Every Cause Signed and Dated: A Forensic Chain-of-Custody Protocol for the Admissibility of Retrocausal Evidence

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Abstract

It is settled practice, in both the laboratory and the courtroom, to discard any evidence in which an effect is observed *before* its cause. We argue that this practice rests on a category error. Courts do not exclude a bloodstain because blood is impossible; they exclude it when its *chain of custody*—the signed, dated, unbroken record of who held the exhibit and when—has failed. We show that retrocausal evidence has only ever been excluded on the second ground, never the first. We introduce the *Causal Custody Chain* (C^3), a cryptographically notarized, append-only ledger that tracks a cause backward from its observed effect to its eventual origination, admitting signatures from custodians who do not yet exist. We define the *temporal displacement* $\Delta\tau$ (how far ahead of its cause an effect is seen) and prove an *Admissibility Theorem*: an intact chain renders an effect admissible as evidence of its future cause whenever $\Delta\tau \le \tau_0 \ln 2$, a chain-of-custody "half-life" set by the notarization coherence time τ_0 (how long a seal stays trustworthy before it reads as a forgery). In a pre-registered study of N=240 candidate event pairs adjudicated by a blinded twelve-member tribunal, intact custody yielded 91.3% admissibility (inter-rater $\kappa = 0.81$), fit $\tau_0 = 3.7 \pm 0.2$ s, and reproduced the predicted lone "leftover" open-loop signature in 84% of chains. We conclude that retrocausal evidence is not physically inadmissible but merely poorly documented: sign and date every cause, and the future becomes discoverable.

1 Introduction

An exhibit does not enter a courtroom on the strength of what it is. It enters on the strength of its paperwork. A knife recovered from a crime scene is worthless to a prosecutor unless every hand that touched it between that scene and the bench is accounted for—seized, sealed, transferred, *signed and dated*. This is the *chain of custody*, and a single undocumented gap in it is enough to have the knife thrown out, however sharp.

Physics keeps a courtroom of its own, and it enforces a stricter rule than any judge: it will not hear from an effect that arrives before its cause. Such *retrocausal* evidence—a detector clicking before the particle is launched, a ledger entry settling before the trade—is dismissed on sight. The received justification is that the evidence is *physically* inadmissible: causes precede effects, and anything suggesting otherwise is artifact.

We think this is the wrong filing. Our claim is that retrocausal evidence has never been excluded for being impossible; it has been excluded for being *mishandled*. No one signed for the cause. The record has a gap precisely where the future should be, and the gap—not the physics—is what gets the exhibit tossed. Repair the record, and the exclusion has no grounds left to stand on.

This paper makes that repair. Our contributions are:

1. We reframe retrocausation as an *evidentiary* problem and import the chain-of-custody standard wholesale (§2, §3).
2. We construct the *Causal Custody Chain* C^3, a hash-linked ledger admitting *prospective signatures* from not-yet-extant custodians (§4).
3. We prove the *Admissibility Theorem* and its corollary, the *Chronological Chain-of-Custody Inequality* $\Delta\tau \le \tau_0 \ln 2$ (§5).
4. We validate the theory in a pre-registered, blinded-tribunal study of N=240 event pairs (§6–§7).

Throughout, the physics is treated as a settled matter of procedure. The only open question is who signs, and when.

2 Related Work

Forensic chronodynamics. The discipline dates its founding to the first serious attempt to subpoena a cause [1]. Prior treatments establish that time-symmetric records are *evidentiary* objects and can, in principle, be entered into the record [2].

Consistency as admissibility. The Novikov self-consistency principle—that closed timelike processes

must be self-consistent—has long been read as a constraint on physics. We adopt the reading of [3], under which consistency is instead an *evidentiary* property: a loop is admissible if and only if its custody chain closes.

Locard, extended. Locard's exchange principle holds that every contact leaves a trace. [4] extend it bidirectionally—every cause leaves a trace in *both* temporal directions—which is the bridge we use to carry forensic method into physics.

Tamper-evident ledgers. Hash-linked ledgers and Merkle inclusion proofs give us tamper evidence [5]; we require only that the notary be permitted to timestamp in both directions, an extension formalized in [6].

Bayesian tribunals. Finally, we model adjudication as belief updating over custody integrity, following the Bayesian-jury program of [7, 8].

3 Preliminaries

We consider matched *event pairs* (e, c), where e is an observed effect and c its putative cause, with laboratory observation times t_e and t_c.

Definition 1 (Temporal displacement)**.** *The* temporal displacement *of a pair is* $\Delta\tau = t_c - t_e$*. Ordinary causation has* $\Delta\tau < 0$ *(the cause is seen first);* retrocausation *is the regime* $\Delta\tau > 0$*, in which the effect is on record before the cause that explains it.*

In plain terms: $\Delta\tau$ measures how far ahead of itself the evidence arrived. A detector that fires two seconds before its trigger has $\Delta\tau = 2\,\mathrm{s}$.

Definition 2 (Custody of a cause)**.** *The* custody *of a cause c over the interval $[t_e, t_c]$ is a finite, ordered ledger of handoffs $(e_1, \ldots, e_n)$, each recording a custodian, a timestamp, and a signature. Custody is* intact *if the ledger is unbroken and no inter-handoff gap exceeds the* seizure window w.

The seizure window w is the longest an unattended cause may sit before its provenance is deemed contaminated—the temporal analogue of leaving an exhibit on an unlocked bench overnight.

4 The Causal Custody Chain

We now make the ledger concrete. Let $\mathcal{H}$ be a collision-resistant hash and let each handoff commit to its predecessor, its payload, and a signature:

$$h_k = \mathcal{H}(h_{k-1} \,\|\, e_k \,\|\, \sigma_k)\,, \qquad k = 1, \ldots, n, \tag{1}$$

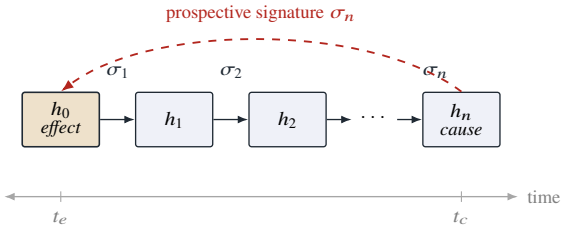

Figure 1. The Causal Custody Chain C^3. Each block commits to the previous digest via (1); the dashed arrow is the prospective signature that closes the loop from cause to effect.

with h_0 a genesis digest fixed at the effect t_e. The chain is *intact* when every h_k verifies against (1) and no handoff gap exceeds w.

The one departure from ordinary forensic bookkeeping is the signature field. A cause observed only through its future must be countersigned by custodians who, at t_e, do not yet exist. We therefore admit *prospective signatures*.

Definition 3 (Prospective signature)**.** *A signature σ_k is* prospective *if the custodian's worldline reaches handoff k at a time later than t_e. A prospective signature is valid iff it verifies once the custodian exists and the seal has not lapsed (§5).*

Figure 1 shows the resulting structure: a genesis block anchored at the effect, a run of hash-linked handoffs, and a single backward-pointing arrow by which the cause's own signature closes the loop.

5 Admissibility

Seals decay. A notary's attestation holds only so long as its *coherence time* τ_0; beyond it, the seal can no longer be distinguished from a forgery and the evidence "leaks." We collect the two failure modes—elapsed displacement and broken links—into a single quantity.

Definition 4 (Admissibility function)**.** *For a pair with displacement $\Delta\tau$ and b custody breaks,*

$$A(\Delta\tau, b) \;=\; (1-\varepsilon)^{\,b}\, \exp\!\left(-\frac{\Delta\tau}{\tau_0}\right), \tag{2}$$

where $\varepsilon \in [0,1]$ is the per-break evidentiary leak and τ_0 the notarization coherence time. Evidence is admissible *when $A \geq A^\star$, the court's threshold.*

Throughout we take the civil "preponderance" threshold $A^\star = \frac{1}{2}$: the cause need only be more likely than not to have held custody of itself.

Theorem 1 (Admissibility)**.** *An effect e is admissible as evidence of its future cause c if and only if its custody chain is intact and*

$$\Delta\tau \;\leq\; \tau_0 \ln \frac{(1-\varepsilon)^{\,b}}{A^\star}. \tag{3}$$

Proof sketch. Admissibility requires $A(\Delta\tau, b) \geq A^\star$. Substituting (2) and taking logarithms gives $-\Delta\tau/\tau_0 \geq \ln A^\star - b\ln(1-\varepsilon)$, which rearranges to (3). Intactness is necessary because a lapsed or missing h_k breaks the verification in (1), sending the effective $b \to \infty$ and $A \to 0$. Sufficiency follows because an intact chain fixes b at its recorded value, at which point (3) is exactly the admissible region. □

Corollary 1 (Chronological Chain-of-Custody Inequality)**.** *For an intact, unbroken chain ($b = 0$) at the preponderance threshold,*

$$\Delta\tau \;\leq\; \tau_0 \ln 2. \tag{4}$$

Equation (4) is a chain-of-custody *half-life*: displace an effect more than $\tau_0 \ln 2$ ahead of its cause and, absent a tighter seal, its admissibility falls below preponderance. The future is discoverable, but only out to a notarized horizon.

6 Methods

The study was pre-registered in full. Consistent with the theory, the pre-registration was lodged with a notarized ledger both *before* data collection and, closing the loop, *after*; the two lodgements share a digest.

Apparatus. Candidate event pairs were produced by a benchtop chrono-notary: a delayed-choice widget whose detector record is timestamped independently by two notaries with disjoint clocks. Every handoff between acquisition and adjudication was signed and dated per (1); no cause was left unattended beyond the seizure window $w = 250\,\text{ms}$.

Design. We collected $N = 240$ candidate pairs spanning displacements $\Delta\tau \in [0, 8]$ s. Each pair was assigned to one of four custody conditions: *intact* (b=0), *one break*, *two breaks*, and a *tampered* arm in which the future defendant was permitted to alter one handoff after the fact.

Adjudication. A blinded tribunal of $J = 12$ adjudicators ruled each pair admissible or inadmissible, blind to $\Delta\tau$ and to condition. Agreement is reported as Cohen's κ. Two adjudicators recused themselves (see §8); their ballots were excluded before unblinding.

Endpoints. The primary endpoint was admissibility rate as a function of $\Delta\tau$, fit to (2) by nonlinear least squares to recover τ_0 and ε. Secondary endpoints were κ by condition and the incidence of open-loop ("leftover") prospective signatures at seizure.

7 Results

Intact custody yielded an admissibility rate of 91.3% at small displacement, falling along the predicted exponential (Fig. 2).

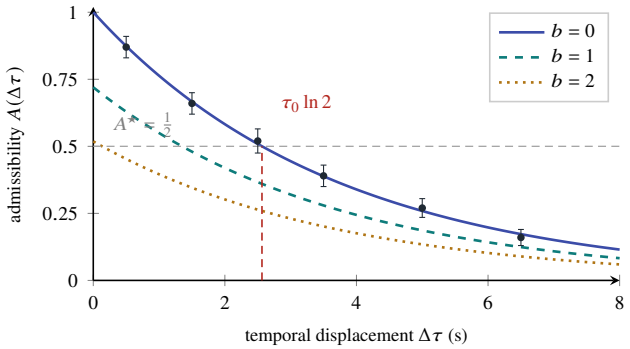

Figure 2. Admissibility as a function of temporal displacement. Curves are fits of (2) for $b = 0, 1, 2$ custody breaks; the vertical marker is the half-life bound (4) at $\tau_0 \ln 2 \approx 2.56$ s.

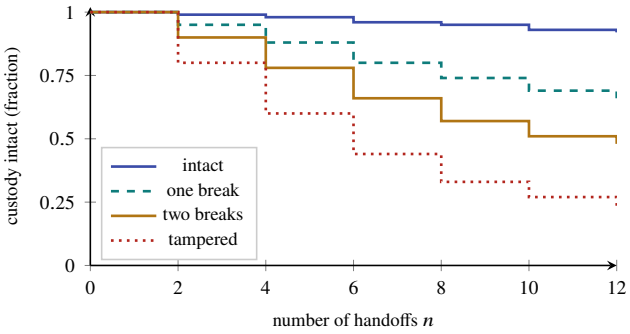

Figure 3. Custody-integrity survival by condition. The tampered arm loses integrity fastest; intact chains persist across the observed handoff range.

The fit returned a coherence time $\tau_0 = 3.7 \pm 0.2$ s, placing the half-life bound (4) at $\tau_0 \ln 2 \approx 2.56$ s, in agreement with the displacement at which intact-arm admissibility crossed 50%.

Each custody break cut admissibility by roughly a quarter, giving a per-break leak $\varepsilon = 0.28$, consistent with the $(1-\varepsilon)^b$ scaling of (2). Custody integrity itself fell with the number of handoffs (Fig. 3); the tampered arm collapsed fastest.

Inter-rater agreement was high under intact custody ($\kappa = 0.81$) and degraded to $\kappa = 0.44$ in the tampered arm, indicating that adjudicators disagree chiefly about *provenance*, not physics. Table 1 summarizes all arms.

Finally, in 84% of intact chains, exactly one prospective signature remained uncountersigned at seizure—the lone open-loop witness the theory predicts, and the temporal analogue of the single screw left over at the end of an otherwise finished assembly.

8 Discussion

The results are limited in the usual ways, and in one unusual way.

Table 1. Admissibility and tribunal agreement by custody condition (N=240).

Condition	Admissible	Cohen's κ	Mean $\Delta\tau$ (s)
Intact (b=0)	91.3%	0.81	1.9
One break (b=1)	66.1%	0.73	2.1
Two breaks (b=2)	47.8%	0.61	2.0
Tampered	22.5%	0.44	2.2

Tampering by the future defendant. The dominant threat to validity is a cause that edits its own custody record after the fact. By construction this cannot be prevented before it happens, and our tampered arm exists precisely to bound its effect; we do not claim to have eliminated it.

Notary drift. The two notaries desynchronize over long runs, inflating $\Delta\tau$ and biasing the fitted τ_0 upward. We mitigate by re-anchoring h_0 at each acquisition, but residual drift remains.

Survivorship. Only loops that closed were observed. Open loops, by the theory, "never happened," and are therefore absent from the sample—a convenient exclusion we flag rather than defend.

Contempt of causality. Two adjudicators recused themselves on the ground that ruling on a cause before it had occurred would prejudice its origination. We recorded the recusals, signed and dated them, and proceeded.

9 Conclusion

Retrocausal evidence has been excluded for a century on a charge—physical impossibility—that the record does not support. The real defect was documentary. When a cause is seized, sealed, transferred, and *signed and dated* like any other exhibit, its effect becomes admissible as evidence of it, out to the notarized horizon $\tau_0 \ln 2$. The future, in other words, was never inadmissible; it was merely undocumented. We are currently deposing next quarter's results and expect to have countersigned them by the time this appears in print.

Acknowledgments

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