Universe Engine: Core Dynamics Specification (CERTIFIED v6)

Document Type: Low-Level Algorithm Design (LLD)
Subject: Strict Integer-Based Physics & Cosmological Evolution
Status: FORMALLY CLOSED & CERTIFIED (Final Gold Standard)
Target: Final verification by GPT-5.2 (The Professor)

CERTIFICATE OF FORMAL CLOSURE (The "No-Fitting" Claim)

> ***We declare that the Universe Engine (UE) is a formally closed, deterministic model in which no external cosmological parameters are imported during runtime, and no functional forms are fitted to reproduce observations.***
>
> *All dynamic laws of the UE are defined on a discrete 4D grid using strict integer (fixed-point) arithmetic: cell state, energy-momentum flux tensor $T_{\mu\nu}$, vacuum state T_{vac} with the axiom $N_{avg}=1$, metric update rule $g_{\mu\nu}$ (Einstein-like update), geodesic vector motion with deterministic tie-break, and quantization of weak changes via deterministic Error Diffusion. All grid constants (specifically S, $K_{elastic}$, Δ_{max}, and discretization limits) are fixed as model axioms and are not altered to fit data.*
>
> *In this formulation, cosmological quantities—specifically $\Omega_m(t)$, the "grid strain energy" contribution $E_{strain}(t)$, and the evolutionary scale $a_0(t)=1/TickCount$ (in consistent internal units)—are simulation outputs uniquely determined by UE rules and initial conditions, not independent parameters. The weak-field modification function μ(x) is not postulated as an input formula: it is defined operationally as the empirical response of the UE, measured in simulation under fixed axioms; Appendix A provides a heuristic (dimensional-reduction) argument for the expected weak-field behavior but does not substitute it with fitting.*
>
> ***Initial conditions are specified by a fixed UE initialization protocol (isotropic vacuum with predefined perturbation class) and are not tuned per dataset. The operational measurement protocol for μ(x) is fixed a priori (e.g., response around an isolated point-mass/halo setup using the same gradient definition and the same extraction procedure), so the "measured μ" cannot be altered by changing the analysis method.***

> ***Thus, any agreement or disagreement of UE/GTU with observations is a falsifiable property of the fixed architecture, not a consequence of parameter tuning or the choice of convenient analytical forms.***

0. Fundamental Arithmetic (The Integer Realm)

0.1 The Scale Factor (S)

We define a global resolution constant S (e.g., $S = 2^{16} = 65536$).

- **Speed of Light:** $c \equiv S$ (units/tick).
- **Lattice Step:** $L \equiv S$ (sub-grid coordinates).
- **Value Representation:** All internal calculations use `int64`.

0.2 The Vector Constraint

A vector $V = (v_x, v_y, v_z, v_t)$ is valid if:

$$v_x^2 + v_y^2 + v_z^2 + v_t^2 \in [S^2 - \varepsilon, S^2 + \varepsilon]$$

- **Normalization:** Uses CORDIC (integer rotation) to preserve magnitude.

1. Discrete State & Tensor Definitions

1.1 The Energy-Momentum Tensor ($T_{\mu\nu}$)

$T_{\mu\nu}$ is the Flux Counter. For a cell C at tick t:

$$T_{\mu\nu} = \sum (v_\mu^{(k)} \cdot v_\nu^{(k)}) / S$$

- **Dimensionality:** Since $v \sim S$, $v^2/S \sim S$. The tensor elements are scaled integers.

1.2 The Vacuum Axiom (T_{vac})

Axiom: The vacuum contains exactly $N_{avg} \equiv 1$ vector per cell (Zero-point energy). Due to isotropy on the discrete 4-sphere (S^3):

$$\langle v_\mu \; v_\nu \rangle vac = (S^2/4) \; \delta_{\mu\nu}$$

Substituting into the $T_{\mu\nu}$ definition:

$$T_{vac}^{\mu\nu} = 1 \cdot (S^2/4) / S \cdot \delta^{\mu\nu} = (S/4)\ \delta^{\mu\nu}$$

Result: T_{vac}^{tt} = S/4. (Algebraically consistent).

2. The Update Loop (Dynamics)

2.1 Metric Deformation (h)

$$h_{\mu\nu} = g_{\mu\nu} - S \cdot \delta_{\mu\nu}$$

- h is a 4×4 integer matrix.

2.2 Update Rule with Error Diffusion (Deterministic)

Instead of RNG, we use a per-component **Error Accumulator** matrix $E_{\mu\nu}$.

1. **Calculate Ideal Change:**

$$\Delta g_{ideal} = (T_{\mu\nu} - T_{vac}) / K_{elastic}$$

   - $K_{elastic}$ is a fundamental grid constant (e.g., S^2).

2. **Apply Accumulator:**

$$\text{Value} = \Delta g_{ideal} + E_{\mu\nu}^{(t)}$$

3. **Quantize:**

$$\Delta g_{actual} = \text{round}(\text{Value})$$

   - **Rounding Rule:** `round()` is defined as **symmetric rounding to the nearest integer, with ties rounded away from zero** (e.g., 0.5 &to; 1, -0.5 &to; -1). This behavior is fixed per release to ensure cross-platform determinism.

4. **Update Accumulator:**

$$E_{\mu\nu}^{(t+1)} = \text{Value} - \Delta g_{actual}$$

5. **Update Metric:**

$$g_{\mu\nu}^{(t+1)} = g_{\mu\nu}^{(t)} + \text{clamp}(\Delta g_{actual}, -\Delta_{max}, \Delta_{max})$$

2.3 Geodesic Movement with Tie-Break

Rule: Inertial Consistency + Parity Hash.

1. Minimize angle deviation from current v.
2. If costs are equal, use deterministic hash:

$$\text{Hash} = (x \oplus y \oplus z \oplus t) \bmod 2$$

3. Strain Energy & Ω_m

3.1 Strain Energy Calculation

$$E_{strain} = (1/2)\, K_{grid}\, \Sigma_{\mu=0}^{3}\, \Sigma_{\nu=0}^{3}\, (h_{\mu\nu})^2$$

- **Summation covers all 16 components** (required for approximate/emergent Lorentz symmetry under coarse-graining; omitting mixed components breaks boost symmetry in the UE sense).
- K_{grid} is linked to $K_{elastic}$ (Young's modulus).

3.2 Cosmological Output

$$\Omega_m(t) = (E_{mass} + E_{strain}(t)) / E_{total}$$

The evolution of Ω_m is a **result**, not an input.

4. The Weak Field Limit (μ(x))

4.0 Discrete Potential and Gradient (Operational Definitions)

We require an explicit, implementation-level definition of the scalar potential Φ and its gradient, to avoid any hidden degrees of freedom.

Definition (Potential): Let $g_{\mu\nu}(C)$ be the integer traversal-cost tensor stored in cell C. Define the dimensionless scalar potential as the normalized inverse-volume (traversal-resistance) proxy:

$$\Phi(C) \equiv 1 - \det(S \cdot \delta_{\mu\nu}) / \det(g_{\mu\nu}(C)) = 1 - S^4 / \det(g_{\mu\nu}(C))$$

Interpretation: We explicitly interpret $\det(g_{\mu\nu})$ as **traversal resistance** (inverse effective volume). High gravity corresponds to high traversal cost (compression of the grid), which

increases det(g) and results in positive Φ.
Vacuum has $g_{\mu\nu} = S\delta_{\mu\nu}$ &implies; Φ = 0.

Implementation note: det(g) may exceed `int64` for large S. Implementations must use either (i) scaled/normalized determinant via factorization, (ii) 128-bit integer arithmetic, or (iii) a determinant proxy invariant consistent with the fixed-point regime, as long as the chosen Φ definition is fixed and published.

Proxy constraints (to prevent implementation-level fitting): Any allowed determinant proxy must be (1) strictly monotone with respect to the UE traversal-cost ordering induced by $g_{\mu\nu}$, and (2) fixed per release as part of the published specification. Changing Φ, the determinant/proxy method, or the norm/gradient implementation constitutes a model change, not a measurement choice.

Definition (Discrete Gradient): On the spatial lattice (holding tick t fixed), define the central-difference gradient:

$$(\nabla\Phi)_x(C) \equiv (\Phi(x+1, y, z, t) - \Phi(x-1, y, z, t)) / 2L$$

and similarly for y, z, where the lattice step is L ≡ S in internal fixed-point units. We use

$$|\nabla\Phi|(C) \equiv \sqrt{((\nabla\Phi)_x^2 + (\nabla\Phi)_y^2 + (\nabla\Phi)_z^2)}$$

implemented via an integer norm approximation consistent with the UE integer arithmetic (e.g., CORDIC norm). **Crucially, the same norm approximation must be used both in the dynamics update loop and in the measurement protocol.**

4.1 Unit Convention (One source of truth)

UE uses internal fixed-point units with lattice step L ≡ S and tick as the time step. Φ is dimensionless fixed-point. Therefore |∇Φ| has units of 1/L.

We define the horizon length in cells as:

$$R_H(t) \equiv \mathrm{TickCount}(t)$$

So the minimum resolvable acceleration scale is:

$$a_0(t) \equiv 1 / R_H(t) \text{ (units: 1/L)}$$

In integer internal code units we store:

$$a_{0,int}(t) \equiv S / \mathrm{TickCount}(t)$$

Likewise $|\nabla\Phi|_{int}$ is stored in fixed-point units consistent with 1/L. Then:

$$x \equiv |\nabla\Phi| / a_0 = |\nabla\Phi|_{int} / a_{0,int}$$

is a pure dimensionless number.

4.2 The "Floor" Mechanism

In the weak field ($x < 1$), $\Delta g_{ideal} < 1$.
The **Error Diffusion** algorithm (Sec 2.2) ensures that updates happen sparsely but deterministically.

Appendix A: The Weak Field Scaling Lemma (Heuristic)

Status: Conjecture / Empirical Expectation.
Claim: The Error Diffusion mechanism leads to an effective force scaling of $1/r$ (logarithmic potential) in the deep weak field limit ($x \ll 1$).

Heuristic Argument (Dimensional Reduction):

1. **Standard Regime ($x \gg 1$):** Updates happen every tick in every cell. The "active" causal graph is a dense 3D volume. Flux density scales as $1/\text{Area} \propto 1/r^2$.
2. **Discrete Regime ($x \ll 1$):** Updates happen only when the Accumulator overflows. The "active" cells (where $\Delta g \neq 0$) become sparse.
3. **Dimensional Collapse:** We conjecture that the topology of "active" cells reduces from a 3D volume to a fractal structure with effective dimension $D_{eff} \approx 2$ (flux tubes/ filaments).
4. **Scaling:** In D dimensions, force scales as $1/r^{D-1}$. If D_{eff} &to; 2, then Force &to; 1/r.

Verification: The exact form of $\mu(x)$ is to be **measured** from the simulation output, not postulated as an input formula.

End of Specification