

# Synth-Fuse v0.1.0

A Modular Fusion Engine for Hybrid Intelligence  
(v0.1.0)

## System Architecture & Computational Principles

### Core Axiom

Every algorithm is a plugin; every fusion is a pipeline; every pipeline is a JAX transform.

### Plugin Contract

**Requirements:** Pure, JIT-compatible, PyTree-structured.

```
def step(key: jax.Array, state: PyTree, params: PyTree) -> PyTree:
    ...
```

- Failure Mode:** Side effects lead to non-deterministic behavior under `vmap`.
- Control Mechanism:** Static analysis combined with `chex.dataclass` enforcement of immutability.

## Fusion Calculus

*Higher-order, closed under JIT.*

Combinator	Semantics	Failure Mode	Control
<code>fuse_seq</code>	$(f \circ g)(x) = g(f(x))$	Exploding gradient	Gradient-norm clipping inside each primitive
<code>fuse_loop</code>	$f^n(x)$	Infinite recursion	Max-iter hard-cap + cos-distance early-stop
<code>fuse_cond</code>	$1_c(x) \cdot f(x)$	Condition never true	Entropy monitor triggers default branch
<code>fuse_parallel</code>	$f(x) + g(x)$	Tree-shape mismatch	Compile-time PyTree structural check
<code>fuse_meta</code>	$M(f)$	Meta-overfitting	$\beta$ -divergence threshold on $\Delta$ drift

# Recipes (Pre-fused, JIT-ready)

Recipe	Core Idea	Failure Mode	Control
FQL-RIME	Flow-guided Lévy escape	Flow collapse ( $\sigma \rightarrow 0$ )	Minimum-entropy latch on latent space
MRBMO-PPO	Siege-elite buffer	Elite set empty	Fallback to full-population update
ISO-VNS	Chaotic perturb	Chaos diverges ( $\lambda > 4$ )	Logistic-map clamp at $\lambda_{max} = 3.9$
CA-SVD-UKF	Rank-collapse	$\kappa(A) > \kappa_{max}$	Trigger full-rank refresh

## Solver: W-Orion (Weierstrass Field Solver)

**Claim:** Smooth surrogate over discrete architectures via heat-kernel:

$$U(x) = \sum_i \exp\left(-\frac{\|x - \tau_i\|^2}{4\sigma^2}\right)$$

- **Failure Mode:**  $\sigma$  too large  $\rightarrow$  landscape flattens, search stalls.
- **Control:** Adaptive  $\sigma$  schedule driven by  $\frac{\Delta U}{\Delta x}$  gradient magnitude.

## Algorithm: STCL (Semantic–Thermodynamic Loop)

**Free-energy functional:**

$$\mathcal{F}(\ell) = \Lambda(\ell) - \beta \cdot C(\ell)$$

- **Failure Mode:**  $\beta$  too high  $\rightarrow$  compression destroys concept ( $\Lambda < \tau$ ).
- **Control:**  $\beta$ -divergence detector triggers rollback to last  $\Lambda \geq \tau$  checkpoint.

## Emergent Behaviours (Observed & Bounded)

Behaviour	Mechanism	Failure Mode	Control
Spontaneous Decentralisation	Consensus dominance	Partition imbalance	Monitor modularity $Q$ ; inject global coupling if $Q < 0.3$

Behaviour	Mechanism	Failure Mode	Control
<b>Crosstalk Avoidance</b>	Zeta pole separation	Over-separation (bandwidth waste)	Adaptive $\sigma_{zeta}$ via gradient of constraint density
<b>Thermal Self-Balancing</b>	Hamiltonian heat term	Runaway diffusion	Quadratic coeff $\kappa$ capped by max current density
<b>Topology Preservation</b>	Semantic load $\Lambda(\ell)$ guide	$\Lambda$ drops below $\tau$	Truncation rejected; fallback to lossless codec
<b>Single-shot Convergence</b>	Weierstrass smoothing	Oversmooth $\rightarrow$ sub-optimum	$\sigma_{min}$ clamped to preserve constraint gradient

# NTEP (Neural Tool-Embedding Protocol)

**Pipeline:** Tool  $\rightarrow$  Vector  $\rightarrow$  Impulse  $\rightarrow$  Execution

- **Claim:** Continuous operator, no schema, no RPC latency.
- **Failure Mode:** Impulse misfire ( $\cos\text{-sim} < \theta$ ).
- **Control:** Phase-locking quorum  $\geq 3$  tools; discard outlier impulses.

# NS<sup>2</sup>UO Field Equation

$$\dot{S} = -\nabla H(S) + \xi(t)$$

Where  $\xi(t)$  is drawn from a  $\Lambda$ -weighted Ornstein-Uhlenbeck process.

- **Failure Mode:**  $\xi$  magnitude too large  $\rightarrow$  instability.
- **Control:** Spectral norm of Jacobian  $\leq 1.02$  for  $> 5$  steps, else reject update.

# Security & Safety Posture

- **Sandboxing:** All inputs treated as hostile; sandboxed in JAX-compiled environment.
- **Meta-Updates:** Must pass differentiable QP trust-region check.
- **Persistence:** Checkpoint every 15 minutes (async); rollback cost  $< 30$ s.
- **Verification:** Formal verification hooks exported for external provers.

