1 Mathematical Formulation

1.1 Productive Capacity (X)

$$X_{\text{real},t} = \max\left(0, \text{PrimaryEnergy}_t + \text{AnimalPower}_t + \text{KWPE}_t\right) \tag{1}$$

$$X_{\text{norm},t} = \frac{X_{\text{real},t}}{X_{\text{real},0}} \tag{2}$$

1.2 Innovation Dividend (X_{bonus})

$$X_{\text{bonus},t} = \theta \cdot \text{STEMshare}_t \cdot \text{EduRate}_t \cdot (1+\text{TFP}_t) \cdot \left(1 + \frac{\text{PatentDensity}_t}{\text{PatentDensity}_{t-1}}\right) \cdot \left(1 + \frac{X_{\text{real},t}}{X_{\text{real},t-1}}\right)^P \tag{3}$$

$$X_{\text{bonus,norm},t} = \text{clip}\left(\frac{X_{\text{bonus},t}}{X_{\text{real},0}}, 0, +\infty\right) \tag{4}$$

1.3 Social Complexity (Z_c)

$$Z_{c,t} = \frac{Gini_t + S_{\text{murder},t} + S_{\text{poverty},t} + \text{MCapGDP}_t + (1 - Trust_t) + Urbanization_t}{n} \tag{5}$$

$$S_{\text{murder},t} = \frac{\text{MurderRate}_t}{100} \cdot \sqrt{2} \tag{6}$$

$$S_{\text{poverty},t} = \frac{\text{PovertyRate}_t}{100} \tag{7}$$

1.4 System Vulnerability (Ω)

$$\Omega_t = f\left(\text{SavingsRate}_t, \text{DebtRate}_t, \text{UnemploymentRate}_t, \text{LPI}_t, \text{OmegaShock}_t\right) \tag{8}$$

1.5 Net Tension Driver (Z_{eff})

$$Z_{\text{eff},t} = g\left(Z_{c,t}, \text{relax}_t, X_{\text{bonus,norm},t}, Z_{\text{shock},t}, \text{DriftTerm}\right) \tag{9}$$

1.6 Societal Stress Index (Y)

$$Y_t = Y_{\text{base},t} + \Delta Y_t \tag{10}$$

$$\Delta Y_t = h\left(X_{\text{norm},t}, Z_{\text{eff},t}, \text{PopPressure}_t, \Gamma_S, \Gamma_X, K_Y\right) \tag{11}$$

1.7 Carrying Capacity (Y_{limit})

$$Y_{\text{limit},t} = X_{\text{norm},t} \cdot k_{\text{limit}} \cdot \Omega_t \cdot (1 + \text{MilitaryRatio}_t) \tag{12}$$

1.8 Crisis Pool (S_t)

$$S_t = \max\left(0, S_{t-1} + \max\left(0, Y_t - Y_{\text{limit},t}\right) - \lambda_S S_{t-1}\right) \tag{13}$$

1.9 Resilience Reset (I_{reset})

$$I_{\text{reset},t} = \phi\left(Y_t, Y_{\text{limit},t}, S_t\right) \tag{14}$$