T4 — Counterfactual Echo Gain (CEG): A Metriplectic Assisted-Echo Experiment Proposal in VDM

A Preprint

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Abstract

VDM (Void Dynamics Model) separates dynamics into a conservative limb J and a dissipative limb M (metriplectic split). The proposed experiment defines and tests *Counterfactual Echo Gain* (CEG) — the improvement in echo fidelity when a system uses its *internal model* of (J) and (M) to assist the time-reversal phase, relative to an energy-matched, model-blind baseline. The preregistered observable is

$$\mathrm{CEG} \equiv \frac{E_{\text{baseline}} - E_{\text{assisted}}}{E_{\text{baseline}}} \in [0, 1],$$

with explicit physics gates: **(i) J-Noether drift** bounded, **(ii) M-monotonicity** (H-theorem) respected, and **(iii) energy-matching** enforced. Passing requires $\mathrm{median}_{\text{seeds}}(\mathrm{CEG}) \geq 0.05$ without gate violations across a preregistered grid of step sizes and split compositions. This elevates echoes from calibration demos to a falsifiable claim about *model-aware self-correction* under metriplectic dynamics. All artifacts, gates, and figures are to be posted in RESULTS-conformant form for provenance.

Keywords metriplectic dynamics · assisted echo · Noether drift · H-theorem · Strang splitting · preregistration · reproducibility

Tier grade	T4 (Preregistered claim); prior support at T2/T3 (meters, smoke tests).
Created	2025-10-30
Commit (repo)	`80ee5476e4f887fed3c34534a99daa878f55382f`
License	See `LICENSE` at repository root.
Contact	Justin K. Lietz <justin@neuroca.ai>

Registration statement. This is a preregistered proposal (T4) with explicit pass/fail gates and a machine-readable spec. Successful passage promotes follow-on work to T5 (Pilot) and broader T7/T8 sweeps.

1 Background & Scientific Rationale

Metriplectic core. VDM enforces two coupled generators on state q:

$$\dot{q} = J(q)\,\frac{\delta \mathcal{I}}{\delta q} + M(q)\,\frac{\delta \Sigma}{\delta q}, \qquad J^\top = -J,\ M^\top = M \succeq 0, \tag{1}$$

with degeneracies $J\,\delta\Sigma/\delta q = 0$ and $M\,\delta\mathcal{I}/\delta q = 0$. The J limb preserves invariants (e.g., discrete Hamiltonian), while M increases a Lyapunov/entropy Σ (discrete H-theorem). The VDM canon documents meters for these properties and composition-error scaling under Strang splitting.

Governing instruments. Validated KG/RD branches and conservation-law diagnostics provide the measurement substrate for the echo tests; e.g., the discrete action and Euler–Lagrange structure (for J), and gradient-flow RD updates (for M). These appear in the EQUATIONS registry used as the computational "instrument manual."

Maturity ladder (T0–T9). Evidence tiers: T0 (Concept), T1 (Proto-model), T2 (Instrument meters), T3 (Smoke), T4–T6 (Preregistered → Pilot → Main), T7–T8 (Out-of-sample → Robustness), T9 (External reproduction). This document is T4, building on T2/T3 artifacts (Noether/H-theorem meters, Strang QC, scaling collapse) and specifying explicit pass/fail gates and configs.

Why now. Meters are certified (T2) for J-reversibility, M-monotonicity, Strang-defect slopes; T3 smoke tests showed scaling collapses and routing discipline. The present T4 proposal upgrades echoes from instrument checks to a *phenomenon test*: whether *internal J/M knowledge* can be exploited to improve a reversible-attempt under dissipation, *without breaking the gates*.

Novelty & targets. Novelty lies in the *gate-bounded, metriplectic assisted-echo* and preregistered metric (CEG). Targets: (i) robust $\text{CEG} > 0$ under energy-matched controls; (ii) zero violations of J-Noether and H-monotonicity; (iii) sensitivity map over assistance strength and composition ordering.

Critiques (and replies). *Energy cheating?* Energy-matching gate. *Numerical artifact?* Instruments QC'd (Noether/H-theorem/Strang) and ablations scramble the model while holding numerics fixed. *Metaphysical self-awareness?* Claim is *operational*: model-aware correction under metriplectic gates.

2 Intellectual Merit and Procedure

Importance. Establishes a falsifiable competency—*model-aware self-correction*—measured under strict conservation/entropy gates.
Impact. If validated, metriplectic assisted-echoes become tools for probing agency-like competencies in field models.
Approach. Treat the numerical scheme as a measuring instrument; pair claims with metrics and gates; preregister parameters, seeds, thresholds; publish artifacts per RESULTS standards.

2.1 Experimental Setup and Diagnostics

State and splits. Domain $\Omega \subset \mathbb{R}^d$ (1D/2D) with field W (KG for J; RD/gradient-flow for M). Discrete action and updates from EQUATIONS registry; canonical constants from CONSTANTS registry.

Integrator. Strang JMJ (or MJM control): symplectic step for J; discrete-gradient step for M. Diagnostics on each limb are enabled during both forward and reverse phases.

Observables. Echo error $E \equiv \|q_{\text{final}} - q_0\|_{\mathcal{H}}$ in a declared discrete energy norm. CEG as in Eq. (2).

$$\text{CEG} \equiv \frac{E_{\text{baseline}} - E_{\text{assisted}}}{E_{\text{baseline}}}, \qquad 0 \le \text{CEG} \le 1. \tag{2}$$

Gates (physics constraints).

- **G1 (Noether-J):** $\max_t \frac{|\Delta \mathcal{I}|}{\mathcal{I}_0} \le 10^{-8}$ (fp64; multi-seed median).
- **G2 (H-M):** $\Delta\Sigma \ge -10^{-12}$ per step (fp rounding tolerance); non-decreasing cumulative Σ in M-only segments.
- **G3 (Energy-match):** assistance work budget equals baseline within 10^{-4} relative.
- **G4 (Composition QC):** Strang defect slope $\beta \in [2.8, 3.2]$ on Δt log–log fit before assisted tests.

Preregistered grid. $N \in \{256, 512, 1024\}$; $\Delta t \in \{0.5, 1, 2\} \times \Delta t_{\text{CFL}}$ (stable envelope per branch); split ordering (JMJ/MJM); assistance $\lambda \in \{0.0, 0.1, 0.2, 0.3\}$; seeds ≥ 12 (fixed list).

Diagnostics (counts). Noether drift monitor (1), H-theorem monitor (1), composition-slope fitter (1), CEG aggregator (1), gate-ledger (1), optional light-cone/dispersion probes (2). Artifacts (CSV/JSON/PNG) paired per RESULTS standards.

New tools/scripts. `experiments/metriplectic/assisted_echo.py` (SMAE micro-sequence during rewind; energy-budget clamp); `metrics/echo_fidelity.py` (norms; CEG); `gates/echo_gates.py` (G1–G4 JSON pass/-fail; contradiction reports); `schemas/echo_artifacts.schema.json`.

Compute environment. x86_64 Linux, Python 3.11+, NumPy/SciPy/FFT; optional ROCm-accelerated FFT/BLAS on AMD GPUs; commit+seed logged for every run; IEEE-754 fp64 discipline.

Pre-Run Config (minimum)

APPROVAL.json (excerpt).

Listing 1: APPROVAL.json (excerpt)

```
[
  {
    "preflight_name": "preflight",
    "description": "Approval manifest stating that the preflight runner must pass
         before real runs that write artifacts.",
    "author": "Justin K. Lietz",
    "requires_approval": true,
    "pre_commit_hook": true,
    "notes": "Preflight runs (Derivation/code/tests) are allowed without approval
       . To run real experiments that write artifacts, a relevant PROPOSAL_*
       must be created at Derivation/Metriplectic/ and approved."
  },
  {
    "pre_registered": true,
    "proposal": "Derivation/Metriplectic/T4_PROPOSAL_CEG_Metriplectic_Assisted-
       Echo_Experiment.md",
    "allowed_tags": ["echo_spec-v1"],
    "schema_dir": "Derivation/code/physics/metriplectic/schemas",
    "approvals": {
      "echo_spec-v1": {
        "schema": "Derivation/code/physics/metriplectic/schemas/echo_spec-v1.
           schema.json",
        "approved_by": "Justin K. Lietz",
        "approved_at": "<auto-generated>",
        "approval_key": "<hashed-key>"
      }
    }
  }
]
```

PRE-REGISTRATION.json (minimum).

Listing 2: PRE-REGISTRATION.json (minimum keys)

```
{
  "proposal_title": "CEG Assisted-Echo",
  "tier_grade": "T4",
  "commit": "80ee5476e4f887fed3c34534a99daa878f55382f",
  "salted_provenance": {
    "schema": "vdm.provenance.salted_hash.v1",
    "generated_utc": "2025-10-30T16:49:47.201492Z",
    "salt_bytes": 16,
    "single_salt": true,
    "salt_hex": "aff7a0cb80e8d430873bc504be978525",
    "items": [
      {
        "path": "Derivation/code/physics/metriplectic/specs/assisted_echo.v1.json
           ",
        "size": 274,
        "base_sha256": "40917004b65550b10dd89dcaeef43df9191ddb2d2f08656bb9c1e37a7
           372116d",
        "salt_hex": "aff7a0cb80e8d430873bc504be978525",
```

```
        "salted_sha256": "7cb47d741d087a65fc5f9eeb73c599904702ba199c101b81ae19546
            58fc51029"
      }
    ]
  },
  "contact": ["Justin K. Lietz <justin@neuroca.ai>"],
  "hypotheses": [
    { "id": "H1", "statement": "Median CEG >= 0.05 under gates G1-G4.", "
        direction": "increase" }
  ],
  "variables": {
    "independent": ["N", "dt", "split", "lambda"],
    "dependent": ["CEG"],
    "controls": ["energy_match", "seed"]
  },
  "pass_fail": [
    { "metric": "CEG_median", "operator": ">=", "threshold": 0.05, "unit": "
        dimensionless" }
  ],
  "spec_refs": ["Derivation/code/physics/metriplectic/specs/assisted_echo.v1.json
      "],
  "registration_timestamp": "2025-10-30T16:49:47.201492Z"
}
```


Specs (assisted_echo.v1.json — minimum keys).


```
[language=json,caption={assisted_echo.v1.json (minimum keys)}]
{
  "tag": "assisted-echo-t4-prereg",
  "grid": { "N": 256, "dx": 1.0 },
  "params": { "c": 1.0, "m": 0.5, "D": 1.0, "m_lap_operator": "spectral" },
  "dt": 0.02,
  "steps": 200,
  "seeds": [1,2,3,4,5,6,7,8,9,10,11,12],
  "lambdas": [0.0, 0.1, 0.2, 0.3],
  "budget": 1e-3
}
```


Schemas (echo_spec-v1.schema.json — minimum).


```
[language=json,caption={echo_spec-v1.schema.json (minimum)}]
{
  "$schema": "https://json-schema.org/draft/2020-12/schema",
  "$id": "urn:metriplectic:echo_spec-v1",
  "title": "assisted_echo spec schema",
  "type": "object",
  "metadata": { "tag": "echo_spec-v1" },
  "properties": {},
  "required": []
}
```


2.2 Experimental Runplan

1. **RP-1 Baseline calibration (meters).** Run J-only reversibility, M-only monotonicity, and Strang defect slope across the grid; must pass G1–G2–G4 before any assisted runs. (Artifacts posted with CSV/JSON and figure captions including slope/R^2 and seed/commit.)
2. **RP-2 Assisted-echo implementation.** Insert a micro-sequence during the reverse M-segment using the internal M estimator, with assistance λ and *energy-match clamp*. Log assistance work; ensure G3.
3. **RP-3 Preregistered evaluation.** For each grid point and seed: forward JMJ $\rightarrow$ perturb ("walker" pulse) $\rightarrow$ reverse. Record E_{baseline} at λ=0 and E_{assisted} for λ>0. Compute CEG and gate statuses.
4. **RP-4 Ablations & controls.** Model-blind assistance (scramble M map), J-scramble, M-scramble, and MJM ordering as controls; same energy budget, same seeds.

5. **RP-5 Publication pipeline.** Prepare `RESULTS_CEG_AssistedEcho.md` with TL;DR, gates, tables, figures with numeric captions, and reproducibility manifests (commit/seed). Emit contradiction reports if any gate fails.

Runtime scope. Total run budget is $(\#\text{grid}) \times (\#\text{seeds}) \times (\#\lambda) \times (\#\text{steps (fwd+rev)})$ with all artifacts retained; RESULTS standards require per-figure paired CSV/JSON and gate JSON per run.

Plan of action (success). If $\text{median}_{\text{seeds}}(\text{CEG}) \geq 0.05$ and all gates pass across ≥80% of grid points, promote to T5 (Pilot) with a ridge map of CEG vs. $(\lambda, \text{M-strength})$.

Plan of action (failure). If any gate fails, emit `CONTRADICTION_REPORT` (gate, threshold, seed, commit, artifact) and quarantine. If gates pass but $\text{CEG} \leq 0$, publish null result; run ablations to bound sensitivity and update assistance design.

3 Personnel

Justin K. Lietz (PI): designs experiment; implements `assisted_echo.py`, metrics, gates, and artifact schemas; runs preregistered sweeps; authors RESULTS note; maintains provenance (commit/seed/logging) and compliance with artifact/figure pairing.

4 References (informal, minimal)

1. White Paper Proposal Template (section structure, narrative discipline, provenance requirements).
2. RESULTS Paper Standards (figure/CSV pairing, numeric captions, gate JSONs, contradiction-reporting norms).
3. VDM EQUATIONS Registry (discrete action/Lagrangian, Euler–Lagrange, and RD/KG update forms).
4. VDM Overview (Canon & Maturity) (Noether/H-theorem checks; metriplectic structure gates).
5. VDM CONSTANTS (canonical default parameters; CFL guidance).
6. Technical & Scientific Principles (numerical-as-instrument, IEEE-754 discipline).

A Instrument Equations Referenced in §1 (KG branch)

Discrete Lagrangian / Euler–Lagrange for the (J) limb (KG branch):

$$\frac{W_i^{n+1} - 2W_i^n + W_i^{n-1}}{(\Delta t)^2} - \kappa \sum_{\mu=1}^{d} \left(W_{i+\mu}^n + W_{i-\mu}^n - 2W_i^n\right) + V'(W_i^n) = 0, \qquad \mathcal{L} = \tfrac{1}{2}(\partial_t \phi)^2 - \tfrac{\kappa a^2}{2}(\nabla\phi)^2 - V(\phi).$$

(Continuum limit and notation as in the registry.)

Reproducibility & provenance. All runs log commit, seed, full parameters, and SHA-256 checksums for CSV/JSON/PNG artifacts, consistent with VDM's reproducibility policy. Claims here are operational and physical (assisted echoes improve fidelity under metriplectic gates); no metaphysical claims are made.

References

[1] J. K. Lietz, *T4 — Counterfactual Echo Gain (CEG): A Metriplectic Assisted-Echo Experiment in VDM (Preregistration / Proposal)*, 2025. Zenodo / repository draft (preregistration text). Commit: `80ee5476e4f887fed3c34534a99daa878f55382f`. Contact: `justin@neuroca.ai`. ORCID: 0009-0008-9028-1366.

[2] J. K. Lietz, *VDM: Metriplectic Assisted-Echo — code and experiment artifacts (repository snapshot)*, 2025. Git repository, commit `80ee5476e4f887fed3c34534a99daa878f55382f` (useful for provenance).

[3] RESULTS Working Group, *RESULTS Paper Standards — figure/CSV pairing, gate JSONs, contradiction reporting*, 2024. Project / standards document (referenced for artifact and numeric caption standards).

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[6] G. Strang, "On the construction and comparison of difference schemes," *SIAM Journal on Numerical Analysis*, 1968. (Classic reference for operator splitting — Strang splitting.)

[7] P. J. Morrison, "Foundations of metriplectic (Hamiltonian + dissipative) formulations," review articles and technical notes (see Morrison's bracket papers on Hamiltonian/dissipative combinations; add DOI if required).

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[9] A. M. Turing, "The Chemical Basis of Morphogenesis," *Philosophical Transactions of the Royal Society B*, 1952. (Classic RD / pattern formation reference.)

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[15] J. K. Lietz, $echo_spec - v1.schema.json^-JSONSchemaforassisted - echospecs$, 2025.$(Derivation/code/physics/metriplectic/schemas/echo_spec - v1.schema.json.)$

[16] J. K. Lietz, *APPROVAL.json — preflight and approval manifest (excerpt)*, 2025. (Derivation/code/physics/metriplectic/APPROVAL.json.)

[17] J. K. Lietz, *LICENSE*, 2025. Project root LICENSE file included with repository and Zenodo deposit.