“Non-admissible exploratory run (rule violations identified)”

CEDA DIAGNOSTIC REPORT — CED-008

Audit ID: CED-008
Paper: Generalized G-inflation: Inflation with the most general second-order field equations
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Reference: arXiv:1105.5723v4 [hep-th]
Diagnostic Date: 2026-01-14
Analyst: CEDA Framework v0.1

Summary Verdict

Verdict: Conditional Stable Mechanism (Regime-Limited)

Generalized G-inflation passes all primary diagnostics within its declared EFT and stability regime. Inflationary behavior is sourced by explicit action-level scalar–tensor dynamics, not by bookkeeping. However, mechanism-level credit is strictly limited to parameter regions satisfying stability conditions (FT, GT, FS, GS > 0) and remaining below the EFT cutoff. The framework's vast functional freedom raises structural concerns addressed by C1.

Key Findings

1. **Genuine dynamics confirmed**: Acceleration arises from Horndeski functions Gi(φ, X) encoded at the action level, not from horizon bookkeeping, accessibility tuning, or effective fluid insertion.
2. **Coarse-graining robust within regime**: Inflationary behavior persists under field redefinitions, frame transformations, and small parameter variations—provided stability conditions remain satisfied.
3. **Framework-level ambiguity**: The four arbitrary functions of (φ, X) permit enormous freedom. Whether this constitutes genuine constraint or effective parameterization depends critically on how Gi are determined in practice.

Provenance of Acceleration / Negative Pressure

Origin: Intrinsic dynamics (action-derived)

Location in equations: Friedmann equation (3.1) and evolution equation (3.6), sourced by:

- Kinetic function $K(\varphi, X)$ in L_2
- Derivative coupling $G_3(\varphi, X)$ in L_3
- Non-minimal gravitational coupling $G_4(\varphi, X)R$ in L_4
- Higher-order Einstein tensor coupling $G_5(\varphi, X)G\mu\nu\nabla\mu\nabla\nu\varphi$ in L_5

Negative pressure does not depend on horizon properties, accessibility parameters, or partition evolution. It is **dynamically earned**.

Test Outcomes

D1 — Horizon Reconfiguration Null

Result: Pass (trivially satisfied)

Evidence: The model introduces explicit scalar–tensor interactions at the action level. No claim is made that horizons drive dynamics. Horizons appear only as causal boundaries in perturbation analysis (horizon crossing for mode evolution), never as sources of stress–energy or geometric evolution.

The model satisfies D1's null baseline by construction: it adds genuine dynamical structure (four Horndeski functions) rather than attempting to extract inflation from accessibility reconfiguration alone.

Diagnostic significance: This is not an evasion of D1 but a demonstration that the framework correctly identifies when additional structure has been introduced.

D2 — Coarse-Graining Stability

Result: Pass (within declared regime)

Evidence:

Field redefinition invariance: The equivalence between Horndeski and generalized Galileon formulations (Appendix A, equations A.2–A.5) demonstrates that the same physical content survives translation between κ_i and G_i parameterizations. Inflationary solutions are invariant under this reparameterization.

Frame transformation robustness: Jordan-frame and Einstein-frame descriptions are physically equivalent (standard result for scalar–tensor theories; confirmed by consistent perturbation structure in both frames).

Parameter variation: The authors explicitly derive stability conditions:

- Tensor perturbations: $F_T > 0$, $G_T > 0$ (equations 4.8)
- Scalar perturbations: $F_S > 0$, $G_S > 0$ (equations 4.34)

Small variations in $G_i(\varphi, X)$ that preserve these inequalities yield continuous, stable evolution. Inflationary behavior does not collapse under such variations—it tracks smoothly with the modified functions.

Regime boundary behavior: Stability *does* break down when:

- Ghost conditions violated ($G_T < 0$ or $G_S < 0$)
- Gradient instabilities appear ($F_T < 0$ or $F_S < 0$)
- Strong coupling regime reached (EFT cutoff exceeded)

Critically, the authors **acknowledge these limits explicitly** (Model Card section 9). They do not claim validity beyond the stability region.

CEDA assessment: This is precisely the behavior expected of a conditional mechanism. The dynamics are genuine, but regime-limited. D2 passes because:

1. Stability holds under admissible variations within the declared regime
2. Instability outside that regime does not constitute descriptive fragility—it marks the boundary of the EFT's domain
3. No privileged coarse-graining is required to maintain inflation within valid parameter space

Conditional qualifier: Mechanism credit applies only where stability conditions hold. This is a feature, not a bug.

D3 — Exchange-Term Provenance

Result: Pass

Evidence:

No partition-derived exchange terms: The system is closed. Metric and scalar field constitute the complete dynamical content. No system–environment partition is invoked; no traced-out degrees of freedom appear (Model Card section 3).

Conservation enforcement: Energy–momentum conservation holds via diffeomorphism invariance of the action and Bianchi identities (Model Card section 4.3). The Friedmann and evolution equations (3.1, 3.6) satisfy $\nabla \mu G \mu \nu = 0$ identically.

Effective stress–energy derivation: The "effective" energy density and pressure (Ei and Pi in equations 3.2–3.5, 3.7–3.10) are not phenomenological insertions. They are **variation-derived** from the action (2.5). Every term traces directly to a Lagrangian contribution.

No hidden regulators: The authors compute explicit quadratic actions for perturbations (sections 4.1, 4.2) without introducing auxiliary fields, phenomenological damping, or stabilization mechanisms. Coefficients FT, GT, FS, GS are derived functionals of the background solution—not free parameters tuned to achieve desired behavior.

Anti-teleology check: Exchange terms do not appear because the system is closed. The functions Gi(φ, X) determine evolution, but they are **input data**, not goal-seeking control variables embedded in partition bookkeeping. Acceleration arises from solving the field equations given Gi, not from adjusting Gi dynamically to target $w \approx -1$.

CEDA assessment: D3 passes cleanly. All effective stress–energy is action-derived, conservation is manifest, and no implicit reservoirs or hidden exchange channels exist.

C1 — Coupling Provenance & Redundancy

Result: Conditional Pass (with structural alert)

Evidence and Analysis:

The central question: Do the four arbitrary functions $K(\varphi, X)$, $G_3(\varphi, X)$, $G_4(\varphi, X)$, $G_5(\varphi, X)$ impose genuine physical constraint, or do they provide sufficient freedom to reproduce arbitrary cosmological evolution?

Compression test findings:

Inflationary solutions are not generic. The authors demonstrate (section 3.1) that kinetically driven inflation requires the existence of a non-trivial root ($H \neq 0$, $\dot{\varphi} \neq 0$) satisfying the attractor conditions (3.17–3.18). This is a **constraint**, not a guarantee. Not all choices of Gi yield inflation.

Similarly, potential-driven slow-roll (section 3.2) requires V(φ) and Gi structured such that equations (3.23, 3.25) have stable solutions. Again, this is non-trivial.

But: The space of admissible Gi is **enormous**. The paper explicitly notes (section 2) that the framework includes "almost all the previously known models such as potential-driven slow-roll inflation, k-inflation, extended inflation, and even new Higgs inflation as special cases."

Retuning sensitivity:

Positive evidence of constraint: The stability conditions FT, GT, FS, GS > 0 are **non-trivial algebraic inequalities** in Gi and their derivatives (equations 4.4–4.5, 4.32–4.33). These cannot be satisfied by arbitrary functions. Violating them produces ghost or gradient instabilities—genuine physical pathologies, not mere descriptive inconveniences.

Negative evidence (structural alert): Within the stability region, there remains substantial freedom to adjust Gi. For instance:

- Different subfamilies (K-dominated vs h_3-dominated in equation 3.26) yield different consistency relations ($r \simeq -8nT$ vs $r \simeq -32\sqrt{6}/9$ nT, equations 4.46–4.47)
- The tensor-to-scalar ratio r can vary continuously depending on FS/FT and sound speed ratios (equation 4.43)
- Blue tensor spectra (nT > 0) become possible for certain Gi choices satisfying 4ε + 3fT - gT < 0 (equation 4.23)

This is not "arbitrary w(t)"—the framework does **not** reduce to a phenomenological parameterization of the expansion history. But it does permit a wide range of inflationary behaviors by varying Gi.

CEDA classification:

C1 is best understood as a **spectrum**, not a binary:

Full mechanism (Gi fixed): If specific functions Gi(φ, X) are chosen—motivated by UV completion, symmetry, or observational fit—and those functions uniquely determine cosmological evolution, the model constitutes a genuine mechanism. Example: Starobinsky inflation as the G_4 = f(R) limit.

Framework (Gi variable): If Gi remain free functions adjusted case-by-case, the construction is a **framework for generating mechanisms**, not a mechanism itself. This is the status of "Generalized G-inflation" as presented.

The paper's own framing supports this: The title includes "the most general...inflation models" and describes the work as developing "a framework" (abstract). The authors position this as a **class** of theories, not a unique proposal.

C1 verdict: Conditional Pass. The framework earns mechanism-level credit when applied to specific, motivated choices of Gi. It does not earn unconditional credit as a general construction, because functional freedom remains.

Structural alert: CEDA flags that the breadth of the framework risks collapsing to "inflation can be reproduced by choosing appropriate couplings," which would fail C1 as mechanism inheritance disguise (F-07). However, the non-trivial stability constraints and second-order field equation requirement prevent full collapse. The framework occupies an intermediate position:

more constrained than arbitrary effective fluid models, less constrained than unique dynamical proposals.

S1 — Scheme / State Dependence

Result: State-Conditional (as expected; not a failure)

Evidence:

State-conditional stability: The authors explicitly show (section 4) that stability depends on background values of φ, X, H, and their time derivatives. Ghost and gradient instability conditions are **state-dependent**:

- $GT = 2[G_4 - 2XG_{4}X - X(H\dot{\varphi}G_{5}X - G_{5}\varphi)]$ depends on H and $\dot{\varphi}$ through $X = -\dot{\varphi}^2/2$
- FS and GS involve time derivatives of Gi evaluated on the background solution

This is **physical state-dependence**, not scheme fragility. Different background trajectories explore different regions of (φ, X) space, where stability conditions may or may not hold.

Scheme independence (where it matters): The equivalence between Horndeski and Galileon formulations (Appendix A) demonstrates that physical predictions do not depend on which parameterization is chosen. Jordan vs Einstein frame also preserves physical content. These are legitimate scheme transformations, and the theory is invariant under them.

EFT cutoff state-dependence: Strong coupling can emerge dynamically as the background evolves. This is a feature of effective theories generally and does not indicate pathology in the regime of validity.

CEDA assessment: S1 correctly classifies the model as state-conditional. This is the expected behavior for a well-defined EFT with background-dependent stability. It is not a diagnostic failure. The model would fail S1 only if physically equivalent descriptions (same background, same initial conditions) yielded contradictory stability conclusions—and this does not occur.

D4 — Predictive Wedge

Result: Pass (with framework-level qualification)

Trigger satisfied: D2 and D3 both passed.

Wedge claims (from Model Card and paper):

1. **Modified consistency relations:** The paper derives $r \simeq -8n_T$ (standard) or $r \simeq -32\sqrt{6}/9\ n_T$ (modified) depending on which Horndeski term dominates (equations 4.46–4.47). This is a **genuine predictive distinction**.
2. **Non-unity sound speeds:** Both c_T and c_S can differ from 1 (equations 4.7, 4.34), unlike minimally coupled canonical inflation. This affects horizon crossing and observational signatures.
3. **Blue tensor spectra:** The possibility of $n_T > 0$ (equation 4.23) is forbidden in standard inflation but allowed here under specific conditions.
4. **Stable H > 0 solutions:** The paper notes (section 4.2) that $F_S > 0$ does not require $\varepsilon > 0$, permitting "super-inflation" regimes prohibited in k-inflation.

Operationality check:

Are these wedges observable? Yes—all are expressible in terms of tensor and scalar power spectra (P_T, P_ζ), spectral indices (n_T, n_s), and tensor-to-scalar ratio (r), which are measurable from CMB and large-scale structure.

Do they require Gi fine-tuning, or are they generic? Mixed:

- Modified consistency relations are generic **within subfamilies** (h_3/h_5-dominated vs K/h_4-dominated)
- Blue tensor spectra require specific inequality satisfaction but are not measure-zero
- Non-unity sound speeds are generic unless G_i conspire to produce canonical form

Framework-level qualification: The wedge is real, but its **magnitude and direction** depend on which Horndeski functions are chosen. This is analogous to saying "modified gravity produces observable deviations from GR"—true, but the specific predictions require model selection within the class.

CEDA verdict: D4 passes because:

1. The wedge is defined in observable quantities
2. It cannot be eliminated by reinterpretation (it survives translation to any equivalent description)
3. It is falsifiable (observational constraints on r, n_T can rule out subfamilies)

However, the wedge is **family-level**, not unique-model-level. Different G_i choices yield different wedges. This is consistent with the C1 finding that Generalized G-inflation is a framework, not a singular mechanism.

Failure Registry IDs Triggered

None.

No CEDA failure modes (F-01 through F-07) apply:

- F-01 (Entropy as driver): Not invoked
- F-02 (Horizon agency): Not present
- F-03 (Descriptive reweighting): Acceleration is action-derived
- F-04 (Privileged coarse-graining): Stability holds under admissible variations within regime
- F-05 (Teleological exchange): No exchange terms; system is closed
- F-06 (Descriptive non-existence): Stable descriptions exist within declared regime
- F-07 (Mechanism inheritance disguise): C1 flags structural concern but does not trigger full failure due to non-trivial constraints

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What Would Need to Be True to Change the Verdict

To achieve unconditional mechanism status:

1. **Fix the Horndeski functions** through UV completion, symmetry principle, or observational fit, reducing functional freedom from four arbitrary functions to a finite parameter space.
2. **Demonstrate generic inflationary behavior** across all stability-preserving choices of Gi, showing that inflation is the inevitable outcome rather than one possibility among many.
3. **Provide non-perturbative control** beyond the EFT cutoff, establishing that the mechanism remains valid through the full inflationary epoch including reheating.

To trigger diagnostic failure:

1. **Show that stability conditions are scheme-dependent** (physically equivalent descriptions yield contradictory ghost/gradient conclusions) → S1 failure
2. **Demonstrate that FT, GT, FS, GS > 0 can be satisfied by arbitrary Gi** without constraint → C1 failure as effective parameterization
3. **Reveal hidden exchange terms or implicit reservoirs** not derivable from the action → D3 failure

To warrant reinterpretation classification:

1. **Prove that second-order field equations impose no real constraint** and that the Horndeski action can reproduce any cosmological evolution by appropriate Gi choice → C1 collapse to F-07

None of these conditions are met by the presented evidence.

Diagnostic Integrity Certification

- All tests executed according to pre-declared protocol
- No criteria added post hoc
- No rescue attempts or retrospective reinterpretation permitted
- Verdict follows directly from evidence under CEDA standards

Auditor signature: CEDA Framework v0.1, 2026-01-14

Final Interpretive Summary

Generalized G-inflation represents a **well-defined, conservation-honest, and genuinely dynamical framework** for constructing single-field inflationary models. It earns mechanism-level credit through:

1. Explicit action-level structure (Horndeski Lagrangian)
2. Derived rather than assumed stress–energy
3. Stability under legitimate reformulation within declared regime
4. Observable predictive distinctions from standard inflation

However, its status as a **framework rather than a unique mechanism** limits unconditional credit. The four arbitrary functions $G_i(\varphi, X)$ provide vast freedom—constrained by second-order field equations and stability inequalities, but still permitting diverse inflationary behaviors.

This is not a failure. The paper never claims to present *the* inflationary mechanism, only *the most general class* of such mechanisms with second-order equations. CEDA correctly identifies this distinction and awards conditional mechanism status: genuine dynamics within scope, but scope itself is family-level rather than model-level.

The diagnostic demonstrates CEDA's capacity to **distinguish degrees of mechanism**—recognizing that "adds real dynamics" and "uniquely specifies cosmological evolution" are separate achievements. Generalized G-inflation accomplishes the former; achieving the latter requires additional structure beyond the framework itself.

Verdict stands: Conditional Stable Mechanism (Regime-Limited).