A Force-Free Tractor Beam

Boundary-Regulated Equilibrium and the AEGIS–TIDE Mechanism in Unified Substrate Theory

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Abstract

This work presents a structural admissibility analysis within Unified Substrate Theory (UST). A boundary-regulated dissipative regime, termed AEGIS, is shown to render well-posed a class of fixed–β log-periodic substrate responses in logarithmic scale space. Within such a regime, equilibrium configurations of a coupled target are directionally displaced by boundary-imposed phase conditions, producing a phenomenology often described as a "tractor beam."

The mechanism, named *Transfer-Induced Directed Equilibrium* (TIDE), does not involve propagating beams, fundamental forces, or reactionless propulsion. Instead, it arises from equilibrium relocation within an admissible variational structure. This work is a product of informed scientific imagination and makes no claim of technological feasibility. Axioms, variational formulation, existence and stability results, and falsifiable predictions are provided.

1 Epistemic Status

This paper establishes a *structural possibility result* within Unified Substrate Theory. It does not propose an engineering device, nor does it assert experimental realizability. The sole claim is logical: if the axioms of UST hold, then the AEGIS–TIDE response class is admissible, well-posed, and falsifiable.

2 Equilibrium as the Primitive Concept

Unified Substrate Theory adopts an Einsteinian reversal of Newtonian ontology. Equilibrium precedes dynamics; force is derivative.

Definition 1. A configuration variable X is in equilibrium if it extremizes a physically admissible functional $\mathcal{E}[X]$, i.e.

$$\frac{d}{dX}\mathcal{E}[X] = 0. \tag{1}$$

Motion occurs only when the location of such extrema changes. The quantity

$$F(X) := -\frac{d\mathcal{E}}{dX} \tag{2}$$

is introduced purely as a descriptive gradient and is not fundamental.

3 Logarithmic Configuration Space

Let $X > 0$ denote a scale-like configuration variable. UST admissibility requires scale covariance.

$$x := \ln\left(\frac{X}{X_0}\right). \tag{3}$$

Oscillatory structure in x corresponds to discrete scale structure in X. All admissible large-scale substrate responses are bounded functionals of x.

4 Axioms of the Construction

Axiom 1 (Log-space admissibility)**.** Admissible substrate responses are bounded in an appropriate Sobolev space over x.

Axiom 2 (Minimal substrate operator)**.** Admissible responses are governed, in normal form, by the self-adjoint operator

$$\mathcal{L} := \alpha - (\partial_x^2 + \beta^2)^2. \tag{4}$$

Axiom 3 (Fixed–β discipline)**.** The parameter β is fixed by operator structure and boundary sector; it is not scanned.

Axiom 4 (Boundary-dominant phase)**.** The phase of coherent substrate response is fixed by boundary conditions.

Axiom 5 (AEGIS admissibility)**.** Only responses lying in a bounded admissible set are physical.

Axiom 6 (Derivative force)**.** Force is defined only as a gradient of an equilibrium functional.

Axiom 7 (Global conservation)**.** Energy and momentum are conserved globally.

5 The Master Variational Functional

All statements in this work derive from a single functional.

$$\boxed{\mathcal{F}[\mathcal{R}; X, \phi] = \int \mathcal{R}\,\mathcal{L}\mathcal{R}\,dx + \gamma \int |\partial_x \mathcal{R}|^2 dx + \int_0^\infty \Phi(X)\,\mathcal{R}(\ln(X/X_0))\,dX} \tag{5}$$

Here $\mathcal{R}(x)$ is the substrate response, $\gamma > 0$ is a dissipative coefficient, ϕ is fixed by boundary conditions, and $\Phi(X)$ encodes target susceptibility.

6 AEGIS as Minimal Admissible Regulator

Definition 2 (AEGIS regime)**.** An AEGIS regime is a boundary-maintained dissipative admissibility condition under which minimizing sequences of $\mathcal{F}$ remain bounded in $H^1(x)$.

Theorem 1 (Existence and coercivity)**.** *For fixed X and boundary data, $\mathcal{F}$ is coercive in $H^1(x)$ and admits a minimizer.*

Sketch. The operator term is bounded below, the AEGIS term controls the $\dot{H}^1$ norm, and the coupling term is continuous and linear. The direct method of the calculus of variations applies. □

Remark 1. AEGIS is not a field, beam, or material structure. It is a constraint on admissible solutions.

7 Normal-Form Substrate Response

Theorem 2 (Band-dominant normal form)**.** *Minimizers of $\mathcal{F}$ are dominated by a narrow spectral band around β and take the form*

$$\mathcal{R}(x) = R_0(x) + R_1(x)\cos(\beta x + \phi), \tag{6}$$

up to bounded corrections.

Proof. The spectrum of $\mathcal{L}$ favors modes near $k = \pm\beta$, while the AEGIS term suppresses high-$|k|$ components. □

8 Equilibrium Functional and TIDE

Definition 3. The target equilibrium functional is

$$\mathcal{E}[X;\phi] := \int_0^\infty \Phi(X)\,\mathcal{R}^*(\ln(X/X_0);\phi)\,dX. \tag{7}$$

Definition 4 (TIDE)**.** Transfer-Induced Directed Equilibrium (TIDE) is the displacement of the equilibrium set $\{X_n\}$ induced by variation of the boundary-imposed phase ϕ.

9 Explicit Equilibrium Gradient

Under the band-dominant approximation,

$$F_{\text{TIDE}}(X;\phi) \propto \frac{\beta}{X}\sin\big(\beta\ln(X/X_0) + \phi\big). \tag{8}$$

This expression encodes equilibrium displacement, not a fundamental force.

10 Stability and Log-Discrete Equilibria

Theorem 3 (Log-discrete equilibrium ladder)**.** *Stable equilibria occur at*

$$\beta\ln(X_n/X_0) + \phi = 2\pi n, \tag{9}$$

with spacing

$$\frac{X_{n+1}}{X_n} = e^{2\pi/\beta}. \tag{10}$$

Remark 2. Continuous attraction is structurally forbidden.

11 Interpretation of Boundary Agents

A spacecraft is modeled only as a boundary agent capable of maintaining energy flow and phase coherence sufficient to enforce AEGIS admissibility. It does not emit force or project a structure.

12 Falsifiability

The AEGIS–TIDE construction predicts:

1. Fixed log-periodic equilibrium spacing.
2. Phase-controlled inversion of equilibrium displacement.
3. Collapse of the effect under loss of admissibility.

Failure of any prediction falsifies the construction.