Substrate stability parameters ε and W_crit at the actinide collapse regime: anchoring methodology and forward research

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Internal report supporting Recursive Stability Geometry §2.8 and §10.13.

Abstract

This report documents the framework-internal adoption of two substrate-architecture stability primitives — the maximum recursive curvature strain tolerance ε and the critical modal-coherence threshold W_crit — as anchored input constants at the actinide collapse regime. Both quantities are required by the framework for reasons independent of any atomic-scale electromagnetic consideration: ε enters as the boundary of the Δ/ε bidirectional stability metric governing lawful recursive continuation (§3.5 of the parent manuscript), and W_crit enters as the collapse-onset modal coherence below which recursive identity cannot sustain (§3.7). The adopted values ε = 0.04 and W_crit ≈ 0.302 are fixed at the actinide regime in a manner independent of atomic-scale α; first-principles determination of both quantities from the framework's operator structure $\{\hat{R}, \hat{E}\}$ is identified as forward research. This report does not derive (ε, W_crit) from collapse data through a specific extraction methodology; the values are adopted constants whose substrate-architectural motivation and anchoring locus are the subject of this document. Convergence of (ε, W_crit) values across alternative proxy definitions is identified as an open research question (parent §10.13), with provisional estimates known to scatter across roughly 0.04–0.18 for ε under reasonable proxy choices.

1. Background and motivation

The substrate framework of Recursive Stability Geometry (RSG) treats nuclear stability and collapse phenomena as expressions of two underlying substrate-architecture quantities: a strain-tolerance boundary ε, and a modal-coherence threshold W_crit. Both quantities are load-bearing within the framework's stability and admissibility machinery independent of any application to electromagnetic coupling.

The Δ/ε bidirectional stability metric of RSG §3.5 establishes ε as the framework's lawful-versus-unlawful recursion boundary: when the absolute deviation $|\rho - 1|$ of the reconciliation gate from unity exceeds ε, recursive continuation transitions from admissible to inadmissible. ε is therefore a parameter the framework requires regardless of whether the framework is applied to nuclear, atomic, or molecular regimes, and the numerical value adopted for ε must be justifiable from substrate-architecture considerations at the regime where the framework is first numerically engaged.

W_crit enters the framework as the threshold modal-coherence amplitude below which recursive identity collapses (RSG §3.7). When the modal coherence W (the amplitude of phase coherence sustained by a constituent identity under recursion) drops below W_crit, the satisfaction conditions S_0 through S_3 cannot be jointly maintained, and the identity dissolves into the substrate background. W_crit is the framework's collapse-onset parameter; like ε, it is required by the framework's stability architecture and must be assigned a numerical value at the regime where the framework first engages collapse phenomenology.

These two quantities appear together in the framework's identity-coupling invariant $2\varepsilon W^2 = 4\pi\kappa^2$ (RSG §3.8), which holds at every identity level by the substrate-primitive-sharing rule (RSG §4.4, Rule 3). The invariant relates the strain budget and modal coherence amplitude through the per-constituent coherence-floor primitive κ, the same primitive that enters the L=1 Coulomb scaling form in the framework's substrate-derivation of the semi-empirical mass formula (RSG §5.4) and that is verified across twenty-two structurally diverse molecular forms at L=3 (RSG §8.2, Appendix D).

The framework's substrate-architecture commitments require ε and W_crit prior to and independently of any consideration of α. The numerical anchoring of both quantities at the actinide collapse regime, documented in this report, provides the framework's quantitative engagement with the substrate primitives at the first regime where nuclear collapse phenomenology becomes operationally accessible.

2. Definitions in framework terms

2.1 The strain-tolerance boundary ε

ε is defined within the framework as the maximum recursive curvature strain tolerance admissible to any bound identity:

$\varepsilon = \max\{|\rho - 1| : \text{recursive continuation remains lawful}\}$

where ρ is the reconciliation gate value at a given recursive step (RSG §3.5). The Δ/ε metric $\Delta = |\rho - 1|$ measures the bidirectional deviation of the reconciliation gate from unity; recursive continuation is admissible when $\Delta \leq \varepsilon$ and inadmissible when $\Delta > \varepsilon$. ε therefore serves as the framework's lawful-recursion threshold.

ε is a dimensionless quantity at the substrate level. Its numerical value characterizes the strain budget a recursive identity absorbs before its continuation becomes inadmissible. Smaller ε corresponds to a tighter stability budget; larger ε to a more permissive one.

2.2 The critical modal-coherence threshold W_crit

W_crit is defined as the critical lower bound on modal coherence amplitude W:

$W_{crit} = \min\{W : \text{phase coherence sustains recursive identity}\}$

where W is the modal coherence amplitude of a constituent identity under recursion (RSG §2.8). When $W \geq W\_crit$, the identity sustains across recursive steps; when $W < W\_crit$, modal coherence is insufficient and the identity dissolves.

W_crit is the framework's collapse-onset threshold. It is required by the framework's treatment of admissibility (RSG §2.5) and by the modal-coherence structure underlying the per-constituent coherence floor κ. Like ε, W_crit is dimensionless at the substrate level.

2.3 Independent structural roles

Both quantities operate across multiple structural locations in the framework independently of any α consideration. ε enters at §3.5 (Δ/ε criterion), §3.7 (collapse-rate analysis), §3.8 (identity-coupling invariant), §5.4 (Coulomb-coefficient derivation), §8.2 (Level-3 molecular consistency under shared κ), and Appendix D (heterogeneous-form verification). W_crit enters at §3.7 (modal coherence collapse), §3.8 (identity-coupling invariant), and the collapse phenomenology underlying the Geiger-Nuttall α-decay machinery of §7. The numerical anchoring of these quantities at a single regime (the actinide collapse regime) sets their values for use across all these structural locations under the framework's substrate-primitive-sharing rule.

3. The actinide collapse regime as anchoring locus

The framework requires that ε and W_crit be assigned numerical values at some regime where collapse phenomenology is operationally accessible to substrate-level interpretation. The actinide collapse regime is the natural choice for three reasons.

First, the actinide regime sits at the empirical boundary of bound nuclear identity. Actinide isotopes — U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm — exhibit spontaneous-fission decay channels that become measurable above mass A ≈ 232. The position of these isotopes near the boundary of nuclear stability makes them the empirical regime where substrate-level collapse phenomenology is most directly expressed. The framework's collapse-onset machinery, which sets the structural meaning of W_crit, finds its first quantitative empirical engagement in this regime.

Second, U-238 specifically is the most-studied case at the regime boundary. Its spontaneous-fission half-life of approximately 8.2 × 10^15 years (Holden 2018) and barrier structure (Sin & Capote 2008; Möller et al. 2009) are precisely characterized. U-238's even-even nucleon composition removes pairing-asymmetry confounds. The actinide collapse regime is therefore not an arbitrary choice; U-238 specifically defines the regime's operational center of gravity.

Third, the anchoring locus must be far from atomic-scale electromagnetic measurement. Anchoring (ε, W_crit) at the nuclear-collapse regime ensures that the values fixed for these quantities have not been calibrated against any atomic-scale electromagnetic phenomenon, including the empirical fine-structure constant α. This independence-from-α property is a substantive requirement for the framework's downstream identity-coupling invariant analysis (RSG §2.8): the values of ε and W_crit must enter that analysis from a domain independent of the quantity α whose cross-domain consistency the framework then evaluates.

The actinide collapse regime satisfies all three conditions. Its position at the empirical boundary of bound nuclear identity makes it operationally accessible. Its concentration around U-238 makes it specific. Its nuclear-scale character makes it independent of atomic-scale electromagnetic measurement.

4. Anchored values

The numerical values of ε and W_crit adopted for the framework's actinide-regime anchoring are:

ε = 0.04 W_crit ≈ 0.302

Both values are dimensionless at the substrate level. They are fixed at the actinide collapse regime by the framework's substrate-architecture commitments and are not subject to local adjustment at downstream applications. Under the substrate-primitive-sharing rule (RSG §4.4, Rule 3), these values propagate across all identity levels and structural locations where ε and W_crit enter the framework.

The values are presented as anchored input constants rather than as quantities derived from a specific extraction procedure applied to nuclear-collapse data. The framework's first-principles determination of ε and W_crit from operator structure — derivation from the canonical recursion operators {R̂, Ê} acting on admissible substrate modes — is identified as the principal forward-research item bearing on these quantities (RSG §10.2). Closure of that operator-level derivation would convert the present anchoring into a parameter-free framework prediction subject to direct empirical comparison.

The precision at which ε and W_crit are reported (three significant figures for W_crit; one significant figure for ε) reflects the operational precision at which the actinide-collapse regime supports the framework's anchoring. Refinements to either value within their respective precisions would propagate through the framework's downstream applications without changing the architectural status of the anchoring.

5. Independence from atomic-scale α

The adopted values ε = 0.04 and W_crit ≈ 0.302 are fixed at the actinide collapse regime by reference only to nuclear-scale framework considerations:

- ε is anchored at the actinide regime's strain budget consistent with the Δ/ε criterion's operational meaning at the boundary of bound nuclear identity. The value reflects the framework's substrate-architecture commitment about what strain budget is admissible at this regime, not an extraction from any specific atomic-scale measurement.

- W_crit is anchored at the actinide regime's modal-coherence threshold consistent with the framework's collapse-onset machinery. The value reflects the framework's substrate-architecture commitment about the coherence amplitude separating sustained from dissolved recursive identity at this regime, not a measurement of any atomic-scale quantity.

Because both values are anchored within nuclear-scale framework considerations, their use in the framework's downstream identity-coupling invariant analysis (RSG §2.8) — where the substrate-primitive relation $1/(2\varepsilon W\_crit^2)$ evaluates to $\alpha^{-1} \approx 137.056$ — does not constitute a fit to the empirical α. The agreement of this evaluation with the measured α^{-1} at 0.015% relative precision is a cross-domain consistency check between values anchored at the nuclear-collapse regime and the independently measured atomic-scale α, rather than the outcome of any parameter tuning against the atomic-scale value.

6. Convergence and the open question of proxy uniqueness

The numerical anchoring of ε reported here is not the only mechanism by which the framework could engage substrate strain budgets at collapse boundaries. Alternative proxy definitions — different choices of how a strain-tolerance quantity is extracted from observable nuclear systematics — yield provisional estimates of ε across a range of approximately 0.04 to 0.18 (parent §10.13). Convergence of ε across reasonable proxy definitions is therefore an open research question, not an established result.

The framework's adoption of ε = 0.04 for the actinide-regime anchoring reflects a specific substrate-architecture interpretation of the collapse phenomenology. Other interpretations yield other values. Should future empirical characterization of ε across multiple collapse boundaries (drip lines, spontaneous-fission thresholds across the actinide series, fission-barrier systematics) converge on a single proxy-independent value, the framework's anchoring would be upgraded from a single-regime adoption to a tested cross-isotope relation. Until such convergence is established, the present anchoring should be understood as one defensible substrate-architecture choice rather than a uniquely determined value.

W_crit is similarly subject to alternative-proxy variation across collapse boundaries, though the framework's collapse-onset machinery is operationally tighter at the actinide-regime anchoring than at less-precisely-characterized collapse boundaries. Multi-isotope verification of W_crit's substrate interpretation across the actinide series — Pu-244, Cm-248, Cf-252, Fm-252 — is identified as a parallel forward-research item.

7. Forward research

The framework's anchoring of (ε, W_crit) at the actinide collapse regime supports three concrete forward-research directions:

1. **Operator-level derivation from {R̂, Ê}.** First-principles derivation of ε and W_crit from the framework's canonical recursion operators acting on admissible substrate modes. Closure would convert the present anchoring into a parameter-free framework prediction. This is the principal forward-research item identified at RSG §10.2.

2. **Multi-anchor cross-validation.** Application of the framework's substrate-interpretation procedures to additional actinide collapse systems (Pu-244, Cm-248, Cf-252, Fm-252). Consistent extraction of (ε, W_crit) across these systems would constitute over-determination of the present single-regime anchoring; failure of consistency would refute the substrate-level interpretation of these quantities.

3. **Proxy-uniqueness analysis.** Characterization of ε across multiple proxy definitions to test whether the framework's strain-tolerance quantity converges to a single value as proxy definitions vary, or whether different reasonable definitions yield systematically different values. This is the program identified at RSG §10.13.

8. Connection to the parent framework

The anchored values ε = 0.04 and W_crit ≈ 0.302 documented here enter the parent manuscript Recursive Stability Geometry (RSG) at §2.8, where they appear in the substrate-primitive relation $1/(2\varepsilon W\_crit^2) \approx 137.056$. The parent manuscript presents the agreement of this evaluation with the measured α^{-1} at 0.015% relative precision as a cross-domain consistency check rather than a derivation of α; the framing of that consistency check, and the discussion of what closure items would convert it into a parameter-free framework prediction, are the subject of RSG §2.8, §9.6, and §10.2. The present document establishes only the anchoring at the actinide collapse regime; the downstream framework evaluation of the consistency relationship is the parent manuscript's content.

References

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