

## Section M-1 — CUWF Entropic Geometry Tensor

Section M-1 establishes the mathematical structure of entropic geometry, the foundational geometric layer of CUWF. Unlike General Relativity, where curvature originates from the spacetime metric  $g_{\mu\nu}$ , CUWF constructs geometry directly from the entropic field  $E(x, \text{DOF})$ .

This section defines the entropic metric  $g_E$ , the derivative operators tied to it, and the curvature objects that govern collapse-node motion, future-vector deflection (FVD), and stability. In this formulation, geometry is not imposed from spacetime; it is induced by the local and internal structure of the entropic field itself.

### M-1.1 Entropic Metric $g_E$

In CUWF, geometry is defined not by spacetime, but by how the entropic field changes across configuration space.

#### Definition

The entropic metric is a symmetric, positive-definite tensor:

$$g_{E,ij}(x, \text{DOF})$$

This tensor induces:

distances;

angles;

gradient structure;

geodesic flow;

curvature;

FVD dynamics.

The metric is not arbitrary. Its components depend on the local structure of the entropic field:

$$g_{E,ij} = \phi(E, \nabla E, \text{DOF})$$

where  $\phi$  is a model-dependent functional chosen to satisfy:

positivity;

smoothness;

compatibility with collapse-node dynamics;

correct reduction to classical curvature limits.

The inverse metric is denoted:

$$g_E^{\{ij\}}$$

and indices are raised and lowered using  $g_E$ . This convention will be used throughout Paper C-2 whenever entropic geometry replaces ordinary Euclidean or spacetime geometry.

## M-1.2 Entropic Gradient and Divergence

The entropic metric defines the gradient and divergence operations used in CUWF. These operations are metric-dependent, but the metric itself is induced by  $E$  rather than by an external spacetime manifold.

### 1. Entropic Gradient

Given a scalar field  $f(x)$ :

$$(\text{grad}_E f)^i = g_E^{\{ij\}} \partial f / \partial x_j$$

This gradient defines the principal direction of steepest entropic ascent or descent, which determines collapse-node drift.

## 2. Entropic Divergence

For a vector field  $V^i$ :

$$\text{div}_E V = \nabla_j V^j$$

where the compatible connection  $\nabla$  satisfies:  $\nabla_k g_{E,ij} = 0$

and is taken to be torsion-free. This ensures that the differential structure generated by  $g_E$  behaves as a coherent geometric system rather than as an arbitrary collection of derivatives.

### M-1.3 Entropic Laplacian $\Delta_E$

The Laplacian is defined in the standard metric form:

$$\Delta_E f = g_E^{ij} \nabla_i \nabla_j f$$

This operator generalizes the configuration-space Laplacian  $\nabla^2 E$  introduced in M-0. It captures diffusion-like behavior, curvature relaxation, and collapse smoothing within the entropic geometry generated by  $E$ .

#### Important Reduction

In flat entropic geometry, where  $g_E$  is constant, the entropic Laplacian reduces to the ordinary configuration-space Laplacian:

$$\Delta_E f \rightarrow \nabla^2 f = \sum_i \partial^2 f / \partial x_i^2$$

Thus the CUWF Laplacian contains the classical Laplacian as a special case. The difference is that  $\Delta_E$  remains meaningful when geometry is no longer externally given but is instead generated by the entropic field.

## M-1.4 Entropic Curvature Tensor $R_E$

The entropic geometry possesses a curvature tensor derived from  $E$  and  $g_E$ :

$$(R_E)^{i_{\{jkl\}}}$$

It is defined using the Levi-Civita connection  $\Gamma$  associated with  $g_E$ :

$$(R_E)^{i_{\{jkl\}} = \partial_k \Gamma^{i_{\{jl\}} - \partial_l \Gamma^{i_{\{jk\}} + \Gamma^{i_{\{mk\}} \Gamma^{m_{\{jl\}} - \Gamma^{i_{\{ml\}} \Gamma^{m_{\{jk\}}$$

### Interpretation in CUWF

$R_E$  measures how “bent” the entropic field is.

Regions where  $R_E$  is large correspond to strong collapse-attraction regions.

FVD geodesics in M-3 are influenced directly by  $R_E$ .

This curvature is not spacetime curvature and is not tied to energy–momentum. It is purely entropic-structural curvature: the curvature of the configuration landscape generated by  $E(x, \text{DOF})$ .

## M-1.5 Link Between $E(x)$ and $g_E$ : Structural Coupling

In CUWF, the metric is not independent: it is functionally tied to  $E(x)$ . A natural leading-order form is:

$$g_{E,ij} = \partial^2 E / \partial x_i \partial x_j + \text{lower-order corrections}$$

This identifies the entropic Hessian as the geometric generator. In weak-curvature regimes:

$$g_E \approx \text{Hessian}(E)$$

Thus CUWF encodes geometry directly from the scalar field. Geometry is not a background arena, but an induced structure arising from the second-order organization of entropic variation.

## M-1.6 Geodesic Motion Under $g_E$ : Foundations of FVD

Collapse-node motion follows geodesics of  $g_E$  with a future-deflecting bias:

$$dx^i/d\tau = - g_E^{ij} \partial E / \partial x_j$$

This equation states that collapse nodes move along the negative entropic-gradient direction determined by the inverse entropic metric. The trajectory is not a Newtonian path through physical space; it is a geometric descent path in the entropic configuration space.

This is the mathematical seed of future-vector deflection (FVD), which will be fully formalized in Section M-3 through the variational action and geodesic equations.

## M-1.7 Connection to M-2 and Higher Modules

This section forms the foundation for:

M-2: defining the Master Operator  $\mathcal{E}_E$  using  $\Delta_E$  and  $D_{DOF}$ ;

M-3: deriving the Action  $S$  and obtaining geodesic equations from variation;

M-4: constructing multi-node curvature matrices and entanglement Hamiltonians;

M-5: eigenvalue-based stability analysis;

M-6: mapping CUWF curvature to GR curvature analogs.

Thus M-1 is the mathematical backbone of CUWF geometric structure. It establishes how  $E(x, DOF)$  generates metric, gradient, divergence, Laplacian, curvature, and collapse-node motion without assuming spacetime geometry as fundamental.