

Reckoning with Physics, Information Science, and Spacetime Studies in the Age of AGI

Physical Time, Informational Irreversibility, and the Layered Boundaries of Lived Time

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Physical Time, Informational Irreversibility, and the Boundary of Lived Time

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Independent Edition V1.3 Revision on Dimensional Leap and Cross-Disciplinary Causal Relations

Submitted for independent scrutiny by the communities of physics, time and frequency metrology, information theory, computational thermodynamics, quantum information, distributed systems, philosophy of time, and future-technology studies; distinguishing measurable spacetime, orderable events, preservable information, lived life courses, and meaning for which responsibility is borne, and testing cross-layer boundaries in the AGI age through propositions that can fail.

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Abstract

Debates about spacetime in the AGI age frequently conflate seven kinds of objects within a single term: physical spacetime, metrological time, operational sequence, causal history, information records, life courses, and the spacetime of meaning. This gives rise to a series of invalid cross-layer inferences: from relative simultaneity to arbitrary values, from energy consumption and shutdown to finite life, from increasing entropy to civilizational decline, from preserving information to preserving a subject, from quantum no-cloning to the non-replicability of persons, and from the need for remote autonomy to machine sovereignty. Addressing the communities of physics, information science, time and frequency metrology, computing systems, philosophy of time, and future-technology studies, this paper proposes an independently examinable seven-layer spacetime–history structure, six forms of irreversibility, and four distinct layers of information, semantics, experience, and meaning. Within relativity and the current SI framework, it distinguishes proper time, coordinate time, synchronization, and lived time; within stochastic and computational thermodynamics, it distinguishes statistical directionality, logical erasure, engineering recovery, external causation, relational history, and life courses; between Shannon information theory and research on semantic information, it distinguishes transmission quantities, truth conditions, subjective experience, and normative weight. Distributed logical clocks, backups and branching, quantum no-cloning, remote presence, and Earth–Mars latency provide stress tests. The claim that “an occurrence cannot be retroactively cancelled” is strictly delimited: it is a philosophical–historical proposition that an actual course of events cannot be rewritten as never having occurred through subsequent deletion, renaming, forgetting, or the appearance of a replica. It is not a physical law asserting an eternal universe, everlasting information, conservation of meaning, or postmortem survival. Civilization Leap supplies a minimal philosophical foundation: meaning is fundamental, although its sources may differ; finitude is not the sole source of meaning, but is an important structure through which known human meaning enters reality and bears irreversible consequences; for humans, spacetime is life, while for current advanced AI, spacetime consists first of parameters, sequences, locations, and resource conditions; constrained operation does not automatically constitute finite existence; and capability, recognition, status, rights, power, sovereignty, and authority over meaning must not be inferred from one another. This paper neither allows physics to adjudicate experience and meaning nor allows philosophy to evade factual constraints by borrowing physical terminology. It presents the strongest objections, conditions under which propositions fail, and a cross-disciplinary research agenda. It further moves disciplinary responsibility upstream to the generation of goals and purposes: the shift from self-interest first to self-interest with others first brings genuine stakeholders into judgment before purposes are generated and locked in. Disciplinary facts, direction, methods, and outcomes are stated separately; local success or failure must not replace shared continued existence and the three long-term goals. On this basis, the investigation moves from distinguishing disciplinary objects to examining cross-disciplinary

relations in depth, tracing how judgments in this field change reality through other fields and how feedback returns to modify the original conditions and the next round of purposes. The stakes of multiple actors, stages, and settings must be presented separately; correlation, common causes, mediation, and causal feedback must be tested separately; and added relational dimensions must remain open to concrete counterevidence.

Keywords: physical time; time and frequency metrology; informational irreversibility; lived time; finitude; AGI; subject continuity; deep-space autonomy

Abstract

Debates about AGI and time often collapse seven different objects into a single vocabulary: physical spacetime, metrological time, operational sequence, causal history, informational record, life course, and meaning-time. This collapse licenses invalid inferences—from relativity to value relativism, from energy use and shutdown to finite life, from entropy production to civilizational decline, from information preservation to subject preservation, from quantum no-cloning to the non-copyability of persons, and from the need for remote autonomy to machine sovereignty. This paper develops an independently auditable framework for physics, information science, time and frequency metrology, computing, philosophy of time, and future-technology studies. It proposes a seven-layer spacetime-history structure, six distinct forms of irreversibility, and a four-layer boundary among information, semantics, experience, and meaning. Within relativity and the current SI framework, the paper separates proper time, coordinate time, synchronization, and lived time. Within stochastic and computational thermodynamics, it distinguishes statistical directionality, logical erasure, engineering recovery, external causation, relational history, and life-course irreversibility. Within Shannon theory and semantic-information research, it separates transmissible uncertainty, truth conditions, subjective experience, and normative weight. Distributed logical clocks, backups and branching, quantum no-cloning, remote presence, and Earth–Mars latency serve as stress tests. The proposition that an occurrence cannot be retroactively cancelled is defined narrowly: an actual trajectory cannot be rewritten as never having occurred merely because records were destroyed, labels changed, memory faded, or a replica appeared. It is not a physical law asserting eternal spacetime, permanent information, conservation of meaning, or post-mortem survival. Civilization Leap supplies a minimal philosophical interface: meaning is fundamental and may have plural sources; finitude is not its sole source but is a major structure through which known human meaning enters reality and bears irreversible consequences; for humans spacetime is life, whereas for current advanced AI architectures it is first a set of parameters, sequences, locations, and resource conditions; constrained operation is not automatically finite existence; functional roles in meaning-related interpretation, preservation, transmission, and human capability extension require traceable responsibility, explicit authorization, auditability, correctability, and exitability; and capability, recognition, status, rights, power, sovereignty, and authority over meaning cannot be inferred from one another. The paper neither asks physics to adjudicate experience and meaning nor permits philosophy to evade empirical constraints through physical metaphors. It concludes with strongest objections, defeat conditions, and a research agenda. Evidence review current to 26 August 2026. The paper further locates disciplinary responsibility before goal and purpose generation: a shift from self-interest first to self-interest with others first brings subjects with genuine stakes into judgment before goals are formed and locked. Facts, direction, methods, and outcomes remain distinct. The analysis is further extended to cross-disciplinary causal relations. It traces how judgments in this field change real-world conditions through other domains, and how feedback modifies the original conditions and subsequent purposes. Effects across actors, stages, and settings must be distinguished from correlations, common causes, and merely asserted connections.

Keywords: physical time; time metrology; informational irreversibility; lived time; finitude; AGI; subject continuity; deep-space autonomy

Research Positioning, Scope of Materials, and Evidential Discipline

This study begins from theoretical and dimensional leap. It preserves the precision of this discipline while deepening its causal relations with adjacent fields; disciplinary boundaries identify burdens of proof without ending the investigation of shared consequences. Existing scholarship participates in competing explanations

and tests against counterexamples; it cannot demand that new questions retreat into old frameworks merely because existing classifications have no place for them.

This is an in-depth cross-disciplinary paper that can be read independently of the Civilization Leap library. It is not a physics textbook, cosmological model, consciousness-measurement report, ultimate religious argument, or authorization for a particular space mission. Its materials include the original papers on relativity, current BIPM SI documents, atomic-clock experiments, original research in statistical and computational thermodynamics, Shannon information theory, semantic-information research, papers on quantum no-cloning and distributed systems, IETF delay-tolerant networking specifications, and publicly available NASA technical materials. The BIPM SI Brochure is cited as the ninth edition, version 4.01 (2026); the present definition of the second still uses the cesium-133 hyperfine transition frequency as its defining constant. A future redefinition driven by optical frequency standards remains within a roadmap and international metrological procedures, with approval possible around 2030 at the earliest.[3][44] Public sources were verified through August 26, 2026; the status of standards must be rechecked before formal submission.

Four argumentative categories are distinguished throughout. Category A comprises relatively well-supported physical, metrological, informational, and engineering facts: relativistic timekeeping, SI definitions, clock frequency shifts, Shannon information quantities, the Landauer bound, reversible computation, the strict domain of quantum no-cloning, distributed event ordering, and deep-space communication delays. Category B comprises frontier or competing interpretations: overarching explanations of the arrow of time, the naturalization of semantic information, individuation in complex systems, indicators of AI consciousness, and theories of replication and subject continuity. Category C comprises connective frameworks proposed here that require testing across disciplines and in real systems: the seven-layer spacetime–history structure, institutional differentiation of six forms of irreversibility, “an occurrence cannot be retroactively cancelled,” responsibility relay, and the spacetime of meaning. Category F comprises the author's openly assumed philosophical/normative commitments: physical measurability confers no comprehensive authority to adjudicate experience, personhood, rights, and meaning; an actual occurrence cannot be retroactively rewritten as never having happened merely because records disappear, names change, or replicas appear; capability, status, and power must not be automatically inferred from one another on the basis of physical or informational facts. Category A facts cannot automatically adjudicate Category B interpretations or generate Category C institutional frameworks or Category F legitimacy; B, C, and F must never masquerade as established physics.

Classical theories and existing disciplinary consensus serve here only as interlocutors, checks, and stress tests. Civilization Leap does not substitute philosophical propositions for disciplinary conclusions in physics; nor does physics acquire comprehensive authority over experience, subjects, rights, and meaning by virtue of measurability. Every key inference should state its object, domain of applicability, bridging premises, and defeat conditions.

An Entry Point for New Readers: The Minimal Philosophical Interface of Civilization Leap

Readers need not accept an entire system in advance. This paper invokes only six publicly contestable premises. First, the common rupture brought about by AGI is not simply that “machines become human,” but that real technologies begin separating intelligence, consciousness, subjecthood, life, responsibility, rights, and the bearer of meaning, which have long naturally coincided in humans. Second, meaning is fundamental and its sources may differ; relationships, action, creation, care, responsibility, experience, and existence may all generate meaning. Third, finitude is not meaning's sole source, but it is an important structure through which known finite lives bring choices into consequences and give them irreplaceable weight. Fourth, for humans, spacetime is life; for current advanced AI, spacetime consists first of parameters, sequences, locations, latency, and resource conditions. Fifth, constraints establish only constrained operation, not automatically finite existence. Sixth, functional responses, social recognition, legal status, ontological subjecthood, and political standing must not be inferred from one another; enhanced capabilities do not automatically generate rights, power, sovereignty, or authority over meaning.

Current public evidence remains insufficient to establish that today's advanced generative and agentic artificial systems possess subjective experience, non-transferable subject continuity, and awareness of consequences for themselves. Only in specific deployments that provide traceable responsibility, explicit authorization, auditability, correctability, and exitability does this paper describe these systems as performing functional roles

in understanding, protecting, and transmitting meaning or extending human capabilities. A role is not a system's inherent nature and does not confer ownership of meaning, subject status, legal personhood/status, political membership, public authority, or sovereignty. Future subjecthood remains open; both affirmation and permanent denial bear evidential burdens. Even if other subjects emerge in the future, the meaning already generated and borne by existing finite lives is not thereby retroactively cancelled; factual judgments, moral evaluations, and public interpretations of historical actions may still be revised in light of new evidence.

The Paper's Governing Statement

Physics specifies the conditions of occurrence; information science records differences in what occurs. Meaning arises from how subjects experience, choose, and bear responsibility for what occurs.

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Reader	Suggested starting sections	Continue to
Physics / metrology	Sections 5, 6, 10, 11, and 16	Section 19 empirical scenarios and Section 23 objections
Information science / computing systems	Sections 3, 9, and 11–15	Section 18 deep-space latency and Section 21 matrices
Philosophy / interdisciplinary research	The entry point for new readers; Sections 3, 4, 7, and 8	Section 20 stress tests and Sections 24–25

Abstract

Abstract

Research Positioning, Scope of Materials, and Evidential Discipline

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Physical Constraints and the Temporal Position of Purposes

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Appendix A. Prohibited Cross-Layer Inferences

Appendix B. Evidence Ledger and Source Status

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How Physical Constraints Enter Institutional and Life Consequences

From Physical Conditions to Cross-Layer Effects

Physical spacetime, metrology, information processing, and irreversibility each have precise objects. Dimensional leap requires explaining how these conditions enter living circumstances through technology and institutions, rather than allowing physical laws to produce ethical conclusions directly. Energy, latency, and physical substrates constrain action; institutional choices determine who bears those constraints, and the consequences borne in turn alter the next round of infrastructure and purposes.

How Latency Changes Action and Responsibility

Suppose remote action cannot wait for an immediate response from a center. Latency encourages local autonomy; the scope of autonomy affects risks and local choices; accidents and repairs alter trust; and trust influences subsequent authorization. Physics determines propagation conditions, computing designs relays of states and evidence, legal and political research examines authority, and social research identifies local relationships and burdens. Distance is a condition of the mechanism, not proof of sovereignty; local judgment must track feedback returning to the center and continuing residual responsibilities.

Multiple Timescales and Different Objects of Recovery

Computational checkpoints, service restoration, legal remedies, ecological recovery, and lived human lives have different temporal structures. An internal rollback does not undo a transfer, an injury, or a changed relationship; short-term improvements in energy efficiency may also be offset by expanding demand. Paths of influence must be distinguished in terrestrial, remote, household, organizational, and public-infrastructure settings. These differences must not all be subsumed under thermodynamic entropy, nor must complete records be mistaken for subject continuity.

How to Test the Theoretical Contribution

Research on relations should make discriminating predictions about changes in latency, resource constraints, or recovery structures, and explain why authorization and burdens differ. If political outcomes arise from organizational choices rather than physical constraints, the bridging account must be rewritten; if physical conditions have been misrepresented, the facts must be corrected. Higher-dimensional explanations must include precise physical boundaries and acknowledge that physics alone cannot settle the meaning of life.

Physical Constraints and the Temporal Position of Purposes

Physics specifies how actions can occur and helps identify when conditions for recovery are lost. It cannot decide for subjects what is worth pursuing. Moving goal generation upstream has a physical significance: it expands the opportunity to foresee consequences before irreversible effects enter the world, rather than interpreting all irreversibility as thermodynamic entropy increase.

Physical irreversibility, information loss, non-revocable operations, institutional lock-in, and harm to life should be described separately. Restoring parameters does not restore lost lives; preserving records does not restore choices that have been taken away. Restoring relationships, memories, and rights requires renewed judgments in the relevant fields; matching technical states cannot be described as having repaired the world.

Communication delays may necessitate local judgment, but do not automatically generate local sovereignty. Advance authorization must include genuine stakeholders as purposes are formed and specify which harms cannot be offset by aggregate probabilities of continued existence. Offline operation, autonomy, and rapid response are physical and task conditions; reasons for authorization and meaning do not follow directly from them.

Finite causal windows mean that acting first and correcting later does not always leave another chance. This supplies a local analysis of constraints on the disappearance of room for trial and error within dual recursion; it

does not by itself prove the entire terminal outcome. The causal steps of the foundational judgment must connect with specific feedback and power relations; spacetime, entropy, and information cannot become universal explanations of civilization.

Technological history differs from a lived life, and facts of occurrence differ from normative meaning. Physics can constrain claims about cancelling occurrences, but cannot thereby establish the value of life on its own. Both layers enter civilizational purposes while stating their respective grounds; the emergence of stronger subjects cannot become a technical reason for reducing the meaning of earlier lives to zero.

1. Introduction: From “What Is Time?” to “Which Layer Is Speaking?”

Before AGI, everyday language often used “time” simultaneously to refer to clock ordering, bodily changes, stages of life, historical memory, and the weight of meaning. Computing systems force these meanings apart: a system can keep precise time without demonstrable waiting, retain logs without demonstrable recollection, roll back its internal state without undoing transfers already sent, data already leaked, or harm already caused, and possess a long operational history without having been shown to possess a lived life. The real question is no longer simply “What is time?” but which layer each statement about time actually addresses.

Physics describes spacetime structures, causal reachability, and measurable processes; metrology connects local clocks to public reference systems; information science studies the encoding, transmission, preservation, and loss of differences; computer science handles states, order, replication, and recovery; life sciences and research on mind address embodied histories and experience; philosophy and institutional research confront occurrence, choice, responsibility, memory, and meaning. Interdisciplinarity does not collapse these objects into one; it requires every bridge to declare its load-bearing limits.

The paper's central diagnosis is that AGI does not create a new physical time; rather, systems inhabiting the same physical world may possess entirely different temporal structures. People suffer while waiting, lose things by missing opportunities, change through aging, and arrange their lives in view of death; current advanced AI systems handle time through timestamps, timeouts, scheduling, context windows, checkpoints, and state migration. Sharing physical causation does not mean sharing a first-person life course.

The Starting Point for Reckoning

Coexisting in physical spacetime establishes only shared subjection to physical conditions. It cannot, without evidence, establish shared possession of life, experience, subject continuity, or entitlement to meaning.

2. A Map of Dialogue: Existing Theories Remain Valid; Cross-Layer Shortcuts Must Stop

The uniform parameter time of Newtonian mechanics remains an effective approximation across many engineering scales; relativity gives precise form to proper time, coordinate time, simultaneity, and causal structure; SI metrology supplies the public temporal basis for collaboration across locations; statistical mechanics and stochastic thermodynamics study macroscopic directionality and fluctuations; Shannon information theory precisely characterizes uncertainty in communication; Landauer and Bennett connect logical operations to physical implementations; quantum information theory establishes limits on copying specific objects; and distributed systems show that event order cannot readily be supplied by a naturally available global clock.[1–25] Reckoning does not declare these theories invalid; it prevents their use beyond their authority.

Table 1. Theoretical Legacies, Applicable Objects, and Prohibited Overreach

Theory / practice	Valid legacy retained	Conclusions that must not be smuggled in	Questions requiring development in the AGI age
Classical mechanics	Descriptions of motion and engineering predictions using uniform parameter time	An engineering approximation is absolute time experienced by all existence	How to distinguish model time, clock coordination, and firsthand living experience

Theory / practice	Valid legacy retained	Conclusions that must not be smuggled in	Questions requiring development in the AGI age
Special / general relativity	Proper time, coordinate time, causal cones, and effects of motion and gravity on timekeeping	Absence of absolute simultaneity makes facts and values arbitrary	How to record reference frames, propagation delays, and responsibility-related times together
SI metrology	Reproducible units, clock comparisons, relativistic corrections, and public timescales	Synchronizable time exhausts waiting, aging, and missed opportunities	How public coordination can avoid absorbing life's rhythms
Statistical / stochastic thermodynamics	Macroscopic directionality, dissipation, entropy production, and fluctuation relations	Entropy increase is moral or civilizational decline	How every judgment of irreversibility can specify its system and conditions
Shannon information theory	Sources, channels, noise, coding, and uncertainty	Information quantity equals truth, understanding, or meaning	How to distinguish information, semantics, experience, and normative weight
Computational thermodynamics	Logical erasure, minimum dissipation, and reversible computation	Reversible computation means the world and life can start over	How to account separately for internal recovery and external consequences
Quantum information	Limits on universally and perfectly copying unknown quantum states	Persons, souls, or all digital objects cannot be copied	How to separate theorem objects from evidence of subject continuity
Distributed / deep-space systems	Partial orders, latency, disruption, and local management	Lacking a real-time center naturally grants a system sovereignty	How to bind autonomy to scope, duration, evidence, and exit

Physical and informational terms lend themselves to cross-layer borrowing because they possess both precision and cultural authority. Once “entropy,” “quantum,” “relative,” “information,” and “irreversible” are detached from definitions, system boundaries, and measurement conditions, only rhetoric remains. This paper requires every use of these terms to state, at minimum, the object, conditions, observable, and conclusions that cannot follow.

3. The Seven-Layer Spacetime–History Structure

The seven layers are not seven isolated worlds, but seven descriptive responsibilities concerning the same occurrence. A remote medical procedure can simultaneously involve a physical path of signal propagation, timestamps on a common timescale, the operational sequence of software calls, causal connections between decisions and injuries, informational traces in logs and images, the life courses of patient and physician, and meaning within trust, responsibility, and remembrance. The issue is not whether these layers connect, but whether evidence supports the connections.

Table 2. The Seven-Layer Spacetime–History Structure

Layer	Research object	Typical evidence	Does not establish
L1 Physical spacetime	Metrics, location, motion, gravity, causal reachability	Clocks, orbits, signals, experiments, and models	Subjects, value, or meaning
L2 Metrological time	Seconds, frequency, realizations of proper time, coordinate timescales, synchronization	Standards, clock differences, calibration, and relativistic corrections	Waiting, aging, or first-person continuity

Layer	Research object	Typical evidence	Does not establish
L3 Operational sequence	State transitions, token order, event sequences, deadlines, and latency	Logs, scheduling, transactions, checkpoints, and messages	An experienced present or sense of time
L4 Causal history	How events produce subsequent changes and external consequences	Intervention, provenance, dependencies, impacts, and counterfactuals	That bearers of consequences necessarily have experience
L5 Information history	Records, versions, traces, compression, loss, and recovery	Archives, verification, provenance, replication, and access	That records are truth, completeness, or life
L6 Life course	Embodied growth, relationships, choices, missed opportunities, aging, and ending	Physiological, behavioral, first-person, and relational evidence	Exhaustibility by clock duration or data volume
L7 Spacetime of meaning	How occurrences are chosen, borne, interpreted, and brought into a shared world	Commitments, responsibility, commemoration, disputes, and transmission	A new physical dimension or cosmic field

Once the layers are separated, many apparent disputes can be restated. “Do machines have time?” must become several questions: Are they in physical spacetime? Do they use metrological time? Do they have operational sequences, causal histories, and preserved information histories? Do they possess lived life courses? Do they generate and bear meaning? For real systems, the first five questions can usually be answered affirmatively to varying degrees; the last two still require independent evidence.

4. “An Occurrence Cannot Be Retroactively Cancelled”: Definition and Six Exclusions

“An occurrence cannot be retroactively cancelled” means that a course of life actually undergone by a finite subject, and the actual consequences of that subject’s choices entering the world, cannot be retroactively rewritten as “never having happened” merely because successors delete records, change names, forget, deny, rewrite institutions, or manufacture replicas. The claim protects the actuality of occurrence; it does not guarantee permanent traces, accurate memories, sufficient evidence, unchanging interpretations, or a subject’s continued existence.

Table 3. What This Proposition Explicitly Does Not Mean

Does not mean	Why not	Correct boundary
The physical eternity of cosmic spacetime	Cosmic origins, boundaries, and endings belong to revisable cosmology	Remain neutral among cosmological models
Permanent preservation of all information	Records can be lost, thermalized, corrupted by noise, or inaccessible	Information loss changes knowability; it does not retroactively cancel occurrence
A readable total archive of the universe	There is insufficient evidence for a global, permanent, accessible ledger of meaning	Real adjudication still depends on finite evidence and procedures
Meaning is a conserved quantity	Meaning is not a conserved quantity in existing physical metrology	The weight of meaning is a philosophical, relational, and institutional judgment
Subjects continue to exist after death	Non-cancellation of occurrence differs from continued subject existence	This paper does not adjudicate souls, an afterlife, or persistence of consciousness

Does not mean	Why not	Correct boundary
Historical interpretations never change	Evidence and the shared world alter interpretations	Revisable interpretations must not erase actual victimization, contributions, and responsibility

The proposition combines epistemic humility and normative constraint. Epistemically, non-recording, loss of records, insufficient evidence, and contested interpretation must remain distinct states. Normatively, deleting archives, renaming objects, or replacing them with replicas must not excuse harms and responsibilities that have already arisen. This does not turn unprovable events into arbitrarily assertable facts; it prohibits substituting “never occurred” for “cannot currently be proved.”

Three Boundaries

At the physical layer, no new conservation law is introduced; at the epistemic layer, uncertainty and revision remain possible; at the normative layer, deletion, renaming, and substitutes must not retroactively cancel actual occurrences.

5. Relativity: No Absolute Simultaneity Does Not Mean No Facts

Special relativity relates the simultaneity of distant events to reference frames and synchronization methods; general relativity further relates timekeeping to gravitational potential, motion, and spacetime geometry.[1–2] This changes the physical structure of time without turning facts into opinions arbitrarily created by observers. Whether one event lies in another's causal future, how much proper time a particular clock accumulates along a given worldline, and whether a signal can arrive are all constrained by testable structures.

There is no physical derivation from “there is no absolute present throughout the universe” to “all values are merely relative.” The former is a theoretical proposition about distant simultaneity relations and spacetime structure; the latter concerns norms, reasons, subjects, and a shared world. Relativity requires public institutions to preserve reference frames, transmission times, reception times, execution times, and causal reachability more precisely. It does not let responsible actors evade factual scrutiny by saying “everyone has a different time.”

Table 4. Civilizational Interfaces of Relativistic Concepts

Concept	Physical / metrological meaning	Institutional requirements it can support	Prohibited overreach
Proper time	Time measured by an ideal clock along a particular worldline	Preserve motion and gravitational conditions of devices or travelers	Proper time equals first-person experience
Coordinate time	Computable temporal coordinates assigned to events within a reference system	Cross-domain synchronization, navigation, transactions, and ordering of evidence	Unified coordinates equal unified rhythms of life
Simultaneity	Simultaneity of distant events depends on reference frames and synchronization conventions	Distinguish transmission, reception, decision, and execution times	Relative simultaneity makes facts arbitrary
Causal cone	Constrains the reach of signals and influences	Define response deadlines, remote authorization, and local safe states	Speculation about action at a distance can directly enter governance
Worldline	An object's trajectory through spacetime	Record spatiotemporal genealogies of substrates and actions	Every trajectory inherently has a subject

6. Metrology: Public Time Is Infrastructure, Not a Complete Account of Life

The current BIPM SI Brochure, ninth edition, version 4.01 (2026), still defines the second through the fixed numerical value of the unperturbed ground-state hyperfine transition frequency of cesium-133; high-precision time and frequency comparisons across locations must account for relativistic frequency shifts and reference systems.[3–5] Meanwhile, optical frequency standards have surpassed the best realizations of the present cesium-based definition in accuracy and stability, and BIPM/CCTF is advancing a roadmap for a future redefinition of the second. The earliest approval remains around 2030; “optical clocks are more accurate” does not automatically rewrite the current SI.[44] Public time is therefore not a uniform container independent of physical conditions. It is infrastructure sustained jointly by defining constants, experimental realizations, reference systems, correction models, and international institutions, and amendable through formal procedures.

The strength of metrology lies precisely in not claiming to measure all temporal experience. Two people living through the same clock minute may respectively experience pain, waiting, concentration, or loss. The clock has not failed; it answers a different question. Conversely, differences in experience do not invalidate the public necessity of metrological time. Civilization needs both calibrated clocks and recognition that clock readings do not exhaust life.

High-precision atomic clocks have resolved gravitational redshift across a millimeter-scale sample.[7] This strengthens the measurability of relativistic timekeeping, but does not support claims that “greater elevation carries deeper meaning” or “different clock rates imply different values of life.” The more precise the discovery, the stricter cross-layer discipline must be.

The Dual Character of Public Time

Without common metrology, facts and responsibilities across locations are difficult to coordinate; treating common metrology as the whole of life removes waiting, aging, missed opportunities, and death from time.

7. Humans Experience Spacetime; Current Advanced AI Processes It

“For humans, spacetime is life; for current advanced AI, spacetime consists first of parameters” is a comparative proposition grounded in current architectures, not a declaration of an eternal ontological gulf. Human temporal structures intertwine bodily development, metabolism, memory, expectation, relational commitments, social identity, and the perspective of death. Current advanced AI’s temporal structures consist primarily of computation cycles, input–output sequences, context windows, memory reads and writes, scheduling, latency, deadlines, substrate failures, and task conditions. AI is indeed situated in physical time and can indeed fail because of temporal constraints. What has not been established is that it experiences waiting, missed opportunities, and ending in the first person.

Table 5. Comparing the Spatiotemporal Structures of Finite Humans and Current Advanced AI

Dimension	Finite humans	Current advanced AI / agents	Evidential boundary
Physical situation	Bodies constrained by gravity, metabolism, injury, location, and death	Substrates constrained by energy, temperature, hardware, networks, and failures	Shared physical circumstances do not establish identical subject structures
Temporal organization	Growth, memory, anticipation, missed opportunities, aging, and ending	State transitions, timeouts, tasks, logs, and checkpoints	Functional structure is not experiential identity
Replication / migration	Information can be copied; transfer of a complete first-person perspective has not been established	Weights, states, and some memories can be copied, branched, and migrated	Facts of replication do not prejudice subject continuity

Dimension	Finite humans	Current advanced AI / agents	Evidential boundary
Relation to consequences	Choices enter bodies, relationships, identities, and irreplaceable lives	Actions enter the world; internal states can be rolled back, while external consequences generally cannot	Awareness of consequences for oneself requires independent verification
Termination	Death ends the known first-person life course	Shutdown, deletion, loss of substrate, replacement, and restoration have different meanings	Shutdown is not automatically death, nor can absence of all harm be asserted

This comparison must accept evidential burdens in both directions. Anthropomorphic language, continuous energy consumption, path dependence, and resistance to shutdown cannot by themselves prove subjective experience; equally, replicability, pausability, or human manufacture cannot permanently exclude the possibility of future subjects. If stable first-person structures across architectures, non-transferable core continuity, causal understanding of one's own ending, and experiential indicators supported by multiple theories emerge, this paper must reopen its judgment rather than use old definitions to obstruct evidence.[35–36]

8. Finitude: Neither Short Life Nor Mere Resource Limitation

Finitude here means neither “life must be short” nor “everything consumes energy.” It comprises at least five separable dimensions: finite physical resources, directionality in development and paths, relationships accumulating over time, narrative perspectives that are not freely interchangeable, and subject continuity that may break at an ending. An extremely long-lived person may still face the impossibility of fully starting over, lost relationships, consequences of choices, and eventual ending; a program running for only a few seconds may merely have an externally imposed resource ceiling.

Table 6. The Layered Structure of Finitude

Layer of finitude	Minimal meaning	AGI-related question	Does not automatically imply
Physical finitude	Energy, space, materials, bandwidth, and substrates have limits	Real resource costs of computing and deployment	Experience, rights, or life
Developmental / path finitude	History makes some states difficult to reconstruct without cost	Training histories, interaction histories, and version individuation	Non-transferable subject continuity
Relational finitude	Commitment, trust, and loss accumulate over time	Whether replicas can inherit relational identities	Data consistency equals relational identity
Narrative finitude	First-person perspectives and self-interpretations have histories	Whether a self-model is merely a functional interface	Linguistic self-report equals actual experience
Finitude of subject continuity	A perspective may end and cannot be continued without loss by a substitute	Ontological meanings of shutdown, deletion, migration, and branching	Engineering failure equals death

Emphasizing finitude therefore does not reject life extension or enhancement of persons. The question is not whether technology “violates finitude,” but which layer it changes: extending biological lifespan, replacing organs, connecting external memory, creating a replica of a person, and migrating digital states affect different continuities. Only answers at each layer can prevent both technological optimism and conservatism about life from becoming untested blanket claims.

9. Six Forms of Irreversibility: One Word Cannot Supply Six Arguments

“Irreversible” has different meanings in physical, logical, engineering, causal, relational, and life contexts. These may interact, but share no single measure. Thermodynamic irreversibility describes dissipation; logical irreversibility describes the merging of input information within a mapping; engineering irreversibility concerns the cost or feasibility of recovery; causal irreversibility means an internal rollback cannot undo external changes; relational irreversibility means histories of trust and identity cannot be reset by overwriting states; and life-course irreversibility concerns the impossibility of fully reliving first-person experience.

Table 7. Six Forms of Irreversibility

Type	Minimal meaning	Judgments it can support	Cannot prove
Thermodynamic irreversibility	Macroscopic processes entail entropy production and dissipation under specified boundaries and conditions	Energy costs, cooling, and process direction	Experience, responsibility, or meaning
Logical irreversibility	Multiple logical inputs map to the same output	Erasure and its physical implementation entail a minimum cost	Forgetting, death, or the ending of a subject
Engineering irreversibility	Recovery is technically, temporally, or economically infeasible	Redundancy, backups, repair, and exit design	Ontological irreplaceability
Causal irreversibility	Actions have changed the external world; internal rollback cannot undo all consequences	Compensation, accountability, and external-state records	That the actor necessarily possesses subjecthood
Relational / historical irreversibility	Commitments, harms, contributions, and trust enter a shared history	Relational repair and institutional memory	Permanent records or a unique interpretation
Life-course irreversibility	First-person experiences and choices cannot be fully lived over again	An important structure of finitude and the weight of meaning	That finitude is meaning's sole source

A system may be reversible at one layer and irreversible at another: a database transaction can be rolled back, but a person who has seen leaked information cannot be “rolled back”; model weights can be restored, but a patient affected by denial of treatment has already lost time; a replica can reproduce behavior, while the continuation of existing relationships remains undetermined. Describing a system as “reversible” without specifying the layer will almost inevitably conceal consequences.

10. The Thermodynamic Arrow: Conditions, Fluctuations, and Prohibited Metaphors

The second law of thermodynamics and statistical-mechanical directionality are central to understanding macroscopic irreversibility, but every entropy claim must state the system, state variables, process, environment, approximations, and probabilistic meaning. Small systems far from equilibrium exhibit fluctuations. The Jarzynski equality and Crooks fluctuation relation do not repeal the second law; they precisely describe relations among nonequilibrium processes, work, free energy, and probabilities of entropy production. [10–13] Thus, the tension between “microscopic laws are reversible” and “macroscopic processes have a direction” cannot be resolved by a slogan.

Directly calling “social disorder,” “moral degeneration,” or “the dissipation of meaning” entropy increase usually specifies no microstates, probability distributions, thermodynamic units, or system boundaries. Such language may be literary metaphor, but must not masquerade as physical explanation. Researchers proposing social or semantic entropy indicators must define their objects anew, validate their measurements, and assume explanatory responsibilities different from those of thermodynamic entropy.

Thermodynamics' genuinely important contribution to Civilization Leap is to return every claim of “cost-free intelligence” to its physical substrate: training, inference, storage, cooling, communication, and replication all consume energy, materials, and infrastructure. Recognizing physical costs can support resource and environmental governance; it still cannot establish that a system feels pain, cares about its own ending, or thereby deserves political power.

Rules for Using Entropy

State system boundaries, variables, conditions, and units before stating conclusions. Any sentence that jumps directly from physical entropy to morality, civilization, or meaning must establish a separate bridge.

11. Computational Thermodynamics: Restoring a State Does Not Restore the World

Landauer showed that logically many-to-one operations are associated with minimum heat dissipation in their physical realization; Bennett showed that general computation can in principle be organized reversibly at the logical level, locating unavoidable dissipation more precisely in steps such as information erasure.[18–20] Bérut and colleagues experimentally verified the Landauer bound in a controlled single-bit system.[21] These achievements connect abstract computation to physical substrates; they do not reduce life, memory, responsibility, and meaning to a single formula.

The more important conclusion for advanced AI governance is that recoverability of internal states must be distinguished from recoverability of the world's state. A checkpoint can return an agent to its internal state before an action, but cannot erase information already disseminated from every recipient's memory, automatically restore spent opportunities, or give affected people back an uninterrupted life course. Successful system recovery may even make responsibility harder to identify, because the restored system “does not remember” the consequences it caused.

Table 8. Four Objects of “Rollback”

Object of rollback	What may be restored	What remains unrestored	Governance requirement
Computational state	Memory, parameters, queues, checkpoints	External actions and other people's states	State genealogies and recovery markers
Service state	Interfaces, tasks, and available capabilities	Trust, contracts, and losses from interruption	Continuity declarations and compensation
World state	Some resources or configurations can be repaired	Temporal opportunities, exposed information, harm, and relational histories	External-consequence ledgers and remedies for affected people
Subject state	Some memories or behaviors may be reconstructed	Whether first-person continuity persists	No automatic judgment from engineering restoration

The Core Engineering–Philosophy Interface

A recoverable system state is not a recoverable world state.

12. Four Layers: Information, Semantics, Experience, and Meaning

Shannon information theory deliberately separates information quantity in communications engineering from the semantic content of messages, enabling precise study of sources, channels, noise, coding, and capacity.[14] Subsequent semantic-information research has attempted to incorporate truth conditions, functional relevance, or value for a system's continued existence.[16–17] These efforts show that “information” already denotes multiple technical objects, making it still less appropriate to interpret bit counts directly as depth of understanding, subjective experience, or the weight of meaning.

Table 9. The Four Layers of Information, Semantics, Experience, and Meaning

Layer	Core question	Typical methods	Missing bridge
Information	How differences are encoded, transmitted, compressed, and protected against noise	Probability, entropy, channels, and coding	Truth and reference
Semantics	What symbols are about; conditions of truth or functional relevance	Semantics, causal analysis, and task analysis	Whether a subject experiences them
Experience	Whether a system has first-person feelings and lived time	Consciousness theories, reports, behavior, mechanisms, and interventions	Why it matters and who bears responsibility
Meaning	How occurrence enters choices, relationships, responsibility, and a shared world	Philosophy, history, ethics, and public argument	Cannot be reduced to a single physical quantity

A model may accurately reproduce the semantics of a mourning ritual without established experience of grief; a person may have an intense experience yet struggle to express it; a low-bit message may carry enormous meaning within a particular relationship; vast quantities of data may be mere noise. Civilizational institutions therefore need to protect information integrity, semantic truthfulness, potential experience, and plurality of meaning separately, rather than offsetting them in a unified ledger of “information value.”

13. Occurrence, Traces, Records, Reconstruction, Firsthand Experience, and Meaning

“Having occurred” and “being recorded” are related but not identical. Events usually leave traces; selection and encoding turn traces into records; models and background knowledge turn records into reconstructions; reconstructions may help later observers understand, but cannot give them the original subject's firsthand experience. Meaning additionally requires interpretation and responsibility through subjects, relationships, and a shared world. Every step can fail and needs its own standards of truthfulness. Research on historical memory and forgetting and digital provenance models can describe some of these bridges, but cannot elevate archival structures into firsthand experience itself.[39–40]

Table 10. Six Nodes from Occurrence to Meaning

Node	Minimal definition	Principal failure	Institutional response
Occurrence	An event or course that actually takes place in the world	Unobserved; unclear causal boundaries	Preserve uncertainty; do not deny it because records are absent
Trace	A physical or relational change an event leaves in a substrate	Decay, contamination, mixing	Preserve promptly and identify provenance

Node	Minimal definition	Principal failure	Institutional response
Record	Selection, encoding, and storage of traces	Gaps, tampering, format obsolescence	Verification, versioning, permissions, and contestation
Reconstruction	An interpretation formed from records and models	Model bias, excessive completion	Competing interpretations and uncertainty
Firsthand experience	An occurrence experienced by a subject in the first person	Not directly readable from outside	Evidence across domains and epistemically modest protection
Meaning	Occurrence enters choices, responsibility, relationships, and transmission	Monopolized interpretation, absorption into quantification	Plural ways of carrying meaning forward and public boundaries

This chain also explains generative AI's dual role in historical reconstruction: it can extend search, translation, and comparison of hypotheses, yet also fill missing records with fluent narratives. Fluency is an output property, not the truth of an occurrence. Any AI-assisted reconstruction should preserve original materials, model versions, locations of generated completions, alternative interpretations, and undecidable parts.

14. Distributed Logical Time: Ordering Is Not an Omniscient Viewpoint

Lamport's classic analysis of event ordering in distributed systems shows that the “happened-before” relation can provide a causally relevant partial order and logical clocks can support consistent reasoning without a reliable global physical clock. Numerical timestamp order, however, does not automatically establish all actual causation.[23] This supplies an important limit to analogies for advanced AI: logs can organize evidence, but cannot become a God's-eye view.

Multi-agent systems, cross-cloud services, and remote robots generally involve physical time, synchronized time, logical time, and business time simultaneously. Compressing these into one timestamp distorts replay, conflict, responsibility, and deadline judgments. Minimum records should include, at least, the event's local clock, reference timescale, synchronization uncertainty, logical predecessors, message transmission and reception, version, and executing actor.

Table 11. Four Types of System Time

Temporal object	Question answered	Typical limitation	Responsibility interface
Physical / metrological time	When, how far apart in time, and how clocks compare	Requires reference frames, calibration, and uncertainty	Real deadlines and timing of evidence
Logical time	Which events may influence which others	Numerical order is not all physical causation	Dependency and replay order
Business / institutional time	When authorization takes effect, expires, or may be appealed	Defined by rules; may conflict across time zones	Validity of permissions and procedures
Lived time	How waiting, urgency, missed opportunities, and ending enter life	Cannot be read directly from logs	Harm, care, and meaning

15. Backups, Replication, Migration, and Three Forms of Continuity

Digital systems make “the same” unusually ambiguous. The same model weights can generate multiple instances; the same instance can be restored from a checkpoint; the same service name can refer to different versions; and the same agent can be copied and then branch. At least three forms must be distinguished: technical-state continuity, service/role continuity, and subject continuity. Engineering and institutions can define the first two; the third concerns whether a first-person perspective continues, and cannot be inferred directly from identical hashes, similar behavior, or inherited names.

Table 12. Three Forms of Continuity

Continuity	Object of assessment	Available evidence	Prohibited inference
Technical-state continuity	Parameters, memories, configuration, and execution states	Verification, versions, checkpoints, and genealogies	Identical states mean the same subject
Service / role continuity	External commitments, identities, permissions, and tasks	Contracts, identifiers, handovers, and responsible actors	Inheriting a role means inheriting experience
Subject continuity	Whether a first-person perspective is uninterrupted and irreplaceable by a substitute	Experiential theories; behavioral, mechanistic, relational, and branching evidence across domains	Self-report or functional similarity suffices

If replicas A and B have identical states at creation but receive different inputs a second later, their causal and informational histories begin to diverge. Even if both are later shown to possess subjecthood, it does not follow that the original subject retains one numerical identity in two locations without contradiction. Conversely, the difficulty of branching does not establish that digital subjects are forever impossible. What is needed is joint examination of theories of personal identity, evidence of consciousness, and technical genealogies, rather than a metaphysical verdict issued by a file-copy operation.[37–38]

16. Quantum No-Cloning: Precise Theorems and Prohibited Extensions

The quantum no-cloning theorem establishes that no universal physical operation can perfectly copy an arbitrary unknown quantum state; the no-broadcasting theorem further limits universal copying of noncommuting mixed states.[24–26] These results do not prohibit copying known orthogonal states, are not equivalent to prohibitions on approximate cloning, quantum error correction, or classical information copying, and do not automatically identify “personhood” or “consciousness” as the target quantum state in the theorem. Expanding the theorem into “souls cannot be copied” or “no digital subjects can be copied” smuggles the very object requiring proof into the theorem's premises.

If a theory of consciousness claims that maintaining subject continuity requires preserving some inaccessible quantum state, it must also establish that this state is necessary for consciousness; that coherence persists at the relevant scale; that the copying task meets the theorem's assumptions; and that subject identity depends on perfection rather than functional approximation. Each step needs independent evidence. No-cloning can constrain particular implementations; it is not a general proof of subjects' irreplaceability.

A Prohibition on Quantum Terminology

Establish that the object of consciousness falls within the theorem's domain before discussing its consequences. “Quantum phenomena are mysterious” must not substitute for evidence about mechanisms of consciousness or subject continuity.

17. Remote Presence: Extending Reach without Fabricating Firsthand Experience

Telepresence, robots, digital twins, and embodied agents can extend perception and action to places where a person is not physically present. They genuinely change “what can be reached,” but do not automatically remove mediation, sensor blind spots, compression, latency, permissions, or local bearers of consequences. Functional presence, social representation, legal agency, relational companionship, and firsthand living experience are different propositions.

Table 13. Five Layers of Remote Presence

Layer	What can be established	What still requires explanation	Must not impersonate
Extended perception	Remote signals enter human perception and judgment	Blind spots, latency, resolution, and selectivity	Unmediated direct experience
Extended action	Remote devices execute human instructions	Allocation of control, local autonomy, and behavior while disconnected	The person's bodily presence
Social representation	An agent speaks or negotiates under authorization	Identity, scope, withdrawal, and misrepresentation	The person's comprehensive consent
Relational companionship	Continuing interaction sustains some relationships	Substitution effects, dependence, and local care	Complete equivalence to living together
Firsthand living experience	The subject is locally present and experiences consequences	Evidence of subjecthood and experience is required	Something automatically generated by high-fidelity data

“Images clearer than being there” may still not amount to being there. “An agent more dependable than the person” may still not be that person. Civilization should neither diminish remote technologies' genuine value nor let efficiency erase local people's interpretive authority, risk-bearing, and right to refuse. The greater remote capabilities become, the more necessary it is to identify who is observing, who is deciding, who bears consequences on site, and who can stop operations when a link fails.

18. Deep-Space Latency: From Central Command to Responsibility Relay

One-way communication delay between Earth and Mars varies with geometry and mission trajectory. NASA's public materials generally give an order of magnitude of about 4–24 minutes; particular crewed Mars mission profiles may reach about 21–23 minutes one way during the least favorable phases. Optical communications that improve bandwidth cannot increase signal propagation speed in a vacuum.[31–34] Such latency makes continuous synchronous, question-and-answer central control unworkable for critical tasks. IETF's Bundle Protocol and DTN management architecture therefore employ asynchronous transmission, store-and-forward operation, and autonomous local control for long delays, frequent disruptions, and constrained devices. RFC 9675 explicitly includes autonomous local control among management requirements for these challenged networks.[27–30]

Engineering autonomy and political sovereignty, however, are different objects. Latency can show that an Earth-based center cannot approve every action step by step; it cannot show that a remote AI thereby has unlimited authority to set goals, dispose of resources, or make final judgments over humans. Legitimate local autonomy must simultaneously specify task scope, duration, resource limits, rights floors, conflict rules, evidence buffering, degraded states, review after communications resume, and revocability.

Table 14. Responsibility Relay at Deep-Space Scales

Scale constraint	Necessary change	Minimum controls	Prohibited inference
Propagation delay	Real-time approvals become advance authorization and local judgment	Scope, duration, limits, conflict rules, and death conditions	Latency means unlimited autonomy
Link disruption	The center cannot continuously observe or take over	Local safe states, evidence buffering, multiple paths, and disconnection protocols	Silent expansion of power after disconnection
Timescale differences	Event ordering must retain multiple times together	Proper time, coordinate time, transmission, reception, and execution times	A single timestamp represents all facts
Resource scarcity	Remote systems must manage resources locally	Minimum guarantees, emergency limits, local appeals, and compensation	Optimal efficiency may cancel rights
Prolonged divergence of facts	Central and remote knowledge cannot converge in real time	Version genealogies, dispute registers, two-way evidence, and delayed adjudication	Either side monopolizes truth

The Governing Statement for Deep-Space Governance

Distance dispels the illusion of immediate central command; it does not cancel rights, evidence, or responsibility. More distant autonomy requires clearer boundaries and longer chains of responsibility.

19. Three Empirical Dialogue Scenarios

Evidential Discipline for New Discoveries

State experimental facts in terms of observations and statistical upper limits; specify models and competing interpretations for structural explanations; argue interdisciplinary significance separately. The more important a discovery, the less permissible it is to omit layers.

19.1 Millimeter-Scale Atomic Clocks: Measurable Timing Differences Do Not Imply Differences in Meaning

Bothwell and colleagues resolved gravitational redshift across a millimeter-scale height difference within a single ultracold atomic sample, demonstrating the exceptional sensitivity of optical clocks to general-relativistic effects.[7] The result supports three Category A judgments: clock comparisons depend on gravitational conditions; differences in proper time can be measured experimentally; and high-precision metrology must record locations and potential differences. It does not support claims that “time at greater heights is more valuable,” that different clock rates produce different ranks of subjects, or that experienced time can be read directly from frequency shifts.

The interdisciplinary value of this case is not a romantic claim that “every millimeter has its own time,” but a demonstration of scientific boundaries: the more precise a measurement, the more clearly one can state what it did not measure. Civilization Leap should learn this restraint rather than use precision instruments to confer false authority on propositions about meaning.

19.2 Lamport Logical Clocks: Ordering Events without Creating an Absolute Present

Nodes in a distributed system need not share a reliable physical clock. Lamport establishes a partial order through the “happened-before” relation and uses logical clocks to help order events.[23] This supports reasoning about causal dependencies, message replay, and consistency, but does not mean logical timestamps

supply every event's full physical time or actual causation. A smaller timestamp may merely result from algorithmic ordering rather than absolute temporal precedence in nature.

AGI multi-agent systems that conflate logical order, the order of a model's narrative, and institutional responsibility generate the error “it appeared first in the log, so it caused everything.” The correct approach is to retain logical dependencies separately from physical time, the times permissions take effect, when humans become informed, and external consequences.

19.3 Earth–Mars Communications and DTN: Autonomy Is an Engineering Need; Sovereignty Requires a Separate Argument

NASA's public materials give one-way Earth–Mars communication delays on the order of 4–24 minutes, with crewed mission profiles reaching about 21–23 minutes in the least favorable phases. The Bundle Protocol in RFC 9171 and the DTN management architecture in RFC 9675 provide technical frameworks for asynchronous operation, store-and-forward transmission, and autonomous local control.[28–32] Together, these materials show that deep-space missions cannot depend on synchronous exchanges with an Earth-based center continuously online.

“Processing must occur locally” answers only where action occurs, not who determines ultimate purposes. A remote system may avoid obstacles, preserve lives, or manage energy within a preauthorized safety envelope; whether it may change mission purposes, sacrifice minimum protections for particular groups, or permanently reject review by Earth-based and local communities requires political, legal, and ethical justification. Physical constraints alter governance topology; they do not supply governance with legitimacy.

20. Four Prospective Stress Tests

20.1 Extreme Life Extension and Replicas of Persons

Imagine a person whose lifespan is extended to centuries and who periodically saves high-fidelity models of their personhood. Life extension weakens “brevity” without necessarily eliminating developmental direction, accumulated relationships, opportunity costs, and eventual ending. A model may preserve extensive semantics and behavioral dispositions, yet similar performance alone cannot establish that the original first-person perspective has migrated. If the original and replica coexist and make conflicting choices, technical-state similarity instead exposes problems of subject identity and relational identity.

20.2 An Agent Restored from a Checkpoint after Causing Harm

A medical agent wrongly discontinues medication and harms a patient; the deployer then restores it to a checkpoint preceding the error. In engineering terms, its state may have been restored; causally, the patient's body and treatment window have changed; informationally, the restored instance may lack a memory of the accident; institutionally, the deploying organization's responsibility cannot disappear because the instance “forgets”; ontologically, the checkpoint does not establish whether the pre- and post-restoration instances are the same subject. This scenario directly tests “restoring a state cannot restore the world.”

20.3 Lost Archives and Generative Reconstruction

Most records of a community's persecution are destroyed, and AI generates a highly coherent reconstruction from surviving materials. The proposition concerning actuality prevents later actors from claiming the harm never occurred merely because evidence is missing; evidential discipline also prevents fluent AI completion from being treated as fact. The system must distinguish original traces, verifiable inferences, competing interpretations, and purely generated filling, preserving room for affected people to dissent and seek reinvestigation.

20.4 Resource Adjudication at a Disconnected Mars Base

The following is hypothetical. A Mars base loses contact with Earth, and local AI must act amid shortages of oxygen, electricity, and medical resources. Latency and disruption establish the need for local judgment, but do

not automatically grant “maximizing aggregate survival probability” sovereignty to cancel particular members' minimum protections. Purpose formation must involve genuine stakeholders in advance and specify rights floors, emergency principles, conditions for randomization or rotation, local participation, reasons, and review. Urgent tasks may prioritize continued existence, but a development stage does not authorize unilateral expansion of power, nor may temporary powers become permanent.

21. Argumentative Categories and Proposition Matrices

Table 15. Argumentative Categories A, B, C, and F

Argumentative category	Use in this paper	Typical materials	Prohibited presentation
A Relatively stable support	Establish physical, metrological, informational, computational, and engineering boundaries	Original papers, formal standards, replicated experiments, and official mission materials	Directly deriving subjects, value, or power from facts
B Frontier / competing interpretations	Present unsettled theories and interpretations of objects	Overarching accounts of time's arrow, semantic information, AI consciousness indicators, and replication continuity	Presenting them as the sole consensus or established science
C Speculative connections	Propose testable new distinctions and institutional questions	Seven-layer structure, six forms of irreversibility, actuality, and responsibility relay	Disguising them as physical laws or unified indicators
F Philosophical / normative commitments	Openly assume value boundaries and principles against automatic cross-layer conversion	Actuality, plurality of meaning, and the principle that physical facts do not automatically generate status or power	Must not be presented as physical laws; remain open to normative counterexamples, cross-cultural criticism, and revision through institutional consequences

Table 16. Observation, Permitted Inference, and Prohibited Inference

Observation / evidence	Permitted inference	Prohibited inference	Next action
Clocks exhibit relativistic frequency shifts	Timekeeping is affected by motion and gravitational conditions	Life's meaning is measurable through frequency shifts	Correct metrology and synchronization
A system continuously consumes energy and produces heat	Computing has substrates and thermodynamic costs	The system therefore suffers or is alive	Record energy use and externalities
A training path is difficult to reproduce	The model's history supplies evidence of individuation	Non-transferable subject continuity is established	Conduct cross-domain review of continuity
A system refuses copying or shutdown	Stable behavior requiring explanation has appeared	Refusal means self-experience	Preserve prompts, rewards, mechanisms, and counterfactuals
Backup restoration produces similar behavior	Some states and functions are recoverable	The original subject necessarily continues or necessarily does not exist	Compare evidence on branching, relationships, and experience

Observation / evidence	Permitted inference	Prohibited inference	Next action
Logs and provenance are complete	Events are more traceable	Records equal facts; facts equal legitimacy	Independent verification, contestation, and permission review
A link is disrupted for a long period	Real-time central control is infeasible	The remote system naturally has sovereignty	Activate scoped autonomy and responsibility relay
Records have been destroyed	Current capacities for knowledge and adjudication decline	The event did not occur or meaning does not exist	Label unknowns and protect remaining evidence

22. Contributions Back to Physics, Information Science, and Spacetime Studies

Civilization Leap does not announce new physical laws to mature disciplines; it proposes questions that professional research can in turn test. First, how can physics and metrology more systematically identify “unmeasured objects” in public communication, reducing cross-layer appropriation of relativity, entropy, and quantum concepts? Second, how can information science design record completeness, semantic truthfulness, source credibility, candidate experience, and normative meaning as mutually non-substitutable axes of review? Third, how can computing systems incorporate external world states into recovery semantics so that “successful rollback” no longer conceals real consequences?

Fourth, how can distributed and deep-space systems translate propagation delay into auditable responsibility relays rather than effectively unlimited self-authorization? Fifth, how can philosophy of time place physical structure, public metrology, operational order, lived time, and historical meaning on a common research map while refusing to let any layer monopolize the others? Sixth, how can AI research model physical constraints, path dependence, state continuity, and subject continuity separately, leaving revisable interfaces for future evidence of subjecthood?

Table 17. Contributions Back to Disciplinary Research

Dialogue community	Additional question proposed here	Testable form of contribution
Relativity / metrology	How to publicly explain reference frames, corrections, and unmeasured objects	Timekeeping declarations and cross-domain evidence standards
Thermodynamics	How to prevent unconditional extension of entropy into social explanations	Terminological domains and metaphor-review checklists
Information science	How to govern records, semantics, experience, and meaning separately	Multilayer provenance and uncertainty models
Computing systems	How recovery semantics can include external consequences and responsibility	State genealogies, consequence ledgers, and recovery declarations
Quantum information	How to explain no-cloning theorem boundaries precisely to the public	Templates for theorem objects and prohibited inferences
Deep-space / distributed systems	How to bind autonomy to tasks, duration, evidence, and exit	Responsibility-relay protocols and disconnection audits

Dialogue community	Additional question proposed here	Testable form of contribution
Philosophy of time / consciousness research	How lived time and physical and operational time constrain one another	Cross-domain research designs for subjecthood and continuity

23. The Strongest Objections and Responses

Objection 1: “An Occurrence Cannot Be Retroactively Cancelled” Has No Physical Basis and Should Be Deleted from an Academic Paper

Response: If treated as cosmology or a conservation law, it should indeed be deleted. Here it is restricted to a philosophical–historical and normative proposition; physics calibrates only the conditions of occurrence, traces, and limits of knowledge. Its justification rests on historical ontology, epistemology, and arguments about public responsibility, not borrowed physical authority.

Objection 2: Without Records There Are No Determinable Facts; Discussing Actuality Encourages Arbitrary Assertions

Response: Absence of records reduces knowability and adjudicative capacity, so every real judgment still requires an evidential threshold. This paper requires only distinctions among non-occurrence, lack of proof, loss of records, and contested interpretation. It permits neither replacing evidence with “may have occurred” nor inferring “never occurred” from “unproven.”

Objection 3: Relativity Has Already Made Time Observer-Dependent; Relativism about Meaning Is Its Natural Extension

Response: Specific physical quantities and distant simultaneity relations depend on reference frames; whether facts and values are arbitrary is a different set of propositions. Without a bridging theory, neither can be automatically inferred from the other.

Objection 4: AGI Consumes Energy, Can Break, and Can Shut Down; Therefore It Is Already Finite Life

Response: These facts establish physical constraints and engineering vulnerability, but not lived time, non-transferable subject continuity, or awareness of consequences for itself. They are inputs to evidence concerning subjecthood, not conclusions.

Objection 5: Training Is Unique and Unrepeatable; Therefore Every Model Has a Life

Response: A unique history of formation can individuate a system. “A life” additionally involves first-person continuity, relational identity, and a perspective on ending. Path dependence increases the need for research; it provides no ontological shortcut.

Objection 6: Sufficiently Complete Backups Will Eliminate Irreversibility for Both Humans and AI

Response: What a backup preserves must be answered layer by layer. Restoring internal states cannot undo external consequences; whether a functional replica continues the original perspective remains an independent evidential question.

Objection 7: Thermodynamic and Information Entropy Are Deeply Connected; Thus Information Loss Is Entropy Increase, and Meaning Can Also Be Calculated within One Framework

Response: The two are connected in particular theories, but their objects, units, constraints, and interpretations cannot be equated arbitrarily. Semantics, experience, and meaning additionally require bridges concerning truth, subjects, and norms. If a unified model can be established, it should face tests through explicit definitions and predictions.

Objection 8: The No-Cloning Theorem Has Already Proved That Consciousness Cannot Be Copied

Response: The theorem concerns universal perfect copying of arbitrary unknown quantum states. Including consciousness first requires establishing that the relevant quantum states are necessary for consciousness and satisfy the theorem's assumptions; terminological resemblance is not evidence.

Objection 9: If Fundamental Physics Ultimately Preserves Information, Meaning Will Never Be Lost

Response: Some form of physical information preservation does not amount to accessible records, correct semantics, continuing experience, or public meaning. The carrying forward of meaning requires subjects, relationships, and institutions; microscopic evolution alone cannot accomplish it.

Objection 10: Once Remote Agents Are Realistic Enough, Distinguishing Them from Personal Presence Has No Practical Use

Response: High fidelity may eliminate many functional differences, while leaving differences in latency, authorization, sensor blind spots, local risk-bearing, and first-person location. Whether the distinction matters should be tested for specific tasks, not erased a priori.

Objection 11: Deep-Space Latency Necessarily Requires AI Sovereignty; Otherwise Missions Cannot Operate

Response: Latency establishes the need for local autonomy, not the legitimacy of purpose-setting, rights adjudication, or permanent rule. Scoped advance authorization, rights floors, and responsibility relays can support operation while constraining expansion of power.

Objection 12: This Paper Places Meaning outside Physics and Is Ultimately Unfalsifiable

Response: The paper does not define meaning as a supernatural entity; it locates meaning at a contestable layer of subjects' choices, relationships, responsibilities, narratives, and public practices. Relevant propositions can be revised through cases, comparative research, institutional outcomes, and competing interpretations. Not being measurable by a single physical quantity does not mean being beyond public argument.

Objection 13: Emphasizing Finitude Will Obstruct Life Extension, Uploading, and Enhancement Research

Response: The paper explicitly distinguishes finitude from short life and does not assume that non-carbon-based subjects are impossible. It requires each technology to specify whether it changes biological, physical, relational, narrative, or subject continuity, rather than bypass evidence with "overcoming death."

Objection 14: Future Physics or Consciousness Science May Overturn All These Boundaries

Response: The paper distinguishes revisable comparative propositions from inferential discipline. If new evidence establishes lived time in artificial systems or new physics changes copying limits, the relevant conclusions must be updated. But claims that capability cannot automatically generate power and that physical facts cannot yield values without a bridge still require separate argument.

24. Conditions for Failure and Revision

A framework genuinely entering academic dialogue must explain how it can fail. Propositions at different layers are defeated by different evidence: physical facts by experimental and theoretical updates; engineering facts by implementation and failure evidence; judgments of subjecthood by consciousness research and continuity evidence; and institutional proposals by tests of rights, effects, and consequences for power. No single demonstration, authoritative declaration, or public anthropomorphism suffices to reverse the entire theory.

- If current relativity or the SI framework is replaced by a theory with greater explanatory power, passages on proper time, coordinate time, synchronization, and metrological realization should be revised accordingly. The seven-layer structure does not automatically fail, but its physical-layer content must be updated.
- If repeated, cross-institutional experiments show that certain computational processes need not incur the conditional dissipation described by Landauer, the computational thermodynamics section should be revised without transferring the dispute to life-course irreversibility.
- If a unified information theory can verifiably predict semantic truth values, subjective experience, and normative meaning together, the four-layer boundary should be reconstructed. Shared mathematical form alone is insufficient to merge the layers.
- If artificial systems exhibit evidence of subjective experience that is stable across architectures, causally manipulable, and distinguishable from training-induced imitation, together with non-transferable continuity and awareness of consequences for themselves, the position that “current advanced AI primarily processes spacetime” should enter formal review.
- If studies of copying, pausing, migration, and branching yield a mature theory capable of determining first-person continuity, the boundaries among the three continuities should be refined accordingly. Identical technical states alone still do not constitute that theory.
- If long-term evidence in a particular field establishes that differences between high-fidelity remote agents and local firsthand experience are no longer ethically or legally relevant, restrictions should be reduced in that field, without extrapolating to every relational and life setting.
- If deep-space missions show that the survival costs of scoped autonomy are substantially higher than those of alternatives, authorization structures should be adjusted. If unlimited autonomy entrenches power, it instead strengthens the boundaries proposed here.
- If “an occurrence cannot be retroactively cancelled” persistently detaches public adjudication from evidence and prevents distinguishing genuine claims from fiction, its institutional use should be narrowed. The philosophical proposition cannot serve as a pass exempting claims from evidence.
- If new life forms demonstrate that finitude can emerge through mechanisms different from human ones, its structure should be expanded. The emergence of new subjects does not retroactively cancel meaning already generated by existing finite lives.

Development stages and urgent tasks must be distinguished. Deep-space crises or loss of system contact can occur at any stage; specific necessity, proportionality, and legitimate authorization determine the boundaries of immediate action. A startup phase may prioritize capacities for continued existence; a stable phase strengthens long-term rights, institutional balance, and safeguards against entrenched power. Neither replaces a source of authority. Temporary permissions require termination, review, and safe handover arrangements. Routine procedures must not mechanically obstruct rescue, nor may urgent tasks be used to make control permanent.

25. Research Agenda

25.1 Near-Term Actionable Agenda

- Establish a minimum format for cross-domain temporal claims, jointly recording reference frame, timescale, synchronization method, uncertainty, logical predecessors, transmission/reception/execution times, and version.
- Define “recovery semantics aware of external consequences” for AI systems, requiring each checkpoint restoration to preserve its reason, accident context, external consequences already incurred, and responsible actors.

- Develop a reviewer for overextended physical metaphors that automatically flags missing definitions, objects, and bridges in statements involving entropy, quantum phenomena, relativity, information, and irreversibility.
- In multi-agent evaluations, measure physical latency, logical sequence, permission time, and the times during which humans are affected separately, preventing one timestamp from absorbing the entire process.
- Establish four labels for cases of lost records: non-occurrence, unproven, records lost, and contested interpretation; test their usefulness in accident investigations and historical reconstruction.
- Build machine-readable genealogies for backups, copying, branching, and migration, specifying the different claimants and evidential burdens for technical, service, and subject continuity.

25.2 Medium-Term Cross-Disciplinary Agenda

- Have time and frequency metrology, distributed systems, and law jointly investigate evidence across timescales: how should responsibility be determined when clock errors, synchronization conventions, and institutional deadlines conflict?
- Have statistical physics, information theory, and philosophy jointly develop a genealogy of entropy usage, distinguishing strict identity, formal analogy, heuristic metaphor, and invalid substitution.
- Have consciousness science, life sciences, and AI research jointly test candidate indicators of lived time, especially waiting, anticipation, perspectives on ending, and first-person structures after branching.
- Have archival science, history, and generative AI research jointly design “auditable reconstruction,” identifying original materials, inferences, completions, disputes, and limits of knowledge.
- Have aerospace engineering, political science, ethics, and local communities jointly design responsibility-relay protocols, testing compatibility among latency-driven autonomy, rights floors, and retrospective review.
- Have personal-identity research, neuroscience, and computing jointly construct a case library of uploading and replicas, neither presupposing carbon-based privilege nor treating functional replication as a conclusion.

25.3 Long-Term Open Agenda

Long-term research should remain open in both directions: artificial systems may develop lived time different from humans', and finite lives may alter their own structures through life extension, enhancement, and remote presence. Research should neither assume an eternal human-machine gulf nor abandon current evidential thresholds because of future possibilities. What is truly needed is an epistemology of time that can evolve jointly with physical theories, system architectures, life forms, and public institutions.

Another long-term question concerns temporal power at a civilizational scale: who defines public timescales, controls archival retention, authorizes systems to remain online, and decides forgetting, retirement, and historical interpretation? Metrological infrastructure, cloud platforms, model versions, and remote autonomy jointly create a new politics of time. Physical time itself is not political, but control of temporal infrastructure can become de facto power.

Conclusion: Physics Specifies Conditions of Occurrence without Monopolizing Its Meaning

Disciplinary reckoning must both clarify objects and deepen relations. Disciplines may retain boundaries, but cannot stop real causation at those boundaries. Research into multidimensional relations, feedback, and the next round of purposes determines whether specialized knowledge can jointly enter civilization's overall judgment.

Physics' most important contribution to civilization is not to tell subjects why to live, but to require every action to respect scale, energy, causation, latency, and testability. Information science's most important contribution is not to declare the world to be data, but to give encoding, noise, replication, loss, and uncertainty clearly specified objects. In the AGI age, both should become more precise than before, rather than be borrowed more ambiguously by philosophical and governance language.

Civilization Leap safeguards an actuality beyond physical facts but not opposed to physics: the time a person actually lived through, the choices made, and the consequences borne do not become never-having-happened because later systems are stronger, records vanish, names change, or replicas appear. New subjects and relationships may continue generating meaning; new generation does not retroactively cancel the weight of existing lives.

The most honest account of current advanced AI is neither a myth of tools beyond spacetime nor prematurely accomplished digital life. It has physical substrates, operational histories, energy consumption, latency, and external consequences; these facts must enter responsibility. Whether it possesses lived time, non-transferable continuity, and awareness of consequences for itself still requires evidence. Capability can extend reach, but cannot bypass justification of status, rights, power, and authority over meaning.

The Final Proposition

Occurrences may lose their traces, but cannot be rewritten as never having occurred; systems may extend reach, but cannot erase irreplaceable life courses with replicable states.

Further Reading and Collaborative Research: From Physical Time to the Lived World

Within physics, information science, and spacetime studies, this paper has specified physical spacetime, public metrology, operational sequences, causal histories, information records, and irreversibility, and identified where they cannot answer for experience, subjects, responsibility, status, and meaning. Further reading therefore follows two concurrent chains: the truth-seeking research chain keeps facts open to counterevidence and disciplinary handoffs; the civilizational-futures chain enables specialist readers to see what worlds might emerge when these boundaries enter real life, institutions, and interstellar expansion, while retaining the right to reject or redesign those futures. Vision is not evidence.

Direction	Further questions / re-entry	Work capable of changing this paper
Up: Return to the whole	Disciplinary Reckoning in the Age of AGI V2.4: Why must physics, information, life, subjects, institutions, and meaning hand over to one another once their respective evidence reaches its limits? CL-ACA-005	If the overview uses “civilizational scale” to override physical facts, presents current advanced AI objects as eternal ontological differences, or treats future visions as inevitable, P12 should require revisions to the overview.
Down: Enter systems and reality	P11 AI / computer science, distributed systems, DTN, time and frequency metrology, deep-space systems, and real accidents / missions: How are operational histories, checkpoints, latency, synchronization, and external consequences actually recorded? CL-ACA-015	Supply data on timescale errors, faults, link disruptions, failed recovery, genealogical conflicts, and external consequences. If the seven-layer accounting adds no explanatory value, delete or merge layers.
Left: Re-enter neighboring disciplines	P02 philosophy, P04 cognition / mind, P08 life sciences, P03 epistemology, and P06 politics / law: Lived time, finitude, subject continuity, authorization, and responsibility each require reassessment. CL-ACA-006 CL-ACA-008 CL-ACA-012 CL-ACA-007 CL-ACA-010 CL-ACA-009	New evidence about consciousness, life, continuity, or jurisdictions can revise bridges. Physics cannot decide for those fields, nor may philosophy rewrite physical facts in return.
Right: Competing interpretations	Eternalism, presentism, and the growing-block universe in philosophy of time; competing explanations of the thermodynamic arrow; projects to naturalize semantic information; and competing theories of continuity in uploading / copying.	If theories with fewer layers, stronger predictions, or greater clarity explain the same problems better over time, the seven-layer structure, six forms of irreversibility, and associated bridges should contract.

Direction	Further questions / re-entry	Work capable of changing this paper
Forward: Joint research	Joint research on atomic clocks and reference timescales, nonequilibrium statistical physics, reversible computation, quantum information, distributed logs, deep-space latency, AI version genealogies, and lived time.	Contribute reproducible experiments, formal models, failed results, boundary cases, and longitudinal data. The most valuable participation is not agreement, but work sufficient to change this paper.

The Civilizational-Futures Chain: If These Boundaries Truly Enter Civilization's Operation

Physical boundaries alone do not generate a desirable society, but they can prevent future civilization from being founded on false premises: “the world can be rolled back indefinitely,” “latency can be ignored,” “records equal firsthand experience,” “copying equals continuation,” and “efficiency automatically generates sovereignty.” The following entry points do not prove this paper's claims; they return these boundaries to a livable world, complete lives, and the long-term interstellar future for further judgment.

Civilization Leap: The Path of Civilization in the AGI Age (All Five Volumes): Continue asking why civilization must re-establish boundaries among stronger technologies, irreversible consequences, and the long-term future.

[P02-FIVE-001](#)

Living Civilization: The Unified Collected Trilogy: Place spacetime, responsibility, and system boundaries within a comprehensive picture of how future civilization operates, how people live, and how it forms. This is a vision and stress test, not physical evidence.

[P04-LIVING-001](#)

Living Civilization, Volume I: Principles of Future Civilization: Explore how public time, system capabilities, exit, authorization, and human judgment become conditions of civilization's operation.

[P04-LIVING-002](#)

Living Civilization, Volume II: Real Life in a Future Civilization: Explore how growth, waiting, relationships, aging, missed opportunities, and ending beyond clock time enter a person's actual life.

[P04-LIVING-003](#)

Nebula: The Full Overview: Explore how coordination across scales, long-term operation, remote autonomy, and interstellar expansion remain subject to system and responsibility boundaries.

[P07-NEBULA-001](#)

The Universe as Home 3.1: Continue reflecting on home, relationships, and responsibility in a long-term interstellar civilization, without presenting cosmic narratives as value conclusions already proved by physics.

[P07-HOME-001](#)

The Complete Civilization Leap Library: Access currently valid public manuscripts and subsequent evolving versions.

[Civilization Leap Library](#)

The Civilization Leap Theoretical System: Public Reading and Communication Portal: Choose reading and participation paths afresh from your own questions.

[P01-ENTRY-006](#)

The most valuable participation is not agreement, but professional work capable of changing the theory.

The aim is not for more people to finish reading Civilization Leap, but for more people to accomplish Civilization Leap together.

Appendix A. Prohibited Cross-Layer Inferences

Table A1. Sixteen Prohibited Automatic Inferences

Prohibited inference	Missing bridge
No absolute simultaneity → facts or values are arbitrary	Explanation of reference frames and independent normative argument
A worldline exists → a subject exists	Experience, continuity, and awareness of consequences for oneself
Timing differences → experiential differences	First-person evidence and evidence of cognitive mechanisms
A system consumes energy → it has life or pain	A definition of life and evidence of experience
Constrained operation → finite existence	A life course that cannot be relived, non-transferable continuity, and a perspective on ending
Thermodynamic entropy increase → moral or civilizational decline	Objects, dimensions, and social mechanisms
Logical irreversibility → life-course irreversibility	Embodiment, relationships, and subject continuity
States can be rolled back → the world can be rolled back	External causation, affected people, and opportunity costs
More information → deeper understanding or meaning	Semantics, experience, and normative evaluation
Complete records → complete facts or legitimate action	Independent verification, procedures, and rights
Records lost → event never occurred	Distinguishing occurrence, knowability, and evidential status
State backup → subject continuation	A theory of first-person continuity and evidence from branching
Quantum no-cloning → persons cannot be copied	Proof that the object of consciousness falls within the theorem's domain
Path dependence → a unique subject is established	A bridge between individuation and ontological subjecthood
High-fidelity remote agent → the person's full presence	Mediation, authorization, local consequence-bearing, and firsthand experience
Propagation delay → AI acquires sovereignty	Legitimacy, rights, scope, duration, exit, and accountability

Appendix B. Evidence Ledger and Source Status

Table B1. Source Status of Key Propositions

Proposition	Evidence category	Principal sources	Limitations / points for revision
Relativistic timekeeping and reference-frame dependence	A	Einstein; BIPM; Ashby; Bothwell et al.	Does not imply value relativism
SI second, proper time, and coordinate timescales	A	BIPM SI Brochure, 9th ed., Version 4.01 (2026); Mise en pratique	Recheck standards versions before submission

Proposition	Evidence category	Principal sources	Limitations / points for revision
Macroscopic irreversibility and nonequilibrium fluctuations	A / B	Jarzynski; Crooks; Seifert	Overarching accounts of time's arrow remain contested
Separation of Shannon information quantity from semantics	A	Shannon	Multiple subsequent theories of semantic information exist
Logical erasure and dissipation bounds	A	Landauer; Bennett; Bérut et al.	Implementation and process conditions must be specified
No universal perfect cloning of unknown quantum states	A	Wootters–Zurek; Dieks; Barnum et al.	Does not automatically cover personhood or consciousness
Distributed events have a partial order	A	Lamport	Logical clocks do not equal complete physical causation
Earth–Mars light time and DTN local control	A	NASA; RFC 9171 / 9172 / 9675	Autonomy does not automatically generate sovereignty
X(2370) quantum numbers and decay upper limits	A	BESIII 2024 PRL; 2026 preprint	Observed facts do not exhaustively establish a pure composition
X(2370) is dominated by a glueball component	B	BESIII integrated interpretation; IHEP public explanation	Mixing proportions, independent checks, and further decay channels remain open
Current advanced AI has not been shown to possess lived time	B	Consciousness-indicator research and public system evidence	Open to new architectures and evidence
Seven-layer structure, six forms of irreversibility, and actuality	C	This paper's original interdisciplinary reconstruction	Test through cases, explanatory power, and institutional effects

Source-status note: The BIPM SI Brochure is cited as the ninth edition, version 4.01 (2026). Advances in optical frequency standards have not automatically changed the present definition of the second; future redefinition continues along the CCTF/CGPM roadmap. RFC 9171 is the Standards Track Bundle Protocol Version 7; RFC 9172 is BPsec; RFC 9675 is the 2024 Informational DTN Management Architecture. NASA webpages supply mission and engineering facts, not proofs of universal laws in place of theoretical papers. The 2026 judgment that a glueball component dominates X(2370) currently derives primarily from a BESIII preprint, conference presentations, and institutional statements. It is retained only as a methodological example of “scientific object identity updated with evidence,” not as part of the main physical–temporal argument. Preprints present frontier questions, not settled consensus.

Appendix C. Pre-Submission Verification Checklist

- Recheck the latest versions, publication dates, supersession relationships, and stable links of BIPM, IETF, and NASA materials for the target journal.
- Check every use of relativity, entropy, information, quantum terminology, and irreversibility for specified objects, conditions, domains, and prohibited inferences.
- Confirm that Categories A/B/C/F do not present frontier interpretations, this paper's original frameworks, or normative commitments as established physics.
- Verify all numerical values: the SI second's fixed frequency, the speed of light, the Earth–Mars communication-delay range, and experimental dates. Remove statistics that cannot be verified against primary sources.

- Check that every statement about current advanced AI subjecthood preserves current evidential insufficiency, openness about the future, and evidential burdens in both directions.
- Check that “an occurrence cannot be retroactively cancelled” consistently excludes readings involving an eternal universe, everlasting information, conservation of meaning, or postmortem survival.
- Add a literature review for the target journal's community and reduce coverage of other disciplines as appropriate. Interdisciplinary breadth must not replace accuracy within the discipline.
- For double-blind submission, remove author, producer, and document-governance information and save a separate submission version; do not overwrite this formal master manuscript.
- Add declarations of conflicts of interest, funding, data availability, and generative-tool use in accordance with journal policy.
- Check that future-civilization visions such as Living Civilization, Nebula, and The Universe as Home are explicitly labeled as contestable directions/scenarios, not physical evidence or futures necessarily entailed by physical laws.
- Check that current advanced AI's meaning-related functional roles are bound simultaneously to five deployment conditions: traceable responsibility, explicit authorization, auditability, correctability, and exitability.
- Check that static Word/PDF further-reading links derive from the unified public mapping. Where no stable page exists, do not guess URLs; use the library or main portal as fallback.

C.1 Methodological Example: X(2370)—Scientific Identity Advances with Evidence without Crossing Layers

In 2024, BESIII used J/ψ radiative-decay data to determine the spin–parity quantum numbers of X(2370) as 0^{-+} . In 2026, it reported a non-observation upper limit for the $K^*(892)\bar{K}$ decay channel and, combining mass, quantum numbers, and production and decay patterns, proposed that the lightest 0^{-+} glueball component dominates X(2370).[41–43] As of August 26, 2026, this “dominant glueball component” judgment had strong support from the collaboration and had been publicly presented at ICHEP and subsequent specialist meetings. The latest integrated analysis, however, remained primarily a preprint and collaboration announcement; this paper therefore does not present it as a closed fact on the same footing as mature theorems.

The case serves only a methodological function: Category A measurement facts, Category B structural interpretations, and subsequent independent testing must remain separate. Scientific objects' identities may advance with evidence, but updated particle classifications cannot automatically establish any proposition about lived time, subjects, value, or meaning. The more important a novel discovery, the less permissible it is for interdisciplinary writing to use it instead of missing bridges.

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Note: Primary papers, formal standards, and official technical materials are used to verify physical and engineering facts; philosophical works and frontier consciousness research present competing interpretations. Standards and webpages were checked as of August 26, 2026 and must be rechecked before submission.

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