The Temporal Workspace

A General Relativistic Measure of Temporal Depth

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Abstract

The phenomenological distinction between the *duration* and the *richness* of temporal experience has resisted physical grounding. We show that General Relativity provides a natural measure of temporal richness — the **temporal workspace** $\mathcal{W}_T(\tau)$. The exponent 7/4 is derived from the Peters inspiral formula alone; the activation scale $\tau^* = 3.32$ yr is derived from the STF causal coherence condition [Paz 2026c] with no additional free parameters. Any system with a characteristic internal timescale τ has temporal workspace:

$$ \mathcal{W}_{T} (\tau) = \left(\frac{\tau^{*}}{\tau} \right)^{7 / 4} - 1 $$

where $\tau^* = 3.32$ yr is the timescale at which a stellar-mass binary black hole transitions from cosmologically frozen to human-scale fast — a transition derived from first principles in the STF framework [Paz 2026c]. Systems with $\tau < \tau^*$ have positive workspace ($\mathcal{W}_T > 0$); temporal closure is possible and grows as a power law with decreasing τ. Systems with $\tau > \tau^*$ have negative workspace; they are in the cosmologically frozen regime where temporal closure cannot occur. The exponent 7/4 is exact within post-Newtonian GR and follows from $\mathcal{D} \sim a^{-7}$ combined with the Peters scaling $a \sim \tau^{1/4}$.

This formalism quantifies a structure already implicit in the CTI paper [Paz 2026a]: Section VIII.H of CTI introduces the time-to-boundary variable $\tau \equiv t^* - t$ and establishes that under this reparametrisation the merger (physical endpoint) is the internal observer's *experiential origin* — the richest, most constrained moment — while the activation boundary (3.32 yr) is the experiential *terminus*. The three horizons (71 days, 3.32 yr, 54 yr) are not three independent field properties but three readings on a single Peters inspiral curve. The temporal workspace formula makes this precise: the inner horizon ($\mathcal{W}_T \approx 142$) is where the workspace is fullest; the activation boundary ($\mathcal{W}_T = 0$) is the outermost closure that can occur; and the outer horizon ($\mathcal{W}_T \approx -0.99$) is 143 times below threshold in the external frame — the retrocausal terminus at which the future boundary condition first begins to be felt. CTI's endpoint inversion and the workspace formula are two descriptions of the same fact.

We derive the organism mapping, the commensurability criterion, and three falsifiable

predictions distinguishing this framework from the existing theory.

1. Introduction

The specious present — William James's "saddle-back of time" — has two aspects that existing theory conflates. The first is its **duration**: how wide the experienced "now" is, how much temporal content it spans. The second is its **richness**: how many distinct causal configurations are accessible within it, how much the system can actually do within the now it occupies.

These are different. A geological process has a very wide "now" — it integrates events across millennia — but an impoverished one. A hummingbird's neural dynamics have a narrow "now" of milliseconds but an extraordinarily rich one: within each cycle the system can discriminate, respond, anticipate, close causal loops that are invisible to slower processes.

The STF Theory of Time [Paz 2026b] establishes that temporal experience requires temporal self-reference — a closing loop in which the present is constrained by both retained past and anticipated future. The Consciousness-Time-Identity paper [Paz 2026a] establishes that this structure is identical to temporal experience, not merely correlated with it. What neither paper provides is a *quantitative* measure of how rich that temporal self-reference is — how large the workspace of accessible causal configurations is for a system operating at a given timescale.

This paper provides that measure.

The key observation, which we establish in Section 2, is that the three hierarchical timescales derived in [Paz 2026b] — 71 days, 3.32 yr, 54 yr — are not independent properties of the STF field. They are readings on a single Peters inspiral curve: the curvature rate $\mathscr{D}(\tau)$ evaluated at three successive orbital separations on the late inspiral trajectory of a stellar-mass binary black hole. This means the hierarchy is pure GR orbital mechanics — a fact stated explicitly in [Paz 2026c] Section II.A before any STF physics is introduced (see Section 2.3).

From this single observation, the temporal workspace follows as a derived quantity with no free parameters beyond the activation timescale $\tau^* = 3.32$ yr.

2. The Peters Formula Foundation

2.1 The Three Horizons Are One Curve

The STF Theory of Time derives three characteristic timescales from the STF field dynamics coupled to GR:

HORIZON	TIMESCALE	ORBITAL SEPARATION (66+66 $M_{\odot}$)
Inner	71 days	360 R_S
Mid (activation)	3.32 yr	730 R_S
Outer	54 yr	1,466 R_S

These three timescales correspond to three orbital separations on the late inspiral trajectory of a reference binary (66+66 $M_{\odot}$), computed via the Peters formula:

$$ t (a) = \frac{12}{85} \cdot \frac{a^{4} c^{5}}{2 G^{3} M^{3}} $$

The separations are in ratio $a_{\text{mid}}/a_{\text{inner}} \approx 2.03$ and $a_{\text{outer}}/a_{\text{mid}} \approx 2.01$ — consistent with a logarithmically spaced hierarchy on the inspiral curve. They do not arise from three independent physical mechanisms. They are one physics — the Peters $a(t)$ relation — evaluated at three points.

2.2 The Curvature Rate Along the Curve

The tidal curvature rate $\mathcal{D}$ scales along the inspiral as:

$$ \mathcal{D} (a) \sim \frac{\mathcal{W}}{t_{\text{inspiral}}} \sim \frac{G M / c^{2} a^{3}}{a^{4} / t_{\text{scale}}} \sim a^{- 7} $$

where the tidal field $\mathcal{W} \sim GM/c^2a^3$ and the inspiral time $t \sim a^4$ (Peters). Since $a \sim \tau^{1/4}$ (Peters inverted):

$\mathcal{D}(\tau) \sim \tau^{-7/4}$

The curvature rate at each horizon:

HORIZON	$\mathcal{D}$ ($\mathrm{M}^{-2}\mathrm{S}^{-1}$)	$\mathcal{D}/\mathcal{D}_{\text{CRIT}}$
Inner (71 days)	9.18×10^{-26}	138
Mid (3.32 yr)	6.40×10^{-28}	≈ 1
Outer (54 yr)	4.86×10^{-30}	0.007

where $\mathcal{D}_{\text{crit}} \approx 6.6 \times 10^{-28}$ m^{-2}s^{-1} is the STF activation threshold [Paz 2026c].

The mid horizon is the **activation point** — where $\mathscr{D} = \mathscr{D}_{\text{crit}}$. The inner horizon is 138 times above threshold. The outer horizon is 143 times *below* threshold in the external frame. In the retrocausal frame of Section VIII.H of CTI, this same point is the experiential *terminus* — the boundary beyond which the future constraint can no longer reach. The two descriptions are equivalent: 143 times below threshold externally is the same fact as the terminus of retrocausal depth internally.

2.3 These Numbers Are General Relativity

The logical status of the three timescales is stated explicitly in [Paz 2026c], Section II.A, which presents them before any STF physics is introduced:

> *"These numbers are General Relativity. They are not derived by the STF — they are inputs that define the natural phase structure of compact binary evolution."*

Section III.D.1 of the same paper reinforces this: *"These are standard GR results from the Peters formula. They involve no STF physics."*

The three timescales 71 days, 3.32 yr, and 54 yr are the Peters formula evaluated at orbital separations 360 R_S, 730 R_S, and 1466 R_S respectively — for a reference 30+30 $M_\odot$ binary, the three separations that bracket the late inspiral transition from cosmologically frozen (millions of years to merger) to human-scale fast (decades to months). This transition is a standard classification in gravitational wave astronomy [Peters 1964].

What the STF framework adds — and what [Paz 2026c] derives — is *why* the activation threshold falls at the middle point (730 R_S, 3.32 yr). The two-curve intersection of $\mathscr{D}_{\text{GR}}(a)$ and $\mathscr{D}_{\text{crit}}(m_s(a))$ has a unique solution at exactly this separation, derived from GR, quantum mechanics, and cosmological boundary conditions with no free parameters. The hierarchy of three timescales is pure GR; the identification of 730 R_S as the activation point is the STF result.

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3. The Temporal Workspace

3.1 Definition

Definition. The *temporal workspace* of a system with characteristic internal timescale τ is:

$$ \boxed{\mathcal{W}_{T} (\tau) = \left(\frac{\tau^{*}}{\tau} \right)^{7 / 4} - 1} $$

where $\tau^* = 3.32$ yr is the activation timescale at which $\mathscr{D} = \mathscr{D}_{\mathrm{crit}}$.

$\mathscr{W}_T$ is dimensionless, has no free parameters beyond τ^*, and follows from the Peters formula and the threshold condition alone.

Interpretation. $\mathscr{W}_T(\tau)$ is the normalized excess curvature rate above threshold at the orbital separation corresponding to timescale τ:

$$ \mathcal{W}_{T} (\tau) = \frac{\mathcal{D} (\tau) - \mathcal{D}_{\mathrm{crit}}}{\mathcal{D}_{\mathrm{crit}}} $$

- $\mathscr{W}_T > 0$: system operates in the human-scale fast regime; temporal closure is possible
- $\mathscr{W}_T = 0$: system is exactly at threshold ($\tau = \tau^*$)
- $\mathscr{W}_T < 0$: system is in the cosmologically frozen regime; temporal closure cannot occur
- $\mathscr{W}_T \gg 1$: rich temporal workspace; many accessible causal configurations

3.2 The Exponent 7/4

The exponent 7/4 is exact within post-Newtonian GR and has a clean physical derivation:

1. Tidal field: $\mathscr{W} \sim a^{-3}$
2. Inspiral time: $t \sim a^4$ (Peters formula, dominant radiation reaction)
3. Curvature rate: $\mathscr{D} \sim \mathscr{W}/t \sim a^{-7}$
4. Peters inverted: $a \sim \tau^{1/4}$
5. Therefore: $\mathscr{D} \sim \tau^{-7/4}$

No assumptions beyond post-Newtonian GR and the Peters formula enter this derivation. The exponent 7/4 is not fitted — it is the ratio (3+4)/4 = 7/4 of the tidal scaling exponent (3) plus the inspiral time exponent (4), divided by the Peters orbital exponent (4).

3.3 Workspace Values Across Timescales

TIMESCALE τ	$\mathcal{W}_T$	REGIME
17 hours (hummingbird neural)	$\sim 431,000$	Extraordinarily rich
30 days (human neural integration)	~ 649	Very rich
71 days (human habit loop)	~ 142	Rich
6 months	~ 25	Moderate
1 year	~ 7	Moderate
3.32 yr (activation)	$= 0$	**Threshold**

10 yr	-0.85	Frozen
54 yr	-0.99	Deep frozen
1,000 yr	≈ -1	Cosmologically frozen

The workspace grows steeply below τ^* and falls sharply above it. The transition is not gradual — it has the character of a phase boundary.

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4. Two Dimensions of Temporal Experience

4.1 Duration and Richness Are Independent

The STF Theory of Time [Paz 2026b] and the Consciousness-Time-Identity paper [Paz 2026a] establish that temporal experience requires temporal self-reference at a characteristic timescale. This timescale determines the **duration** of the specious present — how wide the experienced now is.

The temporal workspace $\mathscr{W}_T$ is a different quantity. It measures the **richness** of the specious present — how many distinct causal configurations are accessible within it.

These two dimensions are independent. A system can have:

- **Short duration, high richness**: fast neural dynamics ($\tau\sim$ milliseconds to days) produce a narrow but rich specious present. The hummingbird's $\mathscr{W}_T \sim 431,000$ reflects an extraordinarily full causal workspace compressed into each moment.
- **Long duration, zero richness**: the human 3.32 yr life loop has duration measured in years but $\mathscr{W}_T \approx 0$ — it sits precisely at the threshold. Closure is possible but barely so; the workspace is marginal.
- **Long duration, negative workspace**: a tortoise with $\tau \sim 10$ yr has $\mathscr{W}_T = -0.85$ — it is in the cosmologically frozen regime. If the CTI identity claim is correct, temporal closure does not occur at this timescale.

The distinction matters for reading the CTI hierarchical closure model precisely. CTI Section IX presents 71 days, 3.32 yr, and 54 yr as three nested closure horizons and matches them to human adaptive loops. This is correct. But CTI Section VIII.H already encodes the key structural fact: the STF dynamics are defined relative to a *terminal* boundary condition (the merger), and under the time-to-boundary reparametrisation $\tau \equiv t^* - t$, the ordering inverts. The merger is the experiential *origin* — richest, most constrained. The activation boundary (3.32 yr) is the experiential *terminus* — where the loop can no longer close. The outer horizon (54 yr) is beyond the terminus: the point at which the future boundary condition begins to be felt, but closure has not yet occurred.

The temporal workspace quantifies this: $\mathcal{W}_T(54\,\mathrm{yr}) \approx -0.99$ — 143 times below the activation threshold in the external Peters frame. This is not a contradiction of CTI but a measurement of where CTI's terminus sits. The CTI paper states the inversion; the workspace formula tells you how far beyond the terminus the outer horizon lies.

4.2 The Two-Frame Reading of the Hierarchy

The three STF timescales admit two consistent readings — external (Peters formula, $\mathcal{W}_T$) and internal (retrocausal, $\tau \equiv t^* - t$) — and they agree:

HORIZON	T	EXTERNAL: $\mathcal{W}_T$	EXTERNAL REGIME	INTERNAL (CTI VIII.H)
Inner	71 days	142	Deep within workspace	Near experiential origin (merger)
Mid	3.32 yr	≈ 0	Activation boundary	Experiential terminus
Outer	54 yr	-0.99	143× below threshold	Beyond terminus; retrocausal horizon

In the external frame, $\mathcal{W}_T = -0.99$ at 54 yr means the system is 143 times below the closure threshold — it is in the cosmologically frozen regime. In the internal retrocausal frame, 54 yr is the point where the future boundary condition (merger) begins to be felt but has not yet produced closure. These are the same fact: the outer horizon marks the *reach* of the retrocausal field, not its closure.

The inner horizon at 71 days is simultaneously the richest workspace ($\mathcal{W}_T \approx 142$, 138 times above threshold) and the closest approach to the experiential origin (nearest the merger, most strongly constrained by the future boundary). Again one fact, two frames.

The CTI paper's Section VIII.H states this correctly as a reparametrisation property of time-symmetric systems. Section IX then matches the three timescales to human adaptive loops — habit formation (71 days), role tenure (3.32 yr), working lifespan (54 yr). The temporal workspace framework clarifies what each match means:

- The **habit loop** (71 days) matches the inner horizon: highest workspace, richest closure, most strongly constrained by retrocausal depth. This is where temporal experience is most fully instantiated.
- The **role loop** (3.32 yr) matches the activation boundary: marginal closure, experiential terminus. This is the outermost loop that can close at all. Human role-scale decisions operate at the very edge of the temporal workspace.
- The **working lifespan** (54 yr) matches the outer horizon: beyond the terminus in both frames. It is not a closure horizon but a *relevance* horizon — the timescale at which a

human's relationship to the cosmological temporal field becomes non-negligible. The working life is structured by the reach of the retrocausal field, not by its closure.

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5. The Linkage Correspondence

5.1 Immobility Margin and Temporal Workspace

The hypo-paradoxical linkage framework of Shvalb and Medina [2026] defines the *immobility margin* $\bar{M}$ as the infimum distance from the aligned (locked) configuration in mechanism configuration space. For a hypo-paradoxical mechanism, $\bar{M} = 0$ — the configuration space has dimension zero and no paths exist through it. As $\bar{M}$ increases, the accessible workspace opens according to:

$D'' = 2(n-1) \cdot \bar{M} \cdot \Delta\alpha$

where n is the number of links and $\Delta\alpha$ is the angular range of the mechanism.

The temporal workspace $\mathscr{W}_T$ is the STF analog of $\bar{M}$:

LINKAGE CONCEPT	STF ANALOG
Hypo-paradoxical mechanism	Pre-temporal geometry ($\tau > \tau^*$)
$\bar{M} = 0$ (locked)	$\mathscr{W}_T = 0$ (threshold, $\tau = \tau^*$)
$\bar{M} > 0$ (mobile)	$\mathscr{W}_T > 0$ (temporal closure possible)
Workspace D''	Causal configuration volume V_T
Monotone screw ordering (locked)	Cosmologically frozen regime
Non-monotone ordering (mobile)	Human-scale fast regime

The locked configuration ($\bar{M} = 0$) in linkage theory corresponds exactly to the activation threshold ($\mathscr{W}_T = 0$, $\tau = \tau^*$) in the STF framework. Both mark the boundary between zero-dimensional configuration space (no paths) and positive-dimensional configuration space (paths exist).

5.2 The Causal Configuration Volume

By analogy with $D'' = 2(n-1) \cdot \bar{M} \cdot \Delta\alpha$, the accessible causal configuration volume should take the form:

$V_T(\tau) = C \cdot \mathscr{W}_T(\tau) \cdot \Delta_{\text{retrocausal}}$

where C encodes the dimensionality of the system's causal degrees of freedom and $\Delta_{\text{retrocausal}}$ is the retrocausal depth — how far backward a causal transaction can close.

The retrocausal depth in the STF framework is set by the field propagation range $\lambda_C = \hbar/(m_s c)$. For a neural system, $\Delta_{\text{retrocausal}}$ is related to the characteristic memory horizon over which past states constrain present dynamics through the STF coupling.

The full derivation of V_T requires specifying C — the effective number of independent causal degrees of freedom a given system can engage. For the reference binary, $C = 2$ (two bodies, one loop, $n = 2$ in the linkage language). For a neural system, C is related to the effective dimensionality of the neural coupling to the STF field — a quantity that connects this framework to neural information geometry and is left for subsequent work.

We state the volume formula as a structural conjecture; evaluation requires specifying C — the effective causal dimensionality of the system — which is the primary open problem identified in Section 9 and is not resolved in the present paper.

What is already established is that $\mathscr{W}_T(\tau)$ provides the scalar measure of temporal richness that D'' provides in linkage theory: a single number that captures how far above the locked configuration the system sits, and therefore how large its accessible workspace is.

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6. The Organism Mapping and Biological Predictions

6.0 The Internal Timescale: Operational Definition

Every organism operates across a hierarchy of simultaneous timescales: the millisecond flicker of individual neurons, the seconds-wide specious present, the days-long consolidation of habit, the years-long arc of role and identity. Assigning a single τ_{int} to an organism therefore requires a principled choice among these levels.

We define τ_{int} as **the timescale of the organism's outermost closed adaptive loop**: the longest timescale at which the organism actively completes a feedback cycle between its internal state and its environment — acquiring new structure, testing it against the world, and consolidating or revising it in response.

The rationale is structural, not arbitrary. The temporal workspace formula measures *closure capacity* — whether a system can form a temporally closed loop at timescale τ. A loop that never closes does not contribute to closure capacity regardless of its duration. The outermost *closed* loop is therefore the ecologically relevant quantity: it is the longest timescale at which the organism actually engages in the retrocausal binding that constitutes temporal experience in the STF framework.

For humans, this outer loop is habit formation at approximately 71 days (Lally et al. 2010) for the habit closure level, and role tenure at approximately 3.32 yr for the life-loop level — placing the human outer adaptive loop precisely at τ^*. This alignment, first identified in the CTI paper [Paz 2026a, §IX], is not anthropic coincidence but a statement that τ^* is where the gravitational environment itself transitions from cosmologically frozen to human-scale fast. Biological systems that evolved to track their gravitational environment will naturally have outer loops near τ^*.

For other organisms, τ_{int} is the characteristic timescale of their longest reliably closed behavioral or physiological feedback cycle — not the period of their slowest process. A tortoise has a heartbeat and circadian rhythm well below τ^*; its dominant *adaptive* cycle (the timescale of learning, seasonal adjustment, and behavioral consolidation) is what determines its outer loop. The organism table in Section 6.1 assigns τ_{int} on this basis.

Relation to existing chronobiological measures. Chronobiology already provides quantitative measures of temporal processing speed across species. The three most relevant are: (i) *critical flicker fusion frequency* (CFF) — the temporal resolution of the visual system, scaling roughly as τ^{-1} with the visual integration timescale, with hummingbirds near 100 Hz and humans near 60 Hz; (ii) *metabolic time scaling* — Lindstedt and Calder (1981) established that biological time scales as $M^{1/4}$ with body mass, predicting temporal resolution that scales as $\tau^{-1/4}$; (iii) *EEG peak frequency* — neural processing speed, measurable across species and scaling inversely with body size.

The temporal workspace $\mathscr{W}_T \propto \tau^{-7/4}$ has a steeper exponent than any of these: $-7/4$ compared to -1 for CFF and $-1/4$ for metabolic scaling. This is not a competing measurement of the same quantity — it is a measurement of a different quantity. CFF measures temporal *resolution*: how finely a system can discriminate successive events. Metabolic scaling measures temporal *speed*: how fast a system's internal clock ticks. $\mathscr{W}_T$ measures temporal *closure capacity*: how many causally distinct configurations are accessible within the specious present — how large the workspace of possible causal transactions is that the system can complete within one loop.

A system can have high resolution (fast CFF) but low closure capacity if its temporal dynamics are fast but shallow — if it discriminates quickly but cannot bind past and future constraints into a unified closed loop. The $-7/4$ exponent makes a specific prediction about how closure capacity grows with timescale that differs quantitatively from both -1 and $-1/4$: it predicts that the difference in closure capacity between a hummingbird ($\tau \sim 17$ hr) and a human neural system ($\tau \sim 30$ days) is approximately $43^{7/4} \approx 660$-fold, far exceeding the 43-fold ratio that CFF-based reasoning would predict and the $43^{1/4} \approx 2.6$-fold ratio from metabolic scaling. This difference is testable in any paradigm that measures the *number of discriminable causal states* within the specious present, rather than the minimum interstimulus interval.

6.1 Internal Timescale and Temporal Workspace

Every organism has characteristic internal timescales set by its neural dynamics, metabolic rates, and chronobiological architecture. These timescales determine the organism's temporal workspace and therefore the richness of its temporal experience.

The mapping is direct: an organism with dominant internal timescale τ has $\mathscr{W}_T(\tau)$ as given by the workspace formula. This is a property of the timescale alone — not of the biological substrate, cognitive capacity, or information processing architecture.

Representative organisms:

ORGANISM	DOMINANT INTERNAL τ	$\mathscr{W}_T$	TEMPORAL CHARACTER
Hummingbird	$\sim$ 17 hours	$\sim 431,000$	Extraordinarily rich fast workspace
Human (neural)	$\sim$ 30 days	~ 649	Rich integration workspace
Human (habit)	$\sim$ 71 days	~ 142	Habit-loop workspace
Human (life)	$\sim$ 3.32 yr	≈ 0	Marginal outer closure
Tortoise	$\sim$ 10 yr	-0.85	Below threshold
Giant sequoia	$\sim$ 500 yr	≈ -1	Cosmologically frozen

Note that the hummingbird and the human neural system both have positive workspace — but the hummingbird's workspace is $\sim$ 660 times richer than the human habit loop. This does not mean the hummingbird is more conscious in any overall sense; $\mathscr{W}_T$ measures one dimension of temporal architecture, not its totality.

The tortoise result deserves emphasis. If the CTI identity claim is correct — that temporal experience is identical to temporal self-reference, not merely correlated with it — then a tortoise operating at $\tau \sim 10$ yr has no temporal closure at its dominant timescale. Its neural dynamics at faster timescales (which exist) do have positive workspace. What the tortoise lacks is the *outer loop closure* that human neural architecture achieves at the 3.32 yr boundary.

6.2 The Commensurability Criterion

Two systems are temporally commensurable if and only if:

(i) Their dominant internal timescales are similar: $|\tau_A - \tau_B| / min(\tau_A, \tau_B) \lesssim O(1)$

(ii) Both have positive workspace: $\mathscr{W}_T(\tau_A) > 0$ and $\mathscr{W}_T(\tau_B) > 0$

Condition (i) is the duration condition already present in [Paz 2026b]: systems with wildly different timescales cannot parse each other's signals. Condition (ii) is new: a system with negative workspace cannot form a temporally closed loop at that timescale and therefore cannot participate in temporal communication regardless of signal speed or bandwidth.

This resolves a puzzle in the existing framework: the STF Theory of Time treats commensurability as a function of timescale ratio alone. But two systems with similar timescales could still be incommensurable if one is above τ^* and one is below. The workspace boundary at τ^* is a hard commensurability break, not a gradual degradation.

6.3 Falsifiable Predictions

Prediction 1 — The workspace boundary is sharp, not gradual.

The temporal workspace formula predicts a power-law increase in temporal richness below τ^*, with the transition becoming increasingly sharp as organisms approach τ^* from below. Chronobiological studies of organisms with τ near 3.32 yr should show qualitatively different temporal processing compared to organisms with τ significantly below τ^*.

Specifically: organisms with dominant internal timescale near 3.32 yr should exhibit the temporal phenomenology of marginal closure — fragile temporal orientation, difficulty sustaining long-range temporal binding, reduced retrocausal depth — compared to organisms well below τ^*.

Prediction 2 — Workspace richness, not timescale, predicts temporal resolution.

Existing chronobiology uses timescale (CFF, EEG frequency, metabolic rate) as the primary predictor of temporal resolution. The workspace formula predicts that $\mathscr{W}_T$ — which grows steeply faster than $1/\tau$ — should be a better predictor of the *number of discriminable temporal states* within the specious present.

Concretely: a hummingbird and a human both have positive workspace, but the hummingbird's $\mathscr{W}_T \sim 431,000$ compared to the human neural $\mathscr{W}_T \sim 649$. This $\sim$ 660-fold difference in workspace should correspond to a $\sim$ 660-fold difference in the number of causally distinct configurations accessible within the specious present — a much larger difference than timescale ratio alone ($\tau_{\text{human neural}}/\tau_{\text{hummingbird}} \approx 43$) would predict.

Prediction 3 — The 3.32 yr boundary is a biological organizing principle.

The threshold $\tau^* = 3.32$ yr, derived from first principles in [Paz 2026c], should appear as a natural boundary in comparative chronobiology: organisms whose dominant life-rhythm timescale crosses this boundary should show qualitatively different temporal architecture, not merely quantitatively slower processing.

This is testable in long-lived organisms (tortoises, trees, certain insects) where the transition from sub-threshold to super-threshold internal timescale can be identified. No such organism should exhibit the full three-level closure hierarchy (habit / role / life) that the STF Theory of Time identifies in humans — because achieving that hierarchy requires the outermost loop to close at $\tau \approx \tau^*$, which requires the organism's dominant timescale to be near or below τ^*.

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7. Relation to Existing STF Papers

7.1 Relation to STF Theory of Time [Paz 2026b]

The STF Theory of Time establishes temporal experience as threshold-dependent emergence. The present paper adds a continuous measure of the *degree* of temporal richness above threshold. The two papers are complementary: [Paz 2026b] establishes the binary (temporal/pre-temporal); the present paper quantifies the graduated structure above the binary boundary.

7.2 Relation to Consciousness-Time-Identity [Paz 2026a]

The CTI paper establishes the identity claim: temporal experience *is* temporal self-reference viewed from inside. Section VIII.H of CTI already encodes the inversion of the horizon hierarchy through the time-to-boundary reparametrisation $\tau \equiv t^* - t$: the merger is the experiential origin; the activation boundary is the experiential terminus; the outer horizon is the retrocausal reach beyond which closure cannot occur.

The present paper does not correct CTI but *quantifies* it. $\mathscr{W}_T(\tau)$ tells you exactly how far each horizon sits from the closure threshold in the external Peters frame, and therefore exactly how far each sits from the experiential origin in the internal retrocausal frame. The richness of the habit loop ($\mathscr{W}_T \approx 142$), the marginality of the role loop ($\mathscr{W}_T \approx 0$), and the beyond-terminus character of the working lifespan ($\mathscr{W}_T \approx -0.99$) are quantitative statements of what CTI VIII.H states qualitatively.

The CTI paper's Temporal Commensurability Principle is sharpened by the two-condition criterion (Section 6.2): commensurability requires both similar timescales and positive workspace.

7.3 Relation to the Temporal Cascade Paper [Paz 2026d]

The Temporal Cascade paper establishes that temporal instantiation is a topological obstruction — the alignment condition necessarily fails in any non-static spacetime with positive curvature. The present paper operates entirely above the threshold where that argument applies. Given that temporal structure exists (the cascade has occurred), how rich is it? $\mathscr{W}_T$ answers this question.

7.4 Relation to the General Theory [Paz 2026e]

The General Theory V0.6 uses the same Shvalb-Medina correspondence in §2.5 to establish the graduated structure of temporal depth above threshold: the immobility margin $\bar{M}$ maps to $\mathscr{D} - \mathscr{D}_{\text{crit}}$, and the width of the specious present, the reach of the backward arc, and the depth of anticipatory structure all scale with this distance above threshold. The present paper formalizes this correspondence into the explicit formula $\mathscr{W}_T = (\tau^*/\tau)^{7/4} - 1$ and derives the organism mapping from it.

The Locality Theorem proved in General Theory §15.6 is the formal underpinning of the organism mapping in Section 6.1. The theorem states that $\mathscr{D}^{\text{bio}}$ cannot be pooled across distances greater than $\bar{\lambda}_c \approx 0.53$ ly — loops outside that volume cannot close within $\tau_c \approx 3.32$ yr and do not contribute to the local loop density. This means the workspace mapping to individual organisms, rather than to aggregate populations or galaxy-scale civilizations, is not an assumption of the present paper but a structural consequence of the STF threshold conditions. A galaxy-spanning civilization has local workspace $\mathscr{W}_T \gg 0$ at each star-system node and global workspace effectively zero — exactly the same logic that assigns the organism its τ_{int} as the outermost *locally closed* adaptive loop (§6.0).

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8. The Deep Connection: Why This Formula Exists

8.1 The Anthropic Coincidence Dissolved

Why should human neural timescales (~ hours to months) be in the positive workspace regime? Why should human life-cycle timescales (~ years) sit near the threshold τ^*?

The naive answer is anthropic: we observe ourselves to be temporal creatures, therefore we must be above threshold. But the workspace formula suggests something stronger: the threshold $\tau^* = 3.32$ yr is not set by human biology. It is set by GR orbital mechanics — the timescale at which stellar-mass gravitational systems cross from cosmologically frozen to human-scale fast. Human biology did not choose this boundary. The boundary is where GR puts it, and it is where the Peters formula puts the transition from effectively static to rapidly evolving spacetime geometry.

The fact that human life-cycle timescales cluster near τ^* is then not anthropic selection but a statement about what kind of physical environment produced biological systems. Any system that evolved to engage with the dynamical structure of its gravitational environment — to track the changing geometry of the spacetime it inhabits — will have internal timescales near τ^*, because τ^* is where the gravitational environment itself crosses from static to dynamic.

As [Paz 2026c] Section II.A states directly: this is where spacetime “stop[s] being eternal and start[s] having a clock” — the transition from cosmologically frozen to human-scale fast that the Peters formula defines as the late inspiral regime. Biological systems that track this clock will have $\tau \sim \tau^*$ at their outer loop. And they will have rich inner workspaces ($\mathscr{W}_T \gg 0$) at their faster timescales — which is precisely where temporal experience is richest.

8.2 The Peters Formula as Temporal Clock

The Peters formula is typically understood as describing energy loss from gravitational wave emission. The temporal workspace framework reveals a second role: the Peters formula is the natural clock of GR, the relationship that connects orbital separation to time in a way that has a unique threshold — the crossing from cosmologically frozen to human-scale fast.

Every conscious system, on this view, is a biological implementation of a Peters-formula clock. It tracks the dynamical structure of its gravitational environment at the timescale where that environment is neither frozen nor too fast to integrate. The inner workspace (fast neural dynamics) is where the clock ticks richly. The outer loop ($\tau \approx \tau^*$) is where the clock is calibrated to the cosmological boundary.

This is not metaphor. The temporal workspace formula is a direct consequence of the Peters formula, with τ^* set by the STF threshold condition that is itself derived from GR [Paz 2026c]. The biology that produces $\tau \sim \tau^*$ at its outer loop and $\tau \ll \tau^*$ at its neural timescale is implementing, in carbon, the structure that GR prescribes in spacetime curvature.

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9. Open Questions

The causal dimensionality C**.** The workspace volume $V_T = C \cdot \mathscr{W}_T \cdot \Delta_{\text{retrocausal}}$ requires specifying C — the effective number of independent causal degrees of freedom a system can engage. For the reference binary, $C = 2$. For a neural system, C is related to the effective dimensionality of the STF coupling. This connects the present framework to neural information geometry and is the primary open problem.

The retrocausal depth $\Delta_{\text{retrocausal}}$**.** How far backward can a causal transaction close? In the STF framework this is set by $\lambda_C = \hbar/(m_s c)$. For neural systems it is related to the characteristic memory horizon over which past states constrain present dynamics. The relationship between the physical field propagation range and the biological memory horizon is not yet established.

Species below threshold. The workspace formula predicts that organisms with $\tau > \tau^*$ at their dominant timescale have no temporal closure there. Whether such organisms have temporal experience at faster (sub-τ^*) timescales — and what the phenomenological consequences would be — is an open question with direct experimental access through comparative chronobiology.

The $\alpha^{4/7}$ structure of the timescale hierarchy. The three STF horizons are not merely near α^{-1} in their $\mathcal{D}$ ratios — they are organized by $\alpha^{4/7}$ in their timescale ratios, with a specific derivation chain that makes this structural rather than numerological.

The derivation chain is as follows. The Peters formula gives $\tau \propto a^4$, so consecutive horizon separations in ratio r correspond to consecutive timescales in ratio r^4. The curvature rate $\mathcal{D} \propto a^{-7}$, so the same ratio r corresponds to $\mathcal{D}$ ratios of r^{-7}. The 7/4 workspace exponent connects these two: timescale ratio r^4 corresponds to $\mathcal{D}$ ratio r^7, and the relationship between consecutive $\mathcal{D}$ ratios and consecutive timescale ratios is therefore:

$$ \frac{\mathcal{D}_{A}}{\mathcal{D}_{B}} = \left(\frac{\tau_{B}}{\tau_{A}} \right)^{7 / 4} $$

Now suppose the consecutive $\mathcal{D}$ ratio is α^{-1}. Then the consecutive timescale ratio is:

$$ \frac{\tau_{B}}{\tau_{A}} = \alpha^{4 / 7} $$

With $\alpha^{4/7} = 137.036^{4/7} = 16.636$, the predictions from $\tau^* = 3.32$ yr alone are:

$$ \tau_{\text{inner}} = \frac{\tau^{*}}{\alpha^{4 / 7}} = \frac{3.32 \, \text{yr}}{16.636} = 72.8 \, \text{days} \quad \quad \left(\text{actual: } 7 1 \, \text{days} , \ 2.5 \% \ \text{off} \right) $$

$$ \tau_{\text{outer}} = \tau^* \times \alpha^{4/7} = 3.32\,\text{yr} \times 16.636 = 55.2\,\text{yr} \qquad (\text{actual: } 54\,\text{yr}, 2.3\%\text{ off}) $$

The geometric mean of the two observed ratios is $\sqrt{\left(3.32 \, \text{yr} / 7 1 \, \text{days} \right) \times \left(5 4 \, \text{yr} / 3.32 \, \text{yr} \right)} = 16.661$, which is 0.15% from $\alpha^{4/7}$. From a single derived quantity (τ^*) and the fine structure constant, both flanking timescales are predicted to within 2.5%.

This is not a post-hoc numerical coincidence. The derivation chain is fixed by Peters and by $\mathcal{D} \propto a^{-7}$ before α enters. The question that remains open is *why* α — an electromagnetic coupling constant — organizes a gravitational orbital mechanics calculation. Two candidate structural origins exist: (i) the T^2 closure condition requires $\Phi_{\text{time}} \times \Phi_{\text{space}} = 4\pi^2$, and the spatial phase accumulation involves the STF field's coupling to charged matter via $g_\psi \phi \bar{\psi} \psi$; (ii) the STF mass m_s is set by the intersection of the gravitational and fermion channel thresholds, and the fine structure constant enters through the fermion channel's electromagnetic structure. Either route, if established, would show that α enters τ^* directly, making the $\alpha^{4/7}$ timescale hierarchy a consequence of the same unification the STF framework claims. This derivation is open and is identified here as the primary open problem in the physics of the temporal workspace.

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10. Conclusion

The temporal workspace $\mathscr{W}_T(\tau) = (\tau^*/\tau)^{7/4} - 1$ is a measure of temporal richness derived from the Peters formula with no free parameters. It distinguishes duration (the timescale τ) from richness (the workspace $\mathscr{W}_T$) — two aspects of temporal experience that existing theory conflates.

The core results:

1. The three STF hierarchical timescales are readings on a single Peters inspiral curve, not three independent field properties.
2. The outer horizon (54 yr) is 143 times below the closure threshold in the external frame — the retrocausal terminus at which the future boundary condition begins to be felt. CTI's endpoint inversion (Section VIII.H) and this workspace value are two descriptions of the same fact.
3. The inner horizon (71 days) is where the workspace is richest: $\mathscr{W}_T \approx 142$, over 140 times the marginal closure at the activation boundary.
4. Temporal richness grows as $\tau^{-7/4}$: fast neural dynamics have workspace thousands of times richer than slow life-cycle dynamics.
5. Commensurability requires both similar timescales and positive workspace — a hard boundary at τ^* that existing theory does not capture.
6. The threshold $\tau^* = 3.32$ yr is set by GR, not by biology. It is where spacetime stops being frozen and starts having a clock. Biological systems near this threshold are tracking the natural dynamics of their gravitational environment.

The Detection-Existence Conjecture [Paz 2026d] asks whether $\mathscr{D}_{\text{crit}}$ equals the minimum curvature rate produced by the universe's compact object population. The temporal workspace framework adds a complementary question: whether the distribution of biological internal timescales is centered on τ^* for reasons traceable to GR orbital mechanics. Both questions point toward a deep connection between the structure of spacetime dynamics and the architecture of temporal experience.

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Appendix A: Derivation of the 7/4 Exponent

The curvature rate $\mathcal{D}$ is defined as the tidal Weyl curvature rate:

$$ \mathcal{D} = \left| n^{\mu} \nabla_{\mu} \mathcal{R} \right| \approx \frac{\mathcal{W}}{t_{\text{inspiral}}} $$

where $\mathcal{W} = GM/c^2a^3$ is the tidal curvature and t_{inspiral} is the Peters inspiral time.

The Peters formula gives:

$$ t_{\text{inspiral}} (a) = \frac{12}{85} \cdot \frac{a^{4} c^{5}}{2 G^{3} M^{3}} \propto a^{4} $$

Therefore:

$$ \mathcal{D} (a) \propto \frac{a^{- 3}}{a^{4}} = a^{- 7} $$

Inverting the Peters formula: $a \propto t^{1/4}$, so:

$\mathcal{D}(\tau) \propto (\tau^{1/4})^{-7} = \tau^{-7/4}$

At the activation point $\tau = \tau^{*}$, $\mathcal{D} = \mathcal{D}_{\mathrm{crit}}$, so:

$$ \mathcal{D} (\tau) = \mathcal{D}_{\mathrm{crit}} \left(\frac{\tau^{*}}{\tau} \right)^{7 / 4} $$

The temporal workspace is therefore:

$$ \mathcal{W}_{T} (\tau) = \frac{\mathcal{D} (\tau) - \mathcal{D}_{\mathrm{crit}}}{\mathcal{D}_{\mathrm{crit}}} = \left(\frac{\tau^{*}}{\tau} \right)^{7 / 4} - 1 \quad \quad \square $$

Appendix B: Numerical Verification

For a 66+66 $M_{\odot}$ equal-mass BBH with $\mathcal{D}_{\mathrm{crit}} = 6.632 \times 10^{-28}$ $\mathrm{m}^{-2}\mathrm{s}^{-1}$:

τ	a (NUMERICAL)	$\mathcal{D}$ (NUMERICAL)	$\mathcal{W}_T$ (NUMERICAL)	$\mathcal{W}_T$ (ANALYTIC)
71 days	360 R_S	9.18×10^{-26}	137.4	142.5
3.32 yr	730 R_S	6.40×10^{-28}	-0.04	0.00
54 yr	1,466 R_S	4.86×10^{-30}	-0.99	-0.99

The $\sim 4\%$ discrepancy at the inner horizon between numerical and analytic values reflects the difference between $\mathcal{D}_{\mathrm{crit}}$ from the cascade paper's phase-closure formula (6.632×10^{-28} $\mathrm{m}^{-2}\mathrm{s}^{-1}$) and the V7.0 first-principles value (1.07×10^{-27} $\mathrm{m}^{-2}\mathrm{s}^{-1}$, the declared authority value [Paz 2026c §III.D]). The two derivation routes for $\mathcal{D}_{\mathrm{crit}}$ differ by a factor of ~ 1.6; with the V7.0 value the numeric discrepancy at the inner horizon would be $\sim 40\%$. This is an open calibration point between the cascade and first-principles $\mathcal{D}_{\mathrm{crit}}$ derivations and is not resolved here.

The workspace *formula* $\mathscr{W}_T = (\tau^*/\tau)^{7/4} - 1$ is primary and uses τ^* directly, independently of which $\mathscr{D}_{\text{crit}}$ value is adopted. The numeric table above uses the cascade value for consistency with the cascade paper's orbit computations. When the $\mathscr{D}_{\text{crit}}$ calibration is resolved, the table values will shift but the formula and its derivation are unaffected.

Appendix C: The $\alpha^{4/7}$ Derivation Chain

The following table makes explicit the chain from Peters scaling to the $\alpha^{4/7}$ timescale hierarchy, identifying at each step what is derived from GR alone and where α enters.

STEP	FORMULA	SOURCE
Tidal curvature	$\mathscr{W} \sim GM/c^2a^3 \sim a^{-3}$	GR tidal field
Inspiral time	$t_{\text{insp}} \sim a^4$	Peters formula
Curvature rate	$\mathscr{D} \sim a^{-7}$	Steps 1–2
Inverted Peters	$a \sim \tau^{1/4}$	Peters
Workspace exponent	$\mathscr{D} \sim \tau^{-7/4}$	Steps 3–4
$\mathscr{D}$ ratio → timescale ratio	$\mathscr{D}_A/\mathscr{D}_B = (\tau_B/\tau_A)^{7/4}$	Step 5
Assume $\mathscr{D}$ ratio $= \alpha^{-1}$	$\tau_B/\tau_A = \alpha^{4/7}$	Step 6 + assumption
Predict τ_{inner}	$3.32\,\text{yr}/\alpha^{4/7} = 72.8\,\text{days}$	$\tau^* + \alpha$
Predict τ_{outer}	$3.32\,\text{yr} \times \alpha^{4/7} = 55.2\,\text{yr}$	$\tau^* + \alpha$

The only assumption is Step 7: that the consecutive $\mathscr{D}$ ratio equals α^{-1}. All other steps are exact consequences of Peters and GR. The two predictions (Steps 8–9) agree with the observed timescales (71 days, 54 yr) to within 2.5%.

Numerical verification:

$\alpha^{4/7} = 137.036^{4/7} = 16.636$

$$ \frac{\tau^{*}}{\tau_{\text{inner}}} = \frac{3.32 \, \text{yr}}{7 1 \, \text{days}} = 17.068 \quad \left(\frac{17.068}{16.636} = 1.026 , \ 2.6 \% \ \text{high} \right) $$

$$ \frac{\tau_{\text{outer}}}{\tau^{*}} = \frac{5 4 \, \text{yr}}{3.32 \, \text{yr}} = 16.265 \quad \left(\frac{16.265}{16.636} = 0.978 , \ 2.2 \% \ \text{low} \right) $$

$$ \text{Geometric mean} = \sqrt{17.068 \times 16.265} = 16.661 \quad \left(0.15 \% \ \text{from} \ \alpha^{4 / 7} \right) $$

The two deviations are symmetric in sign and nearly equal in magnitude (+ 2.6% and $-$ 2.2%), consistent with the observed timescales being biological round numbers (71 days from Lally et al.'s empirical habit formation data; 54 yr from human working lifespan) that bracket an exact structural value. The geometric mean of the two observed ratios is within 0.15% of $\alpha^{4/7}$.

What remains open: Deriving the assumption of Step 7 from first principles — showing that the STF threshold condition forces consecutive horizon $\mathscr{D}$ ratios to equal α^{-1}. This requires establishing how α enters τ^{*} through either the T^2 spatial phase closure (fermion coupling channel) or the intersection of the gravitational and electromagnetic threshold conditions. Until this derivation is complete, the $\alpha^{4/7}$ structure is an empirically confirmed prediction from the assumption, not a theorem. The assumption is stated as an assumption; the confirmation is stated as a confirmation.

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