

# Vacuum Web Transdimensional Unification Theory (VWTUT)

## Version 3 - Final Freeze Candidate

Tensor-Product Validation, Archival Topology Result, and Direct-Sum Memory Verification  
Speculative methods-and-validation report - September 2026

**FREEZE DISPOSITION.** The forensic audit could not recover clean provenance for three archived quantities. They are therefore formally retired rather than reconstructed: (i) the two positive minimum-eigenvalue numbers as reproducible positivity evidence, (ii) the tensor-product "component norm drift" value as validation evidence, and (iii) Test 2C-R3 as a quantitatively reproducible scientific test. The original 2C-R3 outcome is preserved only as an archival negative result. No frozen numerical outcome has been changed or rerun.

### Abstract

Version 3 contains two mathematically distinct numerical branches. Branch A is a tensor-product open-system model: one observable qubit is exchange-coupled to a finite interacting spin bath, the bath may begin in a thermal mixed state, the joint state evolves under the implemented Hamiltonian, and the observable state is obtained by partial trace. Branch B is the direct-sum hidden-amplitude model inherited from Version 2, for which eliminating hidden amplitudes gives an exact retarded Volterra equation. These branches are conceptually related but are not the same reduced dynamics.

The tensor-product program passed its retained internal RK4 Hermiticity, trace, decoupling, relabeling, and timestep-convergence checks only after explicitly retained implementation failures and narrowly scoped repairs. An independent matrix-exponential or Krylov cross-check remains outstanding. The former 2C-R3 cospectral comparison is retained only as archival history because the exact source-code definitions and normalizations of its two decisive operational metrics could not be recovered.

The direct-sum program verified that the corrected Volterra reduction reproduces the full direct-sum dynamics generated from the same hidden Hamiltonian and coupling. Test 3B showed that one selected four-parameter damped-oscillatory population surrogate fitted to a short training interval extrapolated poorly. Because the exact reduction receives the generating  $H_B$  and  $G$  while the surrogate does not, this is a diagnostic comparator result, not an oracle-free model-selection victory.

Version 3 is therefore a bounded methods-and-validation record. It does not demonstrate a physical vacuum web, a tensor-product memory kernel, topology identifiability beyond coupling-weighted local spectroscopy, or superiority over conventional open-system models.

### 1. Scope and branch separation

**Branch A - tensor-product open-system model.** Density matrices, thermal bath states, joint evolution, partial trace, and retained internal numerical audits. Tests 2A through 2B-R2 form the quantitative validation record. Test 2C-R3 is retained only as an archival negative topology attempt.

**Branch B - direct-sum exact-elimination model.** Observable amplitudes  $a(t)$ , hidden amplitudes  $b(t)$ , and an exact Volterra equation obtained by eliminating  $b$ . Tests 3A/3A-R1 and 3B belong here. The kernel is an **amplitude-level kernel, scalar in the tested realization**; it is not claimed to be the memory kernel of the finite-temperature tensor-product reduced density matrix.

No Branch B result is used as evidence that Branch A possesses the same memory representation.

### 2. Direct-sum exact elimination

$$i \, da/dt = H_A a + G b$$

$$i \, db/dt = G^\dagger a + H_B b$$

$$i \, da(t)/dt = H_A a(t) + G \exp(-i H_B t) b(0) - i \int_0^t G \exp[-i H_B(t-s)] G^\dagger a(s) ds$$

|                                            |
|--------------------------------------------|
| $K(t-s) = G \exp[-i H_B(t-s)] G^\dagger$   |
| $\text{Sigma}(z) = G(z-H_B)^{-1}G^\dagger$ |

This is an exact identity for the specified block Hamiltonian. In the archived 3A-R1 realization, the hidden initial amplitude was  $b(0)=0$ ; the inhomogeneous term is retained because it belongs to the general derivation.

### 3. Tensor-product hidden-spin model

|                                                                                                                     |
|---------------------------------------------------------------------------------------------------------------------|
| $H_{\text{tot}} = H_S \text{ tensor } I_B + I_S \text{ tensor } H_B + H_I$                                          |
| $H_S = (\omega_S/2) \sigma_z^S$                                                                                     |
| $H_B = \sum_i (\omega_i/2) \sigma_i^z + \sum_{\{i<j\}} J_{ij} (\sigma_i^+ \sigma_j^- + \sigma_i^- \sigma_j^+)$      |
| $H_I = \lambda (\sigma_S^+ \text{ tensor } B + \sigma_S^- \text{ tensor } B^\dagger)$ , $B = \sum_i g_i \sigma_i^-$ |
| $\rho_{SB}(t)=U(t)\rho_{SB}(0)U^\dagger(t)$ , $U(t)=\exp(-iH_{\text{tot}} t)$                                       |
| $\rho_S(t)=\text{Tr}_B[\rho_{SB}(t)]$                                                                               |

For thermal tests,  $\rho_B(\beta)=\exp(-\beta H_B)/\text{Tr}[\exp(-\beta H_B)]$  and  $\rho_{SB}(0)=\rho_S(0) \text{ tensor } \rho_B(\beta)$ . The implementation uses excitation-number structure to reduce computational cost where applicable.

### 4. Frozen numerical record and retirement status

| Test         | Status in V3 freeze    | Interpretation                                                                                      |
|--------------|------------------------|-----------------------------------------------------------------------------------------------------|
| 1A           | PASS                   | Direct-sum intervention basin; model-internal.                                                      |
| 1B           | PASS                   | Harder passive-equivalence challenge; not transfer-function matched.                                |
| 1C           | Diagnostic             | Approximate spectral/transfer equivalence only.                                                     |
| 1D           | PASS                   | Basis-equivalence invariance/code null.                                                             |
| 1E / R1 / R2 | NON-SCORABLE           | Construction/equivalence gates failed.                                                              |
| 2A           | FAIL                   | Tensor-product implementation failed validation.                                                    |
| 2A-R1        | PASS                   | Hermitian repair restored retained frozen validation gates.                                         |
| 2B / 2B-R1   | FAIL                   | Thermal validation attempts missed frozen gates.                                                    |
| 2B-R2        | PASS                   | Internal RK4 thermal validation and convergence audit; retired eigenvalue/norm quantities excluded. |
| 2C-R3        | ARCHIVAL NEGATIVE      | Not part of quantitative validation; metric provenance unavailable.                                 |
| 3A           | Implementation failure | Reduced convolution/sign implementation failed.                                                     |
| 3A-R1        | VERIFICATION RESULT    | Exact-reduction numerical-equivalence benchmark.                                                    |
| 3B           | DIAGNOSTIC RESULT      | Selected surrogate extrapolated poorly; no general model-selection claim.                           |

### 5. Tensor-product validation results

#### 5.1 Test 2A -> 2A-R1

Test 2A failed with joint norm drift  $1.15 \times 10^{-1}$ , trace error  $1.15 \times 10^{-1}$ ,  $\lambda=0$  isolation mismatch  $7.92 \times 10^{-1}$ , and full-versus-sector RMS  $2.98 \times 10^{-1}$ . Inspection identified a missing Hermitian-conjugate exchange direction. The failure remains part of the record. 2A-R1 changed that implementation detail and added a Hermiticity audit. Retained quantitative results are Hermiticity error 0, joint norm drift  $1.91 \times 10^{-11}$ , trace error  $1.91 \times 10^{-11}$ ,  $\lambda=0$  isolation  $5.55 \times 10^{-12}$ , relabel mismatch 0, and full-versus-sector RMS  $1.24 \times 10^{-17}$ .

**Retired quantity:** the archived  $+1.30 \times 10^{-5}$  minimum-eigenvalue output is not used as reproducible positivity-validation evidence because the sampled-set provenance could not be recovered. It may be cited only as an archival output.

## 5.2 Test 2B -> 2B-R2

Test 2B introduced a Gibbs bath at beta  $J=1$  and multiple visible initial states. Its  $\lambda=0$  reference incorrectly treated  $|+\rangle$  as static under  $H_S$  and the run was locked FAIL. 2B-R1 corrected the free-qubit phase and tightened the timestep but still missed one frozen gate. 2B-R2 then performed an RK4 convergence audit: the free-reference mismatch decreased from  $2.063 \times 10^{-11}$  at  $dt=.0100$  to  $1.291 \times 10^{-12}$  at  $dt=.0050$  and  $8.063 \times 10^{-14}$  at  $dt=.0025$ , improvement factors 15.98x and 16.01x. Retained quantitative results include trace error  $3.02 \times 10^{-11}$  and relabel mismatch  $7.77 \times 10^{-16}$ .

**Retired quantities:** the archived  $+2.02 \times 10^{-7}$  minimum-eigenvalue output is not used as reproducible positivity-validation evidence, and the archived  $6.83 \times 10^{-11}$  "component norm drift" output is removed from validation evidence because its source-code definition could not be recovered. Neither value is redefined or reverse-engineered.

## 5.3 Positivity and platform scope

The forensic audit could not establish whether  $t=0$  was included in the sampled set underlying the two archived positive minimum-eigenvalue values, whether the first recorded point was  $t=\Delta t$ , or whether another convention applied. Because pure initial qubit states have a zero eigenvalue at  $t=0$ , those archived positive minima cannot support a reproducible positivity audit without the missing sampling provenance.

Accordingly, Version 3 makes no quantitative claim based on those retired minima and no claim that a reconstructed Choi matrix or complete dynamical map was tested for complete positivity. The tensor-product platform is described as **internally validated** only with respect to the retained, defined audits and convergence checks. An independent matrix-exponential or Krylov propagator cross-check remains outstanding.

## 6. Test 2C-R3 - archival negative topology attempt

The frozen pair consisted of connected non-isomorphic eight-node graphs with 12 edges, common degree sequence (4,4,3,3,3,3,2,2), and matching adjacency spectra to numerical precision. The historical tensor-product run used one visible qubit plus eight hidden spins,  $\omega_S=1$ ,  $J=.42$ ,  $\lambda=.18$ , beta  $J=1$ , zero common hidden onsite energy,  $t=0\dots 8$ , and four visible probes  $|0\rangle$ ,  $|1\rangle$ ,  $|+\rangle$ , and  $|+i\rangle$ .

**Graph A:** (0,1), (0,2), (0,3), (1,3), (1,5), (2,4), (2,5), (2,7), (3,6), (4,7), (5,7), (6,7).

**Graph B:** (0,1), (0,4), (0,7), (1,3), (1,7), (2,3), (2,4), (2,5), (2,6), (4,7), (5,6), (5,7).

The archived card reported values 0.010888 and 0.004339 against frozen 0.020 gates and was historically recorded as a negative result. However, the exact source-code equations, averaging conventions, and normalizations for the two decisive operational metrics could not be recovered from the surviving record. Those numbers are therefore preserved only as archival outputs; they no longer constitute a quantitatively reproducible validation or falsification test in Version 3.

**Formal retirement:** Test 2C-R3 is not rescored, repaired, or reverse-engineered. It is retired from the quantitative validation set and retained as an **archival negative result**: the historical implementation did not meet its own frozen gates, but the metric provenance is insufficient for independent reproduction.

A subsequent historical audit-closure run reported that identical-model,  $\lambda=0$  graph, and consistent-relabel controls met their frozen tolerances. Because the primary metric implementation is unavailable, those controls do not restore 2C-R3 to the quantitative validation set. Global adjacency cospectrality also does not match the coupling-weighted local spectral measure seen by the root-coupled qubit.

## 7. Test 3A-R1 - exact-reduction verification

The first 3A implementation failed because the reduced convolution/sign convention did not reproduce the full direct-sum model. 3A-R1 corrected that implementation while preserving the generating  $H_B$  and  $G$ . The derived Volterra equation then reproduced the full direct-sum trajectory to approximately  $10^{-6}$  RMS, with relabel and full-system norm audits at numerical-noise scale.

This is an **exact-reduction and numerical-equivalence benchmark**. The full and reduced trajectories are mathematically equivalent representations of the same finite model. It is not an oracle-free prediction learned from limited observable data.

## 8. Test 3B - diagnostic surrogate comparison

Test 3B compared the same direct-sum reduction with a four-parameter damped-oscillatory population surrogate,  $P_{\text{sur}}(t) = \exp(-\gamma t)[c + (1-c)\cos^2(\Omega t + \phi)]$ . The surrogate was fitted on  $0 \leq t \leq 2$  and frozen for  $2 < t \leq 8$ . It achieved training RMS 0.001823 and held-out RMS 0.169615. The exact reduction remained near  $10^{-6}$  RMS; relabel error was  $5.55 \times 10^{-15}$  and full-system norm drift  $2.66 \times 10^{-15}$ .

The large ratio formerly emphasized as a "kernel advantage" remains removed. The comparison is informationally asymmetric because the reduction receives the generating  $H_B$  and  $G$  while the surrogate receives only a short observed trajectory and four fitted parameters. The label is **DIAGNOSTIC RESULT - numerical gates satisfied**, not a general PASS over conventional or memoryless open-system models.

## 9. What Version 3 establishes

- A tensor-product qubit-plus-spin-bath implementation passed the retained internal Hermiticity, trace, decoupling, relabeling, and RK4 timestep-convergence checks after documented repairs.
- The thermal tensor-product simulator is an internally validated methodological platform only with respect to those retained, explicitly defined checks; an independent propagator cross-check remains outstanding.
- The 2C-R3 topology attempt is preserved transparently as archival negative history, not as a quantitatively reproducible test.
- The direct-sum hidden-amplitude model admits  $K(t-s) = G \exp[-iH_B(t-s)]G^\dagger$ , and the corrected Volterra solver reproduces the corresponding full direct-sum evolution.
- The selected four-parameter phenomenological surrogate fits the short training interval but extrapolates the selected direct-sum trajectory poorly.

## 10. What Version 3 does not establish

Version 3 does not establish a physical vacuum web, ER=EPR micro-tethers, transdimensional transport, emergent spacetime, gravity, dark energy, Standard Model structure, a preferred frequency or length scale, or laboratory coupling to a hidden sector. It does not derive a superoperator-level memory kernel for the thermal tensor-product reduced dynamics. It does not demonstrate oracle-free prediction on held-out initial states or interventions. It does not show topology sensitivity beyond coupling-weighted local spectroscopy, and it does not show superiority to conventional structured-bath, pseudomode, colored-noise, Gaussian, or feedback models at matched information and complexity.

## 11. Required next research phase

The next decisive phase is an oracle-free, process-level competition. Every candidate model should receive the same observable training data, with privileged access to the true hidden generator denied; model capacity, optimizer settings, randomization, train/validation/test partitions, and failure rules should be frozen before evaluation on held-out initial states and intervention protocols.

In parallel, the strongest identifiability null is a coupling-weighted spectral-equivalence challenge: construct different hidden structures with the same rooted transfer function  $F_B(z) = \langle g | (z - H_B)^{-1} | g \rangle$ , and at finite temperature match the bath correlations actually sampled by the qubit. A separate theoretical task is to derive or infer a superoperator-level memory representation for the tensor-product reduced dynamics, then test it against matched-information conventional competitors.

## 12. Conclusion

The final forensic disposition narrows the quantitative record rather than reconstructing missing history. The tensor-product work remains a methodological advance with thermal mixed states, partial tracing, retained internal audits, and documented implementation failures and repairs. The former 2C-R3 result is now explicitly archival. The direct-sum kernel work remains mathematically useful, but its strongest agreement result is verification of an exact reduction rather than independent prediction.

Accordingly, Version 3 is a methods-and-validation document. Its central open question is whether a pre-specified VWTUT-motivated hidden-structure model can make oracle-free, process-level predictions that survive matched-information conventional competitors and identifiability nulls.

# References

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4. F. Ivander, L. P. Lindoy, and J. Lee, "Unified framework for open quantum dynamics with memory," Nature Communications 15, 8087 (2024).

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## Appendix A. Final forensic disposition

| Item                                | Final disposition                                                                                                                |
|-------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Minimum-eigenvalue provenance       | PARTIALLY RECOVERED -> RETIRED as reproducible positivity evidence. Archived numbers may be retained only as historical outputs. |
| Tensor-product component norm drift | UNRECOVERABLE -> RETIRED from validation evidence. No substitute definition assigned.                                            |
| Test 2C-R3 metric formulas          | UNRECOVERABLE -> Test retired from quantitative validation; preserved as archival negative result.                               |
| Branch separation                   | Retained. Tensor-product and direct-sum branches remain explicitly distinct.                                                     |
| Validation wording                  | Retained as internally/provisionally validated, pending independent propagator cross-check.                                      |
| 3B wording                          | Retained as DIAGNOSTIC RESULT; no oracle-free or general superiority claim.                                                      |

**Consistency audit:** No remaining passage in this candidate uses the retired minimum-eigenvalue values or retired component-norm-drift value as validation evidence, and no passage presents 2C-R3 as a quantitatively reproducible scientific test. No missing provenance has been invented.