

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

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

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

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

## Temporal priors & diagnostics

---

### Anchored-40 Prior (A40)

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

$\{(\text{DBI}) = \frac{H(p)}{\log |D|} = -\frac{1}{\log |D|} \sum_{d \in D} p(d) \log p(d)\}$ , 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 mean $\pm$ 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.