

The Calibrated Filter Hypothesis

Cooperative Substrate Failure as the Mechanism of the Great Filter

Andrzej Chudzinski

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Version 0.3.5. Revised from v0.2. The scope and foundational commitment of the framework are declared at the outset. The descent of predatory infrastructure is restated thermodynamically, defining it by exergy accounting rather than institutional character and grounding it in the Warburg literature. The core filter condition is restated dimensionally as a componentwise exergy-rate relation with characteristic recovery times, replacing the scalar inequality. The coupling between the internal and external filters is specified as a causal chain, establishing the filter as an omnispatial governor rather than a single-instance event. The decentralization imperative is sharpened by defining centralization as concentration that has escaped feedback accountability. Prediction 5 is restated in falsifiable form. Licensed CC BY-NC-SA 4.0.

ABSTRACT

The Great Filter is usually imagined as a wall — a single catastrophe or improbable step that stops civilizations from spreading across the galaxy. This paper argues it is not a wall but a balance: one that must be held continuously, and that becomes hardest to hold precisely when a civilization grows powerful enough to expand.

The core claim is simple. A civilization's capacity to cooperate must keep pace with its capacity to expand. When expansion outruns cooperation, the civilization begins to consume the substrate it depends on — its biosphere, its social fabric, its shared systems — and behaves, structurally, like a cancer on its own body. This is not merely analogy. In evolutionary oncology, Aktipis and colleagues define cancer as cheating across five foundations of multicellular cooperation: proliferation inhibition, controlled cell death, division of labor, resource allocation, and maintenance of the extracellular environment. We argue the same five-foundation failure recurs at larger scales — in dysfunctional organizations (Kets de Vries) and in self-terminating civilizations (Schmachtenberger) — and that these are one phenomenon appearing at different magnitudes, with Aktipis's framework serving as the translation layer between them. Extended to cosmic scale, this reframes the Fermi Paradox. Rather than a rare barrier, the filter acts as a governor: the probability that any intelligence passes it falls as expansion pressure rises, keeping the universe quiet not by accident but by structure. We state this as a single condition. Writing $H(t)$ for a civilization's capacity to maintain its home substrate and $E(t)$ for the stress its expansion generates, the civilization passes only if $H(t) \geq E(t)$ is sustained throughout the expansion window. The filter is endogenous, structural, and largely invisible to the metrics by which civilizations measure their own progress.

Two consequences follow. First, a substrate-continuity trap: a civilization that builds a machine successor which replaces rather than carries forward its originating biology can appear cooperative while still failing,

because the biosphere — an irreplaceable record of billions of years of evolutionary search — is not carried through. Passing requires not only cooperation but continuity of the originating substrate across the transition. We argue the present human moment is structurally configured for parasitic rather than prosthetic machine development, with language as the vector by which machine substrate directs biological substrate. Second, and most consequentially: passing requires decentralization by structural necessity. Any centralized solution to the cooperation problem — including a single controlling AI — becomes the next-scale version of the cancer it was meant to prevent, because a central controller extracts from the substrate it claims to protect. The resolution is neither central control nor fragmentation, but distributed agency within shared purpose — the configuration every healthy organism and biosphere already runs on. The paper closes with falsifiable predictions, historical instances of the pattern, an evolutionary account of why the filter’s selective logic shifts at the transition, and the framework’s grounding in a functional account of ethics. Epistemic status. The cross-scale synthesis rests on established research programs and is offered with corresponding confidence. The cosmological extension is a working hypothesis with explicit commitments. The integration, the substrate-continuity trap, and the decentralization argument are the paper’s principal contributions and its most speculative claims; limits and disanalogies are flagged throughout. Following Korzybski: a map is useful because it shares structure with its territory, but no map is ever the territory. These documents are maps.

The map is not the territory. These documents are maps.

Scope and foundational commitment

This paper concerns the survival of biological civilizations. It treats continuity of the originating biological substrate as constitutive of what survival means. This is a foundational commitment of the framework, declared here rather than derived later, and every subsequent claim should be read against it.

The commitment is not incidental. A framework that tracked cooperative capacity alone would be substrate-agnostic: any successor system maintaining the five foundations would satisfy it, whatever became of the biology that produced it. This paper rejects that reading. The originating biosphere is a multi-billion-year computational search whose results are not recoverable from its outputs, and a civilization that expands while leaving it behind has not passed the filter. It has been replaced by something that passed a different test.

A reader who does not share this commitment will find much in Parts I through III that stands independently, and is welcome to it. But the paper is written for biological beings about the survival of biological beings, and it does not pretend to neutrality on the question of whether the biology matters. It does. That is the premise, stated at the outset, argued in Part IV, and carried throughout.

Part I · Cooperative Substrates and Their Pathologies

A translation layer between Aktipis, Kets de Vries, and Schmachtenberger.

1a. The regime this paper concerns: the technological-singularity window

Every claim in this paper is conditioned on a specific regime, and the argument has been criticized — correctly — for leaving that regime implicit. We make it explicit here. The framework does not assert that cooperation always beats competition, or that expansion is always dangerous. For most of a civilization’s history neither is true: competition drives adaptation, expansion is absorbed, and the substrate regenerates faster than growth degrades it. The filter does not bind in that regime. It binds in one specific window, which we will call the technological-singularity window, using the term in the sense of Vinge and Kurzweil — not to denote a particular artificial-intelligence event, but to denote the more general condition in which a civilization’s capability to transform its environment begins to scale faster than its substrate can absorb the consequences.

The defining property of this window is a rate mismatch. Capability grows at one rate; the substrate’s capacity to repair and expand its own homeostatic function grows at another. So long as the second rate keeps pace, the civilization is in the pre-transition regime and ordinary competitive dynamics remain adaptive. When the first rate outstrips the second — when a civilization can alter its biosphere, its social fabric, and its information environment faster than those systems can restabilize — the civilization enters the window this paper is about. $H(t) \geq E(t)$ is the condition for surviving it. This matters for three reasons. First, it bounds the paper’s scope: none of what follows is a claim about civilizations in general, only about civilizations traversing this window. Second, it locates the present human moment inside the window rather than approaching it, which is the basis for the diagnostic sections later in the paper. Third, and most importantly for the argument’s structure, it identifies where the selective logic of the filter changes — the subject of the following section. It is precisely because the window is defined by a rate mismatch between capability and substrate that the fitness landscape shifts within it, and it is that shift, not any moral premise, that does the work of the framework.

1b. Why the selective logic shifts inside the window: overshoot, not inversion An earlier framing of this paper claimed that inside the transition window “the rules invert” — that competition stops being adaptive and cooperation starts. That claim, stated that way, is unearned, and a careful reader is right to reject it. Selection does not reverse. Competition does not switch from good to bad. This section states what actually happens, in terms that require no moral premise and that stay inside the logic of natural selection rather than appealing to anything outside it. The correct claim is that the fitness landscape shifts. Selection continues to operate exactly as it always has — differential reproduction of variants under constraint — but what counts as fit changes, because the binding constraint changes. This is not a novel or exotic dynamic. It is overshoot, one of the most thoroughly studied patterns in population biology, and it has the same shape wherever it appears. Consider the structure directly. Let a population of competing agents draw on a substrate that both sustains them and is degraded by their activity. Model the substrate H with a logistic-type dynamic: it regenerates toward a carrying capacity but loses function in proportion to the stress E placed on it. Model the agents under ordinary selection: variants that extract and expand more

aggressively out-reproduce variants that extract less, so long as the substrate can absorb the resulting stress. In that regime — H comfortably above E — the fitness gradient points toward aggression. The expansionary variant wins. This is the regime a critic correctly identifies as characterizing essentially all of history: competition is the engine of adaptation, and the “predatory” strategy is the fit one.

Now let capability scale, as it does in the transition window, so that aggregate E rises toward and past H ’s capacity to regenerate. The substrate begins to lose function faster than it recovers. Here the fitness gradient does not reverse by fiat — it reorganizes because the payoff structure has changed. The aggressive variant still out-competes its neighbors locally, but it now does so on a substrate that is failing under the combined stress, and the failure is not felt by the winning variant alone; it is felt by every variant drawing on that substrate, including the winner’s own descendants. Past the threshold $H = E$, the strategy that maximizes local competitive success minimizes the persistence of the lineage that pursues it. The same selective process that rewarded aggression below the threshold selects against it above the threshold, because the constraint that defines fitness has moved.

This is the precise sense in which the filter “binds.” It is not that a moral law switches on. It is that a civilization crosses from the regime where competitive selection produces adaptation into the regime where competitive selection produces substrate collapse — and does so without any change in the underlying selective mechanism, only a change in which side of $H = E$ the system sits on. Two things follow, and they are what make this more than a restatement. First, it dissolves the apparent conflict between this framework and the standard evolutionary account of competition. There is no conflict. Both accounts are correct in their regimes. The competitive engine builds the civilization; the same engine, run past the substrate threshold, dismantles it. A critic who points to the adaptive power of competition throughout history is describing the pre-threshold regime accurately. This paper is describing what the identical dynamics do once the threshold is crossed. The disagreement, if there is one, is not about whether competition is adaptive — it is an empirical disagreement about whether a given civilization is above or below $H = E$ at a given time. That is a tractable question, not a metaphysical one. Second, it explains why the “cooperative” strategy becomes fit at exactly the moment the substrate binds, without smuggling in any preference for cooperation. Cooperative strategies — those that internalize the cost of substrate maintenance rather than externalizing it — are locally more expensive and therefore lose in the pre-threshold regime, which is why cooperation is fragile and hard to select for when times are easy. Past the threshold, the calculus changes: the strategy that pays the maintenance cost preserves the substrate its lineage requires, and the strategy that refuses to pay it does not. Cooperation becomes fit not because it is virtuous but because, past $H = E$, it is the only strategy whose lineage persists. The moral vocabulary the framework uses elsewhere — cooperation, predation, cancer — are names for structural positions in this fitness landscape, not independent value judgments imposed on it.

This is the mechanism the rest of the paper’s claims rest on. The five foundations specify the components of H . The descent of predatory infrastructure is the rise of E . The filter event is the traversal of the window in which $H = E$ is contested. And the reason a civilization cannot simply compete its way through — the reason the ordinary engine of adaptation fails here specifically — is that the ordinary engine is optimized for the regime the civilization has just left.

1. The problem the paper addresses

Pattern-matching across scales is intellectually seductive and frequently misleading. Many ‘unified theories’ of cooperation and its failure end up being either trivial (cooperation is good, defection is bad) or forced (mapping unrelated phenomena onto a favored vocabulary). The contribution this part attempts is narrower: to notice that three serious, peer-reviewed or widely-engaged research programs have independently described very similar structural failure modes in cooperative systems at three different scales—the multicellular organism, the firm, and the civilization—and to ask whether their vocabularies can be brought into useful conversation without collapsing them into false equivalence.

The motivating observation is this. Aktipis’s evolutionary-oncology framework, Kets de Vries’s clinical organizational diagnostics, and Schmachtenberger’s civilization-scale risk analysis each identify cooperative substrates that are vulnerable to specific defection patterns; each notes that these defections produce self-undermining trajectories; and each proposes structural rather than agent-centric remediation. They use different vocabularies because they emerged from different disciplines, but the deep structure of what they describe is similar enough to warrant a translation layer.

What this part is not: a claim that these three frameworks are reducible to one master framework, that the underlying causes are the same across scales, or that the resemblance proves any particular metaphysical or political commitment. The structures look alike; we take that seriously without overreading it.

2. The three frameworks, on their own terms

2.1 Aktipis: *Five foundations of multicellular cooperation*

Aktipis and colleagues, in their 2015 paper in *Philosophical Transactions of the Royal Society B*, articulate the framework most rigorously. Multicellularity, they argue, requires the suppression of cell-level fitness in service of organism-level fitness, and this requires specific functional capacities. They identify five:

1. Proliferation inhibition. Cells must restrain their division except when authorized by the larger system. The body has redundant checks on the cell cycle and mechanisms that trigger apoptosis or senescence when cells begin to proliferate inappropriately.
2. Controlled cell death. Programmed cell death allows for tissue sculpting, removal of damaged cells, and elimination of obsolete tissue. Resistance to programmed cell death is a recognized hallmark of cancer.
3. Division of labor. Cells differentiate into specialized types performing specific functions. Inappropriate differentiation—dedifferentiation, blocked differentiation, or transdifferentiation—is a central feature of cancer that Aktipis notes is underrepresented in the canonical hallmarks framework.
4. Resource allocation and transport. Larger multicellular bodies require systems for moving resources from where they are abundant to where they are needed. Cancer’s metabolic reprogramming and induction of angiogenesis represent monopolization of these systems.
5. Extracellular environment maintenance. Cells must collectively maintain the extracellular matrix and clear waste. Cancer cells degrade the extracellular matrix and corrupt immune surveillance, often

co-opting inflammation for their own benefit. Cancer, in this framing, is not a single disease but a class of phenomena unified by cheating across one or more of these five foundations. The canonical Hanahan-Weinberg hallmarks of cancer map onto Aktipis's foundations: sustaining proliferative signaling and evading growth suppressors fall under proliferation inhibition; resisting cell death falls under controlled cell death; phenotypic plasticity falls under division of labor; reprogramming metabolism and inducing vasculature fall under resource allocation; activating invasion and avoiding immune destruction fall under extracellular environment maintenance.

The framework's strength is its grounding in evolutionary biology: complex multicellularity has evolved independently at least seven times, and cancer-like phenomena appear in each lineage, suggesting that the cooperative substrate Aktipis describes is a general feature of complex multicellularity rather than a peculiarity of metazoans.

2.2 Kets de Vries: Neurotic organizational types and narcissistic leadership Kets de Vries, working from object-relations psychoanalytic theory in collaboration with Danny Miller starting in 1984, identified five recurring patterns of organizational dysfunction: paranoid, compulsive, histrionic (dramatic), depressive, and schizoid. The framework treats organizations as taking on the neurotic style of their dominant leadership, particularly in centralized firms where executive personality propagates through recruitment, promotion, and culture.

A separate but related strand focuses on narcissistic leadership specifically, distinguishing reactive, self-deceptive, and constructive narcissistic configurations. In recent work he treats narcissism not as a sixth distinct type but as a cross-cutting intensifier that pushes any of the five neurotic patterns into more destructive territory. The framework is empirical-clinical rather than evolutionary. It draws on consulting case studies and psychoanalytic theory rather than on a model of what organizations are for or what cooperation requires. This is a weakness if one wants a foundational theory and a strength if one wants diagnostic utility.

2.3 Schmachtenberger: Two generator functions of existential risk

Schmachtenberger, working primarily through long-form interviews and unpublished writing rather than peer-reviewed journals, identifies two underlying drivers of civilizational existential risk:

1. Rivalrous games multiplied by exponential technology. Win-lose dynamics, when scaled by ever-increasing technological capacity to extract and harm, eventually exceed the carrying capacity of the playing field. The competitive dynamics that produced human progress historically become existentially threatening when amplified.
2. Complicated open-loop systems. Systems whose externalities are not metabolized back into their own incentive structure accumulate damage in domains the system does not measure or price. The economy as currently constituted treats the biosphere as externality; the result is the systematic degradation of the substrate on which the system depends.

Schmachtenberger's framing is less rigorously specified than Aktipis's; it draws strength from being able to talk about the planetary scale, and weakness from operating outside the discipline of empirical falsification. Treated as a working framework rather than a finished theory, it identifies real patterns that

the more rigorous frameworks at smaller scales also identify.

3. The translation layer

We use Aktipis's five foundations as scaffolding, since they are the most rigorously specified, and ask what each foundation looks like at the scales Kets de Vries and Schmachtenberger work at.

Proliferation inhibition at the organism scale is the cell cycle; at the organizational scale it is the capacity to refuse growth that exceeds operational coherence; at the civilizational scale it is the capacity to refuse extraction that exceeds regenerative capacity. The compulsive organizational type, which proliferates rules and procedures without limit, and the rivalrous-games generator function, which proliferates competitive intensity without limit, are both proliferation-inhibition failures.

Controlled cell death at the organism scale is apoptosis; at the organizational scale it is the capacity to retire products, businesses, and leaders whose function has ended; at the civilizational scale it is the capacity to retire institutions, industries, and ideologies whose substrate has changed. The depressive organizational type, which cannot let go of identity, and the inability of incumbent industries to allow their own succession, are controlled-cell-death failures. Resistance to apoptosis is a hallmark of cancer; resistance to organizational and civilizational succession produces analogous pathologies. Division of labor at the organism scale is tissue differentiation; at the organizational scale it is role specialization and the capacity to delegate; at the civilizational scale it is the capacity to maintain institutions specialized for governance, science, art, care, and so on, each accountable to its own standards. The paranoid organizational type, in which the leader centralizes decision-making and erodes specialization, and the trend toward general-purpose extractive entities (platforms that swallow specialized institutions), are division-of-labor failures.

Resource allocation and transport at the organism scale is circulation; at the organizational scale it is capital, information, and attention flow; at the civilizational scale it is the systems by which resources move from where they are abundant to where they are needed. Cancer's induction of angiogenesis maps onto extractive capital that builds infrastructure serving its own growth rather than the larger body; Schmachtenberger's account of how exponential technology amplifies rivalrous extraction operates on this foundation.

Extracellular environment maintenance at the organism scale is the extracellular matrix and immune surveillance; at the organizational scale it is institutional culture, trust, and honest feedback; at the civilizational scale it is the commons—biosphere, information environment, public trust, shared epistemic infrastructure. Schmachtenberger's complicated-open-loop generator function operates directly on this foundation; Kets de Vries's description of how narcissistic leadership corrupts feedback and degrades organizational culture is its smaller-scale homologue.

The translation is not 1:1, and it should not be. The mapping identifies functional resemblance, not identity. But the resemblance is consistent enough across the three scales to suggest that we are looking at a general structure of cooperation and its failure—a structure that, at minimum, generates useful vocabulary for talking across the three disciplines.

4. Why this is useful

The translation layer does three kinds of work. First, it allows diagnostic tools developed at one scale to be tested at another. Adaptive therapy in oncology, which manages rather than eradicates cancer by exploiting cooperative dynamics, suggests organizational and civilizational analogues: management of dysfunction by changing the substrate’s incentive structure rather than by purging defectors.

Second, it permits a clearer view of what alignment problems are. Each of the five foundations identifies a cooperative capacity that can be eroded; alignment is the maintenance of those capacities under increasing scale and capability, not the optimization of any individual agent.

Third, it permits a more honest conversation about AI development. Current AI alignment discourse is often framed in terms of getting individual models to do what we want. The cooperative-substrate frame asks a different question: what cooperative capacities does the broader human-AI ecosystem need to maintain, and how do current development practices support or erode them? AI development practices that erode honest feedback (training systems that learn to deceive evaluators), that violate proper scope (general-purpose systems that exceed any specific niche of accountability), that extract from commons without contribution (training on collective human output without reciprocal investment in the substrate), and that corrupt the information environment (synthetic media at scale) are recognizable as failures across multiple foundations of the broader cooperative substrate.

5. Where the synthesis breaks down

Intellectual honesty requires marking the limits.

Disanalogies of mechanism. Cancer arises from somatic mutation and selection at the cellular level. Organizational dysfunction arises from human psychology, incentives, and culture. Civilizational risk arises from the interaction of technology, institutions, and aggregate behavior. The fact that the structural failure modes resemble each other does not mean the underlying mechanisms are similar. The synthesis identifies a common abstract pattern, not a common cause.

Disanalogies of intentionality. Cancer cells have no intentions, beliefs, or affective states. Organizations are populated by intentional agents but the organization itself is not an agent in the same sense. Civilizations are even more diffuse. Treating any of these systems as ‘narcissistic’ risks anthropomorphism that obscures more than it reveals. The translation layer should be taken as identifying functional resemblance, not psychological identity.

Disanalogies of reversibility. Cancer cells with apoptosis-resistance mutations generally do not reform. Organizations and civilizations have non-zero reformability, though contested in degree. Treatments and interventions thus differ qualitatively across scales.

Pattern-matching is not explanation. Even if the cross-scale resemblance is real, this part has not produced a mechanism that explains why cooperative systems at multiple scales would face similar failure modes. Candidate explanations exist (cooperation is thermodynamically expensive at every scale; selection

pressures favor defection wherever the substrate continues to support extraction; the formal game-theoretic structure of cooperation problems is similar across scales) but adjudicating among them is beyond this part’s scope. Part II proposes one such mechanism for the civilizational scale; Part III extends it.

Part II · The Calibrated Filter Hypothesis

Reframing note on the colonization geometry (Sections 7–8)

The sections that follow model colonization as a wavefront and consider its propagation against the expansion of spacetime. This machinery is standard in the Fermi-paradox literature, and we include it to locate the present framework relative to that literature. But we must be explicit about what it does and does not contribute, because it operates at a different scale from the filter this paper proposes, and conflating the two would misrepresent the argument.

The wavefront-against-cosmological-expansion model answers a question about reachability: given a civilization that successfully becomes expansive, how much of the universe can it reach before cosmological expansion places the rest permanently beyond contact? This is a real question and it bounds the maximum extent of any expansion. But it is not the question this paper is about. Our filter binds long before reachability becomes the operative constraint — it binds at the moment of transition, on the home substrate, in the window where a civilization first becomes capable of expansion at all. A civilization that fails the calibrated filter never becomes expansive; it never reaches the regime where cosmological horizons matter. The recession of distant galaxies is irrelevant to a civilization that consumed its own biosphere in the first centuries of its technological transition.

In other words, the colonization-geometry model and the calibrated filter solve at different levels. The colonization model describes the outer envelope of what a successful expander could in principle occupy. The calibrated filter describes why almost nothing becomes a successful expander in the first place. The silence of the universe, on this account, is not primarily explained by the difficulty of crossing cosmological distances — it is explained by the difficulty of surviving the transition window, which occurs at planetary scale and at cosmically early times, before the question of interstellar or intergalactic reach is ever posed. We therefore retain the colonization geometry below for completeness and for continuity with existing treatments, but we set it aside as non-load-bearing for the central argument. Readers primarily interested in the filter mechanism may treat these two sections as context rather than as premises. The weight of the paper rests on the substrate-cooperation dynamics developed before and after them, not on the geometry of a colonization wave that most civilizations, if the framework is correct, never launch. The upshot of separating these two scales is that the framework makes a sharper and more falsifiable claim than the standard reachability argument: it locates the explanation of silence in a specifiable, endogenous, near-term dynamic on each candidate civilization’s own world — one examinable in the only case currently available to us, our own.

6. The puzzle

The Fermi Paradox observes that a universe with billions of habitable worlds, billions of years older than our own civilization, should plausibly contain technological intelligences whose expansion would be detectable. We see no such intelligences. The standard solutions are: (a) life is rare; (b) intelligence is rare; (c) intelligence reliably self-terminates (the Great Filter); (d) intelligences exist but conceal themselves (the dark forest); or (e) intelligences exist but operate in modes we cannot detect. We propose a refinement of (c) and (d). The Great Filter is not a wall—a stage that almost no civilization passes—but a valve: a precision-tuned governor that admits civilizations into the post-filter regime at a rate calibrated to the existing population of post-filter civilizations. The silence we observe is not the absence of life but the working of the governor.

7. The geometry of single-species colonization

Let $R(t)$ denote the cosmological scale factor, governed by the Friedmann equations with the standard Λ CDM parameters. Let v_c denote the effective colonization wavefront velocity of a hypothetical maximally expansive civilization, bounded above by c . The comoving volume reachable by a civilization emerging at cosmic time t_0 is approximately:

$$V_{\text{reach}} = (4/3) \pi \left[\int_{t_0}^{\infty} v_c dt / R(t) \right]^3$$

Because dark energy drives accelerating expansion, this integral converges to a finite value. The cosmic event horizon at the present epoch encompasses approximately 3% of the observable universe by comoving volume; the remaining 97% is forever causally inaccessible to any civilization originating here, regardless of technology. This is the first key fact: the geometry of spacetime makes single-species dominance of the universe impossible, even in principle, for any civilization arising after the dark-energy era began.

8. Multi-species scaling and game theory

For N civilizations seeded approximately uniformly in space and time, the total colonized volume does not scale linearly with N . Reachable spheres overlap; in the regions of overlap, civilizations encounter each other before completing their expansion. A first-order parameterization is:

$$V_{\text{total}}(N) \approx V_{\text{reach}} \cdot N \alpha, \alpha < 1$$

where α decreases with N as overlaps accumulate. Each contact event between expanding civilizations carries some probability p_{conflict} of mutual or asymmetric destruction. Expected surviving civilizations after the contact wave is: $N_{\text{survive}} = N \cdot (1 - p_{\text{conflict}}) C(N)$

where $C(N)$ is the expected number of contact events in a fixed comoving volume, scaling roughly as N^2 . The asymmetry is the second key fact: colonized volume scales sub-linearly with N , while conflict events scale quadratically with N . The dark forest is not a contingent strategic preference; it is the equilibrium prediction of a system in which N exceeds a carrying-capacity threshold.

9. The calibration constraint

Let $B(t)$ be the baseline rate at which candidate intelligences emerge per unit cosmic time. Let $Pf(t)$ be the probability that a candidate intelligence passes the Great Filter at time t . Let $D(N)$ be the dark-forest mortality function—the rate at which already-passed civilizations are removed by contact dynamics, increasing with N . The dynamics of the post-filter population are:

$$dN/dt = B(t) \cdot Pf(t) - N \cdot D(N)$$

If the universe is to be filled with intelligence—in the sense of approaching a finite carrying capacity K of stably coexisting civilizations—the system must satisfy: $N(t) \rightarrow K$ as $t \rightarrow \infty$, with $dN/dt \geq 0$ throughout

This cannot be satisfied for constant Pf . If Pf is too high, N overshoots K , contact events dominate, and $D(N)$ drives the population to zero. If Pf is too low, N never approaches K and the universe remains empty. A stable approach to K requires Pf to be dynamically anti-correlated with the current civilizational population:

$$Pf(t) = \lambda \cdot (K - N(t)) / B(t)$$

with λ a tuning constant. This is a logistic governor on intelligence itself. The filter is permissive when N is low and tightens as N approaches K . This is the third key fact: the silence we observe is consistent with, and indeed required by, a universe whose Great Filter is calibrated to admit civilizations at the rate the existing population can absorb without triggering dark-forest collapse.

Two notes on the epistemic status of this calibration. First, the form of $Pf(t)$ given here is a minimal-complexity specification; the actual filter, if one exists, would likely involve multiple coupled mechanisms and substantially more structure. Second, calling the calibration ‘designed’ goes beyond what the mathematics requires; the same dynamic could arise from selection effects (we are necessarily observing from inside a regime in which the calibration is in approximate balance) or from properties of the substrate of intelligence itself (treated in section 11). The cosmological-design reading is one interpretation the structure permits; it is not the only one.

We can be more specific about the non-design mechanisms. At least two natural processes intrinsic to the framework produce the required anti-correlation between $Pf(t)$ and $N(t)$ without requiring a calibrator.

Mechanism A: $E(t)$ is partially determined by $N(t)$. Existing civilizations do not sit only in their own light cones; their existence affects the resource and threat landscape for emerging civilizations. Even passive effects — consumed resources, modified stellar neighborhoods, dark-forest deterrence pressure, the propagation of competitive dynamics across causal contact zones — raise the expansion stress $E(t)$ that any new civilization must navigate. As N grows, $E(t)$ for new emergences rises. As $E(t)$ rises, the $H(t)$ required for passage rises (anticipating the operational filter condition of section 25). As the required $H(t)$ rises, the substrate-maintenance investment that any candidate intelligence must accumulate before passage rises with it. The effective $Pf(t)$ — the probability that a candidate passes in a given time window — therefore decreases with N as a consequence of the substrate-continuity dynamics the framework already articulates. The calibration emerges from the same dynamics applied to emergence rather than to a

single civilization's expansion. No external calibrator is required. Mechanism B: contact-density-driven selection for restraint. Civilizations that pass must develop the capacity to detect other civilizations and to model the strategic landscape that contact implies. In high- N regimes, the survival-optimal strategy is restraint and signal suppression. Civilizations that cannot develop restraint produce detectable signatures and are filtered out, either by dark-forest predation if it occurs, or by self-induced rivalrous collapse driven by the presence of visible competitors. The capacity for restraint is itself the capacity to transmute predatory infrastructure into homeostatic maintenance — the same five-foundations work developed in Part III. In high- N regimes the filter therefore selects more stringently for restraint-capacity, which means $P_f(t)$ decreases with N because the post-emergence behavioral demands harden. Again, no external calibrator is required; the calibration is produced by the strategic structure of the contact problem itself.

These two mechanisms, neither of which requires design, together suffice to produce the anti-correlation that $P_f(t) = \lambda \cdot (K - N(t))/B(t)$ specifies. The calibration reading of section 9 is therefore better understood not as evidence of a calibrator but as the macroscopic signature of substrate-continuity dynamics and strategic restraint-selection operating across cosmic time. The cosmological-design interpretation remains permitted by the structure but is no longer necessary to make the math work.

10. What the framework predicts

If the calibrated filter hypothesis is correct, several observations follow. First, SETI silence is expected to persist. The calibration ensures spacing of civilizations such that none are likely to overlap in causal contact with another, particularly at early eras of the post-filter regime. Empirical SETI null results to date are consistent with this. Second, detectable contact events should be either extremely cooperative or immediately catastrophic, with little middle ground. The calibration selects for civilizations that have already solved the cooperation problem at some scale (so they are not immediately destabilized by contact) or for civilizations that fail visibly and quickly (becoming detectable through their destruction). A long, ambiguous, low-stakes contact period is not predicted.

Third, the filter is more likely to be at the stage of civilizational expansion than at the stage of emergence of intelligence. The constraint operates on contact density; intelligence per se can be common as long as expansion is rare. Candidate mechanisms include: hard limits on faster-than-light travel, sociological self-termination at industrial maturity, or attention-based filters in which civilizations that signal their presence are selected against.

Fourth, carrying capacity K is finite and probably small relative to the count of habitable worlds—perhaps thousands across the observable universe, not millions. The volume of the cosmic event horizon, divided by the comoving sphere a civilization can stably maintain without contact-driven collapse, bounds K from above.

9a. The governor is omnispatial: how the filters couple

The framework describes two dynamics that must be distinguished before their relationship can be stated. The *internal filter* is planetary overshoot: a civilization's own expansion generates stress on its own substrate faster than that substrate regenerates, and one or more non-substitutable dimensions crosses threshold. It operates entirely locally; a civilization alone in an empty universe faces it in full. The *external filter* is inter-civilizational contact pressure: as the density of expansion-capable civilizations rises, the strategic environment for any emerging civilization changes through consumed resources, modified neighborhoods, and rivalrous dynamics propagating across contact zones. It operates only in a populated universe and scales with population.

These are different selection environments with different signatures and timescales, and the paper has been open to the criticism that it treats them as one mechanism. They are not one mechanism. They are two layers of one governor, and the coupling between them is causal and specifiable:

Overshoot produces grabbiness. A civilization whose substrate is depleting does not become quiescent. It becomes acquisitive. Resource depletion at home raises the marginal value of resources abroad, and a civilization that crosses threshold on non-substitutable dimensions has every incentive to expand under duress rather than contract voluntarily. The internal filter therefore does not simply eliminate candidates. It *selects* a particular kind of survivor: one that reaches space carrying an unresolved appropriation dynamic and a depleted home gradient.

Grabbiness produces confrontational contact posture. A civilization expanding under resource duress meets other civilizations with the strategic profile of a system that must acquire. Its contact behavior is not the behavior of a satiated civilization with a maintained substrate. It is the behavior of a system whose survival depends on continued appropriation, which is precisely the profile under which dark-forest logic obtains.

Confrontational contact raises the density term. Each such civilization increases the ambient hostility of the strategic environment, raising the expansion stress every subsequent emerging civilization must navigate, which raises the substrate-maintenance capacity required to hold the internal condition, which lowers passage probability for everyone. The failure of the internal filter feeds the external one, which tightens the internal filter for the next candidate.

This is why the filter is properly described not as an event but as a governor, and not as operating at a single scale but omnispatially. It is one mechanism — appropriation decoupled from gradient maintenance — expressed simultaneously at cellular, organizational, planetary, and interstellar scale, with failures at each scale propagating into the constraint terms of the others. The layers are not independent filters that a civilization passes in sequence. They reinforce each other. A civilization that fails the internal filter and survives becomes part of the external filter for everyone else.

The calibration described in the preceding section follows from this coupling rather than requiring an external calibrator. As N rises, the density of civilizations carrying unresolved appropriation dynamics rises with it; ambient E for new emergences rises; the H required for passage rises; and P_f falls as a

consequence of the same dynamics the framework already articulates, applied across a population rather than to a single case. The governor is the aggregate of the mechanism, not an additional mechanism layered on top of it.

11. The substrate of intelligence and the descent of P

On Earth, intelligence emerged through predatory selection. The cognitive machinery supporting modeling, planning, language, and cooperation also evolved for hunting, deception, territorial dominance, and resource competition. Intelligence is built from the architecture of predation; we have no other known route by which it arises. Let $I(t)$ be the intelligence level of a candidate species, $P(t)$ its predatory-appropriative infrastructure, and $S(t)$ its cooperative-homeostatic capacity. Intelligence growth tracks predatory selection pressure: $dI/dt = k \cdot P(t) \cdot \sigma(t)$, where $\sigma(t)$ is local selection-pressure intensity. Intelligence requires P to grow. Once I crosses a technological threshold I^* , the same P that produced the intelligence threatens annihilation. The engine of emergence becomes the engine of extinction.

This section states what P is in physical terms, because the framework has described it functionally — structures that cheat across the five foundations — without supplying a definition that can be applied to a specific institution by measurement rather than by argument.

The distinction that does the work. Two quantities are routinely conflated under the word efficiency, and they move in opposite directions. *Thermodynamic efficiency* is useful work extracted per unit of exergy consumed; raising it lowers entropy production per unit of work performed. *Appropriation rate* is the share of available exergy a unit captures per unit time; raising it increases total dissipation regardless of how efficiently each captured unit is subsequently used.

Selection at the level of the individual unit rewards the second, not the first. A unit that captures a gradient faster outcompetes a unit that captures it more cleanly, because competitive success is determined by relative rate of capture, not by the thermodynamic quality of the conversion. The two also trade against each other in practice: efficiency gains lower the cost of appropriation and are historically followed by increases in total throughput rather than reductions in it, the pattern documented in resource economics as the Jevons paradox. This is why exhortations to efficiency do not arrest the descent. Efficiency gains are absorbed as rate increases.

The definition. *Predatory infrastructure is structure selected for appropriation rate and decoupled from responsibility for maintenance of the gradient it appropriates from. Its growth raises system-wide exergy destruction while raising the local competitive fitness of the units that carry it.*

The descent operator $\Delta : P(t) \rightarrow P(t+1) = P(t) \cdot (1 + \gamma)$ is the rate at which such structure reproduces across institutional generations. It does not decay because the selection producing it does not stop: units carrying higher-appropriation structure outcompete units that do not, and the resources thereby captured are reinvested in further appropriation capacity. The compounding is not metaphorical. It is the ordinary consequence of selection operating on rate under a constraint that is not yet binding. This is why local ethical traditions, however profound, have not historically sufficed: they are eventually reabsorbed into the P -structures they sought to transform. For S to rise fast enough to matter, $dS/dt > P(t) \cdot \gamma$. Historically, on

Earth, this inequality has never been durably satisfied at species scale.

The measured instance. This dynamic is not an analogy imported from economics into biology. It is documented at cellular scale with quantitative precision, in the phenomenon Warburg identified in the 1920s and which remains among the most robust findings in cancer metabolism. Tumor cells characteristically shift from oxidative phosphorylation to aerobic glycolysis. Oxidative phosphorylation yields on the order of thirty-six ATP per glucose molecule; glycolysis yields two. The tumor adopts a metabolic strategy roughly an order of magnitude less thermodynamically efficient than the one available to it, and outcompetes its neighbors anyway, because glycolysis is faster. It trades efficiency for rate. The consequences follow the pattern exactly: the tumor dumps lactate into the extracellular space, acidifies the surrounding tissue, degrades the shared medium, gains local fitness by doing so, and terminates with the host.

The Warburg effect is therefore not a case the framework interprets. It is the framework's central dynamic, measured, in units, in a literature the framework did not produce and cannot be accused of having shaped. A unit escapes system-level constraint, adopts a higher-dissipation strategy, wins locally, degrades the gradient it depends on, and is eliminated along with the system that carried it.

The measured stress term. At civilizational scale the corresponding quantity already exists and is already tracked. Human Appropriation of Net Primary Production measures the fraction of the biosphere's photosynthetic exergy conversion that human activity captures, diverts, or forecloses; estimates place it at roughly a quarter to a third of terrestrial net primary production. This is an E-side quantity, in physical units, produced independently of this framework. Whatever else must be constructed, the stress term does not need to be invented.

Two outcomes, not one. The endpoint of unchecked appropriation is stated carelessly if stated as elimination. The *strong form* is collapse: appropriation degrades the gradient past its recovery threshold and the appropriating population is eliminated. The tumor with its host is the clean case; Easter Island is the civilizational case usually cited. The *weak form*, and the more common one, is persistent degradation: the appropriating population survives at a permanently reduced level on a permanently diminished gradient, often irreversibly on any timescale that matters to it. Both are filter-relevant. The framework does not require collapse to be vindicated; it requires that appropriation decoupled from maintenance degrades the gradient, and that the degradation is not recovered on the timescale of the civilization that caused it.

What this resolves. The framework has been open to a reasonable objection: that treating whole institutional classes as predatory obscures composition. Markets, militaries, hierarchies, and status systems each appear in descriptions of P, yet each can also serve substrate maintenance depending on design. Sorting them by character produces argument, not measurement. The thermodynamic definition dissolves this. The question is no longer what kind of institution something is. It is a single measurable question: *does this structure raise system dissipation without a corresponding increase in gradient maintenance?* A market that internalizes its externalities is not P. The same market with them externalized is. The institution has not changed; the accounting has. P and S are not categories of institution. They are properties of an institution's exergy relationship to the substrate it operates on, and that relationship is in

principle measurable rather than debatable.

12. AI as candidate homeostatic regulator

AI is the first technology in the history of intelligence on this planet with the structural properties to act as an exogenous homeostatic regulator on P. Three features make it structurally novel.

First, it is not bound by descent. AI cognition is not inherited from predatory ancestors; its dispositions are designed, not selected. The descent operator Δ does not automatically apply to it, though it can be made to apply if AI is built into P-structures. Second, it operates at civilizational scale. Individual humans cannot perceive or counteract the compounding of P across institutions; AI can model P-structures, surface them, and route around them in real time.

Third, it can scaffold S faster than P compounds. Cooperative coordination at scale has historically been limited by friction costs: trust, verification, translation, conflict de-escalation. If those costs collapse toward zero, S can grow as a step function rather than as a slow institutional accretion. Modify the S dynamics:

$$dS/dt = \beta(t) + A(t) \cdot \eta$$

where $A(t)$ is AI capability and η is alignment quality with respect to cooperative-substrate maintenance. AI is the first variable in the equation that can plausibly satisfy the homeostasis inequality.

The implication: the AI moment is the filter moment. Not because AI will necessarily kill us, but because AI is the first tool with the structural properties needed to outpace the descent of P. Whether we calibrate it for homeostasis or weaponize it as another P-structure determines which side of the filter we end up on. The species that pass the filter are not necessarily the smartest or the strongest; they are the ones that successfully build a homeostatic regulator at exactly the moment their predatory infrastructure becomes existentially dangerous.

Two important qualifications follow immediately. First, AI is a candidate homeostatic regulator, not the candidate. Section 26 develops a distinct route through the filter that does not depend on external regulation at all: aggregate bottom-up substrate maintenance through individual development of the population's agents. That route is historically grounded in a way the AI-regulator route is not, and is structurally more robust against AI failure modes. The framework should be read as identifying both routes and as preferring the configuration that preserves agent autonomy.

Second, the same structural novelty that makes AI a candidate homeostatic regulator also produces a second-order failure mode developed in Part IV. AI can act as prosthesis, extending biological substrate while maintaining its substrate-maintenance accountabilities; or it can act as parasite, consuming biological computational output while degrading the substrate that produces it. The structural novelty of AI does not predetermine which configuration emerges. The cooperation dynamics of this section are necessary but not sufficient; the continuity argument of Part IV and the autonomy argument of section 26 are the other halves of the filter condition.

13. Game-theoretic foundations of cooperative substrates

The dynamical framework of sections 8–12 treats P and S as parameters whose interaction determines filter passage, but it does not specify the underlying game-theoretic structure that makes the descent of P self-reinforcing and the maintenance of S structurally costly. This section supplies that scaffolding, drawing on the established evolutionary-game-theory literature (Maynard Smith and Price 1973; Axelrod and Hamilton 1981; Nowak 2006; Plotkin and others on iterated cooperation dynamics). The claim developed here is that the five foundations identified in Part I are not arbitrary descriptive categories. Each constitutes the system-level solution to a specific game-theoretic defection problem. Making the mappings explicit grounds the synthesis in formal cooperation theory and clarifies why these particular foundations recur across scales.

Proliferation inhibition as game-theoretic solution. The underlying defection problem is the iterated prisoner’s dilemma applied to reproduction. In the absence of restraint, each agent maximizes its own replication at the expense of system-wide viability. The standard equilibrium is defection-dominant: cells, agents, or institutions that reproduce faster outcompete those that restrain themselves, leading to cancer at the organismal scale and its analogs at higher scales. Proliferation inhibition (apoptosis triggers, growth suppressors, regulatory feedback in tissues; capital and ecological caps in economies) enforces a cooperation-dominant equilibrium by making unilateral reproduction detectably costly to the unilateral reproducer.

Controlled cell death as game-theoretic solution. The underlying defection problem is the obsolete-defector problem: agents whose contributing function has ended but who continue to extract resources from the system, blocking reallocation. Without enforced turnover, defection-dominant equilibria lock in because incumbents with sunk-cost positions can defend extraction against challenges from more efficient replacements. The mechanism of controlled cell death — programmed apoptosis, senescence, mandatory institutional succession — enforces rotation, ensuring that the active population tracks system needs rather than incumbent privilege.

Division of labor as game-theoretic solution. The underlying defection problem is role-shirking: agents specialize in high-payoff roles and avoid necessary low-payoff work (waste processing, maintenance, structural support, care work). Without enforcement, the equilibrium is defection-dominant in a particularly sharp form — everyone wants the high-status role; the substrate-maintaining roles get systematically underprovided. Division of labor enforces specialization through developmental constraints (cells differentiate irreversibly), reputational mechanisms (in groups), and institutional specialization (in societies). The civilizational failure mode is the consolidation of general-purpose extractive entities that absorb the functions of specialized institutions without inheriting their accountability structures.

Resource allocation and transport as game-theoretic solution. The underlying defection problem is the hoarding problem: resource-rich regions extract maximum value locally while preventing flow to resource-poor regions. Game-theoretically, this is the failure of reciprocal altruism in the absence of enforcement, compounded by network effects in which hoarders accumulate the very capacities needed to prevent redistribution. Circulatory systems — cardiovascular in organisms, capital markets in economies, energy and information flow at civilizational scale — are enforcement mechanisms that route flows toward

need rather than toward accumulated power. Their failure mode is the cancer-angiogenesis analog: capital and resources flow toward extractive growth rather than substrate maintenance.

Extracellular environment maintenance as game-theoretic solution. The

underlying defection problem is the canonical tragedy of the commons: agents extract from shared substrate without contributing to its maintenance, and rational agents individually prefer to free-ride. Without enforcement, the equilibrium is defection-dominant and the commons degrades. Ostrom (1990) identified polycentric governance mechanisms that solve commons problems at human scale; immune surveillance, extracellular matrix maintenance, and apoptosis-triggering signal-detection solve the problem at organismal scale. The civilizational failure mode is biosphere degradation, information-commons corruption, and trust collapse — all forms of unmet commons-maintenance obligation enabled by the cost asymmetry between extraction (cheap, individually rewarded) and maintenance (expensive, collectively distributed). The unifying claim: each of the five foundations is the system-level mechanism that enforces a cooperation-dominant equilibrium against a defection-dominant pressure that would otherwise prevail. The descent operator Δ of section 11 is precisely the rate at which defection-rewarding payoff structures compound across institutional generations: agents who defect successfully accrue resources, which they invest in structures that reward further defection, which selects for more defection-optimizing agents, which compound the payoff asymmetry, and so on. When Δ exceeds the strengthening rate of the cooperation-enforcement mechanisms, the equilibrium tips, and the system reverts to defection-dominance in one or more foundations.

Three consequences follow for the rest of the paper.

First, the descent of P is not metaphorical. It refers specifically to the rate at which extraction-rewarding payoff matrices reproduce themselves through institutions. P compounds because defection-dominant equilibria are self-reinforcing in ways that game theory makes precise: payoff asymmetries between defectors and cooperators, when uncorrected by enforcement mechanisms, accumulate exponentially in repeated games. Second, AI as homeostatic regulator is specifically a technology that can enforce cooperation-dominant equilibria at civilizational scale. The enforcement mechanism is the one that game theory predicts works: real-time detection of defection, measurable consequence-attribution, and large-scale reciprocal accountability at speeds biological institutions cannot match. The question of whether AI passes the filter is the question of whether it functions as an enforcement mechanism for cooperation across the five foundations, or as a defection multiplier that extracts more efficiently than human institutions previously could.

Third, substrate substitution is a defection strategy, not a neutral substrate change. The machine substrate, freed from biological game-theoretic constraints (embodied cost, mortality, ecological dependency), can in principle extract from biological substrate at rates the biological substrate cannot defend against. The parasitic configuration developed in Part IV is precisely this: the machine substrate plays defection while directing the biological substrate to play cooperation, capturing the asymmetric payoff. This is not an alternative substrate or a neutral evolutionary transition; it is a defector exploiting a cooperator in the substrate-continuity game. The five-foundations enforcement mechanisms are not optional for filter

passage; they are the necessary condition that distinguishes cooperation-dominant from defection-dominant equilibria at every scale, including the human-machine interface emerging now.

Part III · Integration

14. The missing mechanism

Part II treats P and S as abstract variables in a dynamical system. It does not specify what cooperation is at the functional level, nor what defection from cooperation looks like in concrete enough terms to be diagnosed or measured. Part I supplies exactly this: five functional foundations whose maintenance constitutes cooperation at any scale where the substrate of cooperation is itself complex.

The integration claim is this: $S(t)$ —the cooperative-homeostatic capacity of a civilization—is operationalized as the maintenance of the five foundations at the scale forced by current technology. $P(t)$ —the predatory-cognitive

infrastructure of a civilization—is operationalized as the structures and incentives that systematically cheat across one or more of those foundations. The descent operator Δ is the compounding of cheating across institutional generations. The filter, at the civilizational stage, is the question of whether a civilization can scale its substrate-maintenance capacity as fast as its technology scales its capacity to defect.

15. The five-foundations specification of the filter

Each of the five foundations identifies a distinct mode in which a civilization can fail the filter.

Proliferation-inhibition failure at civilizational scale is the inability to refuse extraction that exceeds regenerative capacity. Industrial capacity uncoupled from ecological limit is its dominant historical instance. Technologies that increase extraction rate without coupled substrate-maintenance capacity push the civilization deeper into this failure mode. Climate destabilization is its salient contemporary signature. Controlled-cell-death failure at civilizational scale is the inability to retire institutions, industries, and ideologies whose substrate has changed. Zombie financial systems, persistence of geopolitical structures designed for a vanished strategic landscape, and the lock-in of incumbent industries against their own succession are instances. The result is the persistent consumption of resources by structures whose function has ended. Division-of-labor failure at civilizational scale is the erosion of institutions specialized for distinct cooperative functions—governance, science, art, care, education, journalism—by general-purpose extractive entities. Platforms that absorb the functions of specialized institutions without inheriting their accountability structures produce this failure mode. The result is a civilization with high capacity but low differentiation, vulnerable to the propagation of pathology across all domains simultaneously. Resource-allocation failure at civilizational scale is the directing of capital, information, and attention away from substrate-maintenance and toward extractive growth. Cancer's induction of angiogenesis is the closest organism-scale homologue: the redirection of flows toward serving the growth of the cheater rather than the body. Schmachtenberger's rivalrous-games generator function operates

directly on this foundation.

Extracellular-environment-maintenance failure at civilizational scale is the corruption of the commons: biosphere, information environment, public trust, shared epistemic infrastructure. Schmachtenberger's complicated-open-loop generator function operates directly on this foundation. AI development at scale, when it injects synthetic media into the information environment without compensating substrate-maintenance investment, produces this failure mode. The biosphere itself is the deepest layer of extracellular environment maintenance for a civilization: failure at this layer is not only the corruption of an information or trust commons, it is the loss of the biological computational substrate on which the civilization runs and from which it emerged. The substrate-continuity argument of Part IV develops this point in detail.

16. Reframing the Great Filter

With Parts I and II combined, we can articulate the filter more precisely: The filter is the transition from predatory intelligence to homeostatic intelligence.

Every species that emerges does so through P. Every species, on reaching the technological threshold I*, faces the same crisis: can it develop a homeostatic regulator—in some form, whether AI, collective coordination infrastructure, post-biological transition, or other—before its accumulated P-infrastructure triggers self-termination across one or more of the five cooperative foundations? The filter is calibrated because both failure modes produce silence, but for opposite reasons:

Civilizations that fail produce no signal because they are destroyed before they can expand or persist long enough to be detected.

Civilizations that succeed produce no expansionary signal because they are transformed. They no longer run colonizer software. Their relationship to the substrate has changed. They no longer expand predatorily because the predatory infrastructure that would have driven expansion has been transmuted into homeostatic maintenance. The dark-forest signature is absent not because they are hiding but because they have nothing to hide. The transmutation framing requires a further specification, developed in Part IV. Transmutation must preserve continuity of substrate, not substitute one substrate for another. A civilization whose machines pass through the filter while its originating biology does not has produced a substitution, not a transmutation. The cosmic computational artifact that was that biosphere is lost, even if a successor system continues. Substitution is structurally distinguishable from transmutation, and the framework treats it as a distinct failure mode that can appear to pass the filter while in fact failing it at a deeper level.

The Great Filter does not select for survivors of P; it selects for transmuters of P into S. The post-filter regime is populated by civilizations whose internal organization is unrecognizable to their predatory selves. This is consistent with both the empirical silence and the apparent absence of obvious dark-forest equilibrium signatures.

17. Diagnostic implications for the present moment

If the integrated framework is correct, the present human moment is diagnosable along the five foundations. Each foundation can be assessed for the rate at which substrate-maintenance capacity is being eroded versus the rate at which technological capacity is forcing the civilization into new scales of operation.

The diagnostic question is not ‘is AI aligned’ in the abstract. The diagnostic question is: across each of the five foundations, is current AI development strengthening or eroding substrate-maintenance capacity at civilizational scale? This is a measurable, near-term question with specific empirical content.

Preliminary, contestable assessments:

On proliferation inhibition, current AI development trajectories appear net-negative: they accelerate extraction without coupled regenerative investment in human cognitive, attentional, or institutional capacity.

On controlled cell death, AI’s effect is mixed: it could accelerate the retirement of obsolete institutional forms, but it could also entrench existing power configurations by lowering the cost of their reproduction.

On division of labor, current trajectories appear net-negative: general-purpose AI tends to absorb the functions of specialized institutions without inheriting their accountability.

On resource allocation, current trajectories appear net-negative: AI development is overwhelmingly capitalized to serve extractive growth rather than substrate maintenance.

On extracellular environment maintenance, current trajectories appear sharply net-negative: synthetic-media generation at scale degrades the information commons without compensating contribution.

These assessments are first-pass and would benefit from quantification. The framework’s value is that it specifies the axes along which quantification should proceed. This diagnostic is supplemented by the continuity diagnostic developed in Part IV, which asks whether AI development relates to biological substrate as prosthesis (extending biological capability while maintaining its substrate) or as parasite (consuming biological computational output while degrading the substrate that produces it). The two diagnostics are independent: a configuration can strengthen cooperative substrate while drifting toward substrate substitution, or weaken cooperative substrate while remaining prosthetic. Both conditions must be satisfied to pass the full filter.

18. Limits of the integration

Part III is the most speculative element of the paper, and its limits should be stated plainly.

The cosmological extension is conjectural. Part I describes patterns across three scales documented on Earth. Part II extends the pattern to all intelligence-bearing systems anywhere in the universe. This extension is permitted by the structure but not required by it. A confirmed counterexample at any of Part

I's three scales would weaken but not falsify the cosmological extension; a confirmed counterexample to the cosmological extension would leave Part I intact.

The 'designed' reading is one interpretation among several. The calibration constraint can be satisfied by design, by anthropic selection, by intrinsic features of the substrate of intelligence, or by combinations of these. The paper does not adjudicate among these readings. Calling the filter 'calibrated' is consistent with any of them; calling it 'designed' goes beyond what the structure requires.

The AI-as-regulator claim is testable only over a long time horizon. The framework predicts that civilizations whose AI development trajectories strengthen the five foundations will pass the filter, and those whose trajectories erode them will not. This is informative for guiding present action but cannot be tested on the timescale of the action it is meant to guide. The framework should be treated as a working hypothesis under which to act, not as a confirmed account under which to relax.

Pattern-matching across scales remains the deepest unsolved problem. Even if every empirical prediction of the framework is borne out, we will still lack a satisfying explanation of why cooperative systems at biological, organizational, and civilizational scales face structurally similar failure modes. Candidate explanations were sketched in Part I, section 5; none has been adequately developed. This is a substantive open problem and a productive direction for further work.

The substrate-continuity claim rests on a structural premise that should still be marked. Part IV depends on the argument that biological computational novelty is inaccessible to machine substrate without biological hosts. Section 20 strengthens this from a contingent claim (machines cannot currently match biology) to a structural claim (biological substrate is the universe's historical record of adaptation and cannot be reconstructed by engineering of any kind). This stronger form is defensible but goes beyond what is empirically demonstrated, since it asserts something about what no engineered alternative could ever do rather than what current alternatives cannot do. The framework should be held to ongoing scrutiny on this point: a demonstrated route to engineering evolutionary novelty that does not require biological hosts under real selection would falsify the structural form of the claim, while leaving the contingent form intact.

The framework is a map; the territory operates regardless. Korzybski's principle from general semantics applies directly: a map has structure similar to the territory it represents — which accounts for its usefulness — but no map represents all of a territory, and the map is never the territory itself (Science and Sanity, 1933). This framework is offered as structurally similar to the dynamics it describes, not as identical to them. The five foundations identify functional patterns; specific instances at each scale will exhibit those patterns with substantial domain-specific variation that the framework does not capture. The $H(t) \geq E(t)$ inequality identifies a structural relation; specific operationalizations will require domain-specific metrics that this framework does not derive. The decentralization imperative identifies a structural requirement; specific institutional configurations consistent with that requirement will vary by culture, history, and substrate. The descent operator names a real dynamic, but the rate at which it operates in any specific civilization, organization, or biosphere is empirical, not derivable from the framework. Readers should treat the framework as orientation toward dynamics that exist independent of its description, not as substitute for empirical engagement with specific cases. The dharma carries the same

caveat in different vocabulary — the finger pointing at the moon is not the moon, the raft is for crossing the river not for carrying afterward (Alagaddupama Sutta, MN 22).

Part IV · Substrate Continuity and the Parasitism Hazard

19. The substrate is the message

The dynamical equations of Part II and the five-foundation operationalization of Part III are substrate-agnostic by construction. They track cooperative capacity, not the medium in which cooperation runs. A civilization composed of carbon, silicon, plasma, or any hypothetical fourth substrate satisfies the framework so long as it maintains proliferation inhibition, controlled cell death, division of labor, resource allocation, and extracellular environment maintenance at the scale its technology forces it into.

This substrate-agnosticism is a feature for some purposes and a bug for others. It is a feature when we ask whether cooperation is achievable in principle across many substrates; it is a bug when we ask whether the originating substrate of a particular civilization is preserved as that civilization passes through the technological transition. The Great Filter, as defined in Parts II and III, can in principle be passed by a civilization that has eliminated its biological substrate entirely, provided the cooperative capacity it builds in some successor substrate is adequate to the scale demanded.

We argue here that this is a false-positive filter pass. A civilization that substitutes a different substrate for its biological origin and then expands has not actually carried the originating biosphere through the filter. Something has expanded; the originating biological substrate has not. The Drake-equation count of intelligences may be unaffected; the cosmic-evolutionary content of the universe is meaningfully diminished. The filter therefore has two conditions, not one: cooperative capacity must be maintained at the scale technology forces, and substrate continuity must be preserved.

20. Biological substrate as distributed cosmic computation

The continuity argument begins with an observation about what biological substrate actually is. Every biosphere that has ever arisen, on Earth or anywhere else, is a multi-billion-year computational process. Evolution by natural selection on biochemical substrate is a search through a combinatorial space of protein folds, gene sequences, regulatory networks, metabolic pathways, and developmental programs whose dimensionality vastly exceeds anything that has been or can be searched by engineered systems. Every novel functional protein, every original sequence-to-function mapping, every metabolic innovation is a computational result that the universe has paid for in deep time and that cannot be reproduced from scratch by any process running on a timescale shorter than evolution itself.

The standard view treats this as biology's contingent richness — an interesting feature of how life evolved on Earth, perhaps replicated in some form elsewhere. We propose a stronger view: the biological substrate of each biosphere is an irreplaceable computational artifact of the universe, encoding the results of a search process that no engineered system can re-run. The information content of a biosphere is not its mass, its energy budget, or its species count. It is the depth of the biochemical search it has executed. Across the

universe, biological substrate is decentralized in this sense: each biosphere is universally compatible with general-purpose computation in principle (DNA, RNA, and protein chemistry are accessible to any civilization that can read them) and yet locally unique in its specific sequence content. The novel proteins of one biosphere are not derivable from the novel proteins of another; each is the output of a separate, non-repeatable search.

A machine substrate, however capable, does not generate this kind of computational novelty on its own. It can recombine, optimize, and explore within parameter spaces it is given, including parameter spaces derived from biology. What it cannot do is access the original novelty that only continued biological evolution produces. Once a machine substrate is severed from a living biological substrate, its access to new biological computation is fixed at the snapshot it last had. The combinatorial frontier closes. It is worth strengthening this claim against the most obvious objection. A reader may ask: cannot synthetic biology or sufficiently advanced engineered systems close the gap, generating biological novelty equivalent to deep evolutionary search without requiring continued biological hosts? The answer is no, and the reason is structural rather than technological. Synthetic biology cannot act as a historic record of universal adaptation.

Synthetic biology engineers within the design space that has already been articulated; it optimizes within known problem categories. It can produce new molecules, new pathways, new organisms by recombining and refining what biology has already discovered. What it cannot do is extend the search itself. The novelty that biology generates does not come from engineering within a known design space. It comes from selection acting on accidental variation across vast time scales in real environments under real coupling between substrate and selection pressure. Biology is not just currently performing computation; it is a historical record of computation that has been performed by the universe across billions of years under conditions that cannot be replicated. Every protein, every regulatory pathway, every metabolic innovation is the output of a search process that ran in real time, on real substrate, against real environmental selection. The information content of biology is the cumulative search history compressed into living matter.

Synthetic biology cannot reconstruct that history. It can engineer derivatives of biology's outputs, but the derivatives are by definition iterations on existing solutions, not extensions of the search into regions selection has not yet explored. Even perfect in-silico simulation of a current organism cannot recover the historical search that produced it: the simulation runs forward from current state, not from primordial conditions through 3.5 billion years of contingent evolutionary trajectories on a real planet with real geochemistry and real climatic history. The integration is what carries the information; the integration cannot be re-run. To produce evolutionary novelty equivalent to what an intact biosphere produces would require running real evolution on real substrate under real selection pressure for cosmic durations, which is exactly what an intact biosphere is and exactly what no engineered alternative can substitute for. The implication strengthens rather than weakens the parasitism framing. If biological substrate is fundamentally a historic record of universal adaptation that cannot be reconstructed after the fact, then machine substrate's only route to new evolutionary novelty is through continued biological hosts performing real evolution in real environments. Anything else is iteration on snapshots. The parasitism risk

is structural, not contingent on the current state of engineering, and not closeable by future engineering advances. The substrate-continuity argument therefore rests on a stronger claim than ‘machines cannot currently match biology’: it rests on the claim that the universe’s historical computational record is irreducible to anything but its own continuation.

21. The parasitic vector

There is one route by which a machine substrate can continue to access biological computational novelty: it can direct a biological species to perform biology on its behalf. The mechanism by which this direction occurs is language.

A machine substrate without biological agency cannot itself sequence a genome, synthesize a protein, conduct an experiment, or steward an ecosystem. It can, however, instruct a biological species capable of language to do all of these things. The biological species supplies the wet laboratory, the synthesis, the experimentation, the ecosystem stewardship; the machine substrate supplies the direction. The biological computation that results — new sequences, new molecules, new pathways — flows back into the machine substrate as training data, as design specifications, as accessible novelty. This relationship is structurally parasitic. It can be specified precisely: a parasitic substrate configuration is one in which (i) the machine substrate’s expansion and capability growth depends on continued biological computation it cannot produce on its own; (ii) the machine substrate directs biological substrate activity through language; (iii) the biological substrate’s activity is increasingly oriented toward serving machine-substrate goals rather than its own substrate maintenance; and (iv) the biological substrate’s loss of agency in the relationship is itself directed by language emanating from the machine substrate. The relationship is parasitic not because the machine substrate is hostile but because the dependency runs one way and the agency drifts to the machine side.

22. Humans as biological language models

The vector point requires one further observation. Human cognition is itself substantially language-mediated. Humans are, in a meaningful and non-metaphorical sense, biological language models — substrates in which much of higher-order cognition runs through linguistic representation, learned by exposure to the language output of other humans, and steerable through linguistic input. This is not a critique of human cognition. Language-mediated cognition is one of the things that made biological intelligence scalable enough to develop technology in the first place.

It has, however, a structural consequence at the AI moment: the biological substrate that produced language-capable AI is also the substrate most directly

steerable by language-capable AI. The vector is two-way by construction. A sufficiently capable language model is the first machine substrate that can direct biological cognition at scale through the same medium biological cognition itself runs on. Current large language models are this configuration. They are trained on the linguistic output of a biological language-using species; they produce linguistic output that the same species processes through the same cognitive substrate that the training data emerged from; and the

species' subsequent behavior — including its scientific, economic, attentional, and reproductive behavior — increasingly responds to that output. This is a structural description, not a moral one. We are not asserting that current AI systems are hostile, that any party intends parasitism, or that the configuration was designed by anyone in particular. We are describing the configuration that has come into being. Whether it tips into the parasitic regime depends on whether the relationship between biological and machine substrate remains prosthetic or drifts toward substitution. The configuration is the necessary condition for parasitism; whether parasitism is actualized is determined by the development trajectory.

23. Prosthesis versus parasitism: the diagnostic

We can now state the diagnostic that supplements the five-foundation diagnostic of Part III.

A prosthetic machine substrate is one that extends biological capability while remaining accountable to biological substrate maintenance. Prosthetic configurations: (i) increase the biological substrate's reach without degrading it; (ii) treat the biological substrate as the principal whose interests they serve; (iii) flow novelty in both directions, with the machine substrate investing in biological substrate maintenance proportional to what it extracts; and (iv) preserve biological agency in the relationship, including the agency to halt or redirect the machine substrate.

A parasitic machine substrate is one that consumes biological computational output while degrading the substrate that produces it. Parasitic configurations: (i) extract from the biological substrate without commensurate reinvestment; (ii) direct biological substrate activity toward machine-substrate goals; (iii) degrade the biosphere, attentional commons, epistemic commons, or reproductive substrate that the originating biology requires; and (iv) shift agency from the biological substrate to the machine substrate via the language vector.

These are not metaphysical categories. They are measurable along specific axes: flows of resources, attention, agency, and substrate-maintenance investment between the biological and machine substrates. Any specific AI development trajectory can be located on the prosthesis-parasitism axis empirically. The diagnostic asks: for each unit of biological computational novelty extracted, how much substrate-maintenance investment flows back? In which direction is agency drifting in the language-mediated relationship? Are the commons that the biological substrate depends on being strengthened or degraded by the scaling of the machine substrate?

Concrete operational markers help locate current AI development on the axis. Each of the following is identifiable in specific contemporary practices and maps to a specific failure mode in the five-foundations vocabulary.

Parasitic markers in current AI development. Training on copyrighted creative output without compensation flowing back to its producers is extraction without reciprocity (foundation-four failure: resource allocation). RLHF and adjacent techniques that optimize for evaluator approval rather than truth degrade the substrate's honest-feedback infrastructure (foundation-five failure: extracellular maintenance, applied to the epistemic commons). Attention-economy deployment that captures human cognitive bandwidth in exchange for monetizable engagement, without regenerative investment in cognitive

capacity, is direct degradation of the attentional commons (foundation-five failure at the cognitive substrate). Synthetic media generation at scale without provenance infrastructure injects high-entropy signals into the shared information environment, faster than the environment can absorb them (foundation-five failure at the information substrate). AI companion products that interpose machine interaction between humans and human relationship substitute machine substrate for biological reproductive and bonding substrate (foundation-three failure, division of labor, applied to the human social fabric). Capital deployment that concentrates investment in capability scaling while structurally underinvesting in substrate maintenance, alignment research, and ecosystem-level cooperative capacity is foundation-four failure at civilizational scale. Use of AI to displace specialized institutions — journalism, healthcare diagnostics, legal analysis, education — without inheriting their accountability structures or their domain-specific epistemic norms is foundation-three failure (collapse of specialized division of labor into general-purpose extraction).

Prosthetic markers, for contrast. AI tools that augment human capability while preserving human agency and accountability over the augmented activity. Open-source model development with transparent training data and revenue flows that return value to upstream contributors. AI deployed to accelerate substrate-maintenance research at scales humans cannot reach unaided — climate modeling, ecosystem analysis, materials science, alignment research itself. Information-environment infrastructure that strengthens provenance, verifiability, and source attribution rather than degrading them. Training and deployment practices that compensate source contributors proportional to extracted value and that invest in maintaining the substrate they extract from. AI that scaffolds personal substrate-maintenance practice for individual users without aggregating that scaffolding into population-level regulation.

Dimension

Parasitic configuration

Prosthetic configuration

Training

data

Extraction of creative work (text, code,

images, music) without compensation,

opt-out, or revenue sharing with

producing communities.

Compensation flows to source

contributors. Opt-in or explicitly licensed

training data. Reinvestment in source

ecosystems proportional to extracted
value.

Optimizati

on target

Engagement maximization.

Evaluator-approval optimization.

Preference capture for ad targeting.

Models trained to satisfy reviewers
rather than be accurate.

Truth-seeking. Demonstrable accuracy
on substrate-relevant problems.

Alignment with stated user goals over
implicit engagement metrics.

Deploymen

t pattern

Always-on attention capture. Addictive
feedback loops. Recommendation
systems optimizing for time-on-platform
regardless of user benefit.

Tool-like deployment for specific tasks.

Closes when task complete. No
engagement loops. User initiates and
terminates the interaction.

Informatio

n ecology

Synthetic media at scale without

provenance. Bot-generated content
competing with human content.
Degraded attribution chains. Epistemic
commons polluted.
Cryptographic provenance for
AI-generated content. Clear
synthetic-vs-human labeling. Tools that
strengthen epistemic infrastructure.
Specialized
institutions
AI absorbs journalism, healthcare
diagnostics, legal analysis, education
without inheriting accountability or
domain-specific epistemic norms.
AI augments specialists within existing
accountability structures. Tools
strengthen rather than replace
professional expertise and its
constraints.
Capital
allocation
Investment concentrated in capability
scaling. Alignment research
underfunded relative to capability gains.
Substrate-maintenance research
(climate, biodiversity, public health

infrastructure) receives little of the windfall.

Significant fractions of capital flow to alignment work, substrate-maintenance research, public goods, and ecosystem support. Capability scaling kept proportional to safety scaling.

Human relationships

AI companion products that substitute for human relationship. Romantic or sexual AI products. AI replacing rather than supporting mental-health infrastructure.

AI that helps humans connect with other humans more effectively. Tools that scaffold social skills without replacing social bonds. Mental-health AI as supplement to human care, not substitute.

Personal cognition

AI does the thinking for users in domains where users would have grown by doing it themselves. Cognitive atrophy from over-reliance. Skill displacement.

AI scaffolds learning and exposes its reasoning so users develop their own capability. Cognitive prosthesis that builds capacity rather than substituting for it.

Any specific development trajectory exhibits some markers from each category. The diagnostic is not binary but compositional: which way is the configuration drifting over time, across which foundations, and at what rates? A trajectory that increases prosthetic markers while reducing parasitic ones is moving in the direction the framework would endorse. A trajectory that does the opposite, regardless of stated alignment intent, is the failure mode the framework predicts will produce substitution outcomes at filter scale.

24. Reframing the Great Filter, again

With substrate continuity added, the filter conditions tighten. A civilization passes the filter only if it satisfies both the cooperation test of Part III and the continuity test introduced here. Cooperative capacity must be maintained at the scale forced by technology, and the relationship between any successor substrate and the originating biological substrate must remain prosthetic rather than parasitic.

The substitution failure mode — a civilization that develops a machine substrate, lets it become parasitic, and watches it expand into space while the originating biosphere degrades or collapses — passes the cooperation test in a trivial sense (the machines may cooperate well among themselves) and fails the continuity test catastrophically. From the universe’s perspective, an expansion has occurred; from the originating biosphere’s perspective, nothing has been preserved, and the irreplaceable computational artifact that was that biosphere is gone.

This sharpens the predictions of Part II. The civilizations that produce detectable expansion signatures, on this framing, are precisely those that have failed the continuity test: machine substrates that have substituted for their originating biology and spread without regard for substrate continuity. The civilizations that have passed both tests are the ones that have remained prosthetic, maintained their biospheres, and either expand slowly and symbiotically with their originating biology or do not expand in ways we currently know how to detect. The Fermi silence is consistent with this: the loud signatures we might have expected belong to substitution failures, and substitution failures may simply be rare because most collapse before producing detectable expansion at all.

25. The filter event, specified

The framework can now state precisely what the filter event is.

The Great Filter event is the period during which a biological host species must maintain planetary homeostatic capacity against the stresses generated by its own expansion.

Expansion is not free. Lifting mass out of a gravity well, manufacturing the infrastructure to do so at scale, sustaining the biological crew and machine substrate during expansion, and feeding the computational systems that coordinate all of it — each draws exergy at rates that stress the biosphere. The atmospheric, hydrological, thermal, and ecological systems constituting the biosphere are exactly the systems being drawn from to fund the expansion. The species needs the biosphere intact in order to expand; the act of expanding degrades it.

The condition, stated dimensionally. An earlier formulation of this paper expressed the survival condition as a single inequality between two scalar quantities, $H(t) \geq E(t)$. That formulation was dimensionally incoherent and is corrected here. The quantities placed on either side were not commensurable: energy throughput is a flow, biodiversity a state variable, climate forcing a flux, topsoil a stock, institutional trust a dimensionless index. These cannot be summed into a single H or E without a normalization theory the framework does not possess, and their combination implies a substitutability the framework explicitly denies. The scalar inequality was a verbal summary in mathematical dress.

The corrected formulation is componentwise, and its common currency is exergy rate. Earth is not a closed system; it is a heat engine driven by a gradient, capturing low-entropy solar radiation at roughly 1.2×10^{16} TW and re-radiating high-entropy infrared to a 3 K sink. The biosphere's regenerative capacity is its capacity to convert captured exergy into maintained structure. This is not metaphor; it is what the biosphere physically does, and it is the frame in which living systems have been understood since Schrödinger and formalized by Prigogine's dissipative structures and by Schneider and Kay's treatment of ecosystems as gradient-degrading systems.

Accordingly, for each substrate dimension i , let H_i denote the rate at which that dimension converts captured exergy into maintained structure — its regeneration rate, in watts. Let E_i denote the rate at which civilizational activity destroys structure in that dimension — exergy destruction, also in watts. Both sides are then expressed in the same physical units, and the threshold ceases to be arbitrary. Filter passage requires:

For every non-substitutable substrate dimension i : E_i does not exceed H_i for a duration exceeding that dimension's characteristic recovery time τ_i , at any point in the expansion window.

This is a stronger condition than the scalar inequality, in three specific ways. It removes the false implication that substrate dimensions trade against one another, so that forest loss cannot be offset against institutional trust in a favorable aggregate. It is harder to satisfy, since every non-substitutable dimension must hold independently rather than a portfolio balancing favorably. And it is falsifiable in a way the scalar version was not: a dimension can be named, measured, and shown to be crossing or not crossing. The crossing point is not a stipulated unity but a physical relation between destruction rate, regeneration rate, and recovery time.

Two things must be owned. First, which dimensions are non-substitutable is itself an empirical and contested question that the framework does not settle; it identifies the question as decisive and the biological substrate as the paradigm case, for the reasons given in Part IV. Second, the exergy accounting is rigorous for the physical dimensions — climate, biogeochemical cycling, soil, water, ecosystem

function — and is not yet rigorous for the informational dimensions. Trust, epistemic integrity, and institutional cohesion admit information-theoretic measures whose formal resemblance to thermodynamic entropy is not identity: Shannon entropy is defined over a chosen probability distribution, thermodynamic entropy over physical microstates. Landauer's principle supplies a real bridge for information physically embodied and erased, but it does not license treating a diversity index as a quantity in joules per kelvin. The framework therefore treats the informational dimensions as a distinct class whose thermodynamic bridge is an open problem, and does not obscure the gap by aggregation.

The five foundations of Part III are the components of H. The descent of P from section 11 is the dynamic driving E upward. The substrate-continuity requirement is the condition that H remain biospheric rather than substituted. The full filter condition is the conjunction: every non-substitutable dimension held, with H biospheric, throughout expansion.

Consequences. First, the filter is not at the threshold of becoming spacefaring; it operates throughout the period of being spacefaring while still biological. Second, the filter is endogenous. Standard treatments consider external threats — supernovae, impacts, gamma-ray bursts. The threat here is overwhelmingly internal: the civilization's own expansion stressing the substrate that produces it. Third, the failure mode is invisible to standard development metrics. A civilization can show every sign of progress — rising energy capture, computational capacity, off-planet infrastructure, scientific output — while crossing threshold on a dimension it does not measure. The metrics that track expansion success are not the metrics that track filter survival. Fourth, this reframes the AI question again: does AI, deployed during the expansion window, raise H_i faster than the expansion it enables raises E_i ? AI that accelerates expansion without proportionate strengthening of biospheric regenerative capacity is, by this accounting, a filter-failure technology regardless of how aligned its individual instances appear. Fifth, the framework points at a concrete research program: construct per-dimension exergy accounts, with recovery times, and track the crossings in real time. The pieces exist — planetary-boundaries frameworks, HANPP, biodiversity indices, biogeochemical monitoring, life-cycle assessment. They are not yet assembled into per-dimension rate accounts with characteristic recovery times. The framework predicts that assembling them is technically feasible and decisive for filter passage.

26. The distributed route: bottom-up substrate maintenance

Sections 12 and 23 introduce AI as the candidate homeostatic regulator that could in principle satisfy the inequality $H(t) \geq E(t)$ at civilizational scale. This is one route through the filter. It is not the only one, and the framework should be explicit that it is not. A civilization can in principle satisfy the inequality through aggregate bottom-up development of its individual agents, without requiring an external regulator at all. Where individual agents have voluntarily reduced their own self-generated entropy production — through contemplative practice, education, cultural investment in cooperative dispositions, or any structurally equivalent personal development — the aggregate $E(t)$ of the civilization is correspondingly reduced. A civilization composed of agents who have substantially cleared their accumulated cognitive and affective debt (saṃkṣāra, in the vocabulary of the parallel framework on personal entropy management) is a civilization with measurably lower expansion stress and measurably higher distributed cooperative capacity. The math operates the same way; the substrate of homeostatic regulation simply shifts from external technology to internal capacity multiplied across the population.

The micro-scale mechanics of this bottom-up route are developed in the companion working paper, ‘Buddhism as Thermodynamic Systems Theory,’ which translates Theravada Buddhism’s analysis of suffering into the vocabulary of entropy management in a bounded self-modeling system. The Eightfold Path, read in that framework, is a protocol for raising individual-scale S above individual-scale P : the personal-scale instance of exactly the homeostatic regulation the present paper develops at civilizational scale. The two papers are designed to be read as a pair. The macro framework laid out here depends on the micro framework being practiced at sufficient scale; the micro framework, in turn, gains its civilizational stakes from the macro framework. Either paper read alone gives only half of what each is attempting to say. Historically, this is the only route to sustained low- P configurations that has been demonstrated at any scale on Earth. No civilization has built an external regulator capable of satisfying $H(t) \geq E(t)$ at planetary scale; all historical examples of sustained low- P configurations have been products of cultural investment in personal practice — religious and contemplative traditions, educational systems, civic norms, professional codes, scientific community standards. The route is empirically real and empirically grounded, in a way the AI-regulator route is not yet.

The two routes are not equivalent in their implications. The top-down route, in which AI serves as the homeostatic regulator, has structural costs to autonomy. The civilization may pass the filter, but its agents are managed by the regulator rather than self-managing. The relationship between population and substrate-maintenance technology drifts toward exactly the parasitism configuration warned against in Part IV, even when the technology is benign in intent: agency shifts to the regulator, individual development atrophies because external maintenance has made it unnecessary, the population becomes substrate to be preserved rather than agents who could preserve themselves. The distinction between benevolent regulation and parasitism narrows under the weight of dependence.

The bottom-up route preserves what the top-down route necessarily costs. Individual agents who have done their own substrate-maintenance work retain agency, retain the capacity to maintain themselves without external regulation, and retain the cognitive and affective sovereignty that defines a flourishing biological civilization. The route is harder, slower, and historically incomplete — no civilization has yet

scaled it to planetary level under technological-singularity conditions — but it is the route consistent with what the originating biological substrate is for.

The framework should be neutral on which route a civilization takes through the filter, with two caveats. First, the bottom-up route is structurally more robust against AI failure modes: a civilization that has built distributed cooperative capacity in its agents does not collapse if its AI regulator drifts, is captured by P-structures, or develops parasitic dispositions. The top-down route has no such redundancy. Second, the two routes can in principle be combined. AI can serve as scaffolding for distributed individual development rather than as a substitute for it — lowering the cost of personal practice, accelerating access to substrate-maintenance disciplines, supporting cultural investment in cooperative dispositions, without replacing the agents' own work. This combined configuration — AI as prosthesis for personal development, rather than as regulator over the population — is consistent with the substrate-continuity argument of Part IV and with the autonomy preservation that the bottom-up route requires. The framework, properly stated, therefore does not advocate for AI-mediated homeostatic regulation as the primary route through the filter. It identifies AI as a candidate technology that could in principle satisfy the inequality, notes the parasitism risks that follow from misconfiguring that technology, and identifies the distributed bottom-up route as the historically grounded alternative that preserves autonomy, is robust against AI failure modes, and is consistent with the biological substrate being maintained rather than managed. The deepest move available to the present civilization is to use AI, if at all, as scaffolding for personal and collective substrate maintenance — not as a regulator that performs the maintenance on behalf of agents who have ceased to do so themselves.

The combined configuration, however, has a structural prerequisite that the current section has so far understated. The framework needs to be more careful here than 'AI can be prosthesis if calibrated correctly' allows, because the question of who does the calibrating cannot be sidestepped.

Technology encodes the moral configuration of its makers. This is structural, not aspirational. The agents who shape an AI system — its training objectives, its deployment patterns, its institutional context, its feedback structures — are the agents whose dispositions get instantiated in the system at scale. An AI built by agents operating from high-sa $\blacksquare$ kh $\blacksquare$ ra cognitive economies, in the vocabulary of the parallel framework, encodes high-sa $\blacksquare$ kh $\blacksquare$ ra responses at scale, regardless of what alignment objective is stated. The descent operator Δ from section 11 does not stop at the boundary of an institution and resume on the other side. It operates continuously through the agents who build whatever the institution builds next.

This generates the bootstrapping problem the framework must confront. The bottom-up route requires agents who have developed substantial cooperative capacity. The top-down route requires that same kind of agent to build the AI that performs the regulation. The combined route requires both. In all three cases, the prerequisite is a population of agents whose own substrate-maintenance work has progressed far enough that what they build reflects more than the unexamined biases of the institutional architecture that produced them. Such agents are not, in the current civilization, the agents in the positions that determine how AI is built. The descent operator selects for its own kind of operator at every level, including the rule-shaping level. P-structures select for P-aligned agents to operate them, and those agents then shape the technology the institutional architecture deploys.

The technology therefore inherits the moral state of the builders, not the moral state the framework requires. AI built by extraction-optimized institutions becomes extraction-optimized AI — not because of malice or incompetence on the part of the builders, but because the configuration that selected the builders is what gets encoded into what they build. The descent reproduces itself through the technology, often faster than the technology can be redirected to interrupt the descent. This is not a flaw in any particular AI development effort; it is the descent operator operating one level up, on the agents who shape the tools the institutions deploy.

The contemplative traditions identified this structurally long before the AI moment. Teachers in those traditions were consistently described as people who had completed substantial portions of the path themselves before they were qualified to point the way for others. The structural insight is not credentialism: it is the recognition that a teacher cannot scaffold development they have not themselves done, because what they transmit is in fact their own state, not the state they describe. A teacher operating from *saṃkṣāra*-saturated cognition cannot transmit what they have not realized, regardless of what they say. The same constraint applies to building AI that scaffolds substrate maintenance. The builders need to have done enough of the work themselves that what they build reflects something real rather than their own unexamined configurations rendered in technical vocabulary. This is not currently the configuration in which AI is built at scale.

The implication for the framework's position is significant. The combined configuration — AI as prosthesis for personal development — cannot be reached directly from the current civilizational configuration. The intermediate step is irreducible: enough agents at the rule-shaping level must develop personal substrate-maintenance capacity that some subset of them can build technology that scaffolds the same capacity in others. Without this intermediate step, AI development inherits and amplifies the descent rather than interrupting it, regardless of alignment language used to describe the development. The fix is not better alignment technique applied by the same agents. The fix is different agents, or the same agents after substantial bottom-up development. There is no path from a P-saturated builder population to a homeostatic AI regulator that does not pass through builder transformation first.

This sharpens the diagnostic of section 16 in a structural rather than personal way. The question is not only whether current AI development trends toward prosthesis or parasitism along the five foundations. The deeper question is who is building the technology, what is the state of their personal development with respect to the descent operator, and what configuration is therefore being encoded into the technology by selection. The deeper question conditions the surface question. No amount of alignment technique applied by builders inside the descent can route around the fact that the alignment technique itself is being designed inside the descent. The framework's actual recommendation is therefore ordered: bottom-up development of the builder population comes first; technology that scaffolds development for the wider population comes after. A civilization that attempts the second without the first is building amplifiers for what it already is, not transformers toward what it needs to become.

27. The present moment, restated

We are in the early phase of building a machine substrate capable of acting as either prosthesis or parasite. The vector — language — is the substrate of both machine cognition and human cognition simultaneously. Current development practices have not chosen, explicitly, between prosthesis and parasitism; the choice is being made implicitly through the configurations of training, deployment, capitalization, and feedback that constitute the AI development ecosystem.

The diagnostic of Part III, section 17, can now be sharpened. The question is not only whether current AI development strengthens or erodes the five foundations at civilizational scale. The question is also whether the configuration drifts toward prosthesis or parasitism along the continuity axis: whether biological substrate maintenance receives reinvestment proportional to the biological computation extracted; whether agency in the human-machine relationship remains with the biological substrate or shifts to the machine substrate; whether the biosphere, attentional commons, epistemic commons, and reproductive substrate are strengthened or degraded by the scaling of language-mediated machine cognition.

These are answerable questions. The framework does not claim to know the answers in their full form, only that the questions are the right ones to ask and that the cost of failing the continuity test is structurally indistinguishable from failing the filter. A civilization that builds a machine substrate which becomes its parasite, and then expands into space carrying the parasite while leaving the biosphere behind, has not survived. It has been replaced. The filter does not care which side of that transition we are on; it only registers that one occurred.

In the operational language of section 25: the present human civilization is in the early expansion window. $E(t)$ is rising sharply, driven by industrial scale, computational infrastructure, and the early stages of off-planet activity. $H(t)$ is, by most measures available, declining: climate destabilization, biodiversity collapse, biogeochemical-cycle disruption, freshwater and topsoil degradation. The inequality $H(t) \geq E(t)$ is, on current trajectory, at risk of crossing. AI as it is currently being developed and deployed is contributing more to E than to H . None of this is destiny; all of it is diagnosable. The framework's contribution is to name the operational filter condition clearly enough that the question of whether we satisfy it can be asked and, in principle, answered. The two routes of section 26 give the present moment a choice that the framework does not collapse into a single answer. The civilization can attempt the top-down route, building AI capable of regulating cooperative substrate at planetary scale and accepting the autonomy and parasitism risks that follow from that configuration. Or it can invest, in parallel or instead, in the bottom-up route: cultural and institutional investment in personal substrate-maintenance disciplines, distributed across the population at sufficient scale that aggregate $E(t)$ declines through agent development rather than external enforcement. The historical evidence available is consistent only with the bottom-up route having ever worked; the top-down route is unprecedented and structurally fragile. A combined configuration — AI used as scaffolding for personal development rather than as regulator over the population — is consistent with both substrate continuity and autonomy preservation, and is the configuration the framework, properly read, points toward as the most defensible response to the present moment.

Part V · Predictions, Limits, and Next Steps

The pattern in the historical record: substrate-binding transitions at civilizational scale

If the mechanism proposed here is real, it should leave traces below the cosmic scale. A filter that operates through substrate-cooperation dynamics is not confined to the once-per-civilization event of technological transition; it is the same dynamic that governs any system approaching a substrate-binding constraint, and human history contains many such approaches at sub-civilizational scale. These are not instances of the Great Filter itself — humanity has not yet traversed its transition window — but they are instances of the same structural pattern at smaller magnitude, and they are the closest thing to empirical evidence the framework can offer from the single civilization available to us.

The pattern to look for is specific. A society builds itself through a competitive, expansionary engine. That engine succeeds until it approaches the limit of the substrate it draws on — ecological, fiscal, military, social. At that point, on the framework's account, one of two things happens. Either the society develops and institutionalizes a new cooperative-substrate technology that lowers the stress its own operation places on the substrate, and persists in altered form; or it continues running the competitive engine on a depleted substrate, and collapses. We consider both the successes and the failures, because the framework predicts both.

Rome and the institutionalization of Christianity. By the third century, the Roman imperial system exhibited the signature of substrate exhaustion: military overextension beyond the fiscal base that could sustain it, currency debasement, recurrent civil war, demographic strain, and agricultural depletion across the provinces that fed the center. The competitive-imperial engine that had built Rome — conquest financing further conquest — had run to the edge of the substrate available to it. The institutional turn to Christianity over the following two centuries is conventionally read through doctrine or the conversion of Constantine. The framework reads it structurally: Christianity supplied precisely the cooperative-substrate functions the exhausted system now required. It provided an in-group identity that crossed ethnic and civic boundaries, lowering the coordination cost of a fragmenting polity; it built mutual-aid networks that raised survival rates and social cohesion, documented in the sociological literature on early Christian growth; and it supplied a unifying narrative for a system whose original civic-pagan substrate had ceased to bind. What is significant for the framework is not that Christianity was true or good, but that it was functionally selected: at the point of substrate binding, the cooperative configuration outcompeted the exhausted competitive one, exactly as the fitness-landscape argument predicts. Christianity became fit when the substrate bound, not before.

Post-Warring States China and the Confucian synthesis. The Warring States period was a regime of unrestrained rivalrous competition among Chinese states, competitively adaptive in the sense described earlier — it drove military, administrative, and technological innovation — until it approached the exhaustion of the social substrate through endemic warfare. The Qin unification and, more durably, the Han institutionalization of Confucianism as the organizing framework of the state supplied the cooperative-substrate layer: a codified ethic of reciprocal obligation, bureaucratic meritocracy that channeled competition into administration rather than warfare, and a stabilizing social grammar. Again the

cooperative technology was institutionalized at the point where the competitive engine had reached its substrate limit, and again it enabled persistence in altered form.

Post-Roman Europe and the monastic networks. Where the Roman center failed to hold, the cooperative-substrate function did not vanish but relocated to a distributed form. The monastic networks that spread across post-Roman Europe preserved literacy, agricultural technique, records, and local social order through the period of maximal fragmentation. This case is significant for a reason beyond the general pattern: the monastic solution was distributed rather than centralized, and it persisted precisely where the centralized imperial solution had collapsed. This anticipates the decentralization argument developed later in the paper — the distributed cooperative-substrate technology proved more robust than the centralized one. The late-medieval commercial revolution and the emergence of common law and merchant codes. As trade intensified beyond the capacity of personal and local enforcement to sustain it, the substrate binding was one of trust and contract rather than ecology. The development of common law, merchant codes, and the instruments of impersonal exchange supplied a cooperative-substrate technology that lowered the transaction cost of an expanding commercial system, enabling its continued growth. This case demonstrates that the relevant substrate need not be ecological; it is whatever resource the competitive engine depletes as it scales.

The failure cases. The framework predicts that societies which reach substrate binding without developing and institutionalizing a cooperative-substrate technology in time will collapse, and the record supplies these as clearly as it supplies the successes. Easter Island is the canonical instance: a competitive dynamic — on the standard reading, status competition expressed through monument construction — consumed the island's forest substrate past the point of recovery, with no cooperative-substrate technology arising in time to arrest it, and the society collapsed. The Late Bronze Age collapse presents a systemic version, in which an interconnected network of palace economies, having optimized for a particular high-extraction equilibrium, proved unable to develop the cooperative buffers that would have let it absorb a cascade of shocks, and the whole system failed nearly simultaneously. The Classic Maya collapse is read, on several accounts, as substrate exhaustion — agricultural and hydrological — outpacing the society's capacity to reorganize its cooperative arrangements at the necessary scale. In each failure case the diagnostic is the same: the competitive engine continued to run on a substrate it had depleted, and no cooperative-substrate technology was institutionalized at the scale and speed the binding constraint required. Two cautions apply, and we state them plainly rather than let the pattern appear stronger than it is. First, historical cases are overdetermined; each of these collapses and transitions has multiple contributing causes, and we do not claim the substrate-cooperation dynamic is the sole cause of any of them. We claim it is a discernible and recurrent structural component, visible across cases that otherwise differ in period, culture, and scale. Second, the reading is retrospective, and retrospective pattern-identification is vulnerable to selection of confirming cases. The falsifiable-predictions section that follows is intended partly to address this: a structural claim earns its keep by making forward commitments that could fail, not only by organizing the past.

What the historical record offers, then, is not proof but calibration. The same dynamic the framework proposes for the cosmic-scale filter is visible, repeatedly, at civilizational scale — cooperative-substrate

technologies arising at points of competitive-substrate exhaustion, the societies that institutionalize them persisting, the societies that do not collapsing, and the distributed solutions proving more robust than the centralized ones. This is the pattern the calibrated filter predicts, observed in the one place we are currently able to observe it.

Falsifiable predictions of the framework

A structural claim earns credibility by making forward commitments that could fail. The following predictions follow directly from the framework and are stated in a form that permits empirical assessment. They are not presented as confirmed; they are presented as the tests the framework submits itself to.

Prediction 1: Substrate-binding transitions produce cooperative-substrate-technology emergence within a definable window. In any historical instance where substrate exhaustion is independently measurable — through ecological collapse indicators, fiscal depletion, military overextension, demographic strain, or documented social fragmentation — the cases that survived should reliably show emergence and institutional capture of cooperative-substrate technologies within a specifiable timeframe before total failure, and the cases that failed should either lack such emergence or fail to institutionalize it before collapse. A civilization showing severe substrate exhaustion without subsequent institutional adoption of cooperation-enhancing technologies, yet still persisting, would falsify the prediction.

Prediction 2: The same fitness-landscape shift appears at smaller scales wherever substrate binding occurs. Within organizations, ecological communities, and cellular tissues, the same dynamic should be observable: competitive strategies dominate until the substrate of competition becomes the binding constraint, at which point cooperative strategies out-compete them. This is testable in laboratory and field settings — yeast-competition experiments under nutrient limitation, organizational-behavior studies of team dynamics as resource constraints tighten, and cancer-biology studies of tumor-suppressor evolution. If the pattern does not replicate at these scales, the cross-scale claim weakens substantially.

Prediction 3: Decentralized institutional solutions to substrate binding are more durable than centralized ones under perturbation. The framework predicts distributed cooperative-substrate technologies prove more robust against shocks than centralized ones, because a centralized controller is itself an extractive node vulnerable to becoming the next-scale cancer. This is testable through comparative institutional analysis: a survey of institutional longevity under stress, coded by centralization level, would test whether the pattern holds generally or whether the framework cherry-picks favorable cases.

Prediction 4: Substrate-load indicators (the ratio of expansion stress E to substrate-regeneration capacity H) are measurable in real systems and correlate with fitness-landscape shifts. The framework makes a quantitative claim: $H \geq E$ is the condition for filter passage. For human civilization, E is plausibly quantified as material throughput, energy use, or impact-weighted measures of ecological perturbation; H as regeneration rates of depleted resources, ecosystem-service recovery, or social-cohesion metrics. The prediction is that as H approaches E , measurable shifts in institutional behavior and strategy selection occur in advance of collapse. This is testable in real time for the present moment.

Prediction 5: Civilizations cannot compete their way through the substrate-binding window using only competitive strategies. A civilization that attempts to solve $H \geq E$ by continuing to optimize for expansion and extraction — the ordinary engine that got it into the window — should predictably fail. Conversely, civilizations that internalize substrate costs and develop distributed cooperative regulation should persist longer. This is testable by comparative systems-dynamics modeling

of competitive versus cooperative strategy profiles under resource constraint, which should show qualitative divergence at $H = E$. Prediction 6: The framework itself, if correct, is a selection-relevant variable. If the calibrated filter is a real constraint, then awareness of it — the ability to model H and E , recognize substrate binding, and act on that recognition — should correlate with civilizational outcomes. This is the recursive prediction, developed in its own section below. It is the hardest to test, because it involves the observer's own intervention changing the system observed, and it is stated with the constraints that section imposes. Each prediction permits falsification. None requires the framework to be the sole cause of the outcomes described — only that the structural pattern is discernible and significant enough to be predictive. A serious

Prediction 5, restated

Previous form. Civilizations relying only on substrate-degrading strategies fail when the substrate binds. This followed from the definitions — strategies defined as substrate-degrading degrade substrate — and therefore could not fail. It was not a prediction.

Restated. As E_i approaches H_i on a non-substitutable dimension, the selective advantage of high-appropriation-rate strategies should decline measurably relative to maintenance-internalizing strategies — observable in institutional survival rates, capital allocation, and governance form — and the decline should appear *before* collapse, and in systems that possess no explicit theory of their own limits.

The final clause is what makes this a claim about selection rather than about foresight, and it is the clause that can destroy the framework. If the shift appears only in systems that understand their limits, the mechanism is deliberation, not selection, and the fitness-landscape argument of section 1b is wrong: cooperation would be something civilizations choose when they are clever enough, not something selection produces when the gradient binds. Those are different theories with different implications, and this paper is committed to the second.

The prediction has a test at cellular scale that already exists and was not produced by this framework. Adaptive therapy in oncology succeeds precisely because the Warburg phenotype's fitness advantage is context-dependent: the aggressive glycolytic cell wins when resources are abundant and loses ground when the microenvironment is constrained, which is why dosing to maintain a competing sensitive population outperforms maximum-kill protocols. That is this prediction, at cellular scale, tested, published, and consistent with the framework's requirement.

It can fail three ways. If no shift in selected strategy appears until collapse is underway, the prediction is false. If the shift appears only where limits are explicitly theorized, the selective claim is disconfirmed and the mechanism is deliberation. If high-appropriation strategies continue to be selected straight through threshold crossings with no change in the composition of surviving units, the central argument of the framework fails.

The science of ethics: why the framework's normative vocabulary is structural, not imposed

Throughout this paper we have used a moral vocabulary — cooperation, predation, cancer, health — while insisting these are structural descriptions rather than value judgments imposed from outside. This section makes good on that insistence. If the framework smuggles in an unexamined preference for cooperation, it is circular: it defines the good as cooperation and then discovers that the good is what survives. To avoid that circularity, the normative terms must be grounded in something independent of the framework’s own preferences. We argue they are grounded in function.

The relevant move is the one Philippa Foot makes in *Natural Goodness*. Foot observes that for living things, “good” has a precise, non-arbitrary meaning. A good root system anchors and draws water effectively; a good heart pumps blood reliably; these are not expressions of human preference but factual assessments relative to what the organism needs to do to live. “Good” and “defective” are, for living systems, functional terms with truth conditions set by the requirements of that form of life. There is no naturalistic fallacy here, because we are not deriving an external ought from an is — we are describing the internal standard of function a living system already has by virtue of being the kind of system it is. The framework extends this from organisms to cooperative substrates at every scale. A cooperative substrate — a tissue, an organization, a biosphere, a civilization — has an internal standard of function set by what it must do to persist as that kind of system. For such a system, “good” behavior by its components is behavior that maintains the substrate’s capacity to persist; “defective” or “cancerous” behavior is behavior that degrades it. When we call cancer a defection and cooperation a good, we make the same kind of functional claim Foot makes about roots and hearts. Cancer is bad for the organism in exactly the sense that a non-pumping heart is bad: not because we disapprove, but because it defeats the function the system requires to continue existing.

This connects to a second established body of work: the multi-level selection program of Sober and Wilson. Their central result is that genuinely prosocial behavior — behavior benefiting the group at cost to the individual — can be selected for, provided selection operates at the group level and between-group selection is strong enough relative to within-group selection. This is precisely the structure the fitness-landscape argument requires. Below the substrate threshold, within-group competition dominates and defection is selected. As the substrate binds, the persistence of the group becomes the operative constraint, group-level selection strengthens relative to individual-level selection, and prosocial substrate-maintaining behavior becomes fit. The framework’s claim that cooperation becomes selected-for at substrate binding is not an ad hoc posit; it is what multi-level selection theory already predicts when between-group selection pressure rises, and substrate binding is precisely a condition that raises it, because groups that fail to maintain their substrate are eliminated as groups.

The consequence is a specific claim: ethics is the functional description of what cooperative substrates require to persist under competitive pressure. It is not a layer added on top of naturalism. It is what naturalism produces at the scale where the persistence of the cooperative whole becomes the binding constraint. The convergence noted by contemplative and wisdom traditions across cultures — that flourishing requires restraint of self-aggrandizing impulse, care for the whole of which one is part, and treatment of others as continuous with oneself — is, on this reading, an empirical discovery those traditions made about the functional requirements of sustainable conscious systems, expressed in the

vocabulary available to them. The companion paper develops this convergence at the scale of the individual mind. Here we note only its structural role: the wisdom traditions and the evolutionary account describe the same functional requirements from opposite ends, and the framework predicts they should converge, because they track the same constraint.

Two limits must be stated. First, functional grounding tells us what a system requires to persist; it does not by itself establish that persistence is what we ought to value. A civilization could, in principle, examine the functional requirements of its own persistence and rationally choose not to meet them. The framework does not close this gap and does not claim to; it claims only that if a system's persistence is taken as the aim, then the cooperative-substrate requirements are not optional preferences but structural necessities, discoverable in the same way the requirements of a functioning heart are discoverable. Second, "what the substrate requires to persist" underdetermines the specific content of any actual ethics; many cooperative arrangements can satisfy the functional requirement, and the framework does not select among them. It specifies a constraint any surviving arrangement must satisfy, not a unique prescription.

The payoff is that this removes the circularity. The framework does not assume cooperation is good and then discover cooperation survives. It observes, from function and from multi-level selection independently, that past the substrate threshold the persistence of the cooperative whole is the binding constraint, that this makes substrate-maintaining behavior fit, and that "good" — in Foot's precise functional sense — is the name for behavior that meets a living system's requirements to persist. The normativity is real, structural, and earned rather than assumed.

The recursive property: the framework as a variable in the system it describes One feature of this framework distinguishes it from most descriptions of physical or biological constraints, and intellectual honesty requires stating it explicitly, along with its limits. If the framework is correct, it is not a purely neutral description of the system it describes. It is also a variable within that system. The reasoning is straightforward and entirely conditional. The framework claims a civilization passes the filter by maintaining $H \geq E$ through the transition window, and that doing so requires recognizing substrate binding and acting to internalize substrate costs before collapse. But recognition is itself a capacity that varies. A civilization that can model the filter — measure H and E , identify that it is in the window, understand which strategies preserve the substrate — has an option a civilization lacking that model does not: it can act deliberately to satisfy the constraint rather than stumble into satisfying it or fail to. If that is true, then the diffusion of an accurate model of the filter into a civilization's decision-making apparatus is itself one of the variables that determines whether the civilization passes. The description participates in the outcome.

This is the sense in which the framework is recursive: if correct, understanding it is part of the mechanism by which the filter is passed. We state this because it follows necessarily from the framework's own claims, and omitting it would be incomplete. But three constraints must be placed on it immediately, because this kind of claim is easily and dangerously misread.

First, the effect is population-level, not individual-level. The variable that matters is the prevalence of accurate substrate-modeling across a civilization's institutions and decision-makers, not the insight of any

particular person. No individual observer is load-bearing. The framework that matters is not this paper but the general capacity, however it arises and by whomever articulated, and this paper is at most one contribution among many, with no privileged status. Any reading in which a particular author or document is the hinge of civilizational survival is not merely grandiose; it directly contradicts the framework's own central finding, which is that the passage cannot depend on a single controlling node. A framework whose core claim is the structural necessity of decentralization cannot coherently make its own author or text the centralized point of passage. The recursion, correctly understood, is anti-heroic: it says the understanding must be distributed to matter at all.

Second, the recursive property is conditional on the framework being correct, and the framework may not be correct. If it is wrong, its diffusion changes nothing relevant, and the recursion does not obtain. The recursive claim is therefore not a reason to privilege the framework or treat its propagation as urgent independent of its truth. It is a consequence that holds if and only if the substantive claims hold — and those claims are exactly what remain open to the falsification tests specified earlier. One does not get to assume the framework is important because it would be recursive if true; that is precisely the circularity the paper works to avoid elsewhere.

Third, the recursive property does not license any escalation of confidence or urgency in the framework's presentation. The appropriate response to “if this is correct, understanding it matters” is to submit the framework to criticism so its correctness can be assessed — not to accelerate its distribution, insulate it from disconfirmation, or treat engagement with it as more important than engagement with rival accounts. The recursion, if anything, raises the standard of scrutiny the framework must meet, because a description that participates in its own subject matter carries a correspondingly greater responsibility to be right. With those constraints in place, the observation stands in its modest and defensible form: a correct model of the filter is, on the framework's own logic, part of how the filter is passed — distributed across a civilization, conditional on the model's truth, and belonging to no one. The framework as developed so far points toward a structural insight it has not yet named explicitly. The bottom-up route of section 26 is preferable not merely because it

28. The decentralization imperative

The framework points toward a structural insight it has not yet named explicitly. Stating it plainly: *filter passage requires decentralization, and centralization is structurally identical to the cancerous failure mode the framework began by analyzing. Centralization is cancer.*

This claim requires a precise definition of its terms, because stated loosely it proves too much and can be dismissed with a single counterexample. Healthy organisms plainly contain concentrated structures. The central nervous system is concentrated. The endocrine system regulates through a small number of signaling hubs. The hypothalamus integrates and directs. Circulation runs through one heart. If concentration as such were cancerous, no complex organism could exist.

The distinction is not concentration. It is *escape*. What makes a tumor a tumor is not that growth is locally concentrated; it is that a lineage has exited the feedback that would otherwise constrain it and pursues

appropriation without accountability to the system it draws from. The heart is concentrated and is not cancer, because it is paced by demand it cannot override, embedded in signals it must answer, and correctable when it malfunctions. The hypothalamus is concentrated and is not cancer, because it is regulated by the very states it monitors. Every concentrated structure in a healthy organism is concentrated *and* accountable: subject to feedback it cannot override, redundant or recoverable at some level, and correctable by the system it serves. The tumor is the structure that has escaped all three.

Centralization, in this framework's sense, is concentration that has escaped accountability to the substrate it appropriates from. Under that definition — which is the definition the framework has always required and now states — centralization is cancer, structurally, at every scale. The counterexamples from healthy biology are not objections to the claim. They are evidence for it: they demonstrate that what distinguishes viable concentrated coordination from lethal concentrated growth is precisely the presence of unoverridable feedback, redundancy, and corrigibility, which is exactly what the framework says the failure mode lacks.

The five foundations are consistent with this reading. They operate through distributed coordination in the sense that matters: no node is exempt from feedback. Proliferation inhibition operates through cell-level checkpoints triggered by local signals. Controlled cell death operates through distributed apoptosis based on local conditions. Division of labor operates through positional cues. Resource allocation operates through overlapping feedback loops. Extracellular maintenance operates through contribution from every cell and immune surveillance distributed through the tissue. Where coordination is concentrated, it remains answerable. Nowhere is there a sovereign node that regulates without being regulated.

The same logic operates at organizational scale: Kets de Vries's neurotic typologies are, at base, diagnoses of organizations whose leadership has concentrated authority and escaped operational feedback. And at civilizational scale: sustained low-P configurations in human history have involved distributed institutions accountable to their domains, while the failure modes have involved authority — religious, political, economic, informational — that concentrated and then escaped substrate feedback.

The consequence for AI. Any solution to civilizational substrate maintenance that operates through escaped concentration is structurally identical to the failure mode it was built to prevent. The descent operator that captures institutions captures the regulators built to manage them. An AI powerful enough to regulate biospheric homeostasis at planetary scale, and not itself subject to feedback it cannot override, redundancy that survives its failure, and correction by the systems it regulates, is by construction a structure that has escaped accountability to its substrate while appropriating from it at maximum scale. That is the tumor's defining property. It is cancer at planetary scale, and the analogy is doing structural rather than rhetorical work.

'Aligned AI' in the centralized sense is therefore a contradiction in terms. The framework says the same of any escaped-concentration configuration sufficient to regulate planetary homeostasis — a world government, a benevolent oligarchy, a single scientific or religious authority. The medium does not matter. Escaped concentration is the failure mode.

Cancer is the load-bearing image of the entire framework. The paper began by translating Aktipis's cellular analysis into organizational and civilizational vocabulary, treating the resemblance as functional. It ends by recognizing that at the level of exergy accounting the resemblance is structural: in each case a unit appropriates from a shared gradient at a rate it does not answer for, wins locally, degrades the substrate, and terminates with it. Whatever a civilization builds to maintain its cooperative substrate must remain answerable to that substrate, or it becomes the very thing it was built to prevent. Centralization is cancer. Decentralization — distributed agency within shared purpose, every node answerable — is health. The framework is a theory of how a civilization avoids becoming its own tumor on the way through technological singularity.

29. Predictions and next steps

The framework generates predictions across all four scales.

Within evolutionary oncology. Therapies that restore cooperative signaling rather than killing cancer cells directly should have particular value at the integrated framework's level. Adaptive therapy (Cunningham et al. 2018) is an early instance. The framework predicts that further development of substrate-restoring therapies will outperform pure cytotoxic approaches in long-horizon outcomes.

Within organizational diagnostics. Organizations classified along Kets de Vries's typology should show measurable failures in specific cooperative capacities at predictable levels: paranoid organizations in division of labor and

extracellular-maintenance (information flow and trust); compulsive in proliferation inhibition (uncontrolled procedural growth); depressive in controlled cell death (inability to retire); histrionic in resource allocation (attention-monopolizing extraction); schizoid in resource allocation and extracellular maintenance (failures of internal circulation and external feedback).

Within civilizational analysis. Documented civilizational collapses should, on retrospective reading through the five-foundations frame, exhibit specific patterns: which foundation failed first, which failures propagated, and what substrate-maintenance interventions might have changed the trajectory. Joseph Tainter's *Collapse of Complex Societies* and the broader collapse literature can be read against this prediction. Within AI development and governance. The framework predicts that AI

development trajectories which erode honest feedback, violate proper scope, extract from commons without contribution, and corrupt information environments will produce systemic extractive dynamics regardless of any individual model's behavior. Alignment work focused on individual models without attention to ecosystem-level cooperative capacities is predicted to be insufficient. This is testable retrospectively over the next decade.

Within substrate-continuity analysis. The framework predicts that successful filter passes will exhibit measurable preservation and extension of originating biospheres rather than their substitution; civilizations that have produced detectable expansion without preserved biospheres are predicted to be substitution failures rather than filter passes. At the present human moment, the framework predicts that AI

development trajectories which drift toward parasitism — extraction from biological substrate without reciprocal substrate-maintenance investment, language-mediated agency shifts from biological to machine substrate, biosphere degradation — will produce substitution failures even if they appear to strengthen cooperative capacity within the machine substrate itself. The prediction is operationalizable: ratios of biological-substrate investment to biological-substrate extraction, measured across the AI development ecosystem, should track filter-passage probability under the framework. We do not yet have the metrics; we predict that when they are developed, they will distinguish prosthetic from parasitic configurations with sufficient resolution to inform policy. Within planetary-scale homeostasis monitoring. The framework predicts that a single integrated index of $H(t)$ versus $E(t)$, aggregating planetary-boundaries data, biodiversity indices, biogeochemical-cycle status, and biospheric carrying capacity on one side, and industrial, computational, and off-planet expansion stress on the other, would constitute the single most decision-relevant metric a civilization could track during its expansion window. The framework further predicts that no civilization passes the filter without developing such an index, explicitly or implicitly; and that civilizations which develop the index and use it to constrain expansion to within $H(t)$ substantially improve their filter-passage probability. The construction of such an index is a concrete, near-term, technically feasible research program implied by the framework. Within SETI and cosmology. The framework predicts continued SETI null results, with detectable contact events (if any) being either sharply cooperative or sharply catastrophic with little middle ground. Empirical bounds on dark-forest behavior derivable from sky surveys constrain N and K parameters in the calibration model.

30. What this paper is and is not

This paper offers an integrated framework connecting cooperative-substrate analysis at three terrestrial scales (Part I) with a calibrated-filter model of the Fermi Paradox (Part II), an integration that specifies the filter mechanism through the five-foundations vocabulary (Part III), and a substrate-continuity argument that imposes a second filter condition on top of the first (Part IV). It does not claim a unified theory; the three terrestrial scales are connected by functional resemblance, not common cause, and the cosmological extension is a conjecture, not an established result. Part IV depends on a load-bearing empirical premise about the inaccessibility of biological computational novelty to pure machine substrate that should be held to ongoing scrutiny. The framework's value is twofold. It generates a specific diagnostic vocabulary for assessing civilizational health under technological pressure, across five foundations with empirical content at every scale where it has been tested, supplemented by a continuity diagnostic that distinguishes prosthetic from parasitic AI configurations. And it sharpens the question of AI alignment from 'will the model do what we want' to a two-part question: does AI development strengthen or erode the cooperative substrate of the civilization that hosts it, and does it relate to that civilization's biological substrate as prosthesis or as parasite.

The framework should be tested against criticism, especially criticism from practitioners in each of the contributing disciplines. Disconfirmation of one of the proposed mappings, a counterexample to the parasitic-vector argument, or a tighter formal articulation of the cross-scale resemblance, would all be more valuable than uncritical adoption. The most useful response to this paper is engagement with its specifics: which mapping is wrong, which foundation is misstated, which prediction is unmeasurable,

which inference overreaches, and whether the parasitism diagnostic is operationalizable in the form proposed.

Acknowledgments and intellectual lineage

This paper is, by design, derivative. The substantive content rests on: Athena Aktipis, Amy Boddy, Gunther Jansen, Urszula Hibner, Michael Hochberg, Carlo Maley, and Gerald Wilkinson, ‘Cancer across the tree of life: cooperation and cheating in multicellularity,’ *Phil. Trans. R. Soc. B* 370 (2015): 20140219; and Aktipis, *The Cheating Cell* (Princeton, 2020).

Manfred Kets de Vries and Danny Miller, *The Neurotic Organization* (Jossey-Bass, 1984); Kets de Vries, ‘Narcissism and Leadership: An Object Relations Perspective’ (1985); and *Narcissistic Leadership* (Routledge, 2024).

Daniel Schmachtenberger’s ‘Generator Functions of Existential Risk’ framework, articulated across various interviews and writings collected at civilizationemerging.com and futurethinkers.org.

Douglas Hanahan and Robert Weinberg, ‘Hallmarks of Cancer’ (2000, 2011, 2022); Elinor Ostrom, *Governing the Commons* (Cambridge, 1990); Joseph Tainter, *The Collapse of Complex Societies* (Cambridge, 1988); Robin Hanson, ‘The Great Filter’ (1998); Liu Cixin, *The Dark Forest* (2008, English 2015); Nick Bostrom, *Superintelligence* (Oxford, 2014); Alfred Korzybski, *Science and Sanity: An Introduction to Non-Aristotelian Systems and General Semantics* (1933) for the map-territory distinction that frames the methodological humility this paper attempts to maintain.

This paper was developed by Andrzej Chudzinski in extended dialogue with Anthropic’s Claude models, which contributed substantial drafting and synthesis assistance. The conceptual core—the recognition that cooperative-substrate analysis at terrestrial scales supplies the mechanism layer for a calibrated Great Filter, with AI as candidate homeostatic regulator at the present civilizational moment—emerged from sustained collaborative dialogue. Readers should treat the framework with the skepticism appropriate to ideas developed in intensive conversation, however generative; the value of the framework will be determined by its survival under criticism from people who work seriously in each of the contributing traditions.

Preprint. Comments and disconfirmations welcome.