Black-Hole Singular Cores as Conditional Admissibility Boundaries

Event Horizons, Classical Non-Closure, and the Nullity Output

Dr. Christoforos N. Panagis

Abstract

Classical general relativity distinguishes sharply between the event horizon of a black hole and the singular boundary predicted by continued gravitational collapse. The event horizon is a causal boundary: it prevents escape to the exterior but remains mathematically defined, numerically determined, and observationally constrained. The singular-core limit has a different logical status. It is not an observed interior object. It is the limit at which classical continuation becomes geodesically incomplete and, in representative solutions, curvature diagnostics cease to remain finite. This paper formulates that distinction under a constructive admissibility criterion: a regime qualifies as physical only if it supplies a governing equation, numerical commissioning, and an observable diagnostic channel, while preserving finite diagnostic closure. The event horizon satisfies this criterion within classical general relativity. The singular-core limit does not. The resulting thesis is not that "nothing exists inside a black hole," nor that the horizon is a mystical boundary. The thesis is conditional: the singular-core limit receives the output Undefined, here called Nullity, if and only if no admissible continuation supplies equation, number, observable, and finite diagnostic closure. Any regular-black-hole, quantum-gravitational, bounce, fuzzball, gravastar, loop-corrected, asymptotically safe, or other interior completion satisfying that burden defeats the Nullity assignment. Until such closure is supplied, the singular core is better treated not as an infinite-density object but as a candidate boundary of licensed physical predication.

1 Jurisdiction and logical level

This paper is not a new black-hole metric, not a quantum-gravity theory, not a collapse simulation, and not an empirical detection claim. Its jurisdiction is admissibility-level classification. Five logical levels must remain separate:

1. **Admissibility level.** Determines whether a proposed regime qualifies as predictive physics.

2. **Operator/equation level.** Specifies the governing law inside an admitted regime.

3. **Effective-physics level.** Applies admitted equations to exterior, horizon, or interior black-hole domains.

4. **Empirical tribunal level.** Tests observable consequences.

5. **Public-communication level.** Provides heuristic language without adding ontology.

The present claim belongs primarily to the first level. General relativity is used as the classical reference regime. The result is not a replacement for general relativity; it is a classification of what classical general relativity licenses and what it does not license. Let

$$R_{\mathrm{GR}}$$

denote the classical general-relativistic black-hole regime,

$$\mathcal{H}^+$$

the future event horizon,

$$\mathcal{S}_{\mathrm{core}}$$

the singular-core limit of classical interior continuation, and

$$\mathcal{N}$$

the Nullity output. The central result is:

$$\boxed{\mathcal{A}_{R_{\mathrm{GR}}}(\mathcal{H}^+) = 1, \qquad \mathcal{A}_{R_{\mathrm{GR}}}(\mathcal{S}_{\mathrm{core}}) = 0, \qquad \mathcal{S}_{\mathrm{core}} = \mathcal{N} \iff \nexists\, \widetilde{R} : \mathcal{A}(\widetilde{R}) = 1.}$$

The horizon is admitted physics. The classical singular-core limit is failed classical continuation. Nullity is assigned only if no admissible replacement regime exists.

2 Definitions

Definition 1 (Predictive regime)**.** *Let $\mathcal{C}$ denote the space of admissible experimental conditions and let $\mathcal{M}$ denote the space of admissible measurement outcomes. A predictive regime R supplies a map*

$$D_R : \mathcal{C} \to \mathcal{P}(\mathcal{M}),$$

where $\mathcal{P}(\mathcal{M})$ is the space of probability measures on $\mathcal{M}$. Deterministic predictions are recovered as delta measures.

A regime is therefore not admitted because it is verbally intelligible or mathematically decorative. It is admitted because it transports predictive content across admissible conditions.

Definition 2 (Constructive regime criterion)**.** *A regime R is constructively admissible iff it supplies the triad*

$$\mathfrak{C}(R) = (E_R, N_R, O_R),$$

where

$$E_R = \textit{governing equation},$$

$$N_R = \textit{numerical commissioning},$$

$$O_R = \textit{observable diagnostic channel.}$$

The criterion is:

$$R \text{ is physical} \quad \Longrightarrow \quad (E_R, N_R, O_R) \text{ exists and is closed.}$$

The contrapositive is binding inside this method:

$$(E_R, N_R, O_R) \text{ fails} \quad \Longrightarrow \quad R \text{ is not admitted as predictive physics.}$$

The failures are structurally different:

$$E_R = \varnothing \Rightarrow \text{no governing transport},$$

$$N_R = \varnothing \Rightarrow \text{underdetermined continuation},$$

$$O_R = \varnothing \Rightarrow \text{no tribunal}.$$

A regime with equation but no number is not fixed. A regime with equation and number but no observable is not testable. A regime that introduces a primitive solely to avoid breakdown is not closure; it is rescue.

Definition 3 (Finite diagnostic closure)**.** *Let*

$$\mathcal{D}(R) = \{\mathcal{D}_{\text{prop}}, \mathcal{D}_{\text{ord}}, \mathcal{D}_{\text{loc}}, \mathcal{D}_{\text{coup}}\}$$

be the indispensable diagnostic ledger of a physical regime: propagation, ordering, localization, and coupling. A regime has finite diagnostic closure iff each indispensable diagnostic remains:

finite,

mutually compatible,

stable under admissible re-description,

attached to an observable tribunal.

Define

$$\mathrm{FDC}(R) = 1$$

iff all components of $\mathcal{D}(R)$ satisfy those conditions.

Definition 4 (Admissibility functional)**.** *Define*

$$\mathcal{A}(R) = \begin{cases} 1, & \mathfrak{C}(R) = (E_R, N_R, O_R) \textit{ exists and } \mathrm{FDC}(R) = 1, \\ 0, & \textit{otherwise.} \end{cases}$$

When the regime is explicitly classical general relativity, write

$$\mathcal{A}_{R_{\mathrm{GR}}}.$$

This regime-indexing is essential. Classical non-admissibility is not absolute non-admissibility. It is non-admissibility relative to the classical regime.

Definition 5 (Nullity)**.** *Nullity is not an object, place, field, vacuum, phase of matter, hidden geometry, alternative universe, or metaphysical nothingness. It is the output assigned when no admissible continuation exists:*

$$\mathcal{N} := \{B : \nexists\, \widetilde{R} \textit{ with } \mathcal{A}(\widetilde{R}) = 1 \textit{ continuing through } B\}.$$

For a boundary candidate B,

$$B = \mathcal{N}$$

iff

$$\nexists\, \widetilde{R}$$

such that

$$\widetilde{R} \supset R_{\mathrm{prior}},$$

$$\mathfrak{C}(\widetilde{R}) \text{ exists},$$

$$\mathrm{FDC}(\widetilde{R}) = 1.$$

Nullity is therefore a disciplined output of non-predication:

$$\mathcal{N} = \text{no closed physical predicate remains licensed.}$$

3 Classical black-hole structure

3.1 Schwarzschild representative

For an ideal non-rotating, uncharged mass M, the Schwarzschild radius is

$$r_s = \frac{2GM}{c^2}.$$

For one solar mass,

$$G = 6.67430 \times 10^{-11}\ \mathrm{m^3\,kg^{-1}\,s^{-2}},$$

$$c = 299792458\ \mathrm{m\,s^{-1}},$$

$$M_\odot = 1.98847 \times 10^{30}\ \mathrm{kg},$$

so

$$r_s(M_\odot) = \frac{2GM_\odot}{c^2} = 2953.3393820668783\ \mathrm{m} = 2.9533393820668783\ \mathrm{km}.$$

This numerical value is not interpretive. It is a commissioning of the horizon scale in the Schwarzschild representative. The compactness parameter is

$$\chi = \frac{2GM}{Rc^2}.$$

The Schwarzschild horizon occurs at

$$\chi = 1.$$

3.2 General causal definition of the event horizon

In asymptotically predictable spacetimes, the future event horizon is defined as

$$\mathcal{H}^+ = \partial J^-(I^+),$$

where $J^-(I^+)$ is the causal past of future null infinity I^+. This is a causal definition, not a material-surface definition.

3.3 Classical singular-core representative

For Schwarzschild spacetime, the Kretschmann scalar is

$$K = R_{abcd}R^{abcd} = \frac{48G^2M^2}{c^4r^6}.$$

Therefore,

$$\lim_{r\to 0} K = \infty.$$

This divergence must not be reified as the observation of an infinite-density object. It marks the failure of finite curvature continuation inside the classical representative. More generally, the theorem-level output of singularity theory is geodesic incompleteness under specified assumptions. Geodesic incompleteness is not identical to direct observation of a physical object. It is the failure of extendibility of relevant curves within the regime. Thus the rigorous classical implication is:

$$\text{trapped-surface and energy-condition assumptions} \Rightarrow \text{geodesic incompleteness},$$

not

$$\text{trapped-surface and energy-condition assumptions} \Rightarrow \text{observed infinite-density substance}.$$

4 Formation without metaphysical excess

Black-hole formation should be stated without unnecessary dependence on visible supernova phenomenology. For stellar black holes, the usual channel is collapse of a sufficiently massive stellar core after pressure support fails. A visible supernova may occur. A weak or failed explosion may also occur. Other black-hole classes, including supermassive black holes and hypothetical primordial black holes, involve different formation questions. The admissibility analysis does not depend on the visible violence of formation. It depends on the formation of causal closure and the status of interior continuation. The relevant sequence is:

$$\text{mass-energy compactness} \to \text{trapped region} \to \mathcal{H}^+ \to \text{classical interior continuation} \to \mathcal{S}_{\text{core}}.$$

The event horizon and the singular-core limit occupy different logical positions in this sequence.

5 Proposition I: Horizon admissibility

Proposition 1. *The event horizon is constructively admissible within classical general relativity:*

$$\mathcal{A}_{R_{\text{GR}}}(\mathcal{H}^+) = 1.$$

Proof. The event horizon supplies an equation or causal definition. In the Schwarzschild representative:

$$r_s = \frac{2GM}{c^2}.$$

In the general asymptotic causal formulation:

$$\mathcal{H}^+ = \partial J^-(I^+).$$

It supplies numerical commissioning. For one solar mass:

$$r_s(M_\odot) = 2.9533393820668783 \text{ km}.$$

It supplies exterior observable tribunals:

$$O_\mathcal{H} = \{\text{orbital dynamics}, \text{accretion structure}, \text{gravitational lensing}, \text{black-hole shadow morphology}, \text{grav}$$

Therefore,

$$\mathfrak{C}_{R_{\mathrm{GR}}}(\mathcal{H}^+) = (E_\mathcal{H}, N_\mathcal{H}, O_\mathcal{H})$$

exists, and finite diagnostic closure is preserved for the horizon as a causal boundary. Hence

$$\mathcal{A}_{R_{\mathrm{GR}}}(\mathcal{H}^+) = 1.$$

Therefore,

$$\mathcal{H}^+ \neq \mathcal{N}.$$

□

6 Proposition II: Classical singular-core non-admissibility

Proposition 2. *The singular-core limit is not constructively admissible within classical general relativity:*

$$\mathcal{A}_{R_{\mathrm{GR}}}(\mathcal{S}_{\mathrm{core}}) = 0.$$

Proof. In the Schwarzschild representative, the formal curvature diagnostic is

$$K(r) = \frac{48G^2M^2}{c^4r^6}.$$

At the singular-core limit,

$$r \to 0,$$

one obtains

$$K \to \infty.$$

The diagnostic therefore fails finite closure. At the theorem level, the singularity result is geodesic incompleteness, not a completed finite physical regime. The classical singular-core limit does not provide a directly observable interior tribunal independent of exterior black-hole evidence. Thus, relative to R_{GR},

$$\mathrm{FDC}_{R_{\mathrm{GR}}}(\mathcal{S}_{\mathrm{core}}) = 0.$$

Consequently,

$$\mathcal{A}_{R_{\mathrm{GR}}}(\mathcal{S}_{\mathrm{core}}) = 0.$$

□

This proposition does not assert absolute Nullity. It asserts only classical non-admissibility.

7 The central theorem: conditional Nullity

Theorem 1. *The singular-core limit receives the Nullity output iff no admissible continuation exists. Formally,*

$$\mathcal{S}_{\mathrm{core}} = \mathcal{N}$$

iff

$$\nexists\, \widetilde{R}$$

such that:

$$\widetilde{R} \supset R_{\mathrm{exterior}},$$

$$\mathfrak{C}(\widetilde{R}) = (E_{\widetilde{R}}, N_{\widetilde{R}}, O_{\widetilde{R}}),$$

$$\mathrm{FDC}(\widetilde{R}) = 1,$$

and

$$\widetilde{R}$$

introduces no uncommissioned primitive solely to avoid singular breakdown.

Proof. By Definition 5, Nullity is the output assigned to a boundary candidate only when no admissible continuation through that boundary exists. Set

$$B = \mathcal{S}_{\mathrm{core}}.$$

Then

$$\mathcal{S}_{\mathrm{core}} = \mathcal{N}$$

iff

$$\nexists\, \widetilde{R} : \mathcal{A}(\widetilde{R}) = 1$$

continuing the black-hole interior through the classical singular-core limit. □

The theorem is conditional. It does not claim that no future theory can regularize the interior. It states the burden required for such a regularization to count as physics.

8 Classification table

Regime	E	N	O	FDC	$\mathcal{A}$
Exterior GR black-hole regime	1	1	1	1	1
Event horizon	1	1	1	1	1
Classical singular-core limit	1_{formal}	0_{finite}	0_{direct}	0	0
Candidate regularized interior	?	?	?	?	?
Nullity output	0	0	0	0	0

The decisive row is not the event horizon. The decisive row is the singular-core limit.

9 Computational admissibility certificate

A minimal computational certificate evaluates the horizon scale and the regime-indexed admissibility distinction. The computation gives:

$$r_s(M_\odot) = 2.9533393820668783 \text{ km},$$

$$\mathcal{A}_{R_{\text{GR}}}(\mathcal{H}^+) = 1,$$

$$\mathcal{A}_{R_{\text{GR}}}(\mathcal{S}_{\text{core}}) = 0.$$

This computation does not prove absolute Nullity. It certifies the methodological separation:

$$\text{horizon} \Rightarrow \text{equation-number-observable closure},$$

$$\text{classical singular-core limit} \Rightarrow \text{failure of finite classical diagnostic closure}.$$

The admissibility functional used in the certificate is

$$\mathcal{A}(E, N, O, F) = \begin{cases} 1, & E = N = O = F = 1, \\ 0, & \text{otherwise}, \end{cases}$$

where F denotes finite diagnostic closure. For the horizon:

$$\mathcal{A}_{\mathcal{H}} = \mathcal{A}(1, 1, 1, 1) = 1.$$

For the classical singular-core limit:

$$\mathcal{A}_{\mathcal{S}} = \mathcal{A}(1, 1, 0, 0) = 0.$$

The certificate is not evidence of a hidden interior ontology. It is a reproducibility check on the classification rule.

10 Relation to regular black holes and quantum gravity

The Nullity criterion is falsifiable. A candidate continuation $\widetilde{R}$ may be supplied by any of the following, without prejudice:

regular black hole,

loop-corrected interior,

Planck-star transition,

fuzzball microstructure,

gravastar,

asymptotic-safety core,

nonlocal quantum-gravity completion,

bounce or white-hole transition.

The admissibility test is the same in every case. The proposal must supply:

$$E_{\widetilde{R}},$$

$$N_{\widetilde{R}},$$

$$O_{\widetilde{R}},$$

$$\mathrm{FDC}(\widetilde{R}) = 1.$$

If it does, then

$$\mathcal{S}_{\mathrm{core}} \neq \mathcal{N}$$

within that theory. If it does not, then it has not replaced Nullity. It has only named an unknown.

11 Exterior observability does not imply core admissibility

The exterior and near-horizon regimes are observationally rich. Black-hole shadows, accretion flows, orbital motions, gravitational waves, quasi-normal modes, and lensing all constrain the exterior and near-horizon structure. But these observations do not directly commission the singular core. Therefore,

$$O_{\text{exterior}} \neq O_{\text{core}}.$$

A theory may be well constrained outside the horizon while remaining undefined at the singular-core limit. This is not a weakness. It is category discipline. The correct distinction is:

$$\mathcal{A}(R_{\text{exterior}}) = 1,$$

while

$$\mathcal{A}_{R_{\text{GR}}}(\mathcal{S}_{\text{core}}) = 0$$

unless a continuation $\widetilde{R}$ is supplied.

12 Binary black holes as exterior population diagnostics

Binary black-hole mergers are relevant only as exterior and population-level diagnostics. They do not observe the singular core. Let $M_{c,i}$ denote the chirp mass of event i. Define

$$x_i = \ln M_{c,i}.$$

For a fixed logarithmic frequency β, define

$$C(\beta) = \sum_{i=1}^{N} \cos(\beta x_i),$$

$$S(\beta) = \sum_{i=1}^{N} \sin(\beta x_i),$$

and

$$T(\beta) = \frac{C(\beta)^2 + S(\beta)^2}{N}.$$

Such a statistic tests whether black-hole populations retain structured exterior, formation-history, or population-level information. It does not test whether the singular core is admissible. The logical separation is:

$$\text{BBH population structure} \Rightarrow \text{exterior or formation-channel information},$$

not

$$\text{BBH population structure} \Rightarrow \text{singular-core continuation.}$$

This distinction prevents empirical overreach.

13 Indirect diagnostic channels

In complex gravitational regimes, structural information need not appear in the mean observable. It may appear in:

$$\text{variance},$$

$$\text{phase lag},$$

$$\text{population drift},$$

$$\text{ringdown residuals},$$

$$\text{horizon-scale image deviations},$$

$$\text{thermodynamic anomalies.}$$

For black-hole interiors, possible indirect tribunals include:

1. deviations from Kerr quasi-normal-mode spectra;
2. robust gravitational-wave echoes;
3. horizon-scale imaging deviations;
4. late-time evaporation constraints;
5. population-level correlations in mass, spin, and redshift;
6. breakdown or confirmation of no-hair consistency tests;
7. correlations between exterior observables and fixed structural modes.

None of these proves Nullity. Each tests whether a proposed continuation has observable consequences. The tribunal asymmetry is:

$$\text{no current direct core observation} \not\Rightarrow \text{Nullity proven},$$

but

$$\text{no proposed observable tribunal} \Rightarrow \text{no admitted continuation.}$$

14 The Reversal Principle is not used

The phrase "Nullity-to-Existence and Existence-to-Nullity" is not admitted as a primitive principle. It may be retained only as a conditional question: If an admissible generation map exists,

$$\Gamma : \mathcal{N} \to R,$$

with

$$\mathcal{A}(R) = 1,$$

then one may ask whether a terminal inverse exists,

$$\Gamma^{-1} : R \to \mathcal{N}.$$

But this inverse is not automatic. It must itself satisfy the constructive triad:

$$\mathfrak{C}(\Gamma^{-1}) = (E_{\Gamma^{-1}}, N_{\Gamma^{-1}}, O_{\Gamma^{-1}}).$$

Without this, the reversal principle is not physics. It is interpretive language. Therefore the present paper does not rely on reversal. The admitted statement is only:

collapse may terminate admissibility.

The inadmissible statement is:

collapse proves ontological return to nothingness.

15 Nullity is not ontology

The following identifications are rejected:

$$\mathcal{N} = \text{empty space},$$

$$\mathcal{N} = \text{vacuum},$$

$$\mathcal{N} = \text{infinite density},$$

$$\mathcal{N} = \text{hidden matter},$$

$$\mathcal{N} = \text{another universe},$$

$$\mathcal{N} = \text{anti-spacetime},$$

$$\mathcal{N} = \text{substrate substance}.$$

The only admissible identification is:

$$\mathcal{N} = \text{failure of licensed physical predication.}$$

Nullity is a rule of scientific silence at a failed boundary.

16 Falsifier ledger

The Nullity assignment for the singular-core limit is falsified if a candidate continuation supplies all of the following:

1. a governing interior equation;
2. numerical constants fixed independently of the singularity problem;
3. an observable diagnostic channel;
4. finite propagation diagnostics;
5. finite ordering diagnostics;
6. finite localization diagnostics;
7. finite coupling diagnostics;
8. stable regeneration under admissible re-description;
9. no uncommissioned primitive introduced solely to avoid divergence;
10. compatibility with exterior black-hole constraints;
11. a clear domain of validity;
12. a structural failure condition.

If these are satisfied, then

$$\mathcal{S}_{\text{core}} \neq \mathcal{N}.$$

If they are not satisfied, then the candidate continuation remains unadmitted. The framework is falsifiable in two directions:

$$\text{admissible continuation found} \Rightarrow \text{Nullity rejected for that core model,}$$

$$\text{no admissible continuation supplied} \Rightarrow \text{Undefined remains the disciplined output.}$$

17 No-predicate theorem

Theorem 2. *If a boundary candidate B admits no continuation $\widetilde{R}$ satisfying equation, number, observable, and finite diagnostic closure, then every positive physical predicate assigned to B is unlicensed.*

Proof. A positive physical predicate $P(B)$ is admissible only if it belongs to a regime R with

$$\mathcal{A}(R) = 1.$$

If no such R exists, then no admissible map

$$D_R : \mathcal{C} \to \mathcal{P}(\mathcal{M})$$

exists for $P(B)$. Therefore $P(B)$ cannot be licensed as a physical claim. The only admitted output is Undefined. $\square$

Applied to the singular-core limit:

$$\nexists\, \widetilde{R} \Rightarrow \neg P(\mathcal{S}_{\text{core}})$$

for every positive physical predicate P. Thus one may not say:

$$\mathcal{S}_{\text{core}} \text{ is an object},$$

$$\mathcal{S}_{\text{core}} \text{ is a place},$$

$$\mathcal{S}_{\text{core}} \text{ is a substance},$$

unless a continuation licenses those predicates. The correct output is:

$$\text{Undefined.}$$

18 Discussion

The paper's result is deliberately narrow. It does not solve the black-hole singularity problem. It classifies the logical status of the classical singular-core limit under a constructive criterion. The event horizon is admitted because it has:

$$E, \quad N, \quad O, \quad \text{FDC}.$$

The singular-core limit, inside classical GR, is not admitted because it has:

$$E_{\text{formal}}, \quad N_{\text{divergent}}, \quad O_{\text{absent/direct}}, \quad \text{FDC} = 0.$$

This distinction is not semantic. It prevents a common category error: treating the singularity as an exotic object rather than as a failure marker of the regime used to describe it. The resulting classification is:

$$\text{black hole} = \text{admissible exterior} + \text{admissible causal horizon} + \text{candidate terminal admissibility boundary}$$

Where regularization succeeds, Nullity is not reached. Where regularization fails, Nullity is not a thing found inside the black hole. It is the absence of licensed continuation.

19 Conclusion

The event horizon is not Nullity. It is an admissible causal boundary formed by sufficient compactness and constrained by exterior observations. It supplies equation, number, observable, and finite diagnostic closure. The singular-core limit has a different status. Classical general relativity supplies geodesic incompleteness and, in representative solutions, divergent curvature invariants. It does not supply an observed finite object at $r = 0$. Under constructive admissibility, the proper classification is:

$$\mathcal{A}_{R_{\mathrm{GR}}}(\mathcal{H}^+) = 1,$$

$$\mathcal{A}_{R_{\mathrm{GR}}}(\mathcal{S}_{\mathrm{core}}) = 0.$$

The Nullity assignment is conditional:

$$\mathcal{S}_{\mathrm{core}} = \mathcal{N} \quad \Longleftrightarrow \quad \nexists\, \widetilde{R} : \mathcal{A}(\widetilde{R}) = 1.$$

This is not a metaphysics of nothingness. It is a methodological necessity. A singularity is not a discovery of an infinite object. It is the point at which a regime loses the right to continue its grammar. The event horizon belongs to physics. The singular core belongs to the tribunal of admissibility. If no continuation restores equation, number, observable, and finite diagnostic closure, then the correct result is not a hidden interior, but the end of licensed description. Where physical description closes, physics speaks. Where it does not close, the correct output is silence. That silence is Nullity.

A Minimal computational certificate

The following computation certifies the horizon/core distinction. Constants:

$$G = 6.67430 \times 10^{-11},$$

$$c = 299792458,$$

$$M_\odot = 1.98847 \times 10^{30}.$$

Schwarzschild radius:

$$r_s = \frac{2GM_\odot}{c^2} = 2.9533393820668783 \text{ km}.$$

Admissibility functional:

$$\mathcal{A}(E, N, O, F) = \begin{cases} 1, & E = N = O = F = 1, \\ 0, & \text{otherwise.} \end{cases}$$

Horizon:

$$\mathcal{A}_{\mathcal{H}} = \mathcal{A}(1, 1, 1, 1) = 1.$$

Classical singular-core limit:

$$\mathcal{A}_{\mathcal{S}} = \mathcal{A}(1, 1, 0, 0) = 0.$$

The computation is not a proof of absolute Nullity. It is a reproducibility certificate for the methodological distinction.

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