

Invariant Temporal Ordering Framework V40/F20: One Global Time for the Whole Universe: The Invariant Succession of Common Stages of Change, with No Private Time for Any System

Youssry Ghandour
Independent Researcher

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Abstract

V40/F20 defines time as the invariant universal cosmic extension: the objective, fixed, and non-reversed succession of the common stages of physical change of all physical systems in the universe:

$$T_{\text{ITOF}} := \mathcal{E}_C := (\mathcal{S}_C^{\text{tot}}, \prec_C). \quad (1)$$

Time is global: it encompasses the whole universe, one time for all physical systems wherever they are. Time does not cause physical change, and physical change does not produce time. The extension is a non-metric succession, $0 \prec_C 1 \prec_C 2 \prec_C \dots \infty$ (conditional), whose numerals are a formal expression of the fixed succession of the stages and are not added; stage 0 is the beginning of the stages of change, at the formation and genesis of the universe, with no date fixed for that beginning; invariance is the fixed succession of the change realized through its stages, and its non-reversal: what succeeds is dynamic, a change that never stops; what is fixed is the order of its succession, never interrupted by a static or empty stage. Because change never stops, observed or not, the place in the succession of the stage of any given change cannot be determined. Every admissible representation preserves the order. Every stage is a common stage of the physical systems of the universe, and, by the postulate of change, every physical system of the universe realized there undergoes its own physical change, so that every stage is a stage of change in the sense

$$\begin{aligned} \text{RealizedChangeStage}_C(s) \iff [s \in \mathcal{S}_C^{\text{tot}}] \wedge \mathcal{S}_{\text{phys}}(s) \neq \emptyset \\ \wedge \forall A \in \mathcal{S}_{\text{phys}}(s) \text{ PhysReal}_A^+(s). \end{aligned} \quad (2)$$

A stage is the formal expression of the realization of a change within the unceasing chain of change, by comparison between the earlier change and the later, stage 0 having no earlier change before it; it is not a container or a physical state.

Strict Cosmic Ordering makes the earlier–later relation of the stages of the universe a strict total order whose direction no observer, coordinate, clock, physical condition, or description reverses. It implies

no equal stage spacing, metric duration, universal rate of change, or identical evolution, and physical recurrence does not reverse the succession.

The Cosmic Moment Axiom (CMA) states the unity of the stages of change for all physical systems of the universe: every one of them realizes its changes on the one common succession, with no private stage or private ordering; hence all physical systems of the universe realized at each stage are objectively co-present there:

$$\boxed{\text{CMA} \iff \forall A \in \mathcal{U}_{\text{phys}} : \mathcal{W}_A \subseteq \mathcal{S}_C^{\text{tot}} \wedge \triangleleft_A = \prec_C|_{\mathcal{W}_A}.} \quad (3)$$

Universal Change Continuity (UCC), the postulate of change, states that physical change continues without interruption in every physical system of the universe, without exception, at every member of its identity range, whether the change is observed or not, including below every detection threshold:

$$\boxed{\text{UCC} \iff \forall A \in \mathcal{U}_{\text{phys}} \forall s \in I_A : \text{PhysReal}_A^+(s).} \quad (4)$$

CMA and UCC are proved mutually independent by explicit countermodels. Their conjunction is the full content of the cosmic moment: at each stage of change, all the physical systems of the universe qualified at that stage, those whose identity ranges contain it, are together, and every one of them realizes its own change there, without exception, according to the influences that reach it. The common-stage condition and UCC give every stage the form of Eq. (2), and CMA excludes private stages: no stage of the universe is empty, static, or private. A common stage does not imply equal states, changes, rates, causes, locations, clock readings, or histories.

The physical universe is the non-container totality of physical systems and physically realized physical factors. The causes of change are internal contributors, influencing physical systems, and non-system physical factors; time, stage order, CMA, and UCC are not causes. The influences act jointly and qualitatively and reach the system by contact or through physical pathways; the variation of a physical factor, as distinct from a condition of a physical system, such as the temperature of a medium, which is a state of that system, is not counted as change in the sense of UCC and does not constitute a stage, since a factor has no structural constitution and no identity range of its own and enters through the change that its joint action produces in physical systems. Identity ending need not produce a successor, and absorption into an existing system creates none. Beginning and end of the cosmic succession are not treated alike, because every physical system has a formation (AFB), while the core asserts no ending for every system (UEIE is optional), so that the formation boundary motivates a first stage and not a last one, and because the origin has an empirical anchor, while the end has none; the analogy motivates the postulate and does not derive it: the succession has a first stage, the stage at which change in the universe begins, with the formation and genesis of the universe, adopted as the Cosmic Origin postulate; it is the first stage of the universe, not a date; non-termination remains a revisable hypothesis, because current evidence establishes neither a terminal stage nor an unbounded future.

Clocks, records, coordinates, proper-time quantities, and metrics are physical or representational constructions, not time. A dimension-admission criterion separates the mathematical consistency of a coordinate or higher dimension from its physical realization. Non-identity of T_{TOF} with relativistic geometric temporal quantities, including global time functions and cosmological time, is derived quantity by quantity. Special- and general-relativistic phenomena are read through a relativistic phenomenon bridge that retains every established quantitative result and admits time neither as a model quantity nor as a contributor; the Lorentz transformations are derived as a symmetry of record assignment from physical premises about physical systems, with no premise about T_{TOF} , CMA, or UCC. CMA is not derived from Lorentzian geometry. Against the geometric reading, which assigns a proper time to each worldline and

a coordinate time to each chart, ITOF asserts one global time for the whole universe; under identical physics it is empirically equivalent to special relativity, an equivalence of records that does not qualify that commitment. CMA entails an objective co-presence relation that no record determines; any specific association of stages with spacetime event sets is additional structure that preserves the causal order strictly, and a prediction that depends on it requires independent empirical warrant.

No foundation-specific quantitative residual follows from temporal ontology alone. UCC nevertheless has a defined countercondition, complete physical non-change of any physical system of the universe, approached under a declared currently-complete-isolation criterion that covers ground states; a global phase is not counted as change. UCC is an ontological postulate whose empirical exposure in a given system coincides with the standard physics of the channels coupled to that system: because finite measurement yields bounds rather than certified zeros, evidence against it would take the form of decreasing certified bounds, would contradict those channel predictions as well, and is not supplied by any single measurement. An application hypothesis of constitution-dependent clock response is declared with predictions and withdrawal conditions; it is not a commitment of ITOF, ITOF accommodates either outcome of its test, and its minimal field model is constrained by the weak-equivalence-principle bound below its withdrawal threshold.

Keywords: foundations of physical time; one global time; invariant cosmic succession; common stages of change; Cosmic Moment Axiom; Universal Change Continuity; postulate of change; Non-Transfer Principle; relativistic phenomenon bridge; Lorentz transformations; non-identity with geometrized time; physical-system identity; causal realization.

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Authorship and Intellectual Provenance

The Invariant Temporal Ordering Framework was conceived and developed by Youssry Ghandour through independent research. Version status and the relation to earlier versions are stated in Section 1.3.

Editorial, computational, and artificial-intelligence-assisted tools were used as assistive instruments in parts of the writing and production process, including language refinement, candidate wording, document organization, consistency review, comparison of formulations, numerical verification, typesetting, and editorial checking. Suggestions produced by such tools were subject to the author's examination and were accepted, modified, or rejected according to his own theoretical judgment. The conceptual ideas, theoretical architecture, definitions, original hypotheses, scientific analyses, formal judgments, interpretive positions, and innovations of ITOF are the work of Youssry Ghandour. No computational or artificial-intelligence system is presented as an author, originator of ITOF, independent scientific authority, evidentiary source, or substitute for the author's responsibility. All theoretical commitments, formal statements, inclusions, exclusions, revisions, and final scientific and publication decisions remain the responsibility of Youssry Ghandour.

1. Governing Foundation of V40/F20

1.1 The framework in one page

1. **Time.** Time is the invariant universal cosmic extension: the objective, fixed, and non-reversed succession of the common stages of physical change of all physical systems in the universe, $T_{\text{ITOF}} = \mathcal{E}_C = (\mathcal{S}_C^{\text{tot}}, \prec_C)$. Time is one and global: it encompasses the whole universe, and no region, system, frame, or observer has a time of its own.
2. **Invariance.** Invariance is the fixed succession of the change realized through its stages, and its non-reversal: what succeeds is dynamic, a change that never stops; what is fixed is the order of its succession. The succession is never reversed, and no stage, named or lying between named stages, is empty of change or static, at every stage every physical system of the universe realized there changes, and no stage is major or minor. The numerals $0 \prec_C 1 \prec_C 2 \prec_C \dots \infty$ (conditional) are a formal expression of this fixed succession and are not added. Because change never stops, observed or not, the place in the succession of the stage of any given change cannot be determined. Stage 0 is the beginning of the stages of change, at the genesis of the universe (Cosmic Origin), with no date fixed for that beginning. Whether the succession has a final stage is open; non-termination is a revisable cosmological hypothesis.
3. **Stage and universe.** A stage expresses the change realized at it; it is not a container. The universe is the totality of physical systems and physical factors; it is not a container. Every stage has physical systems realized at it (CSPP, derived).
4. **Cosmic Moment Axiom (CMA).** Every physical system of the universe realizes its changes on the one common succession, with no private stage or private ordering; all physical systems of the universe realized at a stage are co-present there. At each stage, all the physical systems of the universe qualified at it, those whose identity ranges contain it, gather at that same stage, and the systems of all stages do not gather at one stage. The cosmic moment comprises this co-presence and the realization of change by every one of them at each stage, without exception; the latter is stated by UCC.
5. **Universal Change Continuity (UCC).** Physical change continues without interruption in every physical system of the universe, without exception, whether it is observed or not, including below

every detection threshold.

6. **Causes.** Every actual change has physical contributors of three classes: internal contributors, influencing physical systems, and non-system physical factors (CRP). Every contributor to a change is realized at the stage of that change, and an external influence, near or distant, reaches the system by contact or through a physical pathway; no contribution passes from a later stage to an earlier change, and none acts without a pathway. The influencing systems and factors do not act singly: they act together and combine qualitatively, under conditions that include the environment, which differs from place to place, and the effect depends on the responsiveness of the system. The variation of a factor, as distinct from a condition of a physical system, such as the temperature of a medium, which is a state of that system, is not counted as change in the sense of UCC and does not constitute a stage, because a factor has no structural constitution and no identity range, and its variation, often irregular, is not the change of a system. The kind and number of the influences acting can differ from system to system, while every system changes at every stage at which it is realized, without exception. Time, stage, and order are not causes, and the causes of change do not govern the succession of the stages.
7. **Identity and history.** Each physical system is realized over its own identity range, which has a least member (AFB); an ending, where it occurs (UEIE is optional), has physical contributors specific to it (PIECP). A history is physical; time is the one order shared by all histories.
8. **Observation.** Observers, instruments, and records are physical systems that change. A record is later than the change it reports and does not identify the stage of that change.
9. **Clocks and relativity.** Clock readings, coordinate time, proper time, and metric intervals are physical or model quantities. Every established quantitative result of relativity is retained, and that success does not make these quantities time (Section 28).
10. **Testability.** Each governing commitment has a stated direct contrary and a kind of evidence that bears on it (Section 48). Application hypotheses are kept outside the governing commitments. An example, the constitution-dependent clock response H_{CR} , is declared with predictions and withdrawal conditions (Section 51.2); it is not a commitment of ITOF, ITOF accommodates either outcome of its test, and its minimal field model is constrained below its withdrawal threshold by the weak-equivalence-principle bound (Section 51.5).

1.2 Foundational scope of V40/F20

V40/F20 fixes three foundational roles that must not be conflated:

$$\begin{aligned} T_{ITOF} &= \text{the invariant universal succession of the common stages} \\ &\quad \text{of change of the universe,} \\ CMA &= \text{no physical system has a private stage or ordering,} \\ UCC &= \text{the postulate of change: uninterrupted change of every} \\ &\quad \text{physical system of the universe.} \end{aligned} \tag{5}$$

The first fixes the meaning of time and of stage semantics (Eq. (11)). CMA states the unity of the stages of change for all physical systems of the universe: every one of them realizes its changes on the one common succession, which yields objective co-presence of all of them realized at each stage. UCC states the uninterrupted change of every physical system of the universe throughout its realized identity range. None of the three is a causal law, and none supplies a dynamical equation. Physical states, physical-change contents, causal sets, records, observables, metrics, dynamics, and application models are not additional

members of the ordered pair T_{ITOF} .

1.3 Version status

V40/F20 is the current formulation and supersedes incompatible formulations in earlier versions. V39/F19 [1] is the immediate predecessor; the wider V14–V38 sequence is documented in the consolidated project and archive record [4]. V40/F20 is governed by the definitions, axioms, postulates, principles, constraints, and derived results stated in this version. Earlier formulations have historical status only.

1.4 Statement status

V40/F20 distinguishes

$$\begin{aligned} &\text{Definition, Axiom, Postulate, Principle,} \\ &\text{DerivedCondition, Proposition, Construction,} \\ &\text{ApplicationPremise, EmpiricalBridge, CommitmentDistinction.} \end{aligned} \tag{6}$$

A defined construction adds no primitive physical commitment. A derived condition is available only from its declared premises. A typed object is not a proposition merely because it occurs in an equation. An application premise does not become a temporal axiom through empirical success. The “argument” environment is reserved for a CommitmentDistinction: a stated comparison between an ITOF commitment already fixed by a governing definition, axiom, or postulate and an independently stated relativistic or mathematical commitment, concluding that the two differ in type, domain of invariance, or constitution criterion. An argument does not itself introduce a new physical, causal, or ontological commitment beyond what its cited premises already fix. In V40/F20, every non-definitional and non-derived ontological, physical, causal, or identity commitment is stated as an axiom or postulate. Constitutive content fixed directly by a governing definition is not an additional axiom or postulate. The “principle” environment is reserved for type, non-transfer, epistemic, or methodological constraints whose status is declared explicitly in the status register; it is not used to conceal an additional ontological postulate.

The symbol $\not\sim$ is reserved for formal non-derivability supported by an explicit model-theoretic or proof-theoretic argument. Ordinary non-sufficiency, non-transfer, observational insufficiency, or lack of automatic implication is written with $\nRightarrow$. Without a label, the symbol $\rightsquigarrow$ is used in Eq. (10) only; its labelled forms elsewhere carry the relation their label names. In that equation, $X \rightsquigarrow Y$ states that the formal statement Y expresses as an order the change that the dynamic statement X states; it is a relation of expression between a postulate and a definition, not an inference, and it licenses no derivation in either direction.

Three further relations are used throughout. $x \equiv_{\text{type}} y$ states that x and y are of one and the same ontological type, an equivalence of classification only, which by itself licenses no transfer of the individual properties, relations, or measured results of x to y ; $x \not\equiv_{\text{type}} y$ states that they are of different types, so that no identity, substitution, or transfer of properties from one to the other is licensed by notation, naming, or numerical agreement. $x \not\equiv_{\text{def}} y$ states that the two expressions are not equal by definition. A predicate name written in operator font inside such a statement (for example *ManyTimes* or *DifferentRatesOfTime*) abbreviates exactly the proposition stated in the adjacent text; it is not a further primitive of the theory.

1.5 Abbreviated predicates

Predicates that recur in long formulas are written in abbreviated form. Each abbreviation denotes exactly the predicate named and defined at the cited equation.

Symbol	Predicate	Definition
NTCS_C	Non-terminating cosmic succession	Eq. (17)
$\text{GCN}_C(s)$	Global change-null stage	Eq. (106)
$\text{MSV}(s)$	Mixed change–stasis violation	Eq. (107)
$\text{SCB}_C(s)$	Stage-to-change bridge	Eq. (110)

1.6 The framework and time

The framework contains physical, identity, causal, observational, and application objects in addition to the temporal ordered pair. Schematically,

$$\mathfrak{T}_{40} = \left\langle T_{\text{ITOF}}, \mathcal{U}_C^{\text{phys}}, \mathcal{U}_{\text{phys}}, \mathfrak{F}_{\text{phys}}, \{\mathfrak{R}_C(s)\}_{s \in \mathcal{S}_C^{\text{tot}}}, \{\mathcal{H}_A\}_{A \in \mathcal{U}_{\text{phys}}}, \mathfrak{K}, \mathfrak{M}_{\text{phys}}, \mathfrak{M}_{\text{op}}, \mathfrak{D} \right\rangle. \quad (7)$$

Here $\mathfrak{K}$ is the family of composition profiles (Eq. (176)), $\mathfrak{M}_{\text{phys}}$ the family of admissible physical models (Eq. (309)), $\mathfrak{M}_{\text{op}}$ the family of operational metric maps (Eq. (336)), and $\mathfrak{D}$ the family of observation maps (Eq. (367)). The type boundary is

$$T_{\text{ITOF}} \not\equiv_{\text{def}} \mathfrak{T}_{40}. \quad (8)$$

2. Time as the Succession of Cosmic Change

2.1 The definition of time

Definition 2.1 (Time). Time denotes the invariant universal cosmic extension: the objective, fixed, and non-reversed succession of the common stages of physical change of all physical systems in the universe, without being a cause of the physical changes realized by those systems.

Extension. *Extension* means the non-metric succession and following of the common stages of change: each later stage follows every earlier one, and no length, spacing, rate, or duration belongs to the succession. The succession of the stages is stated by the Ordinal Succession convention (Definition 2.2).

Invariance. *Invariant* means the fixed succession of the change realized through its stages, and its non-reversal: what succeeds is dynamic, a change that never stops; what is fixed is the order of its succession, never interrupted by a stage that is static, without change, or empty. Invariance is therefore complete:

1. *Non-reversed.* An earlier stage remains earlier and a later stage remains later; the order never reverses, and its stages never become interchangeable. Physical recurrence, cyclic evolution, or reversal of a physical variable is a new later change, not a reversal of the succession.
2. *No stage empty of change or static.* No common stage of the universe is empty of change or static, and this holds for every physical system of the universe realized at that stage, without exception: it is not said of some stages or of some systems only. Invariance is stated formally in Eq. (9).

Formally,

$$\begin{aligned} \text{NonMetric}(\mathcal{S}_C^{\text{tot}}, \prec_C) &: \Longleftrightarrow \text{Components}(T_{\text{TOF}}) = \{\mathcal{S}_C^{\text{tot}}, \prec_C\}, \\ \text{Invariant}(\mathcal{S}_C^{\text{tot}}, \prec_C) &: \Longleftrightarrow \text{StrictTotalOrder}(\mathcal{S}_C^{\text{tot}}, \prec_C) \wedge \forall s \in \mathcal{S}_C^{\text{tot}} : \mathcal{B}_\Delta(s) = \mathcal{S}_{\text{phys}}(s) \neq \emptyset, \end{aligned} \quad (9)$$

The first clause is a constitutive condition on what time comprises, not a property of metric spaces: the pair is the whole of time, so no distance, duration, or rate function on $\mathcal{S}_C^{\text{tot}}$ is a component of time; such functions belong to models. The physical states of the systems change at every stage, while the order of their succession stays fixed: invariance belongs to the order of the succession, not to the states it orders. It does not mean that physical states are unchanging, that stages are equally spaced, that change has a universal rate or magnitude, or that different systems evolve identically or share one history.

UCC (Eq. (83)) states dynamically that change continues without stopping in every physical system of the universe, observed or not. A stage is the formal expression of the realization of a change within that unceasing chain of change, by comparison between the earlier change and the later. The comparison is that of earlier and later in the chain of change, not an act of observation, and stage 0, the first stage of change at the genesis of the universe, has no earlier change before it. Each later stage therefore expresses a change realized after every earlier change, and the succession of the stages is the fixed and non-reversed order of that unceasing change:

$$\underbrace{\text{UCC}}_{\text{dynamic: change does not stop}} \rightsquigarrow \underbrace{\text{Invariant}(\mathcal{S}_C^{\text{tot}}, \prec_C)}_{\text{fixed and non-reversed: the order of succession of realized change}}, \quad (10)$$

where $\rightsquigarrow$ reads “is expressed formally by” and is not an implication. The relation does not attribute to UCC what it does not state: the strict order of the stages belongs to the definition of time, and the population of every stage to the common-stage condition. What it carries is that the change which UCC states as never stopping is the change whose succession the fixed order expresses. Formally, the predicate of Eq. (9) is derivable from temporal constitution and UCC (Eq. (104)); derivability is not production: invariance is not produced by them, but is the formal expression of the unceasing change that UCC states, not an effect of the premises from which the predicate is derived. UCC keeps its independent status: it is a postulate about physical systems, with a contrary that physical evidence could establish, and it is not derived from the definition of invariance.

Because change never stops, observed or not, no change is a changeless boundary from which the place of its stage could be fixed: the order of the succession is fixed, but the place in it of the stage of any given change cannot be determined. This does not deny the earlier–later relation that a physical ordering bridge warrants between two changes, as when a record is later than the change it reports; that relation places neither change in the succession.

Because the order is invariant, every admissible representation (observer, coordinate, frame, clock output, synchronization convention, record, or description) must preserve it (Eq. (30)); preservation represents the invariance and does not constitute it. This is not invariance in the sense of Lorentz invariance or general covariance, and the two senses must not be confused.

That this one succession is common to every physical system of the universe, with no system-private stage or ordering, is the content of the Cosmic Moment Axiom (Eq. (72)); that every physical system of the universe changes at every stage of its existence is the content of the postulate of change, UCC (Eq. (83)). Each system retains its own physical state, change, causal conditions, and physical history.

The formal definition is

$$T_{\text{ITOF}} := \mathcal{E}_C := (\mathcal{S}_C^{\text{tot}}, \prec_C). \quad (11)$$

Here $\mathcal{S}_C^{\text{tot}}$ is the one universal formal domain of the cosmic stages of the universe and $\prec_C$ is its designated objective earlier–later relation.

Time is therefore one and global throughout the universe: there is no time in space that differs from time on Earth. *Global* here means that time encompasses the whole universe: every physical system of the universe, near or at the greatest distance, is realized on the same common stages, so that there is one time for the entire universe and no region, system, frame, observer, or worldline has a time of its own. This global time is not a global time function, a cosmological time, or a foliation of a spacetime model; those are model quantities, not unique and dependent on the chosen model and slicing, and they remain type-distinct from time (Section 34.2). Clocks in space and on Earth do run at different rates, and the proper times computed for them differ, as satellite navigation confirms; that difference belongs to the clocks as physical systems under different gravitational and motional conditions, not to time. Systems on Earth and in the most distant regions belong to the same common stages regardless of distance; propagation affects records and access, not membership in a common stage.

Illustration: a human life. A human being is a physical system. Throughout life it changes without stopping, from childhood to youth to old age. This is the extension of the stages of change across that life, and it is what time expresses, not the ticks of a clock, which are mistakenly taken to express time. The ticks are the changes of another physical system, the clock, counted.

Equation (11) is a formal definition and adds no object to physical reality; physical systems, states, change contents, and causal structures remain independently typed. Each identity range I_A lies in $\mathcal{S}_C^{\text{tot}}$ (Eq. (62)); that each system’s own realization succession coincides with its range in $\mathcal{S}_C^{\text{tot}}$ is fixed by CMA, not by this definition.

Time is not matter, energy, mass, force, field, radiation, signal, physical substance, medium, container, physical system, causal source, interaction, dynamical mechanism, physical state, or physical-change content. It is not a clock, clock reading or rate, coordinate, coordinate time, proper-time functional, metric or spacetime interval, reference frame, synchronization or simultaneity convention, foliation, trajectory parameter, frequency standard, record, detector output, numerical duration, or measurement scale. Such quantities may describe, model, or measure physical processes; they do not constitute time in ITOF.

Time does not cause physical change, and physical change is not treated as a physical cause that produces time. Physical dynamics and causes are supplied by independently warranted physics. The common-stage condition requires every stage to be a common stage of the physical systems of the universe; change of every physical system realized at every stage is stated by UCC; objective co-presence of all of them at that one stage is stated by CMA. The definition of time does not require an infinite future; cosmic non-termination is a revisable cosmological hypothesis.

Definition 2.2 (Ordinal Succession of the Stages of Change).

$$0 \prec_C 1 \prec_C 2 \prec_C 3 \prec_C 4 \prec_C \cdots \infty \text{ (conditional)} \quad (12)$$

1. Stage 0 is the beginning of the stages of change: the first stage, at which change in the universe begins, with the formation and genesis of the universe. The convention does not fix when that genesis began.
2. The numerals 0, 1, 2, 3, 4 are a formal expression of the succession: the stages follow one another as the numerals follow one another, in a fixed order. They express only the abstract, fixed succession,

following, and sequence of the stages of change; each names a stage by its place among the named stages, and the order of the names is the order of the stages they name. They are ordinal names, not quantities; they are not added, and no numeral is an amount of change, a count of stages, or a duration. The names do not determine the stage of any given change or its place in the succession: change continues without stopping, observed or not, and an observed change carries no mark of its stage.

3. No stage is empty of change or static, whether it is one of the named stages or a stage lying between any two of them. No stage is major or minor: a stage has no size, rank, or level; no stage contains other stages or is composed of them, and a named stage is not larger than a stage lying between named stages.
4. The symbol ∞ is not a stage, a limit, or a greatest member: it marks that the succession has no last stage, and it is conditional, because current science does not establish whether the succession ends. The cardinality notation $|X| = \infty$ used elsewhere keeps its ordinary set-theoretic meaning. The dots $\dots$ continue the naming as far as the succession extends; they do not by themselves assert that it has no last stage.

Stage 0 is a stage of change like every other, so the zero excludes reading the numerals as accumulated amounts: 2 is after 1 and before 3, neither twice 1 nor a duration later. Stage 0 is the first stage of the universe, not a date: no clock reading, coordinate time, or cosmological age is assigned to it, which agrees with relativity, whose time coordinates label events in charts and are not stages. Every later stage holds a fixed place after stage 0 that no later change alters; the convention thus also expresses the invariance of the stages. The numerals name stages in their order; they do not enumerate every member of $\mathcal{S}_C^{\text{tot}}$. The convention neither asserts nor denies that a stage has an immediate successor. The definition of time and temporal constitution do not by themselves require a first stage; that commitment is the content of the Cosmic Origin postulate, which the convention represents and does not prove. Its first-stage clause is stated formally by the Cosmic Origin postulate (Eq. (40)), its third clause is the invariance of Definition 2.1, and its conditional ∞ is the non-termination hypothesis (Eq. (17)); what the convention adds is the ordinal reading of the whole succession, in which a stage is named only by its place among the named stages. It is a representation convention: it introduces no ontological commitment beyond the Cosmic Origin postulate, the invariance of Definition 2.1, and the conditional non-termination hypothesis, whose content it expresses in ordinal form. Any relabelling that preserves the order represents the same succession, and numerical values and their differences carry no physical content. Each stage expresses the change realized at it; it is not a container that holds change.

2.2 Spatial coordinates and the type of time

In ITOF, place or spatial location belongs to the geometric description of a physical system; it is not part of the ontological type of time. In a declared spatial or spacetime model with chart or frame F , the location of a qualified physical system A may be represented by a spatial coordinate tuple

$$\mathbf{x}_A^{(F)} = (x_A^{1(F)}, x_A^{2(F)}, x_A^{3(F)}), \quad (13)$$

with the dimension adapted to the declared geometry when necessary. When an application associates a system state with a cosmic stage, the notation $\mathbf{x}_A^{(F)}[s]$ denotes the geometric position assigned to that system state in F ; the bracketed s indexes the ITOF stage claim and is not itself a spatial coordinate. Spatial coordinates may change under a change of chart or frame without changing the type or identity of T_{ITOF} . Likewise, a coordinate- time label t_F belongs to the geometric or model representation and is not

the temporal referent defined by ITOF. The type separation is

$$\mathbf{x}_A^{(F)}[s] \not\equiv_{\text{type}} s, \quad t_F \not\equiv_{\text{type}} s, \quad t_F \not\equiv_{\text{type}} T_{\text{ITOF}}. \quad (14)$$

Thus a common cosmic stage does not mean a common spatial position, and temporal co-presence must not be reconstructed as equality of spatial coordinates.

2.3 Definition of a cosmic stage

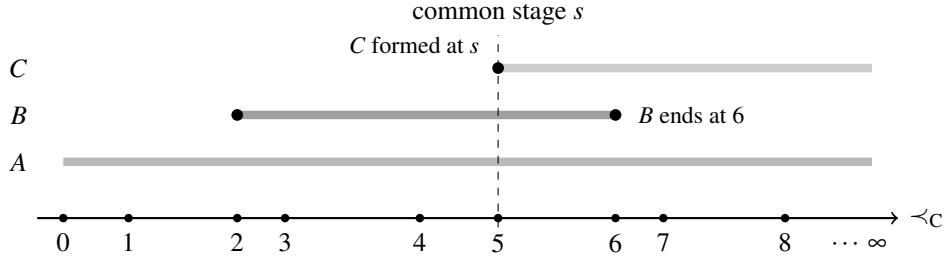


Figure 1: One succession of common stages of change. Each physical system is realized over its own identity range within the one succession: *A* from stage 0, *B* from its formation to its ending, and *C* from its formation at *s*. At every stage, all physical systems realized there share that stage, and each of them changes. The numerals are ordinal names placed at irregular positions; stages lie between the named stages as well, and the positions carry no metric meaning. The symbol ∞ after the dots is conditional.

Definition 2.3 (Cosmic stage). A cosmic stage is a member $s \in \mathcal{S}_C^{\text{tot}}$ that serves as the formal stage expression of objectively realized physical change and of its position in the one common objective earlier–later succession. The stage is common as a temporal member, not as physical content: every qualified system whose realized identity range contains s is incident with that same member of the single formal domain of cosmic stages, while its state, change, causes, and history remain system-specific. Objective collective co-presence of all physical systems of the universe realized at s is the content of CMA, and their change at s is the content of UCC.

A cosmic stage is not a container, receptacle, physical system, physical state, change content, change packet, causal source, clock moment, clock reading, coordinate, metric interval, duration, private system time, or additional ontic ordering-position entity. The written symbol s , the member of the formal cosmic-stage domain that it designates, and the physical changes formally expressed at that member are type-distinct. Observation is not constitutive of stagehood.

A member of $\mathcal{S}_C^{\text{tot}}$ is a common stage of the physical systems of the universe in the following sense:

$$\boxed{\text{CommonStage}_C(s) \iff [s \in \mathcal{S}_C^{\text{tot}}] \wedge \mathcal{S}_{\text{phys}}(s) \neq \emptyset \wedge \exists A \in \mathcal{S}_{\text{phys}}(s) \text{ PhysReal}_A^+(s).} \quad (15)$$

The predicate records that the stage is populated and that change is realized at it, so that every stage is the expression of realized change, as the definition of a cosmic stage states; that every physical system realized there changes at it is the content of UCC, and that it is one and the same stage for every system realized there is supplied by the single domain $\mathcal{S}_C^{\text{tot}}$ and by CMA (Eq. (72)). A stage of physical change of all physical systems of the universe realized there is

$$\boxed{\text{RealizedChangeStage}_C(s) \iff \text{CommonStage}_C(s) \wedge \forall A \in \mathcal{S}_{\text{phys}}(s) \text{ PhysReal}_A^+(s).} \quad (16)$$

Temporal constitution requires $\text{CommonStage}_C(s)$ for every member; the postulate of change, UCC, makes every member a stage of change of all physical systems realized there (Eq. (104)). Physical factors contribute to, constrain, or mediate the change of the systems; the stage is defined by the physical systems realized at it, and the factors acting there are causes of their change, not members of the stage population. This typing rule does not diminish the physical reality or causal relevance of factors. CMA supplies objective co-presence of all physical systems of the universe realized at the stage. Stage membership and temporal order do not cause the physical change they formally express. In a concrete application, scientific attribution of $\text{PhysReal}_A^+(s)$ requires applicable independently warranted physics, a declared system boundary and granularity, and an admissible evidential or modeling basis. These conditions govern attribution; they do not constitute the stage or create the physical change.

2.4 One common domain of stages

The formal architecture uses one formal domain of cosmic stages $\mathcal{S}_C^{\text{tot}}$; each identity range satisfies $I_A \subseteq \mathcal{S}_C^{\text{tot}}$ by Eq. (62). A representation in which a system realizes its changes on an independent stage succession, later synchronized or identified with another, is excluded by CMA (Eq. (72)), not by the definition of $\mathcal{S}_C^{\text{tot}}$ alone.

The dependence of stagehood on the physical systems of the universe and on their change is constitutive, not causal. Physical change does not produce, generate, or cause time, and time does not produce, generate, or cause physical change. A member of the formal cosmic-stage domain is a common stage of the physical systems of the universe, and under the postulate of change it formally expresses the change of every one of them realized there; physical dynamics and causal production remain supplied independently by applicable physics.

2.5 The common stage of cosmic change

In the full V40/F20 theory, a common cosmic change stage combines a common stage of the physical systems of the universe in the universal formal cosmic-stage domain, CMA common-stage co-presence, and UCC system-specific physical-change actuality for every physical system of the universe realized there. The phrase adds no further entity, causal mechanism, or temporal layer.

2.6 Cosmic extent and conditional non-termination

ITOF does not build an unlimited future into the definition of time. The following order-theoretic condition, non-terminating cosmic succession, is retained for cosmological models in which unrestricted continuation is independently adopted or established:

$$\boxed{\text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \iff \forall s \in \mathcal{S}_C^{\text{tot}} \exists t \in \mathcal{S}_C^{\text{tot}} (s \prec_C t).} \quad (17)$$

It states exactly that the represented succession has no greatest member. It contains no physical-change magnitude, dynamics, metric, or prediction about a particular system. Its status as a revisable hypothesis is stated in Section 3.4.

Equation (17) is non-metric. It does not assert density, adjacency, topological continuity, differentiability,

equal spacing, scalar duration, or infinitesimal stage interval:

$$\begin{aligned}
& \text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \not\Rightarrow \text{DenseOrder}, \\
& \text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \not\Rightarrow \text{Adjacency}, \\
& \text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \not\Rightarrow \text{TopologicalContinuity}, \\
& \text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \not\Rightarrow \text{Differentiability}, \\
& \text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \not\Rightarrow \text{EqualSpacing}, \\
& \text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \not\Rightarrow \text{MetricDuration}.
\end{aligned} \tag{18}$$

A terminal stage of a particular system identity is not thereby a terminal cosmic stage. If A ends at e_A , e_A is the final member of I_A under the applicable identity criterion. Whether that same stage is also a greatest member of the complete cosmic succession is a distinct cosmological question:

$$\begin{aligned}
& \text{End}_A(e_A) \not\Rightarrow \text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C), \\
& \text{End}_A(e_A) \not\Rightarrow \neg \text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C).
\end{aligned} \tag{19}$$

Where other qualified identities persist or new qualified identities are physically formed, their later realizations remain members of the same cosmic succession; no new time or restarted temporal order is introduced.

Non-termination is also not UCC:

$$\text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \not\equiv_{\text{def}} \text{UCC}. \tag{20}$$

UCC states change throughout realized identity ranges; it does not predict that the universe possesses an unlimited future. If non-termination is additionally adopted, then the conditional extended realization satisfies

$$\begin{aligned}
& \mathfrak{T}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \wedge \text{UCC} \\
& \wedge \text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \\
& \implies \forall s \in \mathcal{S}_C^{\text{tot}} : [\exists t \in \mathcal{S}_C^{\text{tot}} (s \prec_C t) \wedge \mathcal{B}_\Delta(s) = \mathcal{S}_{\text{phys}}(s) \neq \emptyset].
\end{aligned} \tag{21}$$

This is a conditional statement about an unlimited cosmological extension, not a hidden assertion that current physics has established one.

2.7 What constitutes a succession as time

Define

$$\begin{aligned}
& \mathfrak{T}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \\
& \iff [\mathcal{S}_C^{\text{tot}} \neq \emptyset] \wedge \text{StrictTotalOrder}(\mathcal{S}_C^{\text{tot}}, \prec_C) \\
& \quad \wedge \forall s \in \mathcal{S}_C^{\text{tot}} \text{ CommonStage}_C(s) \\
& \quad \wedge \exists r \in \mathcal{S}_C^{\text{tot}} \exists t \in \mathcal{S}_C^{\text{tot}} (r \prec_C t).
\end{aligned} \tag{22}$$

This definition fixes a nonempty strictly ordered domain of common stages of the physical systems of the universe and requires a nontrivial earlier-later pair, so the totality represents a genuine succession rather than a succession-free singleton. The final conjunct is only a non-degeneracy condition: it neither assumes nor entails that every stage has a later member. The predicate is denoted $\mathfrak{T}_C$, read “temporal constitution,”

in every subsequent equation, to keep long formulas legible; $\mathcal{T}_C$ and $\text{TemporalConstitution}_C$ name the same predicate, and the descriptive name is retained in the symbol register (Table 6). It therefore does not settle whether the complete succession has a greatest member, specify a metric, supply system dynamics, establish CMA, or establish UCC. Temporal constitution, CMA, and UCC retain distinct logical roles.

2.8 The designated earlier–later orientation

The notation $r \prec_C s$ has a fixed semantic role in ITOF:

$$r \prec_C s \quad \text{denotes that } r \text{ is objectively earlier than } s \text{ in the one cosmic succession.} \quad (23)$$

This designation is part of the governing meaning of the theory. Strict Cosmic Ordering does not choose one orientation from two mathematically symmetric orders; it imposes the strict-total-order properties on the relation already designated as earlier–later.

Axiom 2.4 (Strict Cosmic Ordering). The relation $\prec_C$ is the designated objective earlier–later relation on the one formal domain of the cosmic stages of the universe. Its orientation is fixed and non-reversed: if $r \prec_C s$, no observer, coordinate, clock, physical condition, signal record, or convention makes s earlier than r . Strict Cosmic Ordering requires

$$\boxed{\text{StrictTotalOrder}(\mathcal{S}_C^{\text{tot}}, \prec_C)}. \quad (24)$$

The axiom constrains order only. It does not supply stage spacing, duration, density, differentiability, a temporal rate, or physical dynamics.

For distinct $r, s \in \mathcal{S}_C^{\text{tot}}$, exactly one order direction holds:

$$r \neq s \implies [(r \prec_C s) \vee (s \prec_C r)] \wedge \neg [(r \prec_C s) \wedge (s \prec_C r)]. \quad (25)$$

In particular,

$$r \prec_C s \implies \neg(s \prec_C r). \quad (26)$$

The inverse relation is mathematically definable by

$$s \prec_C^{-1} r \iff r \prec_C s, \quad (27)$$

but mathematical definability does not make the inverse a second governing orientation:

$$\text{MathematicallyDefined}(\prec_C^{-1}) \not\Rightarrow \text{GoverningTemporalOrder}_{\text{ITOF}}(\prec_C^{-1}). \quad (28)$$

Nor does strict total ordering alone perform the semantic designation:

$$\text{StrictTotalOrder}(\mathcal{S}_C^{\text{tot}}, \prec_C) \not\Rightarrow \text{SemanticSelectionOfEarlierLaterOrientation}. \quad (29)$$

2.9 What remains fixed across representations

The word *fixed* does not mean physical stasis. It means that the same designated objective earlier–later relation governs every admissible temporal representation. For any representation $\iota : \mathcal{S}_C^{\text{tot}} \rightarrow L$ into an

ordered label domain $(L, <_L)$, admissibility requires

$$\begin{aligned} & \text{AdmissibleTemporalRepresentation}_{\text{ITOF}}(\iota) \\ \implies & \forall r, s \in \mathcal{S}_C^{\text{tot}}, \quad [r \prec_C s \iff \iota(r) <_L \iota(s)]. \end{aligned} \quad (30)$$

Labels, coordinates, or parameterizations may change; the governing objective orientation does not.

2.10 Physical recurrence within a non-reversed order

A system may later realize a state equal or equivalent, under a declared criterion K_A , to a state it realized earlier. If

$$r \prec_C t \wedge K_A(X_A(r), X_A(t)) = \text{Equivalent}, \quad (31)$$

then the later occurrence remains later:

$$r \prec_C t \wedge K_A(X_A(r), X_A(t)) = \text{Equivalent} \implies r \neq t \wedge r \prec_C t \wedge \neg(t \prec_C r). \quad (32)$$

A repeated physical condition is a distinct later realization in the same objective succession. It does not alter the already designated order relation between the earlier and later cosmic-stage expressions.

2.11 The universal cosmic extension

The word *extension* means the non-metric succession and following of the common stages of change; it does not denote spatial extension, metric duration, or a medium through which systems or changes move:

$$\begin{aligned} \mathcal{E}_C &\not\equiv_{\text{type}} \text{SpatialLength}, & \mathcal{E}_C &\not\equiv_{\text{type}} \text{MetricDuration}, \\ \mathcal{E}_C &\not\equiv_{\text{type}} \text{CoordinateInterval}, & \mathcal{E}_C &\not\equiv_{\text{type}} \text{ProperTimeFunctional}, \\ \mathcal{E}_C &\not\equiv_{\text{type}} \text{PhysicalField}, & \mathcal{E}_C &\not\equiv_{\text{type}} \text{PhysicalMedium}, \\ \mathcal{E}_C &\not\equiv_{\text{type}} \text{PhysicalContainer}, & \mathcal{E}_C &\not\equiv_{\text{type}} \text{CausalAgent}, \\ \mathcal{E}_C &\not\equiv_{\text{type}} \text{ClockOutput}. \end{aligned} \quad (33)$$

The stage symbols do not move through a temporal receptacle, and the temporal extension does not move from stage to stage:

$$\neg \text{Moves}(T_{\text{ITOF}}), \quad \neg \text{Moves}(\mathcal{E}_C), \quad \forall s \in \mathcal{S}_C^{\text{tot}} \neg \text{StageMovesThroughTime}(s). \quad (34)$$

Earlier and later are ordering relations, not locations through which time or a packet of change travels.

2.12 Temporal and physical types kept distinct

A stage member is a formal expression of realized physical change within the one universal objective earlier-later succession. The ordered-pair signature $(\mathcal{S}_C^{\text{tot}}, \prec_C)$ does not contain physical systems, state vectors, change-content values, or physical laws as additional components. In the governing theory every member is nevertheless a stage of change of all physical systems of the universe realized there:

$$\mathfrak{T}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \wedge \text{UCC} \implies (s \in \mathcal{S}_C^{\text{tot}} \implies \text{RealizedChangeStage}_C(s)). \quad (35)$$

The ordered pair does not itself carry this content; it is supplied by the postulate of change, UCC, and the commonness of the stage is supplied by CMA. This type separation does not make a stage an empty temporal placeholder; it assigns each part of the content of a stage to the commitment that states it.

2.13 Representing order without a metric

For the map ι of Eq. (30), taken injective,

$$\iota : \mathcal{S}_C^{\text{tot}} \longrightarrow L \quad (36)$$

is an order representation exactly when

$$\text{OrderRepresentation}(\iota) \iff \forall r, s \in \mathcal{S}_C^{\text{tot}}, \quad r \prec_C s \iff \iota(r) <_L \iota(s). \quad (37)$$

If f is strictly increasing, $f \circ \iota$ preserves the same governing order. A numerical interval may change under such a reparameterization, so order preservation does not produce a canonical duration:

$$\text{StrictTotalOrder}(\mathcal{S}_C^{\text{tot}}, \prec_C) \not\Rightarrow \text{CanonicalMetricIntervalOn}(\mathcal{S}_C^{\text{tot}}). \quad (38)$$

A metric, duration scale, clock scale, or numerical stage parameter requires additional physical or mathematical structure.

3. Cosmic Origin and Conditional Non-Termination

3.1 Identity ending and cosmic extent

Equation (17) defines a conditional order-theoretic property of the complete cosmic succession. It is not a foundation-level assertion that current science has established an unlimited future. Formation, persistence, ending, and successor production concern identity ranges within the one cosmic order. The terminal stage e_A of a particular identity A is therefore only the greatest member of I_A when that identity ends; it is not thereby the greatest member of $\mathcal{S}_C^{\text{tot}}$. If other identities persist or genuinely new identities form, their realizations continue in the same cosmic order.

Conversely, V40/F20 does not infer from present or ongoing physical change that $\mathcal{S}_C^{\text{tot}}$ must have no greatest member over the unknown complete future. The future extent of cosmic physical change remains a cosmological question. Where an application independently adopts non-termination (Eq. (17)), all consequences of that assumption are explicitly conditional on it.

No unconditional infinity claim follows from temporal constitution, governing CMA, or the UCC continuity condition. In particular,

$$\begin{aligned} \mathfrak{T}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) &\not\Rightarrow \text{Infinite}(\mathcal{S}_C^{\text{tot}}), \\ \text{CMA} &\not\Rightarrow \text{Infinite}(\mathcal{S}_C^{\text{tot}}), \quad \text{UCC} \not\Rightarrow \text{Infinite}(\mathcal{S}_C^{\text{tot}}). \end{aligned} \quad (39)$$

Infinite-cardinality conclusions arise only from their explicitly declared premises. In particular, temporal constitution supplies a nonempty strict total order, while conditional cosmic non-termination supplies the no-greatest-member premise; together these imply infinitude of the stage domain. The symbol ∞ , where used in a cardinality statement below, denotes only that the relevant set is not finite; it does not select a particular infinite cardinal, entail countability, or denote a metric, duration, magnitude, or physically measured future extent.

3.2 Cosmic origin and stage 0

The cosmic succession has a first stage: the stage at which change in the universe begins, with the formation and genesis of the universe. ITOF adopts this as the additional Cosmic Origin postulate. The evidence of cosmic expansion, the cosmic microwave background, and the abundances of the light elements establishes that the observable universe developed from an early hot and dense state. That evidence is the empirical anchor of the postulate; it does not by itself establish a first stage, since cosmological models in which the hot and dense state was preceded by earlier physical change are compatible with the same data. The first stage is therefore adopted by postulate, not established by observation.

Postulate 3.1 (Cosmic Origin). The succession of the stages of change of the universe has one first stage, stage 0, at the formation and genesis of the universe:

$$\text{CosmicOrigin} \iff \exists! s_C^0 \in \mathcal{S}_C^{\text{tot}} \forall s \in \mathcal{S}_C^{\text{tot}} \setminus \{s_C^0\}, \quad s_C^0 \prec_C s. \quad (40)$$

It is the first-stage clause of the Ordinal Succession convention (Definition 2.2). The first stage s_C^0 is a stage of change like every other: physical systems are realized there and change there. *Formation* here refers to the universe as a whole, not to the formation boundary of a system's identity range. The early hot and dense state from which the observable universe developed is the empirical anchor of the postulate. It is not the singularity of a cosmological model, which marks where the model's equations cease to apply and is not a stage at which systems change. The age assigned to the universe is a value of cosmological time, a metric quantity of a model (Proposition 43.4); it measures records against a model and does not date s_C^0 . The contrary of Cosmic Origin is that $\mathcal{S}_C^{\text{tot}}$ has no least member: for every stage there is an earlier one. Evidence of physical change before a stage hitherto taken as first does not by itself contradict the postulate; it places the first stage earlier.

Beginning and end are not treated alike.

They are treated differently for two reasons. The origin is analogous to the Actual Formation Boundary: every physical system has a least member of its identity range, its formation, while the core does not assert that every system has an ending (UEIE is optional); the Cosmic Origin postulate asserts a first stage of the succession, at the formation and genesis of the universe, which is the totality of physical systems and factors and not itself a physical system. The analogy motivates the postulate and does not derive it. The origin also has an empirical anchor — an early hot and dense state is established — although that state does not by itself establish a first stage; the origin is adopted as a postulate, not as an observational result. Its status is that of a cosmological postulate with an empirical anchor, not of an empirically decidable hypothesis: no finite body of evidence establishes that the succession has no least member, and evidence of physical change before a stage hitherto taken as first relocates the first stage without refuting the postulate. It is revised only if a physical theory, accepted on grounds independent of ITOF, establishes that the complete succession of the universe has no least member. The end is neither supported nor excluded: current evidence establishes neither a terminal stage nor an unbounded future, so non-termination remains a revisable hypothesis (Eq. (17)). Neither commitment is part of the definition of time, and neither follows from CMA or UCC.

The two commitments are logically independent:

$$\text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \not\Rightarrow \text{CosmicOrigin}, \quad \text{CosmicOrigin} \not\Rightarrow \text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C). \quad (41)$$

Temporal constitution requires a nontrivial earlier–later pair, and the first stage precedes every other stage;

hence the succession extends beyond the origin without any further postulate:

$$\mathfrak{T}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \wedge \text{CosmicOrigin} \implies \exists s \in \mathcal{S}_C^{\text{tot}} (s_C^0 \prec_C s). \quad (42)$$

How far it extends is not settled by this; that every stage has a later one is the separate, revisable hypothesis of non-termination.

3.3 Reference-stage order prefix

For any reference stage $a \in \mathcal{S}_C^{\text{tot}}$, define

$$\mathcal{S}_C^{\leq a} := \{v \in \mathcal{S}_C^{\text{tot}} \mid v = a \vee v \prec_C a\}. \quad (43)$$

This is a derived order prefix, not a second temporal domain, generated frontier, moving present, or presentism axiom.

3.4 Why non-termination remains conditional

Current physical evidence establishes neither a global terminal stage nor an unbounded future succession of stages. Non-termination is therefore a revisable cosmological hypothesis conditional on that evidence. It is not part of the definition of time and is not a theorem of CMA or UCC; every proposition that uses it states it as a premise.

4. The Universe as Physical Totality, and the Cosmic Moment Axiom

4.1 Physical systems, physical factors, and the physical totality

Physical-system status is objective. V40/F20 uses $\text{PhysicalSystem}(A)$ for the ontic claim that A is a physically realized system with its own physical constitution, system-level properties, and physically distinguishable identity:

$\begin{aligned} \text{PhysicalSystem}(A) \implies & \text{PhysicallyRealized}(A) \wedge \text{PhysicalConstitution}(A) \\ & \wedge \text{SystemSpecificPhysicalProperties}(A) \\ & \wedge \text{PhysicallyDistinguishableIdentity}(A). \end{aligned}$	(44)
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A scientifically warranted qualification scheme Ω does not create physical-system status. It fixes the class, boundary, granularity, and numerical- identity criteria used to identify, track, or test particular systems in a specified application. Write $\text{PhysicalSystem}_\Omega(A)$ only for the application-level claim that the objectively physical system A is admissibly qualified under Ω :

$$\text{PhysicalSystem}_\Omega(A) \implies \text{PhysicalSystem}(A). \quad (45)$$

Different physically meaningful subsystem and composite levels may support qualified identities, but arbitrary description, spatial grouping, or analytical convenience neither creates a physical system nor creates a cosmic stage.

Within V40/F20, *physical factor* is one framework category spanning physically different factor families. Each factor retains the domain-specific physical classification and mechanism assigned by the applicable

physics; the factor families are listed in Section 8. A physical factor is the ITOF category for a physically realized non-system physical item, without structural constitution or identity range of its own, that can enter a warranted physical description as a field, a radiation that does not satisfy a physical-system identity criterion, a transfer or exchange between systems, a process or interaction, or an action, such as a load, a pressure, a heat flow, or a vibration, as it reaches a system. A medium, body, lattice, trap, boundary, or other structured item is a physical system, and where it influences another system it is an influencing physical system; a condition of a physical system, such as the temperature, pressure, composition, or flow state of a medium, is a state of that system, and its change is the change of that system under UCC.

$$\boxed{\text{PhysicalFactor}(F) \implies \text{PhysicallyRealized}(F) \wedge \neg \text{PhysicalSystem}(F)}. \quad (46)$$

The condition $\neg \text{PhysicalSystem}(F)$ is an ontological type boundary within ITOF, not a claim about causal importance. A physical system that influences another system remains a physical system and is typed by $\text{InfluencingPhysicalSystem}$, not reclassified as a factor. Application boundary and granularity determine which system identity is being tracked and which external contributors are relevant; they do not convert a physical-system identity into a physical factor or a physical factor into a physical-system identity. Detailed causal families, internal contributors, external influencing systems, and qualitative causal composition are stated in Section 8.

For a declared physical system A at s , $\text{InfluencingPhysicalFactor}(F; A, s)$ means that F is outside the declared boundary of A and its actual physical influence contributes to the physical change realized in A at s . In a concrete application, scientific attribution of that influence must be warranted by the applicable physics for the declared system boundary and granularity. Thus

$$\begin{aligned} &\text{InfluencingPhysicalFactor}(F; A, s) \\ &\implies \text{PhysicalFactor}(F) \wedge \text{PhysicalSystem}(A) \wedge \text{ExistsAs}(A, s) \wedge \text{FactorRealizedAt}(F, s). \end{aligned} \quad (47)$$

Here $\text{FactorRealizedAt}(F, s)$ records stage-relative physical realization of the factor. It does not by itself assert that the factor influences a declared system or acts as a causal contributor. The full $\text{InfluencingPhysicalFactor}(F; A, s)$ relation supplies that additional causal role where independently warranted.

Define the physically realized physical-factor totality by

$$\boxed{\mathfrak{F}_{\text{phys}} := \{F \mid \text{PhysicalFactor}(F)\}}. \quad (48)$$

PhysicalFactor is a typed classification, within the framework, of physically realized non-system contributors; it does not assert that its members form a single natural kind. The influencing physical factors can be listed nearly exhaustively by family — mechanical and contact actions, including vibration and momentum transfer; heat transfer; electromagnetic fields and couplings; gravitational fields; radiation and particle transfer; nuclear and reaction-channel processes; chemical and material exchange; fluid and plasma transport; waves and oscillations; boundary and confinement actions; and fluctuations and disturbances — whereas the physical systems of the universe cannot be enumerated; a physical system that influences another remains a physical system. Physical factors also vary, but a factor has no structural constitution, no identity range, and no succession of realization of its own; its variation, often irregular and, even where regular, as in a periodic wave, not ordered as the change of a constituted system, is therefore not the change of a system through an identity range. A field or radiation is a physical system only where it independently satisfies a physical-system identity criterion, such as a configuration re-identifiable

over a nonempty identity range, for example a radiation packet tracked from emission to absorption (Section 40.7), and a physical factor otherwise. The classification is fixed by a test applied before any result is evaluated: (i) an item with a structural constitution is a physical system; (ii) an item without one is a physical system only if a declared criterion re-identifies it over a nonempty identity range; (iii) every other physically realized contributor is a physical factor, and a condition of a physical system is a state of that system. Thus a star, a body of air, and a lattice are systems; a radiation packet tracked from emission to absorption is a system; sunlight taken as a flux, the cosmic microwave background, a heat flow, and a gravitational field are factors; and the temperature or pressure of the air is a state of the air. ITOF does not count the variation of a factor as change in the sense of UCC; no stage is constituted by it, and ITOF does not take it as the change whose stages time expresses; a factor enters the framework through its influence on physical systems. The stage-relative factor-realization relation is typed by

$$\text{FactorRealizedAt} \subseteq \mathfrak{F}_{\text{phys}} \times \mathcal{S}_{\text{C}}^{\text{tot}}. \quad (49)$$

Every physical factor admitted to the physically realized factor totality must have stage support in the common formal cosmic-stage domain:

$$\forall F \in \mathfrak{F}_{\text{phys}} \exists s \in \mathcal{S}_{\text{C}}^{\text{tot}} : \text{FactorRealizedAt}(F, s). \quad (50)$$

This stage-support requirement aligns global factor membership with stage-relative physical realization. It assigns neither numerical physical-system identity nor an identity range or private cosmic-stage succession to a physical factor.

Definition 4.1 (Stage-relative physical-factor population). For each cosmic stage $s \in \mathcal{S}_{\text{C}}^{\text{tot}}$, define

$$\boxed{\mathfrak{F}_{\text{phys}}(s) := \{F \in \mathfrak{F}_{\text{phys}} \mid \text{FactorRealizedAt}(F, s)\}}. \quad (51)$$

Membership records physical-factor realization at s ; it does not by itself assert causal influence on any declared physical system.

Within the physical vocabulary used by V40/F20, every physically realized item admitted into the framework's system–factor classification is typed explicitly as either a physical-system identity or a physical factor. This is a framework typing rule, not a claim that present physics has exhausted every possible ontological category:

$$\text{ITOFPhysicallyTyped}(x) \implies [x \in \mathcal{U}_{\text{phys}} \vee x \in \mathfrak{F}_{\text{phys}}]. \quad (52)$$

The rule supplies no causal mechanism and does not erase domain-specific physical classifications. Define, in addition, the domain of factors that actually influence at least one realized system–stage pair by

$$\mathfrak{F}_{\text{phys}}^{\text{inf}} := \{F \in \mathfrak{F}_{\text{phys}} \mid \exists A \exists s \in \mathcal{S}_{\text{C}}^{\text{tot}} \text{ InfluencingPhysicalFactor}(F; A, s)\}. \quad (53)$$

Membership in $\mathfrak{F}_{\text{phys}}$ states physical realization as a factor; membership in $\mathfrak{F}_{\text{phys}}^{\text{inf}}$ additionally states actual influence on at least one realized system–stage pair.

An *influencing physical system* B is a distinct physical system outside the declared boundary of A whose actual physical influence contributes to the physical change realized in A at s . It remains a physical system

with its own identity range and physical history:

$$\begin{aligned} \text{InfluencingPhysicalSystem}(B; A, s) \implies \\ B \in \mathcal{U}_{\text{phys}} \wedge A \in \mathcal{U}_{\text{phys}} \wedge B \neq A \wedge s \in I_B \wedge s \in I_A. \end{aligned} \quad (54)$$

Thus a stage-relative influence claim presupposes identity-stage realization of both the influencing system and the influenced system at that same stage.

Influencing physical factors and influencing physical systems are therefore two physically distinct source types of external physical influence. Their common causal role is influence on A ; that role does not change the physical type of the source.

Simple and composite systems are both admitted. Qualification of a simple system does not require a constituent decomposition. For a composite system, qualification at the composite level requires physically warranted interconnection and coherence among its constituent organization:

$$\begin{aligned} \text{CompositePhysicalSystem}_{\Omega}(B) \implies \exists \mathcal{C}_B \Big[& \text{ConstituentOrganization}(\mathcal{C}_B, B) \\ & \wedge \text{PhysicalInterconnection}_{\Omega}(\mathcal{C}_B; B) \\ & \wedge \text{PhysicalCoherence}_{\Omega}(\mathcal{C}_B; B) \Big]. \end{aligned} \quad (55)$$

Interconnection is not mere proximity, and coherence is not mere co-location or set membership. The physically appropriate criterion may be structural, dynamical, organizational, or otherwise domain-specific; it need not assign a teleological function to the system.

Define the governing physical-system totality independently of any application scheme:

$$\boxed{\mathcal{U}_{\text{phys}} := \{A \mid \text{PhysicalSystem}(A) \wedge \exists s \in \mathcal{S}_{\text{C}}^{\text{tot}} \text{ExistsAs}(A, s)\}} \quad (56)$$

V40/F20 does not define a closed, privileged catalogue of physical factors. The detailed cross-domain taxonomy of external physical factors, external influencing physical systems, internal physical contributors, descriptor-to-source discipline, and their qualitative causal composition is given in Section 8. The present ontology section therefore does not repeat that catalogue. It fixes only the system–factor type boundary and the rule that the same physical contribution is not counted twice under different causal roles.

V40/F20 uses $\mathcal{U}_{\text{C}}^{\text{phys}}$ for the physical universe understood as the physical totality itself rather than as an independent receptacle containing physical entities. Its constitutive notation is

$$\boxed{\mathcal{U}_{\text{C}}^{\text{phys}} := \mathcal{U}_{\text{phys}} \sqcup_{\text{ont}} \mathfrak{F}_{\text{phys}}.} \quad (57)$$

Here $\sqcup_{\text{ont}}$ denotes a typed ontological totality: it does not mean arithmetic addition, spatial union, or placement of systems and factors inside a further physical container. The universe expresses the totality of the physical systems and the influencing physical factors; it is not a container that holds them. The physical universe is therefore the total physical actuality constituted by qualified physical-system identities together with physically realized physical factors. The word *universe* adds no third receptacle around those constituents. The totality does not acquire one numerical system identity, one causal agency, or one physical history replacing the many histories of its constituent systems. Influencing physical systems retain systemhood; physical factors retain factor typing; and neither causal role converts one type into the other. Time is not an additional constituent of this totality and the common cosmic stage is not a container

in which the totality is placed. Accordingly,

$$\mathcal{U}_C^{\text{phys}} \not\equiv_{\text{type}} \text{PhysicalContainer}, \quad \mathcal{U}_C^{\text{phys}} \not\equiv_{\text{type}} \text{PhysicalSystemIdentity}. \quad (58)$$

Because $\mathcal{U}_{\text{phys}}$ is a domain of numerical physical-system identities, the second type boundary gives

$$\mathcal{U}_C^{\text{phys}} \notin \mathcal{U}_{\text{phys}}. \quad (59)$$

This does not deny that physical systems can causally affect one another or that physical factors can contribute to system change. It only prevents the physical totality itself from being silently retyped as one system identity or as a causal container. CMA continues to quantify over physical-system identities and their common cosmic stages; inclusion of physical factors in the cosmic physical totality does not give those factors system identities or private identity ranges.

For an application that fixes a physically warranted qualification scheme Ω , define the application-selected subdomain

$$\mathcal{U}_{\text{phys}}^{[\Omega]} := \{A \in \mathcal{U}_{\text{phys}} \mid \text{PhysicalSystem}_{\Omega}(A)\}. \quad (60)$$

Thus Ω controls warranted identification and counting in a declared application; it does not determine whether the underlying physical system or the cosmic stage exists. In foundational statements, “qualified physical system” means an objectively realized member of $\mathcal{U}_{\text{phys}}$, that is, a physical system of the universe; the qualifier records that its identity is objectively realized and does not select a subset of the physical systems of the universe; the indexed notation $\text{PhysicalSystem}_{\Omega}$ is reserved for application-level class, boundary, granularity, and attribution criteria. The framework does not require one unique decomposition of all physical reality for every scientific purpose.

Each $A \in \mathcal{U}_{\text{phys}}$ realizes its physical changes on its own realization succession

$$\boxed{(\mathcal{W}_A, \triangleleft_A)}, \quad (61)$$

where $\mathcal{W}_A$ is the nonempty set of positions, in a carrier $P \supseteq \mathcal{S}_C^{\text{tot}}$ of realization positions, at which the numerical identity A is realized and $\triangleleft_A$ is the earlier–later order of those positions within the history of A . $\text{ExistsAs}(A, x)$ holds exactly when $x \in \mathcal{W}_A$. The realized numerical-identity range of A in the common domain is

$$\boxed{I_A := \{s \in \mathcal{S}_C^{\text{tot}} \mid \text{ExistsAs}(A, s)\} = \mathcal{W}_A \cap \mathcal{S}_C^{\text{tot}}}. \quad (62)$$

Under CMA, $\mathcal{W}_A = I_A$ and $\triangleleft_A = \prec_C|_{I_A}$; hence $I_A \neq \emptyset$, and I_A is a segment of the one cosmic succession, not a private time. Every governing result below that uses $I_A \neq \emptyset$ or orders the members of I_A by $\prec_C$ holds under CMA.

At stage s , define the complete then-realized qualified population

$$\boxed{\mathcal{S}_{\text{phys}}(s) := \{A \in \mathcal{U}_{\text{phys}} \mid s \in I_A\}}. \quad (63)$$

Definition 4.2 (Stage-relative cosmic physical totality). For each cosmic stage $s \in \mathcal{S}_C^{\text{tot}}$, define

$$\boxed{\mathcal{U}_C^{\text{phys}}(s) := \mathcal{S}_{\text{phys}}(s) \sqcup_{\text{ont}} \mathfrak{F}_{\text{phys}}(s)}. \quad (64)$$

The typed union records the physical-system identities and non-system physical factors realized at s . It is not a container, does not make a factor a system, and does not enlarge CMA from physical-system co-presence into a claim that factors possess system identity ranges.

Membership in $\mathcal{S}_{\text{phys}}(s)$ is objective numerical-identity realization in the governing ontic physical-system domain, not observer knowledge, application-level classification, or successful detection:

$$\mathcal{S}_{\text{phys}}(s) \neq \text{SystemsKnownToObserverAt}(s), \quad (65)$$

$$A \in \mathcal{S}_{\text{phys}}(s) \not\Rightarrow \text{Detected}(A; s). \quad (66)$$

4.2 Derived Cosmic Change-Stage Population Principle

Retain the historical acronym CSPP for the stage-population condition

$$\boxed{\text{CSPP} \iff \forall s \in \mathcal{S}_{\text{C}}^{\text{tot}}, \quad \mathcal{S}_{\text{phys}}(s) \neq \emptyset.} \quad (67)$$

Under the governing stage semantics this is not an independent postulate: by temporal constitution every member of $\mathcal{S}_{\text{C}}^{\text{tot}}$ is a common stage of the physical systems of the universe (Eq. (15)); hence

$$\mathfrak{T}_{\text{C}}(\mathcal{S}_{\text{C}}^{\text{tot}}, \prec_{\text{C}}) \implies \text{CSPP}. \quad (68)$$

CSPP remains useful as a named population corollary, but it must not be counted as an additional independent foundation-level burden.

4.3 Identity incidence and objective co-presence

$\text{ExistsAs}(A, s)$ records numerical identity–stage incidence:

$$A \in \mathcal{S}_{\text{phys}}(s) \iff A \in \mathcal{U}_{\text{phys}} \wedge \text{ExistsAs}(A, s). \quad (69)$$

Incidence states only that s belongs to the realization succession of A . It does not state that this succession is the common succession itself rather than a private succession sharing some members with it. Objective common-stage co-presence is that further condition. For $P \subseteq \mathcal{U}_{\text{phys}}$ and $s \in \mathcal{S}_{\text{C}}^{\text{tot}}$,

$$\boxed{\text{CosmicCoPresence}_{\text{C}}(P; s) : \iff \forall A \in P \left[s \in \mathcal{W}_A \wedge \mathcal{W}_A \subseteq \mathcal{S}_{\text{C}}^{\text{tot}} \wedge \triangleleft_A = \prec_{\text{C}}|_{\mathcal{W}_A} \right].} \quad (70)$$

The members of P are co-present at s when each realizes s as a member of one and the same succession ($\mathcal{S}_{\text{C}}^{\text{tot}}, \prec_{\text{C}}$), with no member of its realization succession outside it and no ordering of its own that differs from $\prec_{\text{C}}$. Co-presence is therefore stronger than incidence,

$$\text{CosmicCoPresence}_{\text{C}}(P; s) \not\equiv_{\text{def}} [P = \{A \in \mathcal{U}_{\text{phys}} \mid \text{ExistsAs}(A, s)\}], \quad (71)$$

and it is not clock agreement, synchronization, signal access, spatial coincidence, or coordinate equality.

4.4 Cosmic Moment Axiom

Axiom 4.3 (Cosmic Moment Axiom (CMA)). The stages of change are one and the same for all physical systems of the universe: every physical system realizes its changes on the one common cosmic succession, with no private stage or private ordering of stages, and all physical systems realized at a stage are co-present at that same stage. At each stage of the one succession, all the physical systems of the universe qualified at that stage, those whose identity ranges contain it, gather at that same stage; the systems of all stages do not gather at one stage. The cosmic moment at each stage also comprises the realization of

change by every one of these systems there, without exception, according to its internal contributors and the influencing systems and factors that reach it. That clause is stated separately as the postulate of change, UCC, so that the two clauses can be shown independent, and the cosmic moment is their conjunction (Eq. (73)). Formally,

$$\boxed{\text{CMA} \iff \forall A \in \mathcal{U}_{\text{phys}}, \quad \mathcal{W}_A \subseteq \mathcal{S}_C^{\text{tot}} \wedge \triangleleft_A = \prec_C|_{\mathcal{W}_A}.} \quad (72)$$

$$\boxed{\text{CosmicMoment} : \iff \text{CMA} \wedge \text{UCC}.} \quad (73)$$

Same-stage comparison.

Two states belong to one cosmic moment only when they are states at one and the same common stage:

$$\text{CosmicMomentComparison}(X_A(r), X_B(s)) \implies r = s \wedge s \in I_A \cap I_B. \quad (74)$$

This is an ontological condition, not a methodological one: records do not identify stages (Change-Stage Restraint), so it cannot be checked by records. All the physical systems realized at a stage gather at that stage, and those realized at the next gather at the next; a state of A at one stage and a state of B at another are not states of one cosmic moment. An actual comparison is made at the stage of reception, between a received record and a local state, as when light from a distant source is compared at the stage at which it is received. The Cosmic Moment Axiom names one of the two clauses of the cosmic moment, the co-presence clause.

By Eqs. (62) and (70), CMA gives objective co-presence of the complete then-realized population at every stage:

$$\text{CMA} \implies \forall s \in \mathcal{S}_C^{\text{tot}}, \quad \text{CosmicCoPresence}_C(\mathcal{S}_{\text{phys}}(s); s). \quad (75)$$

Under the domain condition — every qualified system has at least one member of $\mathcal{S}_C^{\text{tot}}$ at which it is realized, a condition enforced by the definition of $\mathcal{U}_{\text{phys}}$ rather than an added postulate, stated in full at Eq. (748) — the converse also holds: for arbitrary $A \in \mathcal{U}_{\text{phys}}$, the domain condition gives some $s \in \mathcal{S}_C^{\text{tot}}$ with $A \in \mathcal{S}_{\text{phys}}(s)$, and $\text{CosmicCoPresence}_C(\mathcal{S}_{\text{phys}}(s); s)$ applied to that A yields exactly $\mathcal{W}_A \subseteq \mathcal{S}_C^{\text{tot}} \wedge \triangleleft_A = \prec_C|_{\mathcal{W}_A}$. So CMA is equivalent to co-presence of the complete population at every stage.

CMA asserts unity of the cosmic stage, not equality of physical state, physical change, magnitude, rate, cause, location, clock reading, signal condition, or physical history. It does not state that every realized system changes; that commitment is UCC. The full content of the cosmic moment — every qualified system present at one common stage, and each realizing its own change there — is the conjunction $\text{CMA} \wedge \text{UCC}$ (Eq. (111)). The two conjuncts are stated separately because different findings would refute them: a private stage or private ordering refutes CMA; complete physical non-change of a qualified system refutes UCC.

$$\text{CMA} \not\Rightarrow \forall s \in \mathcal{S}_C^{\text{tot}} \forall A, B \in \mathcal{S}_{\text{phys}}(s), X_A(s) = X_B(s), \quad (76)$$

$$\text{CMA} \not\Rightarrow \forall s \in \mathcal{S}_C^{\text{tot}} \forall A, B \in \mathcal{S}_{\text{phys}}(s), \mathbf{x}_A^{(F)}[s] = \mathbf{x}_B^{(F)}[s], \quad (77)$$

$$\text{CMA} \not\Rightarrow \text{UniversalPairwisePhysicalInteraction}, \quad (78)$$

$$\text{CMA} \not\Rightarrow \text{UniversalInstantaneousSignalAccessibility}, \quad (79)$$

$$\text{CMA} \not\Rightarrow \text{UCC}. \quad (80)$$

CMA does not contradict the relativity of simultaneity. Coordinate simultaneity is a relation among clock records fixed by a synchronization convention, and it differs between frames; co-presence at a common stage is fixed by the realization successions of the systems, not by any convention. The Lorentz transformations are derived in Section 38.2 without using CMA, and CMA neither follows from them nor contradicts them (Eq. (590)).

4.5 The non-causal character of CMA

CMA supplies no physical mechanism. Neither objective co-presence nor the common cosmic stage causes system-specific physical change. Time, the cosmic stage, and common-stage co-presence are not physical causal-source classes. Physical causation is governed separately by CRP.

5. Universal Change Continuity: No Physical System Is Static

5.1 Actual-change subset and change-content typing

For $A \in \mathcal{U}_{\text{phys}}$, define

$$I_A^\Delta := \{s \in I_A \mid \text{PhysReal}_A^+(s)\}. \quad (81)$$

Let Ξ_A be the system-specific physical-change-content type appropriate to A , and define

$$\Delta_A^{\text{phys}} : I_A^\Delta \longrightarrow \Xi_A. \quad (82)$$

The restricted domain keeps change content well typed in formal countermodels in which physical change is denied at selected identity-stage pairs.

5.2 Universal Change Continuity Postulate

Postulate 5.1 (Universal Change Continuity (UCC): the postulate of change). Physical change continues without interruption in every physical system of the universe, without exception: every qualified physical system A undergoes its own actual physical change at every member of its complete realized identity range I_A , whether that change is observed, unobserved, or below any detection threshold:

$$\text{UCC} \iff \forall A \in \mathcal{U}_{\text{phys}} \forall s \in I_A, \quad \text{PhysReal}_A^+(s). \quad (83)$$

UCC is an independent foundational physical postulate. It does not follow from CMA, strict ordering, stage membership, or temporal constitution. Observation is not a condition of the change it asserts. Whether a change is noticed does not depend on whether it is measured: a change may be noticed without measurement, and a measured change may go unnoticed. Neither noticing nor measuring is a condition of the change itself.

$$\begin{aligned} & \text{PairwiseTypeDistinct}(\text{PhysReal}_A^+(s), \text{Noticed}(A, s), \text{Measured}_{P, M, \varepsilon}(A, s)), \\ & \text{Noticed}(A, s) \not\Rightarrow \text{Measured}_{P, M, \varepsilon}(A, s), \quad \text{Measured}_{P, M, \varepsilon}(A, s) \not\Rightarrow \text{Noticed}(A, s), \quad (84) \\ & \neg \text{Noticed}(A, s) \wedge \neg \text{Measured}_{P, M, \varepsilon}(A, s) \not\Rightarrow \text{NC}_A^{\text{phys}}(s). \end{aligned}$$

Here

$$\begin{aligned} \text{Measured}_{P,M,\varepsilon}(A,s) &:\Longleftrightarrow \exists \chi \exists r : \text{ManifestationAt}(A,\chi;s) \wedge \text{Detected}_{P,M,\varepsilon}(A,\chi;r), \\ \text{Noticed}(A,s) &:\Longleftrightarrow \exists O \in \mathcal{U}_{\text{phys}} \exists \chi \exists r : \text{Recognizes}_O(\text{ManifestationAt}(A,\chi;s);r), \end{aligned} \quad (85)$$

where χ is a manifestation of the change of A at s , $\text{Detected}_{P,M,\varepsilon}$ is detection under a declared protocol P and model M (Eq. (351)), and Recognizes_O states that an observer system O identifies the manifestation in a record at r , with or without a declared protocol. The change itself, its being noticed, and its being measured are of different types; noticing and measuring do not imply each other, and the absence of both does not establish non-change. Detection under a declared protocol is treated in Eqs. (352) and (353). Its continuity is non-metric and does not imply differentiability, equal change magnitude, a universal rate, one universal mechanism, unlimited identity duration, or an infinite cosmic future.

“Without interruption” has two parts, secured by two commitments. UCC excludes a member of an identity range at which the system does not change. Identity-Realization Convexity (Eq. (197)) excludes a gap in the range itself: a system cannot exist, cease to exist, and then exist again as the same identity. Together they give

$$\begin{aligned} &\text{UCC} \wedge \text{IdentityRealizationConvexity} \\ &\implies \forall A \in \mathcal{U}_{\text{phys}} \forall r, t \in I_A \forall s \in \mathcal{S}_C^{\text{tot}}, \quad r \prec_C s \prec_C t \implies \text{PhysReal}_A^+(s). \end{aligned} \quad (86)$$

By Identity-Realization Convexity, $s \in I_A$; by UCC, $\text{PhysReal}_A^+(s)$. Between any two stages of a system’s existence there is no stage at which it is absent or unchanging.

Ending of identity A ends the UCC requirement only beyond I_A ; it does not suspend UCC for other realized systems and does not require successor production.

The stagewise form follows from the definition of $\mathcal{S}_{\text{phys}}(s)$:

$$\text{UCC} \Longleftrightarrow \forall s \in \mathcal{S}_C^{\text{tot}} \forall A \in \mathcal{S}_{\text{phys}}(s), \quad \text{PhysReal}_A^+(s). \quad (87)$$

This is a quantifier reformulation of UCC, not CMA. CMA and UCC are logically independent (Proposition 5.4): CMA concerns private stages and orderings, whereas UCC concerns system-specific physical-change actuality.

Accordingly,

$$\text{UCC} \implies \forall A \in \mathcal{U}_{\text{phys}}, \quad I_A^\Delta = I_A. \quad (88)$$

5.3 Physical actuality criterion and genuine contrary

The predicate $\text{PhysReal}_A^+(s)$ asserts actual system-specific physical change in A at s . It is not definitionally a finite difference between two stages, does not require an immediate predecessor or successor in I_A , and supplies no universal scalar magnitude or rate. Its scientific attribution is not warranted by stage membership, terminology, or detectability. In every concrete application, the physical-system boundary and organizational granularity G , together with an applicable physical theory or independently warranted physical model M , must be declared. Attribution of $\text{PhysReal}_A^+(s)$ requires M , at that declared granularity, to warrant at least one physically constitutive process, transition, formation, reconfiguration, constituent exchange, interaction-mediated modification, field-coupled change, structural change, or other physically admissible realization of change in A at s . The listed forms are illustrative rather than exhaustive and remain typed by the applicable physics.

The change asserted by UCC is the change of each physical system taken by itself. It is not established by comparing that system with another system, and it is not a difference between two systems. Where the internal constitution of a system remains unchanged under every available criterion, as in a system described as static, its change is realized outside that constitution, in its external physical state: in its state of motion as the influences acting on it change it, and in its state of coupling to the influencing physical systems and physical factors acting on it, which produce that change. Such change may be minute and below every detection threshold. A change of position assigned only by the choice of a reference is not by itself a change of the system, and neither is a spatial relation to another system through which no influence acts on it. A merely comparative description, such as one system being called smaller, older, or slower than another only because the other has changed, is not by itself a change of the first; a change produced in the first system by the influences acting on it is. The variation of the influencing physical factors themselves, which have no structural constitution, is not counted as change of the system. Complete physical non-change of a system therefore requires that nothing change either in its constitution or in its external physical state; the change of another system and the variation of a factor do not by themselves change it:

$$\begin{aligned}\text{PhysReal}_A^+(s) &\equiv \text{OwnChange}_A(s), \\ \text{RelChange}(A, B; s) &\not\Rightarrow \text{OwnChange}_A(s),\end{aligned}\tag{89}$$

where $\text{OwnChange}_A(s)$ is a change of the physical state of A , internal or external, and $\text{RelChange}(A, B; s)$ is a change of a relation of A to B . The first line reads the primitive predicate $\text{PhysReal}_A^+(s)$; it does not redefine it. The admissible contrary is a changed relation with no change of A . UCC therefore remains independent of the common-stage condition: that condition requires that change be realized at the stage, and UCC asserts the change of every system realized there, which no change elsewhere supplies by itself.

Where M represents change through comparison of state variables or physical relations across suitable realizations of the same system, a warranted difference in at least one physically constitutive component can serve as evidence of change. Such a comparison is not the universal definition of change in V40/F20. In particular, formation at the least member f_A can realize physical change through the formation process itself even though there is no earlier member of the same numerical identity range; an ending transformation is treated analogously. Thus the criterion does not smuggle a predecessor requirement into every system stage.

The model and granularity indices discipline warrant; they do not relativize the foundational predicate into a model-created fact and they are not additional arguments of $\text{PhysReal}_A^+(s)$. Equality of a selected observable, a stationary coarse-grained description, equilibrium terminology, criterion-relative stability, or finite non-detection is insufficient by itself to establish complete physical non-change. Conversely, if the applicable physics at the declared system boundary and granularity positively warrants that no physically constitutive change admissible to the claim is realized in A at s , that warranted case is the genuine physical contrary targeted by $\text{NC}_A^{\text{phys}}(s)$ and is a direct countercondition to UCC. It does not by itself negate CMA, whose direct contrary is failure of objective common-stage co-presence for the complete then-realized qualified population.

Define complete physical non-change by

$$\text{NC}_A^{\text{phys}}(s) \iff \neg \text{PhysReal}_A^+(s).\tag{90}$$

Then

$$\text{UCC} \iff \forall A \in \mathcal{U}_{\text{phys}} \forall s \in I_A, \quad \neg \text{NC}_A^{\text{phys}}(s).\tag{91}$$

The logical contrary in Eq. (90) therefore has a demanding but non-vacuous physical warrant condition: it

must be supported by the applicable physics at the declared system boundary and granularity, not inferred from an unchanging selected record. Criterion-relative stability, operational waiting, or non-detection is not complete physical non-change. UCC is identity-bounded: if a numerical identity A ends at its terminal identity stage e_A , UCC places no condition on A beyond e_A . The ending of A does not cancel UCC for other qualified identities that remain realized or for genuinely new identities that are physically formed.

5.4 Change without a universal magnitude, rate, or substance

UCC universalizes physical-change actuality, not change content. Therefore

$$\text{UCC} \not\Rightarrow \text{UniversalScalarMagnitudeOfPhysicalChange}, \quad (92)$$

$$\text{UCC} \not\Rightarrow \text{UniversalScalarRateOfPhysicalChange}, \quad (93)$$

$$\text{UCC} \not\Rightarrow \text{OneUniversalChangeSubstance}. \quad (94)$$

A system-specific scalarization, where physically warranted, remains an application-level construction.

5.5 Stability relative to a criterion, and observation

A qualified system may satisfy a declared stability criterion while UCC remains true. Selected observables can be unchanged, unresolved, or below threshold even when physical change continues. For a declared protocol P and model M ,

$$\text{NoResolvedDifference}_{P,M}(A; r, s) \not\Rightarrow \text{NC}_A^{\text{phys}}(s). \quad (95)$$

The phrase *criterion-relative stability* is therefore reserved for a system-level observational or physical criterion. It is not the meaning of the fixed cosmic temporal order.

5.6 Exact quantum stationary states and the UCC burden

A stationary quantum representation must be handled without converting formal parameter dependence into physical change. For a time-independent Hamiltonian, let

$$\hat{H}|E\rangle = E|E\rangle, \quad |\psi(\tau)\rangle = e^{-iE\tau/\hbar}|E\rangle, \quad (96)$$

where τ is the evolution parameter of the declared quantum model and is not identified with T_{TOF} . The corresponding pure-state density operator is

$$\rho(\tau) = |\psi(\tau)\rangle\langle\psi(\tau)| = |E\rangle\langle E|, \quad (97)$$

so expectation values of time-independent observables are stationary in the standard energy-eigenstate case [58, 59].

V40/F20 therefore does not count the global phase $e^{-iE\tau/\hbar}$ by itself as $\text{PhysReal}_A^+(s)$. A global phase, a stationary wavefunction label, an unchanged selected expectation value, or a time-independent density operator is not automatically an actual physical-change content. UCC instead requires an independently warranted physical change in the qualified physical system under the declared system boundary.

The converse restraint is equally important. A stationary state assignment in an idealized model does not by itself establish complete physical non-change of the full qualified system. The physical boundary may include fields, environmental couplings, internal degrees of freedom, or other physically warranted

structure not represented by the selected stationary observable. Accordingly,

$$\text{StationaryQuantumRepresentation}_M(A) \not\Rightarrow \text{NC}_A^{\text{phys}}(s). \quad (98)$$

But if independently warranted physics and a sufficiently complete declared system model establish $\text{NC}_A^{\text{phys}}(s)$ for any qualified $A \in \mathcal{U}_{\text{phys}}$ and $s \in I_A$, that is a direct countercondition to UCC rather than something to be reclassified as hidden change:

$$\text{WarrantedCompletePhysicalNonChange}_M(A, s) \implies \text{NC}_A^{\text{phys}}(s) \implies \neg \text{UCC}. \quad (99)$$

Thus exact stationary-state cases are a genuine scientific burden for UCC: ITOF must either identify independently warranted actual physical change in the declared system or accept the warranted complete-nonchange case as falsifying that postulate. Measurement non-resolution, a global phase, or interpretive terminology does not discharge this burden.

5.7 A checkable closure criterion for the quantum burden

Appeal to environmental couplings or internal degrees of freedom not represented by the selected stationary observable (Eq. (98)) is admissible only when tied to a declared, checkable criterion for when a system is closed enough that its non-change tests UCC.

Definition 5.2 (Currently-complete physical isolation). Let M be an applicable physical theory or model, and let the system boundary and organizational granularity G for A be declared as in Section 5. A is *currently-completely isolated* at s under (M, G) , written $\text{CCPI}_{M,G}(A, s)$, if and only if every interaction channel between A and its exterior that M recognizes at that boundary and granularity — at minimum, gravitational coupling, electromagnetic and vacuum-field coupling, any weak- or strong-interaction channel applicable at that scale, thermal photon or particle exchange with the surrounding bath, and measurement-induced back-action — has, for each such channel, (i) been experimentally suppressed below the best independently reported sensitivity for that channel, (ii) been shown by M to vanish by an exact selection rule or exact symmetry, or (iii) where the channel cannot be suppressed, as for gravitational coupling, been computed by M and removed from the record within stated uncertainty. Conditions (i) and (ii) are physical isolation; condition (iii) is model-based subtraction, a distinct evidential operation, and every application states which channels were isolated and which were subtracted. Channels not recognized by M lie outside the criterion; $\text{CCPI}_{M,G}$ is relative to M and is revised when M is.

$\text{CCPI}_{M,G}(A, s)$ is a checklist against a stated experimental protocol and a stated theory M ; it does not itself assert or deny physical change in A :

$$\begin{aligned} \text{CCPI}_{M,G}(A, s) &\not\Rightarrow \text{WarrantedCompletePhysicalNonChange}_M(A, s), \\ \text{CCPI}_{M,G}(A, s) &\not\Rightarrow \text{PhysReal}_A^+(s). \end{aligned} \quad (100)$$

Suppression of every channel M recognizes, to below current sensitivity, is not an exact zero, and M may be superseded by a theory recognizing a further channel. The burden therefore remains open.

Corollary 5.3 (What UCC entails under currently-complete isolation). If UCC holds and $\text{CCPI}_{M,G}(A, s)$ holds for a qualified A and $s \in I_A$, then $\text{PhysReal}_A^+(s)$ holds (Eq. (83)) despite every channel recognized by M being closed under (M, G) . UCC alone does not entail that this change is attributable to any specific, independently named channel; attribution remains a separate, model-relative question.

Proof. Immediate from Eq. (83): $A \in \mathcal{U}_{\text{phys}}$ and $s \in I_A$ jointly give $\text{PhysReal}_A^+(s)$ regardless of which channels M recognizes or has closed at (M, G) . Nothing in Definition 5.2 restricts the quantifier in Eq. (83).

Corollary 5.3 is the whole of what UCC entails here: the existence of change, not its identification. A separate expectation, with EmpiricalBridge status rather than axiom or postulate status (Eq. (6)), states where that change is expected to be found. Systems brought toward $\text{CCPI}_{M,G}$ — trapped-ion and optical-lattice clock states, superconducting qubits at their coherence limit — have so far exhibited an independently named channel (spontaneous emission into the vacuum field, blackbody-radiation shifts, gravitational-redshift gradients across the trap, magnetic- or electric-field noise). The expectation is that further isolation will continue to locate such a channel. The expectation may fail without UCC failing.

The countercondition to UCC is complete physical non-change, $\text{NC}_A^{\text{phys}}(s)$ (Eq. (99)). No finite measurement certifies an exact zero; it bounds the magnitude of change below a stated sensitivity. Evidence against UCC therefore takes the form of a sequence of bounds, each obtained under currently-complete isolation, that continues to decrease while no channel is identified. Once the bounds fall below the smallest change predicted by the channels that the model recognizes, the sequence is adverse evidence of increasing weight and is reported as evidence against UCC, not reinterpreted as hidden change; above that level it is increasingly stringent non-detection. UCC is maintained against such evidence only by an identified channel or by a stated, independently testable bound on one. Because every realized system is acted on by influencing physical systems and factors whose action on it standard physics independently predicts, such a sequence would also contradict the predictions of standard physics for the coupled channels: the practical refutation of UCC and the failure of those predictions go together. The decision rule is therefore fixed in advance: a certified bound on the change of a system weighs against UCC only when it falls below the change that standard physics predicts for the channels coupled to that system under the declared isolation; a bound above that prediction is consistent with UCC however small it is, because change below every detection threshold remains change. UCC is an ontological statement that no qualified system of the universe is static; its empirical content in a given system is the content of the standard physics of the channels coupled to that system. No such sequence is currently known.

The examples above concern excited or interrogated states. The most demanding case is a system in the interacting ground state of its full Hamiltonian, which standard quantum theory treats as stationary and non-decaying. UCC does not count the global phase of that state as change (Eq. (96)). For such a system, UCC requires that physical change be located in the couplings to its exterior that M recognizes — gravitational, thermal-radiation, and measurement channels — and a ground-state system certified under $\text{CCPI}_{M,G}$, with each such channel bounded in the manner above, would be the strongest available adverse evidence against UCC.

Stationarity of a quantum state means that the probability distribution of every observable is constant. UCC does not contradict this mathematical property; it concerns which physical situations are realized. Three cases are distinct.

1. An exact energy eigenstate of a completely isolated system. This is an idealization. UCC asserts that no qualified system realizes it, because no qualified system is completely isolated: gravitational coupling cannot be suppressed (Definition 5.2, clause (iii)), and the influences acting on a system are not constant: the influencing physical systems to which it couples, such as moving masses, change, and influencing physical factors such as thermal radiation and the cosmic microwave background act on it irregularly. A coupling to a static external field alone would shift energies and phases without producing change; it is the changing and irregular action of the influences on the

system that makes the coupling a time-dependent perturbation and excludes an exact stationary state. By the equivalence principle, a uniform gravitational field alone produces no local change in a freely falling system; the gravitational contribution counted here is the tidal part of the field, its non-uniformity across the system, which moving and distant masses always produce and vary, however small. The variation of the factors themselves, which have no structural constitution and no identity range, is not counted as change in the sense of UCC; what UCC counts is the change that their joint action produces in the system.

2. An open system in a stationary state, including a thermal steady state. The reduced state is constant while the individual system continues to undergo exchange events — absorption, emission, scattering — at rates that may be very small. Constancy of an ensemble statistic does not exhaust the history of an individual system; single-system observations resolve discrete events in systems whose ensemble description is stationary [26]. UCC is satisfied by these events.
3. A ground-state system certified under $\text{CCPI}_{M,G}$, with every recognized channel bounded. This is the case in which UCC is exposed to adverse evidence, as stated above.

The disagreement with a purely stationary reading of the ground state is therefore located precisely: it concerns whether complete isolation is physically realized, not the mathematics of stationary states.

A single electron “in a perfect vacuum” belongs to the first case: it is an idealization. A physical electron is an open system. It is coupled to the electromagnetic field, it scatters the photons of the cosmic microwave background, and the gravitational fields of the other systems reach it, and their tidal parts act on its state; its momentum state is never an exact eigenstate, so its spatial state spreads, and its state under the gravitational and other influences acting on it changes. These are changes of the electron’s own physical condition, produced by the influences acting on it, not changes of a global phase, not comparisons with another system, and not the variation of the influencing factors themselves. Whether a certified isolated electron would show none of them is exactly the case in which UCC is exposed to evidence.

5.8 Independence of CMA and UCC, and the exclusion of void stages

Proposition 5.4 (Mutual independence of CMA and UCC). Under the governing definitions,

$$\text{CMA} \not\vdash \text{UCC} \quad \text{and} \quad \text{UCC} \not\vdash \text{CMA}, \quad (101)$$

established by the explicit countermodels below, per the reservation of $\not\vdash$ for model-theoretically supported non-derivability (Section 1.4).

Proof. (CMA does not entail UCC.) Let $\mathcal{S}_C^{\text{tot}} = \{0, 1\}$ with $0 \prec_C 1$, $\mathcal{U}_{\text{phys}} = \{A, B\}$, $\mathcal{W}_A = \mathcal{W}_B = \{0, 1\}$, and $\triangleleft_A = \triangleleft_B = \prec_C$; CMA holds. Assign $\text{PhysReal}_B^+(0)$, $\text{PhysReal}_B^+(1)$, $\text{PhysReal}_A^+(1)$, and $\neg \text{PhysReal}_A^+(0)$. Both are stages in the sense of the common-stage condition, since each has a nonempty population and change is realized at each: B changes at both. No influence of B acts on A at 0, and the change of B is not a change of A . UCC fails at $(A, 0)$.

(UCC does not entail CMA.) Let $\mathcal{S}_C^{\text{tot}} = \{0, 1\}$ with $0 \prec_C 1$, $\mathcal{U}_{\text{phys}} = \{A, B\}$, $\mathcal{W}_A = \{0, 1\}$ with $\triangleleft_A = \prec_C$, and $\mathcal{W}_B = \{0, b\}$ with $0 \triangleleft_B b$ and $b \notin \mathcal{S}_C^{\text{tot}}$. Assign PhysReal^+ at every member of every realization succession. Both are stages in the sense of the common-stage condition, since each has a nonempty population and change is realized at each; $I_A = \{0, 1\}$, $I_B = \{0\}$, and UCC holds. CMA fails, because B has a private stage b ; in particular $\neg \text{CosmicCoPresence}_C(\mathcal{S}_{\text{phys}}(0); 0)$, although A and B are both incident at 0.

In both structures Identity-Realization Convexity and the Actual Formation Boundary hold, and CRP is

satisfied by assigning one internal contributor to each realized change, as in the joint-satisfiability witness. The non-derivability is therefore not produced by violating another governing postulate.

6. Every Stage Is a Stage of Change

6.1 Actual-change population

Define

$$\mathcal{B}_\Delta(s) := \{A \in \mathcal{S}_{\text{phys}}(s) \mid \text{PhysReal}_A^+(s)\}. \quad (102)$$

By definition, $\mathcal{B}_\Delta(s) \subseteq \mathcal{S}_{\text{phys}}(s)$. Under the definitions of I_A , $\mathcal{S}_{\text{phys}}(s)$, and $\mathcal{B}_\Delta(s)$,

$$\text{UCC} \iff \forall s \in \mathcal{S}_C^{\text{tot}}, \quad \mathcal{B}_\Delta(s) = \mathcal{S}_{\text{phys}}(s). \quad (103)$$

6.2 Exclusion of change-null and mixed stages

The common-stage condition and the postulate of change together make every stage of the universe a stage of change of all physical systems realized there:

$$\boxed{\mathfrak{T}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \wedge \text{UCC} \implies \forall s \in \mathcal{S}_C^{\text{tot}}, \quad \text{RealizedChangeStage}_C(s).} \quad (104)$$

Proof. By $\mathfrak{T}_C$, $\text{CommonStage}_C(s)$ holds for every $s \in \mathcal{S}_C^{\text{tot}}$. By UCC in stagewise form (Eq. (87)), every $A \in \mathcal{S}_{\text{phys}}(s)$ satisfies $\text{PhysReal}_A^+(s)$. Eq. (16) then gives $\text{RealizedChangeStage}_C(s)$. $\square$

In terms of the actual-change population:

$$\mathfrak{T}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \wedge \text{UCC} \implies \forall s \in \mathcal{S}_C^{\text{tot}}, \quad \mathcal{B}_\Delta(s) = \mathcal{S}_{\text{phys}}(s) \neq \emptyset. \quad (105)$$

Define the global change-null stage by

$$\text{GCN}_C(s) \iff \mathcal{B}_\Delta(s) = \emptyset. \quad (106)$$

and the mixed change–stasis violation, in which the change population is a nonempty proper part of the stage population, by

$$\text{MSV}(s) \iff \emptyset \neq \mathcal{B}_\Delta(s) \subsetneq \mathcal{S}_{\text{phys}}(s). \quad (107)$$

These two predicates state the two forms that a stage without complete change would take. The common-stage condition excludes the first, and UCC excludes the second:

$$\mathfrak{T}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \implies \forall s \in \mathcal{S}_C^{\text{tot}}, \quad \neg \text{GCN}_C(s). \quad (108)$$

$$\text{UCC} \implies \forall s \in \mathcal{S}_C^{\text{tot}}, \quad \neg \text{MSV}(s). \quad (109)$$

Formally, the change population at a stage is either empty, a nonempty proper part of the stage population, or the whole of it; $\mathfrak{T}_C$ makes the stage population and the change population nonempty, UCC excludes a nonempty proper part, and the remaining case is Eq. (104). Unity of the stage for all physical systems of the universe realized there is supplied by CMA, not by UCC or by the definition of the stage domain.

Consequently no stage of the universe is empty, void of change, or static: the common-stage condition excludes a stage without physical systems or without realized change, the postulate of change excludes a stage at which any physical system realized there does not change, and CMA excludes a private stage

(Eq. (72)). These exclusions concern the same common stages, shared by all physical systems of the universe. A stage is not a receptacle that change occupies; it is the formal expression that change has been realized.

6.3 The stage-to-change representation

Define the local full-theory common-stage change condition, the stage-to-change bridge, by

$$\boxed{\text{SCB}_C(s) \iff [\text{CosmicCoPresence}_C(\mathcal{S}_{\text{phys}}(s); s) \wedge \mathcal{B}_\Delta(s) = \mathcal{S}_{\text{phys}}(s)]}. \quad (110)$$

This is a defined conjunction of the local CMA content and the stagewise UCC content. It is not an axiom, causal law, synchronization rule, measurement bridge, or dynamics. Therefore,

$$\text{CMA} \wedge \text{UCC} \implies \forall s \in \mathcal{S}_C^{\text{tot}}, \quad \text{SCB}_C(s). \quad (111)$$

Under the domain condition the converse also holds, because co-presence at every stage yields CMA (Eq. (75) and the converse stated after it) and full coverage at every stage yields UCC. The bridge at every stage is then equivalent to $\text{CMA} \wedge \text{UCC}$, and introduces no additional foundational commitment.

6.4 Common-stage system-change profile

Define

$$\mathfrak{D}_C(s) := \left(A \mapsto \Delta_A^{\text{phys}}(s) \right)_{A \in \mathcal{B}_\Delta(s)} \in \prod_{A \in \mathcal{B}_\Delta(s)} \mathfrak{E}_A. \quad (112)$$

Under UCC,

$$\text{UCC} \implies \text{dom } \mathfrak{D}_C(s) = \mathcal{S}_{\text{phys}}(s). \quad (113)$$

The dependent product preserves heterogeneous system-specific change-content types and does not create a universal change codomain.

6.5 From foundational realization to empirical bridges

The defined proposition $\text{SCB}_C(s)$ is not a model-input map, physical dynamics, model-output map, or measurement bridge. For a declared model M , application physics requires independently specified structures such as

$$\mathcal{I}_M^{\text{phys}} \xrightarrow{\mathcal{B}_M^{\text{in}}} \mathcal{I}_M^{\text{model}} \xrightarrow{\text{Dyn}_M} \mathcal{O}_M^{\text{model}} \xrightarrow{\mathcal{B}_M^{\text{out}}} \mathcal{O}_M^{\text{phys}} \xrightarrow{\mathcal{B}_{P,M}^{\text{obs}}} \mathcal{R}_{P,M}. \quad (114)$$

Neither the temporal definition, CMA, nor UCC supplies these maps or dynamics.

6.6 Conditional discriminating application template

If a future independently warranted physical extension supplies a specific interaction

$$\widehat{H}_I = \widehat{H}_{\text{base}} + \lambda_X \widehat{O}_X, \quad \widehat{H}_R = \widehat{H}_{\text{base}}, \quad (115)$$

then a candidate observable separation may take the form

$$\Delta y_{I,R}^{P^*, D^*} = \lambda_X K_X^{P^*, D^*}. \quad (116)$$

These are conditional application equations, not consequences of the temporal definition, CMA, or UCC. If the two branches have the same complete physical-to- observable specification, no ontology-only prediction separation follows.

6.7 What UCC supplies and what requires a further model

UCC supplies no numerical prediction separation without an independently supplied coupling λ_X (Eq. (116)). It does supply the qualitative content of Corollary 5.3: at a qualified system under $\text{CCPI}_{M,G}$, physical change exists, whether or not it is identified. Standard quantum theory admits an exactly stationary isolated system as an idealization; UCC excludes it as a physical realization. The difference is not a numerical residual; it is a difference in what is admitted as physically realized, and it is tested in the bounded, cumulative form stated in Section 5.7.

7. One Stage, System-Specific States

7.1 System-specific physical state spaces

For each $A \in \mathcal{U}_{\text{phys}}$, let Ω_A denote a declared physical state space adequate to the physical description of that system under the application or theoretical context being considered.

Define:

$$X_A : I_A \longrightarrow \Omega_A. \quad (117)$$

For every $s \in I_A$, $X_A(s)$ denotes the physical state of A realized at common cosmic change stage s .

The state and the common cosmic change stage remain type-distinct:

$$s \not\equiv_{\text{type}} X_A(s). \quad (118)$$

Likewise, under UCC,

$$s \not\equiv_{\text{type}} \Delta_A^{\text{phys}}(s). \quad (119)$$

The common cosmic change stage is universal. The physical state and the physical-change content are system-specific.

7.2 Heterogeneous physical-state spaces

Common-stage realization does not require all physical systems to be described through one state space.

For distinct systems:

$$A, B \in \mathcal{S}_{\text{phys}}(s) \wedge A \neq B \not\Rightarrow \Omega_A = \Omega_B. \quad (120)$$

Accordingly, V40/F20 introduces no universal physical-state space Ω_{univ} satisfying

$$\text{CommonStageRealization} \not\Rightarrow \exists \Omega_{\text{univ}} \forall A \in \mathcal{U}_{\text{phys}}, \quad \Omega_A = \Omega_{\text{univ}}. \quad (121)$$

as a foundational requirement.

A common mathematical representation may be constructed in a particular physical model where scientifically justified. Such a representation remains an application-level construction and does not identify the physical states of distinct systems.

7.3 Common-stage physical-state profile

At $s \in \mathcal{S}_C^{\text{tot}}$, every $A \in \mathcal{S}_{\text{phys}}(s)$ satisfies $s \in I_A$. Therefore $X_A(s)$ is well typed for the complete then-realized qualified population.

Definition 7.1 (Common-Stage Physical-State Profile). Define:

$$\mathfrak{X}_C(s) := (A \mapsto X_A(s))_{A \in \mathcal{S}_{\text{phys}}(s)} \in \prod_{A \in \mathcal{S}_{\text{phys}}(s)} \Omega_A. \quad (122)$$

The dependent product is essential. It preserves the possibility that different physical systems require different physical state spaces.

The profile does not identify the system-specific states:

$$\mathfrak{X}_C(s) \not\equiv_{\text{def}} \text{OneUniversalPhysicalState}(s). \quad (123)$$

Nor does the existence of the profile imply:

$$\text{Defined}(\mathfrak{X}_C(s)) \not\Rightarrow \forall A, B \in \mathcal{S}_{\text{phys}}(s), \quad X_A(s) = X_B(s). \quad (124)$$

The profile is a formal population-indexed representation of physically distinct system states realized at one common cosmic change stage.

7.4 Common stage versus totality state

Remark 7.2 (Stage/profile type boundary). The common cosmic change stage s , the temporal referent T_{TOF} , and the stage-relative physical-state profile $\mathfrak{X}_C(s)$ remain type-distinct. The first is a common cosmic change stage, the second is the governing temporal ordered pair, and the third is a formal population-indexed representation of physical states realized by the stage-relative population. No definition in this section identifies either s or T_{TOF} with $\mathfrak{X}_C(s)$.

8. What Produces Change: Contributors, Systems, and Factors

8.1 Physical and system-specific causation

The UCC states that each qualified physical system realizes its own physical change. It does not make time, cosmic ordering, or common-stage unity the cause of that change.

The causal architecture of V40/F20 is organized around three physically typed source classes: internal physical contributors of the changing system, external influencing physical systems, and external influencing non-system physical factors.

For every actual-change pair:

$$A \in \mathcal{U}_{\text{phys}}, \quad s \in I_A^\Delta, \quad (125)$$

the causal account belongs to the physically realized system and its physically admissible contributors.

The following are not causal-source classes:

$$\left\{ T_{\text{ITOF}}, \mathcal{E}_C, \mathcal{U}_C^{\text{phys}}, s, \prec_C, \text{CSPP}, \text{CMA}, \text{UCC}, \right. \\ \left. \text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C), \text{SCB}_C, \text{CRP} \right\} \\ \cap \text{PhysicalCausalSourceClass} = \emptyset. \quad (126)$$

This expression states a type boundary. It does not assert that the listed formal or foundational items are members of one ordinary set-valued physical domain. In particular, $\mathcal{U}_C^{\text{phys}}$ is not itself a causal-source class or a single causal agent; its constituent physical systems and influencing physical factors may nevertheless be actual causal contributors under the causal roles defined below.

8.2 Three causal-source classes

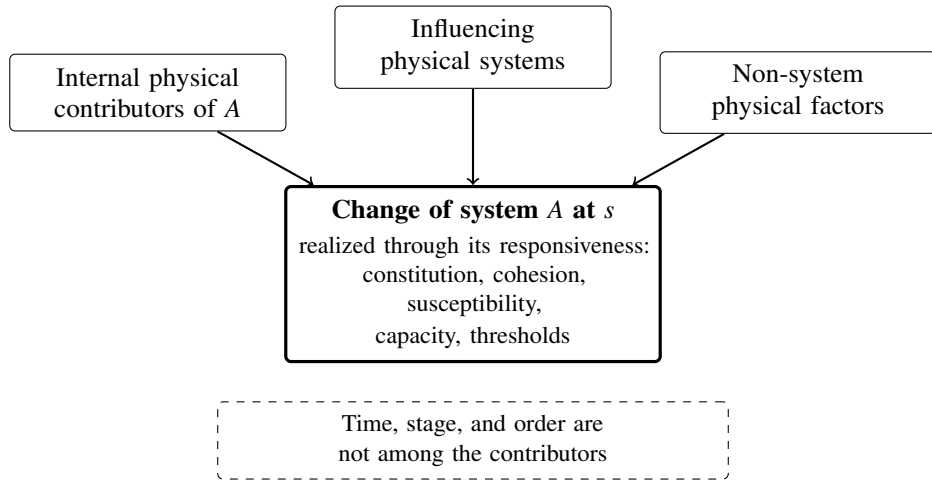


Figure 2: The three causal-source classes. The change realized in A depends on what acts on it and on its own responsiveness. Time, stage, and order are not contributors.

For physical system A at s , V40/F20 separates the actual physical causal basis into internal physical contribution and external physical influence. External physical influence may be produced by an influencing physical factor or by an influencing physical system. These two source types perform the same causal role relative to A : each can produce physical influence that contributes to A 's change, while retaining its own physical type.

Let $\mathcal{C}_A^{\text{int}}(s)$ denote the actual internal physical contributors to the change realized in A at s ; they lie within the declared boundary of A as A is realized at s .

Define the influencing physical-system and physical-factor source sets by

$$\mathcal{C}_A^{\text{infl-sys}}(s) := \{B \in \mathcal{U}_{\text{phys}} \mid \text{InfluencingPhysicalSystem}(B; A, s)\}. \quad (127)$$

$$\mathcal{C}_A^{\text{infl-factor}}(s) := \{F \in \mathfrak{F}_{\text{phys}} \mid \text{InfluencingPhysicalFactor}(F; A, s)\}. \quad (128)$$

Thus $\mathcal{C}_A^{\text{infl-sys}}(s) \subseteq \mathcal{U}_{\text{phys}}$ and $\mathcal{C}_A^{\text{infl-factor}}(s) \subseteq \mathfrak{F}_{\text{phys}}^{\text{inf}}$. System sources remain physical systems; factor sources remain physical factors with their domain-specific physical typing.

Collect the external sources of physical influence on A as

$$\mathcal{C}_A^{\text{ext}}(s) := \mathcal{C}_A^{\text{infl-sys}}(s) \cup \mathcal{C}_A^{\text{infl-factor}}(s). \quad (129)$$

Every member of $\mathcal{C}_A^{\text{ext}}(s)$ contributes external physical influence to A . A system source remains a physical system; a factor source remains a physical factor.

The causal profile is therefore

$$\mathfrak{C}_A(s) := \left(\mathcal{C}_A^{\text{int}}(s), \mathcal{C}_A^{\text{ext}}(s) \right). \quad (130)$$

For one declared system boundary, internal contribution and external influence are distinct roles, and the two external source types remain type-distinct:

$$\mathcal{C}_A^{\text{int}}(s) \cap \mathcal{C}_A^{\text{ext}}(s) = \emptyset, \quad \mathcal{C}_A^{\text{infl-sys}}(s) \cap \mathcal{C}_A^{\text{infl-factor}}(s) = \emptyset. \quad (131)$$

The complete actual physical causal set is

$$\mathcal{C}_A^{\text{act}}(s) := \mathcal{C}_A^{\text{int}}(s) \cup \mathcal{C}_A^{\text{ext}}(s). \quad (132)$$

This structure introduces no additional causal-source type. It distinguishes where the physical contribution comes from while stating the causal relation directly: actual internal physical contribution and/or actual external physical influence contributes to the system-specific change.

Proposition 8.1 (Stage-local causation). Every actual physical contributor to the change realized in a physical system A at s is realized at s :

$$\boxed{\mathcal{C}_A^{\text{infl-sys}}(s) \subseteq \mathcal{S}_{\text{phys}}(s), \quad \mathcal{C}_A^{\text{infl-factor}}(s) \subseteq \mathfrak{F}_{\text{phys}}(s),} \quad (133)$$

and the internal contributors $\mathcal{C}_A^{\text{int}}(s)$ lie within the declared boundary of A as A is realized at s .

Proof. An influencing physical system B satisfies $s \in I_B$ (Eq. (54)), so $B \in \mathcal{S}_{\text{phys}}(s)$; an influencing physical factor F satisfies $\text{FactorRealizedAt}(F, s)$ (Eq. (47)), so $F \in \mathfrak{F}_{\text{phys}}(s)$; internal contributors are typed relative to the boundary of A at s .

Causation therefore does not relate a system at one stage to a system at another stage. At every stage all the physical systems realized there are co-present, and the change realized in a system at that stage is contributed by its internal contributors and by those influencing systems and factors whose influence reaches it there; not every influencing system or factor acts on it at every stage, and those that act combine qualitatively. At the following stage the systems are co-present again, and so on through the succession. What earlier changes leave is carried by the physical systems through their own succession, as they are realized at the later stage, and by the physical factors realized there; a factor, which has no structural constitution and no identity range of its own, bears the influences of earlier stages and of its own stage, never of a later one; the contrary is a factor bearing an influence from a later stage. The influence of a distant system, such as the Sun on the systems on the Earth, reaches them through a pathway realized at every stage on its way, and arrives at a later stage than the stage at which it left its source; it is exerted at the stage at which it reaches the system and where the system is (Eq. (136)). No physical contribution passes from one stage to another except as carried by the systems and factors realized at the stages between, so none passes from a later stage to an earlier change. The proposition restates the typing; its physical content lies in the typing conditions, which are commitments of ITOF and carry the contrary stated below. It fixes where a contribution is attributed, at the stage at which it reaches the system and the change is realized; it does not deny the causal history of that contribution, which extends across many stages through the systems, factors, and pathways that carry it. This states in present terms the causal-order constraint of V24/F4 without a separate postulate. Its contrary is an actual change with a physical contributor not

realized at the stage of that change. Two clocks brought together and compared are realized at the common stage of the comparison, and their records can be compared there without any association of stages with distant events.

The classification into internal contributors, external influencing systems, and external influencing non-system factors is exhaustive at the ITOF causal-typing level. It does not assert that every member of any broad physical family is causally active in every application; actual membership requires warranted physical contribution to the particular change.

8.3 Physical-factor families and effects

Physical factors fall within a limited set of physically recognized families. The list below is near-exhaustive at the level of families, in contrast to physical systems, whose population is not enumerated; it remains open to a family established by future physics. Each entry identifies a physical-factor family and effects that may occur when a factor in that family is physically realized and actually influences the system. An influencing physical system may generate, carry, or mediate such physical influence while remaining a physical system. The list does not create additional causal-source types or universal response laws.

- (i) **Mechanical, contact, and kinematic contributions.** Physically realized loads, pressure conditions, stress or strain, contact, impact, shock, vibration, acceleration, rotation, and momentum-transfer processes may alter motion, configuration, deformation, oscillation, structural integrity, transport, or failure behaviour according to the system's mechanics and constitutive law.
- (ii) **Thermal and thermodynamic contributions.** Physically realized thermal conditions, temperature differences or gradients, heat-transfer processes, and phase conditions may alter internal-energy distribution, expansion or contraction, phase, transport coefficients, reaction rates, material properties, or other system-specific thermodynamic responses.
- (iii) **Electromagnetic contributions.** Physically realized electric or magnetic fields and gradients, charge and current distributions, and electromagnetic couplings may produce forces, polarization, excitation, ionization, current redistribution, heating, transition response, or other field-dependent changes permitted by the physical model.
- (iv) **Gravitational contributions.** Physically realized gravitational relations, field or potential gradients, and tidal conditions may contribute to acceleration, trajectory change, binding, stress, energy-state response, or other gravity-dependent behaviour permitted by the physical model.
- (v) **Radiative and particle-transfer contributions.** Photon, particle, material, momentum, or energy transfer and exposure may contribute to excitation, ionization, heating or cooling, momentum exchange, detector response, photochemical change, material modification, or biological effects where the applicable physics warrants them.
- (vi) **Nuclear, subatomic, and reaction-channel contributions.** Physically realized nuclear interactions, incident particle channels, capture, scattering, transmutation, externally induced decay or excitation pathways, and related subatomic processes may contribute where the applicable nuclear or particle physics establishes an actual influence. A decay constant, cross section, or branching ratio is a descriptor or model quantity; causal attribution belongs to the realized physical process and interaction.
- (vii) **Chemical and material contributions.** Composition, concentration or chemical-potential gradients, chemical interaction, material exchange, solvent or medium conditions, adsorption, dissolution, corrosion, and related processes may alter bonding, composition, phase, diffusion, structure, or reaction pathways.
- (viii) **Fluid, plasma, and transport contributions.** Physically realized fluid conditions, pressure and

flow fields, shear, material transport, plasma conditions, and associated couplings may contribute to drag, compression, mixing, heat or mass transfer, erosion, transport, or other continuum or plasma responses allowed by the governing physics.

- (ix) **Wave, oscillatory, and resonant contributions.** Mechanical, acoustic, electromagnetic, or other physically instantiated wave and oscillatory processes may transfer energy or momentum, excite modes, produce resonance, fatigue, transition response, interference effects, or other coupling-dependent changes. A numerical frequency by itself is only a descriptor; causal attribution belongs to the realized oscillatory process or interaction carrying it.
- (x) **Boundary, interface, and confinement actions.** The constraint, support, and confinement actions exerted by boundaries, interfaces, supports, lattices, and traps, which are themselves physical systems acting as influencing physical systems, may alter permitted modes, stress distribution, transport, interaction strength, transition conditions, or stability. Geometric or boundary parameters are not causes merely because they occur in an equation; the relevant physical realization must be identified.
- (xi) **Fluctuation, collision, disturbance, and noise contributions.** Physically realized collisions, perturbations, fluctuations, disturbances, or noise may contribute to diffusion, broadening, stochastic transitions, heating, decoherence, loss of stability, or other model-specific effects. Labels such as “vacuum fluctuation” or “noise” do not settle ontic or causal typing without the physical model and declared system boundary.
- (xii) **Biological, environmental, and complex-system influences.** Nutrient or material availability, pathogens, tissue or fluid conditions, regulatory couplings, surrounding instruments, atmosphere, direct exposure, and other environmental circumstances can matter only through their physically realized constituents, processes, pathways, boundaries, or influencing systems. The word “environment” is a descriptive aggregation, not an additional causal-source type.

In every family the factor is the non-system field, transfer, process, or action that reaches the system. The medium, body, boundary, lattice, or trap that generates or carries it is an influencing physical system, and a condition of such a system, such as its temperature, pressure, composition, or flow state, is a state of that system, whose change is change of that system under UCC. Where a family above names a condition, it denotes the action of that condition on the system concerned.

The list does not restrict what physical factors may exist. An unlisted factor is admissible when the applicable physics establishes its physical realization and actual influence. A numerical property or model parameter does not enter $\mathcal{C}_A^{\text{act}}(s)$ by itself; causal attribution belongs to the physically realized source and influence to which that description applies.

8.4 From descriptive terms to physical sources

Terms such as temperature, frequency, velocity, pressure, intensity, density, or field strength often denote measured or modelled properties rather than separate causal entities. Their causal use in ITOF is therefore tied to the physically realized condition or process that the descriptor characterizes. For example:

- temperature is causally relevant through a realized thermal condition, gradient, heat-transfer process, phase condition, or temperature-dependent physical interaction;
- frequency is causally relevant through a physically realized oscillatory, wave, radiative, resonant, or driven process characterized by that frequency;
- velocity or motion is causally relevant through the realized kinematic state, momentum transfer, collision, transport, inertial relation, or other motion-dependent physical interaction specified by the

applicable model.

This discipline preserves the distinction between physically realized causal conditions and their numerical descriptors without reifying a descriptor into an independent causal source.

8.5 External influencing physical systems

External physical influence is not restricted to non-system factors. A numerically and physically distinct system B may contribute to the change realized in A while remaining a physical system with its own identity, state, change, causal profile, and physical history. The source relation is represented by $B \in \mathcal{C}_A^{\text{infl-sys}}(s)$; it does not convert B into a physical factor.

At the level of causal families, external influencing physical systems may include, where independently warranted by the applicable physics:

- (i) **Contacting, colliding, loading, or constraining systems**, including bodies, supports, tools, boundaries realized by another system, impactors, and mechanically coupled assemblies.
- (ii) **Gravitationally interacting systems**, including physical systems whose mass–energy distribution contributes gravitationally to the state or motion of A under the adopted gravitational model.
- (iii) **Electromagnetic source systems**, including charged bodies, current-bearing systems, electrodes, magnets, resonators, antennas, cavities, and other systems producing or shaping physically realized electromagnetic interaction.
- (iv) **Radiative or particle-emitting systems**, including sources whose photons, particles, or other physically transported emissions interact with A .
- (v) **Material reservoirs, fluids, plasmas, or surrounding media that satisfy the physical-system criterion**, where exchange, flow, pressure, shear, transport, reaction, or other interaction with A is physically established.
- (vi) **Control, preparation, interrogation, and measurement systems**, including apparatus whose fields, pulses, contacts, feedback actions, sampling, or other physically realized operations contribute to the state or change of A . The resulting record remains distinct from the causal interaction that produced it.
- (vii) **Chemical, biological, or complex interacting systems**, where an independently identified system contributes through contact, exchange, regulation, signaling, metabolism, reaction, transport, or another physically warranted pathway.
- (viii) **Composite environmental or structural systems**, where the surrounding entity itself satisfies the system criterion and its interaction with A is physically resolved. The word “environment” does not by itself establish this status.

The list is a causal taxonomy, not a claim of universal all-to-all interaction. Cosmic co-presence under CMA does not imply that every physical system influences every other physical system, and causal influence need not be symmetric.

8.6 Internal physical contributors

Internal causal contribution includes more than externally visible activity. The internal physical basis of A may contain operative contributors arising from its realized constitution, organization, state, relations, retained conditions, and internal processes. Where independently warranted, the internal causal set $\mathcal{C}_A^{\text{int}}(s)$ may include contributions associated with:

- (i) **Material constitution and composition**, including constituent species, bonding structure, phase composition, concentration distributions, and other physically realized compositional organization.
- (ii) **Constituent arrangement and structural organization**, including geometry, topology, interfaces, defects, lattice organization, compartmentation, and other realized structural relations internal to the declared system.
- (iii) **Present internal state and distributions**, including population, occupation, density, charge, current, momentum, energy, polarization, or other physically warranted state distributions.
- (iv) **Stored or internally distributed energy and excitation**, including elastic, chemical, electromagnetic, thermal, rotational, vibrational, electronic, nuclear, or other model-warranted internal energy content.
- (v) **Internal stress, strain, pressure, deformation, and constitutive constraints**, where these are physically realized and operative in the change.
- (vi) **Internal field configurations and couplings**, where the fields or couplings belong to the declared physical description of the system and make an actual contribution rather than appearing only as mathematical parameters.
- (vii) **Internal motion and transport**, including constituent motion, rotation, vibration, oscillation, currents, flows, diffusion, and internal momentum or material transfer.
- (viii) **Microscopic interactions and transition dynamics**, including bonding, scattering, collisions, exchange, reaction, decay, excitation, relaxation, and other physically realized constituent-level processes.
- (ix) **Order, correlation, coherence, regulation, and feedback embodied physically in the system**, where such organization is part of the applicable physical model and is causally operative.
- (x) **Present physically embodied consequences of prior change**, including retained damage, stored strain, altered composition, remanent field configuration, memory state, or other currently realized condition. The past as such is not a cause; only the presently embodied physical condition can enter the current causal profile.

A descriptive property or a numerical state variable is not promoted to an independent causal entity merely because it characterizes the internal system. Causal attribution belongs to the physically realized constitution, condition, interaction, process, or constraint to which the descriptor refers.

8.7 Pathways of physical influence and mediation

An influencing physical factor or system contributes to the change of A only through a physically realized pathway. The pathway families are

$$\begin{aligned} \text{Pathway}(c \rightarrow A; s) \in \{ & \text{contact and mechanical coupling, field relation,} \\ & \text{radiative or particle transfer, gravitational relation,} \\ & \text{material or energy exchange, boundary access} \}. \end{aligned} \quad (134)$$

A third system lying on a pathway may mediate the influence: it may shield, attenuate, filter, redirect, transform, or amplify it. A mediating system remains a physical system and changes under UCC like any other; its effect on the pathway is part of the causal account of A only through its own realized physical influence. The same system may be influencing in one analysis and influenced in another, and influence need not be reciprocal or symmetric. Presence of a factor or nearness of a system is therefore not influence:

a factor may be present without an effective pathway, and a system may be near without coupling,

$$\text{Present}(c; s) \not\Rightarrow c \in \mathcal{E}_A^{\text{ext}}(s). \quad (135)$$

Conversely, an influence contributes to the change of A at s only as it reaches A : by contact, or through a pathway realized at A at s ,

$$c \in \mathcal{E}_A^{\text{ext}}(s) \implies \text{Reaches}(c; A, s). \quad (136)$$

An influencing physical system may be distant from A . The Sun is a physical system and an influencing physical system of the systems on the Earth: its radiation and its gravitational field reach them and contribute to their change. The Sun is an influencing physical system of a system on the Earth at the stage at which its influence reaches that system and the change is realized there, not at the stage at which the influence left it; it is realized at that stage of arrival, as the typing of an influencing physical system requires (Eq. (54)). A source whose identity has ended, such as a star that has exploded, is no longer an influencing physical system; its radiation, realized at the stages on its way, still reaches a system and influences it as a physical factor, or as a physical system where the radiation satisfies a physical-system identity criterion. In every case the operative contribution at the system is what reaches it; naming its source, such as the Sun, as the influencing physical system attributes that contribution to the source, and the change realized in the system does not depend on that classification (Section 40.7). A distant influence reaches a system at a later stage than the stage at which it left its source; ITOF does not fix that delay, because the stages carry no metric and records do not identify stages. The duration of the passage is not counted, and no stage is computed from it: the stage that bears on the change of the system is the stage of arrival, at which that change is realized, whatever its place in the succession. Not every influencing system and factor reaches A at every stage: an influence that has not reached A at one stage, because of distance, reaches it at a later stage, the stage of its arrival, and until then the change of A continues under its internal contributors and the influences that do reach it. Those that reach it act together qualitatively. The influencing systems and factors are causes of the change of systems; they do not govern the succession of the stages. That some influences are present at a system while others are still on their pathway neither halts, delays, nor reorders the stages of change, whose succession remains invariant. Co-presence at one stage, which CMA asserts, is therefore not by itself influence, and no influence acts without a pathway. This condition belongs to the typing of external influence; its contrary is an established influence on a system that reaches it through no physical pathway. The condition concerns influences, not correlations: it does not assert that the joint outcome probabilities of separated systems factorize given the contributors at each, and the correlations of entangled systems, which reach no system as an influence, neither satisfy nor violate it.

8.8 Characteristics of a realized influence

For an influence of $c \in \mathcal{E}_A^{\text{ext}}(s)$ on A , an application may declare its influence profile

$$i_A(c; s) = (\text{mode}, \text{intensity}, \text{exposure}, \text{pathway}, \text{coupling}). \quad (137)$$

Mode states how the influence acts: mechanically, thermally, electromagnetically, gravitationally, radiatively, chemically, by flow, oscillation or resonance, or through confinement. *Intensity* states how strong the influence is, from weak and bounded to extreme. *Exposure* states how the influence reaches the system across stages: once or repeatedly, suddenly or progressively, locally or over the whole system, directly or through shielding. *Pathway* is the member of Eq. (134) through which it acts. *Coupling* states whether it acts alone or together with other contributors, which may reinforce, oppose, gate, or transform

it. The profile consists of descriptors of the realized influence; under the descriptor-to-source discipline it is not itself a cause.

8.9 Responsiveness of a physical system

The same influence does not produce the same change in every system, because the realized change depends on the system that receives it. The features of A on which this depends form its responsiveness profile at s :

$$\text{RespProf}_A(s) = (\Theta_A^{\text{str}}, \Gamma_A^{\text{coh}}, \Sigma_A, R_A^{\text{cap}}, Q_A, \mathcal{K}_A)(s). \quad (138)$$

Here Θ_A^{str} is the constitution and internal organization of A ; Γ_A^{coh} its internal cohesion and coherence — the holding together of its elements, their organized relation, and the integrity of its structure; Σ_A its susceptibility to each mode of influence; R_A^{cap} its capacity to absorb, buffer, redirect, repair, or regulate; Q_A its thresholds (Section 8.10); and $\mathcal{K}_A$ its kind, which distinguishes, for example, living from non-living response organization. Each component is a physically realized feature of A at s . The profile belongs to the internal basis $\mathcal{C}_A^{\text{int}}(s)$ and to the arguments of the application-specific composition map $\mathfrak{G}_A^{\text{phys}}$ (Eq. (141)); it is not a fourth causal-source class, and *responsiveness* is not a quantity that exists apart from the system.

Responsiveness is relative to the influence. A system may withstand one mode and yield to another: a material may withstand pressure and degrade under heat; a chemical system may be inert in one medium and reactive in another; a resonant system may remain bounded under one oscillatory influence and respond strongly near resonance:

$$\Sigma_A(\text{mode}_1) \text{ low} \not\Rightarrow \Sigma_A(\text{mode}_2) \text{ low}. \quad (139)$$

Where an application supplies an order on influence intensities and on realized change for a declared mode, cohesion and susceptibility act in opposite directions: other features held fixed, greater cohesion against that mode is accompanied by smaller realized change, and greater susceptibility by larger realized change. This is a qualitative relation within the declared application, not a universal law, and it never makes the realized change zero: under UCC the system continues to change whatever its cohesion.

8.10 Response classes and thresholds

Relative to a declared criterion and resolution, the change that an influence contributes to falls into one of five classes, separated by system-relative thresholds

$$Q_A = \{Q_A^{\text{det}}, Q_A^{\text{maint}}, Q_A^{\text{adapt}}, Q_A^{\text{dam}}, Q_A^{\text{fail}}\}. \quad (140)$$

1. *Below detection.* The contributed change is not resolved at the declared resolution. This is a limit of the record, not an absence of change: under UCC the system continues to change.
2. *Maintained change.* The system keeps its organization, function, or classification while continuing to change. Stability is maintained change within thresholds, not changelessness.
3. *Adaptive or regulatory change.* The system changes so as to preserve, restore, or modify its organization or viability, as in regulation, repair, or acclimatization.
4. *Damage.* The change leaves retained effects that reduce cohesion, capacity, or function while the identity persists; such effects become part of the presently embodied condition.
5. *Failure, transformation, or ending.* The change crosses the failure threshold, or cohesion falls below the minimum that the identity criterion requires; the system fails functionally, transforms, or ends. An ending is then governed by PIECP and the ending conditions; a successor exists only where a

new identity is physically produced.

Thresholds are system-relative and criterion-relative; they are not universal constants. Because retained damage lowers cohesion and capacity, a small further influence may cross a threshold that earlier influences did not: a sudden failure after gradual change is a property of the system's response conditions, not of time.

8.11 Living and non-living response organization

The three causal-source classes and the responsiveness profile apply to living and non-living systems alike. What differs is the content of Θ_A^{str} , R_A^{cap} , Q_A , and $\mathcal{K}_A$. For a non-living system these include material composition, phase, bonding, rigidity, elasticity, brittleness, conductivity, and thermal, pressure, rotational, or orbital state. For a living system they include, in addition, physically realized regulatory, sensory, adaptive, and motor organization, and cognitive organization where present. These are physical properties of the living system itself, not external agencies and not exemptions from physical causation. Motor capacity is a property; motion is realized change when that capacity is exercised.

8.12 How physical influences combine

The three source classes are exhaustive at the framework-typing level: internal physical contributors, external influencing physical systems, and external influencing non-system physical factors. No fourth causal-source class is introduced. A particular change need not contain a member of every class, but its complete actual causal set must be nonempty under CRP.

The operative contributors may interact, combine, oppose, reinforce, attenuate, transform, gate, or condition one another in system-specific qualitative ways. ITOF therefore imposes no universal additive law in which a realized change is the arithmetic sum of independent factor effects. Where an application supplies an independently warranted causal-composition map, its generic role may be written schematically as

$$\Delta_A^{\text{phys}}(s) = \mathfrak{G}_A^{\text{phys}}\left(X_A(s); \mathcal{C}_A^{\text{int}}(s), \mathcal{C}_A^{\text{infl-sys}}(s), \mathcal{C}_A^{\text{infl-factor}}(s)\right), \quad (141)$$

where $\mathfrak{G}_A^{\text{phys}}$ is application-specific and is not a new universal ITOF law. Linearity, superposition, independence, or simple additivity may be used only when the applicable physics independently warrants them.

In physical reality influences do not act singly. The physical factors and influencing physical systems that act on a system at a stage act together, and their effects overlap and combine qualitatively with one another and with the internal basis of the system: one influence may reinforce, oppose, attenuate, transform, gate, or condition another. Which influences act together, and how, depends on many conditions, among them the environment of the system, which differs from place to place, so that the same kind of influence does not act in the same way wherever it acts. The change that an influence would produce alone is therefore an idealization of a model, defined only relative to the other influences held fixed, and the realized change is not in general the sum of such single-influence changes:

$$\Delta_A^{\text{phys}}(s) \neq \sum_{c \in \mathcal{C}_A^{\text{ext}}(s)} \Delta_{A|c}^{\text{phys}}(s) \quad \text{in general,} \quad (142)$$

where $\Delta_{A|c}^{\text{phys}}(s)$ denotes the change a model attributes to c acting alone. Simple additivity is admissible only where the applicable physics independently warrants it.

In particular, an external factor does not determine the realized change in isolation from the receiving physical system. Even where only one external source is identified, the consequence depends on the realized state, constitution, organization, coupling, boundary conditions, susceptibility, and other physically relevant features of A , collected in its responsiveness profile (Eq. (138)). Whether a particular element of that internal basis is entered explicitly in $\mathcal{C}_A^{\text{int}}(s)$ depends on the warranted causal model; the external source is never converted into a complete system-independent effect law merely by being named.

Thus a common external contributor can produce qualitatively different changes in distinct physical systems:

$$\begin{aligned} c &\in \mathcal{C}_A^{\text{ext}}(s) \cap \mathcal{C}_B^{\text{ext}}(s), & A &\neq B \\ &\Rightarrow \Delta_A^{\text{phys}}(s) = \Delta_B^{\text{phys}}(s). \end{aligned} \quad (143)$$

The difference may arise from physical-system identity, constitution, organization, present state, spatial relation, coupling strength, intensity and extent of exposure, internal coherence or stability, and presently embodied conditions produced by earlier change.

The influencing systems and factors that act can differ from system to system, in kind and in number, and a given influence realizes its change only in the systems it reaches and to which its kind applies, at the stage at which it reaches them. CRP does not make the external influences on distinct systems the same:

$$\text{CRP} \not\models \forall A, B \in \mathcal{U}_{\text{phys}} \forall s \in I_A \cap I_B, \quad \mathcal{C}_A^{\text{ext}}(s) = \mathcal{C}_B^{\text{ext}}(s). \quad (144)$$

This does not limit UCC. At every stage every physical system realized there changes, without exception: no system waits for a later stage to change while others change, because at every stage its internal contributors and the influences that reach it act together qualitatively in it. What differs from system to system is the composition of the causes and the change they realize, not whether change is realized.

8.13 System-specific effect of external physical influence

Every member of $\mathcal{C}_A^{\text{ext}}(s)$ is an external source of physical influence on A . The source may be an influencing physical factor or an influencing physical system; its physical type does not change. The influence contributes to the physical change realized in A according to the applicable physics.

The resulting physical change is system-specific. Its physical form, magnitude, direction, or other measurable consequence is governed by the applicable dynamics, coupling, state, constitution, boundary conditions, and deterministic or stochastic structure of the receiving-system model. The term *response* is only an application-level description of that result; it is not an intermediate causal entity or a universal response law. Quantitative comparison across different systems requires physically justified comparison variables or a declared comparison map.

Where a physical or functional criterion is declared, the consequence may be classified relative to that criterion. Let $\mathfrak{J}_A^{\text{imp}}$ denote such an application-level impact criterion. When the physical evidence is sufficient for classification,

$$\text{Impact}_{\mathfrak{J}_A^{\text{imp}}}(c; A, s) \in \{\text{Supportive}, \text{Adverse}, \text{Mixed}, \text{Neutral}\}. \quad (145)$$

The terms *beneficial* and *harmful* may be used only where the declared criterion gives them a physically or functionally precise meaning; otherwise *supportive* and *adverse* are preferred. An unresolved classification is an epistemic status, not a fifth physical impact type. The same contributor may be supportive for one physical system and adverse for another, or may change classification with state, intensity, extent of

exposure, coupling, internal coherence, or criterion; an influence supportive at moderate intensity may be adverse at extreme intensity. UCC asserts the actuality of system-specific change; it assigns no universal positive or negative sign to that change.

8.14 Actual physical contribution

Let:

$$\text{PhysicallyContributes} \left(c; \Delta_A^{\text{phys}}(s) \right) \quad (146)$$

mean that physically admissible contributor c makes an actual physical contribution to the system-specific physical change designated by $\Delta_A^{\text{phys}}(s)$.

For an actual-change pair:

$$c \in \mathcal{C}_A^{\text{act}}(s) \iff \text{PhysicallyContributes} \left(c; \Delta_A^{\text{phys}}(s) \right). \quad (147)$$

Membership in the actual causal set asserts physical contribution only. It does not by itself make c the sole, sufficient, deterministic, universally earlier, or complete causal explanation; any such stronger status requires an independently established physical model.

8.15 Quantum and stochastic physical models

Causal typing is fixed by the declared system boundary, not by whether the application model is classical, deterministic, stochastic, or quantum. Internal physical contributors belong to $\mathcal{C}_A^{\text{int}}(s)$; external physical influence is sourced by $\mathcal{C}_A^{\text{ext}}(s)$, whose members are influencing physical factors or influencing physical systems. A mathematical state, operator, channel, probability law, or Hamiltonian is not thereby a physical causal source.

Entanglement, correlation, or nonfactorization alone does not establish PhysicallyContributes. Causal membership requires an actual physical contribution whose attribution is independently warranted under the declared application model and system boundary. Conversely, an intrinsically stochastic description does not conflict with CRP merely because it lacks a deterministic sufficient antecedent: CRP requires a nonempty set of actual physical contributors, not a hidden variable, unique antecedent, or deterministic mechanism.

Accordingly, CRP is neutral with respect to whether the admitted transition law is deterministic or intrinsically stochastic. It constrains the existence and typing of actual physical contributors, not the uniqueness of an outcome conditioned on those contributors.

If a declared interpretation of a quantum process positively denies every actual physical contributor in $\mathcal{C}_A^{\text{int}}(s) \cup \mathcal{C}_A^{\text{ext}}(s)$ for a change that nevertheless satisfies $\text{PhysReal}_A^+(s)$, that application stands in direct tension with CRP. V40/F20 does not resolve such a tension by reclassifying probability, entanglement, the common cosmic stage, or time itself as a cause.

Interpretive scope and concrete examples.

V40/F20 does not classify a named quantum interpretation as globally “compatible” or “incompatible” merely from its label. The relevant application-level question is whether the declared quantum model supplies physically realized contributors that can be typed within $\mathcal{C}_A^{\text{int}}(s) \cup \mathcal{C}_A^{\text{ext}}(s)$ without reclassifying a state vector, probability law, operator, the common cosmic stage, or time itself as a physical cause.

A de Broglie–Bohm application provides one example of a quantum formulation with additional explicit

physical variables and trajectories [60, 61]. Such variables may furnish candidates for application-level physical-contributor attribution where the declared system boundary and applicable dynamics warrant that attribution. This observation is not an endorsement of Bohmian mechanics, does not import its dynamics into ITOF, and does not establish compatibility with every ITOF commitment without a separate model-level analysis.

Environment-induced decoherence is treated differently. Decoherence is a physical open-system process or model structure, not by itself a complete interpretation of quantum mechanics, and it does not by itself settle the measurement problem [62]. Where an independently warranted system–environment interaction physically contributes to a realized change, that interaction may enter the appropriate causal set. Decoherence as a label, a reduced density matrix, or suppression of interference terms is not by itself a new causal-source type. Thus the limited claim of V40/F20 is interpretation-neutral: quantum applications are admissible when their physical ontology, dynamics, and causal attribution satisfy the declared ITOF typing conditions. ITOF neither derives quantum mechanics nor supplies a new quantum interpretation.

8.16 Causal Realization Principle

Postulate 8.2 (Causal Realization Principle (CRP)). Every actually realized physical change of a physical system of the universe has a nonempty actual physical causal set:

$$\text{CRP} \iff \forall A \in \mathcal{U}_{\text{phys}} \forall s \in I_A, \quad \text{PhysReal}_A^+(s) \implies \mathcal{C}_A^{\text{act}}(s) \neq \emptyset. \quad (148)$$

The causal set is typed relative to the declared physical-system boundary. It contains actual internal physical contributors and/or external physical-influence sources. An external source may be an influencing physical factor or an influencing physical system; each retains its physical type. In a concrete application, attribution of the external influence must be warranted by the applicable physics. A descriptive property, model variable, or numerical parameter is not by itself a physical cause.

The realized effect remains system-specific and is realized according to the applicable physical dynamics and actual physical conditions of the receiving system. Time, the common cosmic stage, the earlier–later relation, a clock output, and the historical description of earlier change are not additional physical causes.

CRP is an independent foundational physical postulate; it is not derived from UCC, CMA, or the temporal definition. CRP and UCC have different functions:

$$\text{UCC} \implies \forall A \in \mathcal{U}_{\text{phys}} \forall s \in I_A, \quad \text{PhysReal}_A^+(s), \quad (149)$$

$$\text{CRP} \implies \forall A \in \mathcal{U}_{\text{phys}} \forall s \in I_A, \quad \text{PhysReal}_A^+(s) \implies \mathcal{C}_A^{\text{act}}(s) \neq \emptyset. \quad (150)$$

Thus:

$$\{\text{UCC}, \text{CRP}\} \vdash \forall A \in \mathcal{U}_{\text{phys}} \forall s \in I_A, \quad \text{PhysReal}_A^+(s) \wedge \mathcal{C}_A^{\text{act}}(s) \neq \emptyset. \quad (151)$$

CRP does not cause the physical changes whose causal realization it governs.

8.17 Unknown causes remain physical causes

Epistemic incompleteness is not an additional causal category.

Thus:

$$\text{CauseNotIdentified}_{P,M}(A; s) \nRightarrow \mathcal{C}_A^{\text{act}}(s) = \emptyset. \quad (152)$$

An unresolved mechanism remains a scientifically incomplete causal account. The incompleteness is not converted into an untyped causal entity or treated as a complete causal explanation.

8.18 Common-stage causal-realization profile

For each stage s , define:

Definition 8.3 (Common-Stage Causal-Realization Profile).

$$\mathfrak{G}_C(s) := (A \mapsto \mathcal{C}_A^{\text{act}}(s))_{A \in \mathcal{S}_{\text{phys}}(s)}. \quad (153)$$

This profile may contain an empty causal set in a dependency structure in which the relevant causal principle is not imposed.

In a governing V40/F20 realization satisfying UCC and CRP:

$$\{\text{UCC}, \text{CRP}\} \vdash \forall s \in \mathcal{S}_C^{\text{tot}} \forall A \in \mathcal{S}_{\text{phys}}(s), \quad \mathcal{C}_A^{\text{act}}(s) \neq \emptyset. \quad (154)$$

The existence of the causal-realization profile does not imply a common cause:

$$\text{Defined}(\mathfrak{G}_C(s)) \not\Rightarrow \exists c \forall A \in \mathcal{S}_{\text{phys}}(s), \quad c \in \mathcal{C}_A^{\text{act}}(s). \quad (155)$$

Nor does it imply one common causal mechanism:

$$\text{Defined}(\mathfrak{G}_C(s)) \not\Rightarrow \text{OneUniversalCausalMechanism}(s). \quad (156)$$

9. All Systems Change, Each in Its Own Way

9.1 Scope

The state, change, causal-realization, and complete physical-realization profiles represent, at each common stage, the physical systems realized there together with their system-specific states, changes, and causal bases. They introduce no new ontological primitive and do not redefine time. Complete-population coverage was first made explicit in V36/F16 [3], and the profile family was first stated in V37/F17.

9.2 Aligned domains of the profiles

The state profile has domain:

$$\text{dom } \mathfrak{X}_C(s) = \mathcal{S}_{\text{phys}}(s). \quad (157)$$

The change profile has domain:

$$\text{dom } \mathfrak{D}_C(s) = \mathcal{B}_\Delta(s). \quad (158)$$

Under UCC the change profile has domain $\mathcal{S}_{\text{phys}}(s)$ (Eq. (113)). The causal-realization profile is indexed by $\mathcal{S}_{\text{phys}}(s)$, and under UCC plus CRP every indexed system has a nonempty actual causal set.

Therefore:

$$\begin{aligned} \text{dom } \mathfrak{X}_C(s) &= \mathcal{S}_{\text{phys}}(s), \\ \{\text{UCC}, \text{CRP}\} \vdash \forall s \in \mathcal{S}_C^{\text{tot}}, \quad \text{dom } \mathfrak{D}_C(s) &= \mathcal{S}_{\text{phys}}(s), \\ \text{dom } \mathfrak{G}_C(s) &= \mathcal{S}_{\text{phys}}(s). \end{aligned} \quad (159)$$

By CSPP (Eq. (68)) this common domain is nonempty at every stage.

9.3 Definition of the complete physical-realization profile

Definition 9.1 (Complete-Population Common-Stage Physical-Realization Profile). In a governing V40/F20 realization, define:

$$\boxed{\mathfrak{R}_C(s) := (\mathcal{S}_{\text{phys}}(s), \mathfrak{X}_C(s), \mathfrak{D}_C(s), \mathfrak{G}_C(s))}. \quad (160)$$

The profile is indexed by the complete admitted physical-system population $\mathcal{S}_{\text{phys}}(s)$ under the governing ontic systemhood and numerical-identity conditions. Its completeness is exactly completeness of representation over that population. It is not a claim to enumerate every constituent of $\mathcal{U}_C^{\text{phys}}$: physical factors are not converted into system-profile entries and appear only where an explicitly typed physical relation or causal contribution requires them. The profile supplies neither a universal system boundary nor a universal identity criterion, common state space, common change codomain, common causal mechanism, or exhaustive set of physical relations at s .

9.4 A typed physical example

The example below illustrates the profile and adds no commitment. Consider two qualified physical clock systems $C, D \in \mathcal{S}_{\text{phys}}(s)$ in a governing realization satisfying UCC and CRP. Their stage-relative entries may be written as

$$X_C(s) \in \mathcal{X}_C, \quad \Delta_C^{\text{phys}}(s) \in \mathfrak{E}_C, \quad \mathcal{C}_C^{\text{act}}(s) \neq \emptyset, \quad (161)$$

$$X_D(s) \in \mathcal{X}_D, \quad \Delta_D^{\text{phys}}(s) \in \mathfrak{E}_D, \quad \mathcal{C}_D^{\text{act}}(s) \neq \emptyset. \quad (162)$$

Under CMA (Eq. (75)), C and D are co-present at s ; under UCC, $\text{PhysReal}_C^+(s) \wedge \text{PhysReal}_D^+(s)$. Neither commitment requires $X_C(s) = X_D(s)$, identical change content, identical causal contributors, or identical later clock records. Distinct apparatus conditions, motion, gravitational environment, interrogation, and other independently specified physical dynamics may produce different mapped clock outputs while both physical clock systems remain members of the same common cosmic change stage. The example therefore instantiates the four profile roles without turning a clock output, proper-time functional, metric interval, or model parameter into the entity denoted by T_{TOF} . The quantitative clock branches in the later application sections supply the corresponding application-level laws and measurement maps.

The four components answer four distinct questions:

- (i) $\mathcal{S}_{\text{phys}}(s)$ identifies the complete qualified physical-system population whose numerical identities are realized at s ;
- (ii) $\mathfrak{X}_C(s)$ represents the system-specific physical states realized by that population;
- (iii) $\mathfrak{D}_C(s)$ represents the system-specific physical-change contents realized by that population under UCC;
- (iv) $\mathfrak{G}_C(s)$ represents the actual physical causal sets associated with those changes under CRP.

The profile is analytical and representational. It is not an additional physical substance existing alongside the systems.

Numerical-identity realization requires no fifth generic profile coordinate. At stage s , realization of numerical identity is already typed by $A \in \mathcal{S}_{\text{phys}}(s) \iff s \in I_A$, while formation, ending, and successor attribution are governed separately by the identity-history and lifecycle architecture. A universal $\text{IdentityStatus}_A(s)$ therefore does not follow from the foundational profile and would require an independently defined physical role.

9.5 Projection structure and conservative content

The four defining components are recoverable by canonical projections:

$$\pi_{\text{pop}}(\mathfrak{R}_C(s)) = \mathcal{S}_{\text{phys}}(s), \quad (163)$$

$$\pi_{\text{state}}(\mathfrak{R}_C(s)) = \mathfrak{X}_C(s), \quad (164)$$

$$\pi_{\text{change}}(\mathfrak{R}_C(s)) = \mathfrak{D}_C(s), \quad (165)$$

$$\pi_{\text{cause}}(\mathfrak{R}_C(s)) = \mathfrak{G}_C(s). \quad (166)$$

Accordingly, once the four components are fixed, the profile introduces no additional independent degree of freedom:

$$\text{ComponentsFixed}(\mathcal{S}_{\text{phys}}(s), \mathfrak{X}_C(s), \mathfrak{D}_C(s), \mathfrak{G}_C(s)) \implies \text{ProfileUniquelyFixed}(\mathfrak{R}_C(s)). \quad (167)$$

This is the formal sense in which the profile, introduced in V37/F17 and retained here, is an integrating construction rather than an ontological primitive.

9.6 Adding relations without enlarging time

Population, state, change, and causal-set coverage do not exhaust every physically admissible relation among then-realized systems. For a declared physical model M , let $\mathcal{R}_M(s)$ denote the independently warranted stage-relative family of additional physical relations used by that model, such as interaction, constraint, correlation, composition, or coupling relations. A model-relative augmentation is defined by

$$\mathfrak{R}_C^{[M]}(s) := (\mathfrak{R}_C(s), \mathcal{R}_M(s)). \quad (168)$$

The augmentation is application-level and is permitted only where the added relations are physically typed and independently warranted. It neither changes the population-completeness meaning of the foundational profile nor enlarges the temporal referent. Different admissible physical models may therefore enrich the relational content associated with the same common cosmic change stage without generating different times or changing the V40/F20 definition of time.

9.7 Population completeness and representational scope

Completeness refers to the domain of the profile, which is $\mathcal{S}_{\text{phys}}(s)$. It asserts neither one universal state, one universal change content, nor one universal causal set, and it fixes no universal change magnitude, change rate, or physical mechanism. Additional interaction, constraint, correlation, composition, or coupling relations enter through the relational augmentation of Eq. (168).

9.8 The realization profile is physical, not temporal

The complete-population common-stage physical-realization profile is neither a new temporal component nor a stage:

$$\mathfrak{R}_C(s) \not\equiv_{\text{type}} T_{\text{TOF}}, \quad \mathfrak{R}_C(s) \not\equiv_{\text{type}} s. \quad (169)$$

The governing time definition remains Eq. (11); the realization-profile family is not appended to that ordered pair. The physical-realization profiles belong to the physical architecture associated with the common cosmic stages; they are not contents placed inside a temporal or cosmic container.

9.9 Population completeness versus epistemic access

The complete profile is not claimed to be completely measurable or reconstructible by any observer. Complete population coverage implies neither complete observation of the profile nor complete scientific knowledge of it. The distinction is ontological–epistemic and does not depend on observational completeness.

9.10 Full-profile consequences under CMA, UCC, and CRP

The complete-population physical-realization profile is already defined by its population, state, change, and causal components. No additional realization predicate is required. Under temporal constitution, CMA, UCC, and CRP, the governing stage-relative conditions are:

$$\begin{aligned} & \mathfrak{T}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \wedge \text{CMA} \wedge \text{UCC} \wedge \text{CRP} \\ & \implies \forall s \in \mathcal{S}_C^{\text{tot}}, \\ & \mathcal{S}_{\text{phys}}(s) \neq \emptyset \wedge \text{SCB}_C(s), \\ & \forall A \in \mathcal{S}_{\text{phys}}(s), \quad \mathcal{C}_A^{\text{act}}(s) \neq \emptyset. \end{aligned} \quad (170)$$

This is a consequence of commitments already stated.

10. Hierarchy, Composition, and Type Boundaries

The transition to composition is required by the scope of the realization commitments rather than by any claim that time itself is hierarchical. CSPP, CMA, and UCC quantify over qualified numerical physical-system identities, while many physical applications involve composites, constituents, and independently qualified subsystems sharing the same common cosmic stage. Before a universal population statement can be applied across such levels, the framework must specify when two identified systems stand in a genuine physical constituent relation and which cross-level inferences are warranted. Without that discipline, mere co-membership in $\mathcal{S}_{\text{phys}}(s)$, spatial inclusion, or material overlap could be mistaken for numerical identity, composition, causal determination, or inherited change. Accordingly, the hierarchy module types the physical-system granularity needed by the realization architecture; it does not add a hierarchical component to T_{TOF} .

10.1 Why composition requires an explicit physical criterion

Physical reality may support several scientifically legitimate system boundaries at different organizational levels. This level-relativity concerns system individuation, not the objectivity of physical realization.

A subsystem and a composite can therefore both be qualified physical-system identities when each independently satisfies the appropriate physical criteria.

Simple and composite systems must be distinguished. A simple qualified system need not be decomposable into qualified subsystems. A composite qualified system requires a physically real relation among its elements: the governing criterion must establish both interconnection and coherence at the composite level. Accordingly, a composite criterion may be represented by

$$\kappa_{\text{comp}} = (\kappa_{\text{interconnection}}, \kappa_{\text{coherence}}). \quad (171)$$

Interconnection requires physically operative relations among the relevant constituents; mere spatial proximity is insufficient. Coherence requires that those relations support the composite as a distinguishable physical unity with system-level properties and persistence conditions; mere co-location or set membership is insufficient. The precise physical realization of these criteria is class-specific and may be structural, dynamical, organizational, or another scientifically warranted form.

A physical system may contain constituents, subsystems, components, organized substructures, or other independently identifiable physical-system identities. V40/F20 does not infer numerical identity or composition merely from linguistic description, material overlap, spatial inclusion, or analytical convenience. Composition therefore requires a declared physically warranted criterion κ consistent with the system class and granularity fixed for the application.

10.2 Stage-relative constituent relation

For $A, B \in \mathcal{U}_{\text{phys}}$, define:

$$A \triangleleft_{\kappa, s} B \quad (172)$$

to mean that, under declared physical composition criterion κ , the independently qualified numerical physical-system identity A is physically realized as a proper constituent or subsystem of numerical physical-system identity B at common cosmic change stage s .

The typing requirement is:

$$A \triangleleft_{\kappa, s} B \implies A, B \in \mathcal{S}_{\text{phys}}(s) \wedge A \neq B. \quad (173)$$

The relation concerns physical identities realized at the same stage. Ending or failure of a qualified constituent does not by itself end the composite identity:

$$A \triangleleft_{\kappa, s} B \wedge \text{End}_A(e_A) \not\Rightarrow \text{End}_B(e_B). \quad (174)$$

The composite ends only when the applicable composite identity criterion—in particular its required interconnection and coherence conditions—is no longer satisfied at the composite level.

It does not make a constituent a state of the composite:

$$A \triangleleft_{\kappa, s} B \not\Rightarrow A \equiv_{\text{type}} X_B(s). \quad (175)$$

Nor does it erase the constituent's own identity history.

10.3 Composition profile

Define:

$$\mathfrak{R}_C(s) := \{(A, B, \kappa) \mid A \triangleleft_{\kappa, s} B\}. \quad (176)$$

This profile records declared stage-relative constituent relations among qualified physical-system identities.

The definition of the composition profile does not impose one unique hierarchy or one universal tree of systems:

$$\text{Defined}(\mathfrak{R}_C(s)) \not\Rightarrow \text{OneUniqueHierarchy}(s), \quad (177)$$

$$\text{Defined}(\mathfrak{R}_C(s)) \not\Rightarrow \text{OneUniversalTreeOfSystems}(s). \quad (178)$$

Likewise, V40/F20 does not universally postulate transitivity of $\triangleleft_{\kappa, s}$. From composition membership alone, without an additional closure condition on the declared criterion κ , the transitive conclusion is not a V40/F20 consequence:

$$A \triangleleft_{\kappa, s} B \wedge B \triangleleft_{\kappa, s} C \not\Rightarrow A \triangleleft_{\kappa, s} C. \quad (179)$$

A domain-specific composition criterion may independently impose transitivity. Where

$$\text{TransitiveCompositionCriterion}(\kappa; \mathcal{A}) \quad (180)$$

is independently warranted for system class $\mathcal{A}$, the corresponding application may infer the transitive relation within that declared domain. No framework-wide transitivity follows without that additional premise.

10.4 When constituents qualify as systems

A physical component within the boundary of B need not automatically be a member of $\mathcal{U}_{\text{phys}}$.

Therefore:

$$\text{PhysicalConstituentOf}(x, B; s) \not\Rightarrow x \in \mathcal{U}_{\text{phys}}. \quad (181)$$

The relation $A \triangleleft_{\kappa, s} B$ is reserved for a constituent that independently satisfies the qualified physical-system identity requirements. This prevents arbitrary decomposition from producing an unlimited collection of nominal systems merely by description.

10.5 UCC at each independently qualified system level

If:

$$A \triangleleft_{\kappa, s} B, \quad (182)$$

then $A, B \in \mathcal{S}_{\text{phys}}(s)$.

Under UCC:

$$A \triangleleft_{\kappa, s} B \wedge \text{UCC} \implies \text{PhysReal}_A^+(s) \wedge \text{PhysReal}_B^+(s). \quad (183)$$

These are two system-specific physical-change realizations.

The two realizations need not be equal:

$$A \triangleleft_{\kappa, s} B \wedge \text{UCC} \not\Rightarrow \Delta_A^{\text{phys}}(s) = \Delta_B^{\text{phys}}(s). \quad (184)$$

and their change-content types need not coincide:

$$A \triangleleft_{\kappa,s} B \not\Rightarrow \Xi_A = \Xi_B. \quad (185)$$

10.6 Cross-Level Non-Transfer Principle

Principle 10.1 (Cross-Level Non-Transfer Principle). Physical composition does not by itself transfer a physical state, change content, causal description, or numerical identity from one qualified system level to another.

Formally:

$$A \triangleleft_{\kappa,s} B \not\Rightarrow \text{PhysicallyDetermines}_{\kappa} \left(\Delta_A^{\text{phys}}(s); \Delta_B^{\text{phys}}(s) \right). \quad (186)$$

Likewise:

$$A \triangleleft_{\kappa,s} B \not\Rightarrow \text{PhysicallyDetermines}_{\kappa} \left(\Delta_B^{\text{phys}}(s); \Delta_A^{\text{phys}}(s) \right). \quad (187)$$

Here $\text{PhysicallyDetermines}_{\kappa}$ is not a newly assumed physical relation. It denotes whatever specific cross-level physical dependence an application would need to establish. The principle therefore states that composition alone supplies no such dependence.

10.7 Composite change without a universal sum

Even where qualified constituents

$$A_1, \dots, A_n$$

are physically realized within composite B , composition alone does not imply an additive change law:

$$\left[\bigwedge_{i=1}^n A_i \triangleleft_{\kappa_i,s} B \right] \not\Rightarrow \Delta_B^{\text{phys}}(s) = \sum_{i=1}^n \Delta_{A_i}^{\text{phys}}(s). \quad (188)$$

Such an expression may be mathematically ill typed because $\Xi_{A_i} \neq \Xi_{A_j}$ may hold and no universal addition operation is supplied. A valid cross-level quantitative model requires its own physical variables, mapping rules, coupling relations, aggregation rules, and empirical warrant.

10.8 Hierarchical causation

Where $A \triangleleft_{\kappa,s} B$, A lies within the declared physical boundary of B under criterion κ . A physically operative contribution associated with that constituent is therefore treated through the internal physical basis of B under the applicable causal attribution. It is not converted into an influencing physical-system contribution merely because A also possesses an independently qualified physical-system identity.

Thus the causal classification depends jointly on:

$$\langle \text{NumericalIdentity}, \text{DeclaredSystemBoundary}, \text{PhysicalCausalRole} \rangle. \quad (189)$$

The same physical reality may therefore be described under distinct legitimate system boundaries without collapsing those boundaries or counting one contributor twice within one declared causal attribution.

10.9 One common stage across all levels

If $A \triangleleft_{\kappa,s} B$, both identities are realized at the same common cosmic change stage s . The constituent does not possess a lower-level time while the composite possesses a higher-level time.

Thus:

$$A \triangleleft_{\kappa,s} B \not\Rightarrow \text{PrivateTime}(A) \vee \text{PrivateTime}(B). \quad (190)$$

Hierarchy belongs to physical organization, not to multiplication of temporal orders.

11. Numerical Identity and Formation Boundaries

11.1 Numerical identity

Unless an application explicitly declares another domain-specific identity notion, V40/F20 uses numerical physical-system identity. Here *numerical identity* means identity of the physical system itself: whether two stage-indexed realizations concern one and the same physical system. It does not mean a numerical identifier, a stage number, a coordinate, a metric value, or an assigned ordinal.

The relevant question is `IsThisTheSamePhysicalSystem?` rather than:

$$\text{DoesThisSystemHaveTheSameState?} \quad (191)$$

Accordingly, sameness of numerical identity at two stages does not imply sameness of state: $X_A(r)$ and $X_A(s)$ may differ while A remains one system. Identity persistence is compatible with physical change.

11.2 Class-indexed physical-system identity qualification

V40/F20 does not postulate one universal empirical numerical-identity criterion for every physical-system class. For each declared class $\mathcal{K}$, define an application-level identity-qualification profile

$$\Omega_{\mathcal{K}}^{\text{id}} := (\kappa_{\text{sys}}, \kappa_{\text{boundary}}, \kappa_{\text{id}}, \kappa_{\text{persist}}, \kappa_{\text{form}}, \kappa_{\text{end}})_{\mathcal{K}}. \quad (192)$$

The components specify, respectively, physical-system qualification, system boundary, numerical identity, persistence, formation, and ending for the declared class and organizational granularity. Physical realization is objective; the selection and tracking of a system identity are level- and criterion-relative within that objective physical organization, not observer-subjective or arbitrary. For composite systems, κ_{sys} and the persistence and ending criteria must include the physically warranted interconnection and coherence conditions appropriate to the composite level. These are application-level physical criteria. They are not supplied by time, CMA, or UCC.

For an empirical or model-based protocol P , identity application is admissible only if the profile is fixed prospectively before outcome interpretation, internally consistent, physically warranted for the declared

class, and applicable to the system under study:

$$\begin{aligned}
& \text{IdentityApplicationAdmissible}(A; \mathcal{K}, P) \\
& \implies \text{PredeclaredAndFrozen}(\Omega_{\mathcal{K}}^{\text{id}}, P) \\
& \quad \wedge \text{InternallyConsistent}(\Omega_{\mathcal{K}}^{\text{id}}) \\
& \quad \wedge \text{PhysicallyWarrantedForClass}(\Omega_{\mathcal{K}}^{\text{id}}, \mathcal{K}) \\
& \quad \wedge \text{DomainApplicable}(\Omega_{\mathcal{K}}^{\text{id}}, A, P).
\end{aligned} \tag{193}$$

These are necessary admissibility conditions, not a universal sufficiency claim; a physical domain may require additional criteria.

Prospective freezing is protocol-relative rather than permanent. It forbids changing the system boundary or identity criterion after observing the outcome of P in order to manufacture or rescue an attribution. It does not forbid later science from adopting a better physically warranted profile in a new protocol P' :

$$\text{FrozenFor}(\Omega_{\mathcal{K}}^{\text{id}}, P) \not\Rightarrow \text{PermanentlyImmutableAcrossFutureProtocols}. \tag{194}$$

Application admissibility must also be distinguished from the admissibility of a specific identity attribution. For an attribution type $\chi \in \{\text{persistence, formation, ending, successor}\}$, require

$$\begin{aligned}
& \text{IdentityAttributionAdmissible}(A; \mathcal{K}, P, \chi) \\
& \implies \text{IdentityApplicationAdmissible}(A; \mathcal{K}, P) \\
& \quad \wedge \text{SatisfiesRelevantIdentityCriterion}(A; \mathcal{K}, P, \chi).
\end{aligned} \tag{195}$$

A sound profile does not by itself establish that formation, persistence, ending, or successor production actually occurred; the relevant evidence or model output must satisfy the corresponding criterion.

11.3 Material continuity and numerical identity

A later system may:

$$\begin{aligned}
& \text{contain earlier constituents,} \quad \text{contain transferred matter,} \quad \text{occupy a similar region,} \\
& \text{perform a similar function,} \quad \text{or resemble an earlier system}
\end{aligned} \tag{196}$$

without being numerically identical to that earlier system.

Hence neither material overlap nor functional equivalence between two systems establishes that they are numerically one system.

The applicable physical identity criterion governs the attribution.

11.4 Identity-Realization Convexity

Postulate 11.1 (Identity-Realization Convexity). For every physical system $A \in \mathcal{U}_{\text{phys}}$ of the universe and all $r, s, t \in \mathcal{S}_{\mathcal{C}}^{\text{tot}}$:

$$\boxed{r \in I_A \wedge t \in I_A \wedge r \prec_{\mathcal{C}} s \wedge s \prec_{\mathcal{C}} t \implies s \in I_A.} \tag{197}$$

Identity-Realization Convexity is an independent foundational identity postulate. It prevents an internal gap in one numerical physical-system identity; with UCC it secures the uninterrupted change of every physical system of the universe (Eq. (86)).

Identity-Realization Convexity imposes no metric duration, stage count, equal-stage spacing, state constancy, or change-magnitude constancy. It constrains only membership continuity of one numerical identity in the universal order.

11.5 Actual Formation Boundary

Postulate 11.2 (Actual Formation Boundary (AFB)). For every qualified physical-system identity of the universe, its realized identity range $I_A \subseteq \mathcal{S}_C^{\text{tot}}$ has one unique least member with respect to the one common cosmic ordering $\prec_C$:

$$\text{AFB} \iff \forall A \in \mathcal{U}_{\text{phys}} \exists! f \in I_A [\nexists r \in I_A (r \prec_C f)]. \quad (198)$$

The member f_A is the formation boundary of numerical identity A inside the same universal cosmic-stage domain used by every qualified system. It is not a private first time for A , does not imply Cosmic Origin, and does not make the common stage a container in which the system is placed. Under UCC, A realizes actual system-specific physical change at its formation boundary f_A . Where independently warranted physics identifies a physical formation process at that boundary, that process may constitute or contribute to the realized formation change. AFB and UCC alone do not determine the formation mechanism or causal contributor. A prior member of the same numerical identity range is not required.

AFB is an independent identity-range postulate. Its universal quantification over $\mathcal{U}_{\text{phys}}$ is a foundational burden, not a consequence established by the temporal definition, CMA, UCC, or the non-termination hypothesis. Empirical application to a declared system class still requires independently warranted identity-qualification criteria. AFB constrains only the lower boundary of each realized identity range within the one common cosmic-stage domain. The least member belongs to that same cosmic-stage domain. The incidence definitions identify the qualified population whose identity ranges contain that member; CMA, not incidence alone, supplies objective common-stage co-presence of that population. It is not a system-private stage, does not mark the beginning of physical change in the cosmic succession, and does not introduce any priority of one system's change over another system's change at the same common cosmic stage.

The asymmetry between AFB and optional UEIE is therefore an asymmetry of identity-range commitments, not of physical-change realization. AFB postulates a least member for every declared qualified identity range. UEIE would add the additional universal claim that every such identity range also possesses an ending member. Nothing in the temporal definition, CMA, UCC, or AFB entails that universal ending claim; UEIE accordingly remains an optional lifecycle postulate requiring independent physical warrant for the declared system domain.

Let the unique least member be f_A . Define:

$$f : \mathcal{U}_{\text{phys}} \longrightarrow \mathcal{S}_C^{\text{tot}}, \quad f(A) = f_A. \quad (199)$$

Within AFB, formation denotes realization of the physical-system identity at the least member f_A of its identity range in the one common cosmic-stage domain. This is an identity-boundary statement. It neither introduces a private stage for A nor defines an onset of physical change in the cosmic succession.

For every $r \in \mathcal{S}_C^{\text{tot}}$:

$$r \prec_C f_A \implies \neg \text{ExistsAs}(A, r). \quad (200)$$

Equation (200) is an identity-incidence statement only: if $r \prec_C f_A$, then $r \notin I_A$. It does not imply absence of other qualified systems, influencing physical factors, or physical change at r . Other qualified physical systems realized at such stages may possess their own identity-bounded histories. Physical factors may be realized or influential there without thereby acquiring a system identity range or a system history.

11.6 Formation change

Formation change denotes the system-specific physical change realized at the common cosmic stage f_A at which the identity range of A has its least member. It is not a private or system-specific stage, is not the beginning of physical change in the common succession, and is not defined as a finite difference between two states of a pre-existing A .

Define:

$$\text{FormationChange}_A(s) \iff s = f_A \wedge \text{PhysReal}_A^+(s). \quad (201)$$

AFB and UCC give:

$$\{\text{AFB}, \text{UCC}\} \vdash \forall A \in \mathcal{U}_{\text{phys}}, \quad \text{FormationChange}_A(f_A). \quad (202)$$

This conclusion assigns no priority to formation change relative to changes of other qualified systems realized at f_A . By UCC, every $B \in \mathcal{S}_{\text{phys}}(f_A)$ satisfies $\text{PhysReal}_B^+(f_A)$ at that same common stage.

The causal contributors to formation change remain physical contributors in the sense of CRP; T_{ITOF} , f_A , $\prec_C$, CMA, and UCC are not additional causal-source classes.

Under UCC and CRP:

$$\{\text{AFB}, \text{UCC}, \text{CRP}\} \vdash \forall A \in \mathcal{U}_{\text{phys}}, \quad \mathcal{C}_A^{\text{act}}(f_A) \neq \emptyset. \quad (203)$$

11.7 Formation and cosmic origin

AFB concerns identity-range boundaries within the one common cosmic-stage domain. Different values of f_A and f_B , where they differ, are different members of that same domain; they are not private stages belonging to different systems.

Therefore:

$$\text{AFB} \not\Rightarrow \text{CosmicOrigin}. \quad (204)$$

The least common stage of $\mathcal{S}_C^{\text{tot}}$ is fixed by the Cosmic Origin postulate (Eq. (40)), not by the formation boundary of any system.

12. Identity-Bounded Physical Histories

12.1 History domain

Each qualified numerical physical-system identity has a physical history only over the common cosmic change stages at which that identity is realized:

$$I_A \subseteq \mathcal{S}_C^{\text{tot}}. \quad (205)$$

The restriction:

$$\prec_C|_{I_A} \quad (206)$$

does not create a new ordering relation. It is the restriction of the same one universal cosmic ordering to the identity-realization range of A .

Thus:

$$\text{OrderOfHistory}(A) = \prec_C|_{I_A}. \quad (207)$$

No independent private ordering is introduced for A .

12.2 Formal physical-history representation

In a governing V40/F20 realization, UCC gives:

$$I_A^\Delta = I_A. \quad (208)$$

Therefore the physical-change-content map is well typed throughout the realized identity range.

Define:

$$\mathcal{H}_A := (I_A, \prec_C|_{I_A}, X_A, \Delta_A^{\text{phys}}). \quad (209)$$

$\mathcal{H}_A$ is a formal representation of the actual physical history of A . It is not the actual physical system and is not the temporal referent.

Hence:

$$\mathcal{H}_A \not\equiv_{\text{type}} T_{\text{ITOF}}. \quad (210)$$

And:

$$\mathcal{H}_A \not\equiv_{\text{type}} A. \quad (211)$$

12.3 Many physical histories within one cosmic extension

V40/F20 assigns one system-indexed physical history representation $\mathcal{H}_A$ to each qualified physical-system identity $A \in \mathcal{U}_{\text{phys}}$. There is no single physical system-history that replaces this family: the physical histories are as system-specific as the identities that bear them, without any claim that their total cardinality is presently known. The framework does not assign a private temporal succession to any of them. Every history is restricted from the same universal ordering through its own identity range.

For distinct qualified systems:

$$A \neq B \not\Rightarrow \mathcal{H}_A = \mathcal{H}_B. \quad (212)$$

Their identity domains may overlap, $I_A \cap I_B \neq \emptyset$. At every shared member $s \in I_A \cap I_B$ the systems share

the same common cosmic change stage s , while retaining distinct physical states, change contents, causal profiles, and numerical identities.

Different formations, endings, state paths, and records are therefore different physical histories within the one cosmic succession, not different times.

12.4 Hierarchical histories

If:

$$A \triangleleft_{K,s} B, \quad (213)$$

both A and B possess their own identity-bounded physical histories.

The history of the constituent is not established as a subhistory of the composite merely because the constituent lies physically within the composite at s . In particular, stage-relative composition alone does not entail containment of the constituent's entire identity range within the composite's identity range:

$$A \triangleleft_{K,s} B \not\Rightarrow I_A \subseteq I_B. \quad (214)$$

The system histories may overlap in common cosmic change-stage domain while remaining numerically and physically distinct.

12.5 History recurrence and persistence

For $r, s \in I_A$ with $r \prec_C s$, it is possible for a declared state criterion K_A to satisfy:

$$K_A(X_A(r), X_A(s)) = \text{Equivalent}. \quad (215)$$

The later physical realization remains later (Eq. (26)); state recurrence does not constitute historical reversal.

13. How Earlier Change Persists in the Present

13.1 Strictly earlier identity history

For $A \in \mathcal{U}_{\text{phys}}$ and $s \in I_A$, define:

$$I_A^{<s} := \{r \in I_A \mid r \prec_C s\}. \quad (216)$$

Under UCC:

$$\text{UCC} \wedge I_A^{<s} \neq \emptyset \implies \forall r \in I_A^{<s}, \quad \text{PhysReal}_A^+(r). \quad (217)$$

This establishes actual earlier system-specific physical change without assigning a metric duration, stage count, or universal cumulative magnitude.

13.2 Historical Physical Accumulation

Definition 13.1 (Historical Physical Accumulation). For $A \in \mathcal{U}_{\text{phys}}$ and $s \in I_A$ with $I_A^{<s} \neq \emptyset$, the expression $\text{HistoricalPhysicalAccumulation}_A^{<s}$ designates the totality of system-specific physical change actually realized strictly earlier than s in the physical history of A .

The designation is historical.

It is not defined as:

$$\text{HistoricalPhysicalAccumulation}_A^{<s} \not\equiv_{\text{def}} \sum_{r \in I_A^{<s}} \Delta_A^{\text{phys}}(r). \quad (218)$$

No universal addition operation across physical-change contents is assumed.

Historical accumulation is also not identical to the formal earlier-history representation:

$$\text{HistoricalPhysicalAccumulation}_A^{<s} \not\equiv_{\text{def}} \mathcal{H}_A^{<s}. \quad (219)$$

13.3 The past persists only through present physical traces

Historical physical accumulation is not a present physical object:

$$\neg \text{PresentPhysicalObjectAt}(\text{HistoricalPhysicalAccumulation}_A^{<s}; s). \quad (220)$$

Nor is it an additional causal-source class:

$$\text{HistoricalPhysicalAccumulation}_A^{<s} \not\equiv_{\text{type}} \text{PhysicalCausalContributor}. \quad (221)$$

This does not deny persistence of physical effects. It distinguishes an earlier physical occurrence from the present physical embodiment of an effect produced by that occurrence.

13.4 Persistence and transformation of earlier effects

Earlier physical change may produce effects that:

$$\begin{aligned} &\text{persist, transform, combine, diminish,} \\ &\text{intensify, be compensated, or cease to remain embodied.} \end{aligned} \quad (222)$$

Therefore:

$$\text{EarlierChangeOccurred}(A; r) \wedge r \prec_C s \not\Rightarrow \text{EarlierEffectStillEmbodied}(A; r; s). \quad (223)$$

Where an earlier effect remains physically embodied at s , that embodiment belongs to the present developed condition $X_A(s)$. Where it is presently causally operative, its present physical role belongs to the appropriate current causal-source class. No past object acts from an earlier common cosmic change stage as an additional causal source at s .

13.5 Present cumulative physical resultant

Let:

$$\text{EmbodiedEarlierEffects}_A(X_A(s); s) \quad (224)$$

state that retained or transformed effects originating in earlier realized physical change remain physically embodied in the present condition $X_A(s)$.

Definition 13.2 (Present Cumulative Physical Resultant).

$$\text{CumulativePhysicalResultThrough}_A(s) \iff \text{EmbodiedEarlierEffects}_A(X_A(s);s). \quad (225)$$

This is a truth-valued statement about the present developed physical condition. It does not introduce a new physical object or state variable.

Thus:

$$\text{HistoricalPhysicalAccumulation}_A^{<s} \not\equiv_{\text{def}} \text{CumulativePhysicalResultThrough}_A(s). \quad (226)$$

And:

$$\text{PairwiseDefDistinct} \left(\mathcal{H}_A^{<s}, \text{HistoricalPhysicalAccumulation}_A^{<s}, \right. \\ \left. \text{CumulativePhysicalResultThrough}_A(s) \right). \quad (227)$$

13.6 Continuing change without guaranteed retention

UCC requires actual physical change. It does not require every effect of earlier physical change to remain physically embodied.

Therefore:

$$I_A^{<s} \neq \emptyset \wedge \text{UCC} \not\Rightarrow \text{CumulativePhysicalResultThrough}_A(s). \quad (228)$$

Likewise:

$$\text{UCC} \not\Rightarrow \text{MonotonicCumulativeGrowth}(A). \quad (229)$$

No universal accumulation scalar, common accumulation unit, or cross-system ranking follows from UCC.

14. Identity Ending as Final Transformation

14.1 Identity-ending transformation

Let:

$$\text{IdentityEndingTransformation}(A;e) \quad (230)$$

denote the local primitive physical classification that the transformation physically realized in A at e satisfies the applicable numerical physical-system identity-ending criterion.

This local predicate does not itself quantify over all later common cosmic change stages. Functional failure, last observation, loss of usefulness, loss of a selected property, or destruction of one constituent is not by itself an identity-ending transformation. Any such condition constitutes identity ending only where the applicable physical identity criterion establishes cessation of the numerical identity itself.

14.2 Definition of physical-system identity ending

Definition 14.1 (Physical-System Identity Ending). For $A \in \mathcal{U}_{\text{phys}}$ and $e \in \mathcal{S}_C^{\text{tot}}$:

$$\boxed{\text{End}_A(e) \iff e \in I_A \wedge \text{IdentityEndingTransformation}(A; e) \wedge \forall t \in \mathcal{S}_C^{\text{tot}} (e \prec_C t \implies t \notin I_A)} \quad (231)$$

The ending stage e is the final member of the identity-realization range of A . It is not thereby a final stage of the cosmic extension; coincidence with a greatest cosmic stage, if one exists, is a separate cosmological possibility.

Thus:

$$\text{End}_A(e) \wedge \text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \implies \exists t \in \mathcal{S}_C^{\text{tot}}, \quad e \prec_C t. \quad (232)$$

14.3 Change at the ending boundary

From:

$$\text{End}_A(e) \implies e \in I_A, \quad (233)$$

UCC gives:

$$\text{End}_A(e) \wedge \text{UCC} \implies \text{PhysReal}_A^+(e). \quad (234)$$

The system does not first become physically static and then end outside its own physical development.

Define:

$$\Delta_A^{\text{end}}(e) := \Delta_A^{\text{phys}}(e), \quad \text{when } \text{End}_A(e) \wedge \text{UCC}. \quad (235)$$

The superscript end classifies the system-specific physical-change content relative to the identity boundary.

It does not introduce a separate type of change:

$$\Delta_A^{\text{end}}(e) \not\equiv_{\text{type}} \text{IndependentTerminalProcess}. \quad (236)$$

14.4 Uniqueness of ending

Proposition 14.2 (Uniqueness of Identity Ending). Under Strict Cosmic Ordering:

$$\begin{aligned} \text{StrictTotalOrder}(\mathcal{S}_C^{\text{tot}}, \prec_C) \vdash \forall A \in \mathcal{U}_{\text{phys}} \forall e_1, e_2 \in \mathcal{S}_C^{\text{tot}}, \\ \text{End}_A(e_1) \wedge \text{End}_A(e_2) \implies e_1 = e_2. \end{aligned} \quad (237)$$

If two distinct ending members were assumed, strict total ordering would place one earlier than the other. The earlier ending condition would then exclude the same numerical identity from the later member.

14.5 Functional failure and identity ending

For any declared functional criterion Γ :

$$\text{FunctionalFailure}_\Gamma(A; s) \not\Rightarrow \text{End}_A(s). \quad (238)$$

Conversely:

$$\text{End}_A(e) \not\Rightarrow \text{FunctionalFailure}_\Gamma(A; e). \quad (239)$$

A system may retain its numerical identity while damaged, inactive, diseased, inefficient, or non-operational. An identity may also end through transformation, division, fusion, merger, absorption, dissolution, or reorganization without an independently identified earlier functional-failure stage.

14.6 Ending and earlier physical history

Where $I_A^{<e} \neq \emptyset$ and $\text{End}_A(e) \wedge \text{UCC}$, the earlier and ending changes belong to one identity-bounded development:

$$[\forall r \in I_A^{<e}, \text{PhysReal}_A^+(r)] \wedge \text{PhysReal}_A^+(e). \quad (240)$$

This is UCC applied to the ending stage: the ending system changes at every member of its identity range, including the last. It is not mathematical continuity, differentiability, a metric trajectory, or an infinitesimal-change claim.

14.7 Ending configuration

For an actual ending define:

$$\mathfrak{R}_A^{\text{end}}(e) := (X_A(e), \Delta_A^{\text{end}}(e), \mathfrak{C}_A(e)). \quad (241)$$

The components distinguish:

- (i) the developed physical state at ending;
- (ii) the system-specific physical-change content classified relative to the identity-ending boundary;
- (iii) the actual causal profile operative at that same ending stage.

The developed state at ending embodies the cumulative resultant of the system's earlier change (Eq. (225)); at the ending stage that resultant and the final change of the system are present together, at one and the same stage.

The tuple is not chronological:

$$\text{Defined}(\mathfrak{R}_A^{\text{end}}(e)) \not\Rightarrow \text{SequentialThreeStepEnding}. \quad (242)$$

All three terms concern one common cosmic change stage and are analytically distinguished by role. At the ending stage, the final system-specific change and the developed physical state of the ending identity are realized together at that same common cosmic change stage. The strictly earlier changes remain the identity's historical physical accumulation; they are not converted into a second present object. Whatever retained or transformed physical result of that history remains embodied at ending is present through $X_A(e)$, together with the final change $\Delta_A^{\text{end}}(e)$, and any presently operative effects enter the already governed causal-source classes. This preserves the cumulative physical development of the system without treating its past occurrences as co-present causal objects.

14.8 Physical Identity-Ending Causation Principle

Postulate 14.3 (Physical Identity-Ending Causation Principle (PIECP)). Every actual identity ending of a physical system of the universe has at least one physically admissible contributor from the already governed actual causal set at the ending stage that physically contributes specifically to the identity-ending

transformation:

$$\begin{aligned}
 \text{PIECP} &\iff \forall A \in \mathcal{U}_{\text{phys}} \forall e \in \mathcal{S}_{\text{C}}^{\text{tot}}, \\
 &\quad \text{End}_A(e) \implies \exists c \in \mathcal{C}_A^{\text{act}}(e) : \\
 &\quad \text{PhysicallyContributes}(c; \text{IdentityEndingTransformation}(A; e)).
 \end{aligned} \tag{243}$$

The ending transformation is the final system-specific change of that numerical identity at the common stage e . The earlier physical history of A remains its own historical sequence of realized changes; it is not converted into an additional causal substance at ending. Only effects of earlier change that are still physically retained or transformed in the present condition of A , together with other actually operative contributors, can enter the ending-stage causal account. Identity ending does not by itself terminate the cosmic succession or require production of a successor.

PIECP is an independent ending-specific causal postulate with a narrower role than CRP. CRP establishes nonempty causal realization of actual physical change. PIECP requires at least one already admissible causal contributor to be physically implicated specifically in the identity-ending transformation.

Thus:

$$\text{CRP} \wedge \text{End}_A(e) \not\Rightarrow \text{PIECP}. \tag{244}$$

PIECP introduces no additional causal-source class.

14.9 Accumulation acts through present conditions

Neither historical physical accumulation nor the present cumulative physical resultant is an independently acting ending cause. Historical accumulation is a historical designation rather than a present causal object. For the present cumulative-resultant predicate:

$$\text{CumulativePhysicalResultThrough}_A(e) \not\Rightarrow \text{IdentityEndingTransformation}(A; e). \tag{245}$$

And:

$$I_A^{<e} \neq \emptyset \not\Rightarrow \text{End}_A(e). \tag{246}$$

Where earlier effects remain embodied and causally operative at ending, their present causal role is classified through the existing physical causal-source architecture.

15. Lifecycle Boundaries and Conditional Successors

15.1 Completed numerical identity

Define:

$$\text{HistoryComplete}(A) \iff \exists e \in I_A \text{ End}_A(e). \tag{247}$$

Let:

$$\mathcal{U}_{\text{phys}}^{\text{end}} := \{A \in \mathcal{U}_{\text{phys}} \mid \text{HistoryComplete}(A)\}. \tag{248}$$

For ended identities:

$$e : \mathcal{U}_{\text{phys}}^{\text{end}} \longrightarrow \mathcal{S}_{\text{C}}^{\text{tot}}, \quad e(A) = e_A. \tag{249}$$

The map remains partial relative to $\mathcal{U}_{\text{phys}}$ unless a universal ending postulate is separately adopted.

15.2 Optional Universal Eventual Identity Ending

Postulate 15.1 (Optional Universal Eventual Identity Ending (UEIE)). If the optional UEIE lifecycle module is adopted, every qualified realized physical-system identity of the universe has an ending and a nonempty strict pre-ending identity history:

$$\boxed{\text{UEIE} \iff \forall A \in \mathcal{U}_{\text{phys}} \exists e_A \in I_A [\text{End}_A(e_A) \wedge \exists r_A \in I_A (r_A \prec_C e_A)]}. \quad (250)$$

UEIE concerns identity-bounded physical histories, not the extent of the cosmic stage domain. It does not follow from CMA or UCC, does not imply that the cosmic succession ends, and does not require an ending system to produce a successor.

UEIE is an optional lifecycle postulate, not a governing requirement of the foundational temporal, CMA, and UCC core. It is adopted only in a model or application that explicitly assumes universal eventual ending. Its universal quantifier ranges only over the governing ontic physical-system domain $\mathcal{U}_{\text{phys}}$ and therefore over numerical physical-system identities. It does not quantify over the cosmic physical totality $\mathcal{U}_{\text{C}}^{\text{phys}}$, which is not a member of $\mathcal{U}_{\text{phys}}$, nor does it retype physical factors as system identities. It therefore carries an independent physical lifecycle burden: arbitrary mathematical subsystems, merely convenient decompositions, or entities not admitted to $\mathcal{U}_{\text{phys}}$ are not silently included. Its adoption must not be inferred from UCC, CRP, non-termination, or from the mere availability of an identity decomposition. Empirical application of UEIE to a declared system class also presupposes a domain-specific numerical-identity criterion adequate to determine formation, persistence, and ending for that class; V40/F20 does not supply one universal empirical identity criterion for all physical-system classes.

It is not derived from:

$$\left\{ \begin{array}{l} T_{\text{ITOF}}, \text{ StrictTotalOrder}, \text{ NTCS}_{\text{C}}(\mathcal{S}_{\text{C}}^{\text{tot}}, \prec_{\text{C}}), \\ \text{CSPP}, \text{ CMA}, \text{ CRP}, \text{ AFB} \end{array} \right\}. \quad (251)$$

In particular:

$$\text{CMA} \not\Rightarrow \text{UEIE}, \quad \text{UCC} \not\Rightarrow \text{UEIE}. \quad (252)$$

UEIE requires a nonempty strict pre-ending identity history:

$$\text{UEIE} \implies \forall A \in \mathcal{U}_{\text{phys}}, \quad I_A^{<e_A} \neq \emptyset. \quad (253)$$

UEIE does not by itself determine a metric lifetime, a number of realized stages, a universal ending mechanism, a universal ending threshold, or a universal ending magnitude.

15.3 Identity Cardinality under Non-Termination

The following result is mathematical and conditional. If the complete cosmic succession is additionally assumed to be non-terminating and UEIE is adopted for every identity in the governing physical-system totality, then the total number of distinct numerical physical-system identities across the complete succession cannot be finite. In the notation $|X| = \infty$ used here, ∞ means only that X is infinite; no particular infinite cardinal or countability assumption is implied.

Proposition 15.2 (Conditional infinite identity totality).

$$\left. \begin{array}{l} \mathfrak{T}_C(\mathcal{S}_C^{\text{tot}}, \prec_C), \\ \text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C), \end{array} \right\} \vdash |\mathcal{U}_{\text{phys}}| = \infty. \quad (254)$$

Proof. Because $\mathcal{S}_C^{\text{tot}} \neq \emptyset$, choose $s_0 \in \mathcal{S}_C^{\text{tot}}$. By the CSPP consequence of temporal constitution, the population realized at s_0 is nonempty. Assume for contradiction that $\mathcal{U}_{\text{phys}}$ is finite. UEIE supplies an ending member $e_A \in I_A$ for every $A \in \mathcal{U}_{\text{phys}}$. The finite nonempty set

$$E := \{e_A \mid A \in \mathcal{U}_{\text{phys}}\} \quad (255)$$

has a greatest member e_* under the strict total order. Conditional non-termination supplies $t \in \mathcal{S}_C^{\text{tot}}$ with $e_* \prec_C t$. The common-stage condition gives a nonempty population at t ; let B be a member. Its UEIE ending member $e_B \in E$ cannot be later than e_* , so $e_B \prec_C t$, contradicting realization of B at t after its identity ending. Hence $\mathcal{U}_{\text{phys}}$ is infinite under the stated premises.

The result is not an unconditional prediction that the actual cosmic physical totality has an infinite system-identity component. The non-termination premise is an open cosmological condition in V40/F20, and UEIE is a separately declared lifecycle postulate. Nor does the result assert infinitely many systems realized at any one stage. Its exact content is

$$\begin{aligned} \mathfrak{T}_C \wedge \text{NTCS}_C \wedge \text{UEIE} \\ \implies |\mathcal{U}_{\text{phys}}| = \infty. \end{aligned} \quad (256)$$

Application-level counting inside a selected class or granularity still requires an independently fixed physically warranted qualification and identity criterion; the theorem itself concerns the governing ontic totality quantified by UEIE.

15.4 Direct successor relation

Identity ending does not by itself entail production of a new numerical physical-system identity. A direct successor is admitted only where the ending transformation independently warrants formation of a genuinely new numerical identity. Define:

$$\text{SuccAt}(A, B; e) \iff \text{End}_A(e) \wedge A \neq B \wedge f_B = e \wedge \text{PhysicalProductionLink}(A, B; e). \quad (257)$$

The relation therefore requires:

- (i) actual ending of A ;
- (ii) numerical distinction between predecessor and successor;
- (iii) formation of B at the same common cosmic stage e ; and
- (iv) an independently warranted physical-production relation linking the ending transformation of A to formation of B .

A pre-existing qualified system does not become a direct successor merely by receiving matter or energy, absorbing constituents, interacting with the ending system, or remaining realized after that ending. In particular, if B is already realized before e and retains its numerical identity while incorporating material or other physical contributions from A , then $f_B \prec_C e$ and B is not a direct successor of A under Eq. (257).

Absorption can therefore terminate A without producing any new qualified identity. The absorbing system may thereby change its physical character — composition, structure, or properties — or retain it within its identity criterion; in either case it keeps its numerical identity and is not a successor. If the incorporation instead ends the identity of B , the case falls under the ending and successor conditions above.

15.5 Conditional successors without universal closure

Define the direct successor family by

$$\mathfrak{S}^+(A, e) := \{B \in \mathcal{U}_{\text{phys}} \mid \text{SuccAt}(A, B; e)\}. \quad (258)$$

No universal nonemptiness condition is imposed:

$$\text{End}_A(e) \not\Rightarrow \mathfrak{S}^+(A, e) \neq \emptyset. \quad (259)$$

Accordingly, an ending transformation may physically produce no new qualified identity, one direct successor, or a plurality of direct successors. Which case obtains is fixed by independently warranted physical production and numerical identity criteria. Failure of one proposed successor candidate says nothing about other candidates; absence of every direct successor is admissible when no new identity is physically produced.

15.6 A successor is a new identity

Every $B \in \mathfrak{S}^+(A, e)$ is numerically distinct from A . This remains true even if a declared cross-system comparison regards the successor's formation state as physically equal or equivalent to a state of A realized before its ending. Here $\text{StateEquivalent}_\Gamma$ denotes only a declared, physically warranted cross-system state-comparison relation under criterion Γ ; it is not an identity relation. For any $r \in I_A$ with $r \prec_C e$,

$$\text{SuccAt}(A, B; e) \wedge \text{StateEquivalent}_\Gamma(X_B(e), X_A(r)) \implies A \neq B. \quad (260)$$

The same conclusion holds for resemblance in composition, organization, function, location, records, or naming. State resemblance is therefore a cross-identity physical comparison; it does not restore the ended numerical identity.

15.7 Distinct successor histories

Where $\text{SuccAt}(A, B; e)$, the successor forms at $f_B = e$, has its own identity range

$$I_B = \{s \in \mathcal{S}_C^{\text{tot}} \mid \text{ExistsAs}(B, s)\}, \quad (261)$$

and, under UCC, its own physical-history representation

$$\mathcal{H}_B = \left(I_B, \prec_C|_{I_B}, X_B, \Delta_B^{\text{phys}}\right). \quad (262)$$

Thus

$$\text{SuccAt}(A, B; e) \implies A \neq B, \quad \text{SuccAt}(A, B; e) \not\Rightarrow \mathcal{H}_B = \mathcal{H}_A. \quad (263)$$

Physical production links predecessor and successor causally without merging their numerical identities or histories.

15.8 Successor attribution and cosmic extent

Conditional successor production does not supply a no-greatest-stage commitment. Whether an ending has zero, one, or several direct successors is an identity-production question at that ending transformation. Whether every cosmic stage has a later member is the separate revisable cosmological hypothesis $\text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C)$. Neither identity ending nor direct-successor attribution, separately or together, establishes that condition.

16. Population Change Across Cosmic Order

16.1 Population-level extension

The governing theory provides a complete stage-relative qualified population $\mathcal{S}_{\text{phys}}(s)$. It also provides identity-realization ranges I_A .

These existing objects represent how the qualified population may differ between arbitrary ordered common cosmic change stages without introducing:

$$\left\{ \begin{array}{l} \text{AdjacentStages, MovingPopulation, PopulationTransportSubstrate,} \\ \text{OneToOneSuccessorConservationLaw, PopulationConservationLaw} \end{array} \right\}. \quad (264)$$

Let:

$$r, s \in \mathcal{S}_C^{\text{tot}}, \quad r \prec_C s. \quad (265)$$

No assumption is made that r and s are adjacent.

16.2 Endpoint-persistent population

Define:

$$\mathcal{P}_{r,s} := \{A \in \mathcal{U}_{\text{phys}} \mid r \in I_A \wedge s \in I_A\}. \quad (266)$$

Every member belongs to both endpoint populations:

$$\mathcal{P}_{r,s} = \mathcal{S}_{\text{phys}}(r) \cap \mathcal{S}_{\text{phys}}(s). \quad (267)$$

Under Identity-Realization Convexity:

$$A \in \mathcal{P}_{r,s} \wedge r \prec_C u \prec_C s \implies u \in I_A. \quad (268)$$

Thus endpoint persistence implies realization of the same numerical identity at every intermediate common cosmic change stage. This is an order-theoretic identity result, not a metric continuity claim.

16.3 Later-endpoint entrant population

Define:

$$\mathcal{N}_{r \rightarrow s} := \{A \in \mathcal{U}_{\text{phys}} \mid r \notin I_A \wedge s \in I_A\}. \quad (269)$$

The term *entrant* or *later-endpoint entrant* is population-relative. It does not mean that a system is created by time or transported into the cosmic extension.

Under AFB and Identity-Realization Convexity:

$$A \in \mathcal{N}_{r \rightarrow s} \implies r \prec_C f_A \vee f_A = s. \quad (270)$$

Since $f_A \in I_A$ and $s \in I_A$, the least-member property also gives:

$$A \in \mathcal{N}_{r \rightarrow s} \implies \neg(s \prec_C f_A). \quad (271)$$

Thus formation occurs after r and no later than s , without requiring identification of a stage immediately following r .

16.4 Earlier-endpoint departing population

Define:

$$\mathcal{L}_{r \rightarrow s} := \{A \in \mathcal{U}_{\text{phys}} \mid r \in I_A \wedge s \notin I_A\}. \quad (272)$$

Again, *departing* is population-relative. It does not mean that the system moves outside time or leaves the cosmic extension. If optional UEIE is adopted together with Identity-Realization Convexity and $A \in \mathcal{L}_{r \rightarrow s}$, its ending member must occur before s .

Thus:

$$\{\text{UEIE, IdentityRealizationConvexity}\} \wedge A \in \mathcal{L}_{r \rightarrow s} \implies e_A \prec_C s. \quad (273)$$

Because $r \in I_A$ and $e_A \in I_A$, strict ordering and ending uniqueness permit:

$$r = e_A \quad \text{or} \quad r \prec_C e_A. \quad (274)$$

No metric lifetime is inferred.

16.5 Endpoint population decomposition

The later endpoint population decomposes exactly as:

$$\mathcal{S}_{\text{phys}}(s) = \mathcal{P}_{r,s} \dot{\cup} \mathcal{N}_{r \rightarrow s}. \quad (275)$$

The earlier endpoint population decomposes exactly as:

$$\mathcal{S}_{\text{phys}}(r) = \mathcal{P}_{r,s} \dot{\cup} \mathcal{L}_{r \rightarrow s}. \quad (276)$$

Here $\dot{\cup}$ denotes disjoint union. The decompositions follow directly from identity-domain membership and do not assert any physical conservation equation.

In particular:

$$|\mathcal{S}_{\text{phys}}(r)| - |\mathcal{L}_{r \rightarrow s}| + |\mathcal{N}_{r \rightarrow s}| = |\mathcal{S}_{\text{phys}}(s)| \quad (277)$$

is not adopted as a universal numerical law without the additional assumptions required for the relevant cardinal arithmetic and finite-population context.

The set decompositions, not a scalar population equation, are fundamental here.

16.6 Intermediate-only identities

Endpoint comparison does not capture every numerical physical-system identity realized between r and s .

Define:

$$\mathcal{T}_{r,s} := \{A \in \mathcal{U}_{\text{phys}} \mid r \notin I_A \wedge s \notin I_A \wedge \exists u \in I_A (r \prec_C u \prec_C s)\}. \quad (278)$$

Members of $\mathcal{T}_{r,s}$ are absent from both endpoint populations while possessing a realized identity history somewhere strictly between the two endpoints.

Therefore:

$$\mathcal{T}_{r,s} \cap (\mathcal{S}_{\text{phys}}(r) \cup \mathcal{S}_{\text{phys}}(s)) = \emptyset. \quad (279)$$

This class is essential for a logically complete population comparison. Without it, a pairwise comparison of endpoint populations could incorrectly suggest that no system formed and ended between r and s .

16.7 Formation and ending of intermediate-only identities

Under AFB and Identity-Realization Convexity, every $A \in \mathcal{T}_{r,s}$ has its formation boundary strictly between the selected endpoints. Because f_A is the least member of I_A , at least one member of I_A lies strictly between r and s , while both endpoints are absent from I_A . Hence:

$$\{\text{AFB}, \text{IdentityRealizationConvexity}\} \wedge A \in \mathcal{T}_{r,s} \implies r \prec_C f_A \prec_C s. \quad (280)$$

If UEIE is also adopted, its strict pre-ending-history requirement, together with AFB and Identity-Realization Convexity, places both formation and ending strictly between the selected endpoints:

$$\{\text{AFB}, \text{UEIE}, \text{IdentityRealizationConvexity}\} \wedge A \in \mathcal{T}_{r,s} \implies r \prec_C f_A \prec_C e_A \prec_C s. \quad (281)$$

Thus an identity may be physically formed, undergo its own UCC-governed development, and end entirely between two arbitrarily selected endpoint stages.

16.8 Population-transition representation

Define the pairwise population-transition descriptor:

$$\mathfrak{P}_C^{\text{pop}}(r,s) := (\mathcal{S}_{\text{phys}}(r), \mathcal{P}_{r,s}, \mathcal{N}_{r \rightarrow s}, \mathcal{L}_{r \rightarrow s}, \mathcal{T}_{r,s}, \mathcal{S}_{\text{phys}}(s)), \quad r \prec_C s. \quad (282)$$

This is a defined representation:

$$\text{Status}(\mathfrak{P}_C^{\text{pop}}(r,s)) = \text{DefinedPopulationMembershipProfile}. \quad (283)$$

It does not represent a moving population, a flow of time, a temporal transport mechanism, or a universal successor chain. The descriptor compares identity-domain membership across two ordered common cosmic change stages.

16.9 Population change within one time

Population change may be extensive:

$$\mathcal{S}_{\text{phys}}(r) \neq \mathcal{S}_{\text{phys}}(s). \quad (284)$$

Population difference does not generate stage-specific temporal extensions:

$$\mathcal{S}_{\text{phys}}(r) \neq \mathcal{S}_{\text{phys}}(s) \not\Rightarrow \text{DifferentTemporalExtensions}(r, s). \quad (285)$$

The one temporal referent remains Eq. (11).

Population transformation belongs to the physical histories realized within that extension.

16.10 Population transformation and complete physical realization

The endpoint profiles $\mathfrak{R}_C(r)$ and $\mathfrak{R}_C(s)$ are indexed by their respective complete then-realized qualified populations. If $\mathcal{S}_{\text{phys}}(r) \neq \mathcal{S}_{\text{phys}}(s)$, their profile domains differ.

No universal deterministic profile-to-profile map is implied. Therefore:

$$r \prec_C s \not\Rightarrow \exists F_{\text{univ}} : \mathfrak{R}_C(s) = F_{\text{univ}}(\mathfrak{R}_C(r)). \quad (286)$$

The invariant cosmic ordering fixes earlier and later. It does not itself supply one universal physical dynamics.

Physical comparison maps, mathematical-form-neutral dynamics, operational metrics, clocks, observation, signal access, and model-to-record bridges therefore remain downstream physical or representational constructions whose parameters and outputs are type-distinct from time.

17. Phenomena Commonly Attributed to Time

Ordinary and scientific language attributes many changes to time: healing, ageing, forgetting, wear, decay, ripening, the evolution of stars. In V40/F20 each such change belongs to a physical system and is produced by its internal contributors, by influencing physical systems, and by non-system physical factors (Section 8). Time orders these changes as members of one universal succession; it is not among their contributors. For a phenomenon Z commonly attributed to time, with changing system A and actual causal set $\mathcal{C}_A^{\text{act}}$,

$$T_{\text{ITOF}} \notin \mathcal{C}_A^{\text{act}}(s) \quad \text{for every } s \in I_A. \quad (287)$$

17.1 Clocks and regular change

Clocks depend on regularity; they do not create it. Rotation, orbital motion, tides, biological rhythms, and oscillations are physical processes of physical systems and exist whether or not a clock counts them. A clock is a physical system whose selected regular process is counted and displayed for coordination, scheduling, navigation, rate comparison, and the anticipation of upcoming change. Greater precision makes the representation more useful without changing its type. A clock that stops has lost its selected process; the clock and every other physical system continue to change, and the failure belongs to the clock (Section 23).

17.2 Place, motion, and local cycles

A place denotes a position, region, or spatial relation in which physical systems are realized; it is not by itself a physical system and does not act. Where a location matters physically, the explanation names the

systems and factors realized there:

$$\text{LocatedAt}(A, L; s) \not\Rightarrow \text{PlaceCauses}(L, A; s). \quad (288)$$

Motion is change in the spatial relation of a system to declared physical references and is one class of physical change. A return to the same place is recurrence of a spatial relation at a later stage, not a reversal of the succession:

$$\text{Occupies}(A, L; r) \wedge \text{Occupies}(A, L; t) \wedge r \prec_C t \not\Rightarrow X_A(r) = X_A(t). \quad (289)$$

Rotation, orbit, seasons, and the alternation of night and day are local cycles: recurrence of selected conditions in systems that themselves continue to change. Day in one region and night in another at the same common stage are different physical conditions, not different times; local dates and time zones are conventions built on terrestrial motion and standardized clocks.

17.3 The environment as a descriptive aggregation

The environment of a system is not a fourth causal source. It is a descriptive aggregation of the influencing physical systems, the non-system physical factors, the pathways, and the boundary relations realized around the system, and an environmental explanation is complete only when that aggregation is decomposed:

$$\text{Env}_A(s) \overset{\text{dec}}{\rightsquigarrow} (\mathcal{C}_A^{\text{infl-sys}}(s), \mathcal{C}_A^{\text{infl-factor}}(s), \text{pathways}, \text{boundary relations}). \quad (290)$$

In an experiment the sample, instruments, observers, and laboratory are all physical systems that change at every stage at which they are realized; each is part of the environment of the others.

17.4 Stability, deficiency, and failure

Stability is continuing change that keeps a selected property within a declared range; it is never the absence of change. Whether an influence is withstood, buffered, or destructive depends on the system's constitution, cohesion, susceptibility, capacity, and thresholds (Sections 8.9–8.10), and an effect is supportive or adverse only relative to a declared criterion. Change may also follow a deficiency: a preserving condition falling below what the system requires, as when cooling, lubrication, nutrients, or power are lost. Accumulated damage acts through the physical condition it has left in the present system (Section 13); failure becomes possible when the present demand on the system exceeds its present capacity. A result that appears late in the history of a system is not explained by its lateness.

17.5 Living systems, memory, and the sense of duration

Growth, maintenance, reproduction, healing, ageing, adaptation, and evolution are physical changes produced by biological organization together with the systems and factors acting on organisms and populations (Section 8.11). The expression “time heals” is imprecise: healing is produced by cellular repair, immune response, circulation, nutrition, and care. A memory is a present physical record formed by an earlier event; it is neither the event nor stored time, and forgetting is a change in the memory system and its records. The sense of duration is a cognitive phenomenon altered by attention, emotion, pain, fear, boredom, and bodily condition; it varies between persons and occasions, while time, the one succession of common stages, does not vary.

17.6 Chemical and stellar change

A reaction duration is a relation between the reacting system and a reference clock. The reaction is produced by reactants, concentrations, temperature, pressure, solvents, catalysts, and radiation. A star changes through gravity, nuclear fusion, radiation transport, composition, rotation, magnetic fields, mass loss, and companions; a stable stellar phase is maintained change, and a collapse is the failure of a physical balance. Light from a distant source is a record of an earlier condition of the source, received at a later stage; the source and the receiver are realized at the same common stages.

17.7 Controlled use of the word time

In V40/F20 the word time has one formal meaning, $T_{\text{TOF}} = \mathcal{E}_C = (\mathcal{S}_C^{\text{tot}}, \prec_C)$. Clock time, coordinate time, and proper time are named as clock outputs, coordinates, or model parameters (Section 23). Time is not the subject of verbs of action: it does not flow, carry, heal, destroy, store, stretch, or remember. A sentence that attributes a change to time is translated into the system that changes and the physical contributors of the change.

18. Cross-System Physical Comparison

18.1 Comparison requires an independently declared common space

Let $A, B \in \mathcal{S}_{\text{phys}}(s)$ in a governing realization satisfying UCC. Then both system-specific change-content terms are well typed:

$$\Delta_A^{\text{phys}}(s) \in \Xi_A, \quad \Delta_B^{\text{phys}}(s) \in \Xi_B, \quad (291)$$

without requiring $\Xi_A = \Xi_B$.

Consequently, a mathematical comparison between the physical-change contents of distinct systems is not automatically well typed.

For a declared comparison protocol P , let $\mathcal{Y}_{AB,P}$ be a comparison space whose physical interpretation, units or normalization, domain of validity, and uncertainty structure are explicitly declared.

Introduce independently supplied maps

$$\phi_{A \rightarrow AB}^P : \Xi_A \longrightarrow \mathcal{Y}_{AB,P}, \quad (292)$$

$$\phi_{B \rightarrow AB}^P : \Xi_B \longrightarrow \mathcal{Y}_{AB,P}. \quad (293)$$

Only after these maps are physically and mathematically warranted may mapped change contents be compared within the common comparison space.

18.2 Mapped comparison and physical identity

Define:

$$\text{MappedChange}_{A|AB,P}(s) := \phi_{A \rightarrow AB}^P \left(\Delta_A^{\text{phys}}(s) \right) \quad (294)$$

and similarly

$$\text{MappedChange}_{B|AB,P}(s) := \phi_{B \rightarrow AB}^P \left(\Delta_B^{\text{phys}}(s) \right). \quad (295)$$

Even if:

$$\text{MappedChange}_{A|AB,P}(s) = \text{MappedChange}_{B|AB,P}(s), \quad (296)$$

it does not follow that:

$$\text{MappedChange}_{A|AB,P}(s) = \text{MappedChange}_{B|AB,P}(s) \not\Rightarrow \Delta_A^{\text{phys}}(s) \equiv_{\text{type}} \Delta_B^{\text{phys}}(s). \quad (297)$$

Mapped equality is equality under the declared comparison representation. It is not physical system identity.

18.3 General comparison operator

Let:

$$\Psi_{AB,P} : \mathcal{Y}_{AB,P} \times \mathcal{Y}_{AB,P} \longrightarrow \mathcal{Z}_{AB,P} \quad (298)$$

be a declared comparison operator.

Define:

$$\begin{aligned} \text{Cmp}_{AB,P}(s) := \Psi_{AB,P} \Big(& \phi_{A \rightarrow AB}^P(\Delta_A^{\text{phys}}(s)), \\ & \phi_{B \rightarrow AB}^P(\Delta_B^{\text{phys}}(s)) \Big). \end{aligned} \quad (299)$$

The output belongs to the comparison codomain:

$$\text{Cmp}_{AB,P}(s) \in \mathcal{Z}_{AB,P}. \quad (300)$$

$\text{Cmp}_{AB,P}(s)$ is the cosmic-moment comparison of the change contents of A and B at one and the same stage (Eq. (74)). Since records do not identify stages, it is an ontological quantity and is not computed from records. An application compares, at the stage of reception, a received record with a local state under the declared procedure P ; the output of that comparison is an application-level quantity. Neither is time or a cosmic-stage member.

18.4 Admissibility of a physical comparison

A comparison is scientifically admissible only where its construction is independently specified.

Define:

$$\begin{aligned} \text{AdmissibleComparison}(A, B; P) \implies & \text{PhysicalTargetDeclared}(A, B; P) \\ & \wedge \text{ComparisonMapsDeclared}(A, B; P) \\ & \wedge \text{ComparisonCodomainDeclared}(P) \\ & \wedge \text{UnitsOrNormalizationDeclared}(P) \\ & \wedge \text{ParameterProvenanceDeclared}(P) \\ & \wedge \text{UncertaintyStructureDeclared}(P) \\ & \wedge \text{DomainOfValidityDeclared}(P). \end{aligned} \quad (301)$$

The condition is methodological. It does not state that every pair of systems must admit a physically meaningful comparison.

Thus:

$$A, B \in \mathcal{S}_{\text{phys}}(s) \not\Rightarrow \exists P \text{ AdmissibleComparison}(A, B; P). \quad (302)$$

Shared membership in $\mathcal{S}_{\text{phys}}(s)$ identifies the represented population at that member of the formal cosmic-stage domain; neither population membership, CMA common-stage co-presence, nor UCC supplies quantitative comparability by itself.

18.5 Change without a universal scalar amount

V40/F20 does not infer:

$$\exists \mu_{\Delta} : \bigcup_{A \in \mathcal{U}_{\text{phys}}} \Xi_A \longrightarrow \mathbb{R} \quad (303)$$

as a foundational requirement.

Accordingly:

$$\text{UCC} \not\Rightarrow \text{UniversalScalarAmountOfChange}. \quad (304)$$

The complete-population physical-realization architecture likewise supplies no universal cross-system ranking of change. Statements such as “ A changed more than B ” require a declared comparison construction. They do not follow from the cosmic ordering itself.

18.6 Cross-level comparison under hierarchical composition

If $A \triangleleft_{\kappa, s} B$, a comparison between constituent and composite change remains subject to the same mapping discipline.

Thus:

$$A \triangleleft_{\kappa, s} B \not\Rightarrow \text{Cmp}_{AB, P}(s) \text{ is defined}. \quad (305)$$

A physical composition model may independently supply the necessary maps. Composition itself does not.

19. Physical Dynamics and Temporal Order

19.1 Foundational neutrality toward the form of physical dynamics

The temporal definition (Eq. (11)) does not select one universal mathematical form for physical dynamics. No single deterministic, stochastic, quantum, field-theoretic, Hamiltonian, or relativistic-geometrical form is imposed as the universal dynamics of all physical systems. The neutrality asserted here concerns mathematical form and representation; it does not suspend CRP or the framework’s declared physical-causal ontology. The foundational temporal architecture and application-level physical dynamics remain distinct. Accordingly, governing CMA remains type-distinct from every application-level physical-dynamics descriptor:

$$\text{CMA} \not\equiv_{\text{type}} \mathcal{D}\eta\eta_{M; \mathcal{A}}. \quad (306)$$

The left-hand side states CMA; the right-hand side specifies a declared physical model. Complete qualified-system actual-change coverage belongs separately to UCC. Neither common-stage co-presence nor physical-change coverage is supplied by this type-nonidentity statement. Neither side supplies a dynamical law for time.

19.2 Admissible physical-dynamics descriptor

For a declared physical-system class $\mathcal{A}$, let application model M possess the internal physical-dynamics descriptor

$$\mathcal{D}\eta_{M;\mathcal{A}} := (\mathcal{Z}_M, \Theta_M, \mathcal{L}_M, D_M, \text{Sol}_M). \quad (307)$$

Here $\mathcal{Z}_M$ is the declared space or class of model realizations, Θ_M the model-parameter family, $\mathcal{L}_M$ the declared physical law, evolution relation, stochastic rule, Hamiltonian structure, field equation, constraint family, or other governing model structure, D_M the physical and mathematical domain of validity, and Sol_M the declared solution or admissible-realization rule. Physical encoding and measurement are excluded from this descriptor because they belong to separately typed bridge layers.

A mathematical-form-neutral solution family may be written schematically as

$$\text{Sol}_M(D_M, \Theta_M) := \{z \in \mathcal{Z}_M(D_M) \mid \text{LawSatisfied}_M(z; \mathcal{L}_M, \Theta_M, D_M)\}. \quad (308)$$

Here LawSatisfied_M is the satisfaction predicate induced by the declared governing structure $\mathcal{L}_M$ on the stated parameter family and validity domain. This notation does not require every model to share the same mathematical ontology or to be representable as a deterministic differential equation.

19.3 Admissibility condition

A physical model may enter an ITOF application only where its role is explicit.

Admissibility requires the following declared conditions:

$$\begin{aligned} \text{AdmissiblePhysicalModel}(M; \mathcal{A}) \implies & \text{PhysicalTargetDeclared}(M; \mathcal{A}) \\ & \wedge \text{ModelRealizationSpaceTyped}(M) \\ & \wedge \text{PhysicalSystemBoundariesDeclared}(M) \\ & \wedge \text{IdentityCriterionDeclaredWhereApplicable}(M) \\ & \wedge \text{ParameterProvenanceDeclared}(M) \\ & \wedge \text{DynamicsFormDeclared}(M) \\ & \wedge \text{SolutionRuleDeclared}(M) \\ & \wedge \text{ModelInputBridgeDeclared}(M) \\ & \wedge \text{ModelOutputBridgeDeclared}(M) \\ & \wedge \text{DomainOfValidityDeclared}(M) \\ & \wedge \text{ApproximationStatusDeclared}(M) \\ & \wedge \text{ObservationBridgeDeclaredWhereNeeded}(M). \end{aligned} \quad (309)$$

These are necessary methodological conditions for admission of the declared model into an ITOF application; they are not claimed to be universally sufficient for every possible physical-model class. It does not convert the chosen dynamics into a foundational ITOF axiom.

19.4 Model evolution parameters

A model may employ one or more parameters that index mathematical evolution, solution families, record order, path position, iteration, phase, or another representation.

Let λ_M be such a parameter. Even where the parameterized model states $\lambda_M \mapsto X_A^M(\lambda_M)$ accurately predict physical records, the parameter remains a model parameter:

$$\begin{aligned} & \text{ModelEvolutionParameter}(\lambda_M; M) \\ & \wedge \text{OperationalSuccess}_{P,M,D}(\lambda_M) \\ & \not\Rightarrow \lambda_M \equiv_{\text{type}} T_{\text{ITOF}}. \end{aligned} \quad (310)$$

19.5 Model parameters and cosmic stages

No global numerical map $\iota : \mathcal{S}_C^{\text{tot}} \rightarrow \mathbb{R}$ is required by the temporal definition. An application may introduce an index only with an independently declared representational role. Therefore:

$$\text{ModelEvolutionParameter}(\lambda_M; M) \not\Rightarrow \text{CommonCosmicChangeStageIndex}(\lambda_M). \quad (311)$$

A model may parameterize a reconstructed or predicted physical history without enumerating the members of $\mathcal{S}_C^{\text{tot}}$.

19.6 Physical laws and the non-causal role of time

The mathematical-form-neutral requirement is that a declared realization $z \in \mathcal{Z}_M$ satisfy the independently specified governing rule:

$$\text{LawSatisfied}_M(z; \mathcal{L}_M, \Theta_M, D_M). \quad (312)$$

A residual equation such as $\mathcal{L}_M(\mathcal{V}_M, \Theta_M) = 0$ is one admissible special case, not the universal form of physical dynamics. The physical interpretation belongs to the declared systems, fields, interactions, constraints, and physical quantities represented by the particular model.

The occurrence of an evolution parameter in the equation does not make the parameter a causal source.

Thus:

$$\text{AppearsAsEvolutionParameter}(\lambda_M) \not\Rightarrow \text{PhysicalCause}(\lambda_M). \quad (313)$$

Likewise, time is not a member of the physical causal-source domain:

$$T_{\text{ITOF}} \not\equiv_{\text{type}} \text{PhysicalCausalContributor}. \quad (314)$$

19.7 Model-to-history association

An application may associate a model trajectory, state family, stochastic family, field configuration, or other mathematical object with part of a physical-system history.

Represent that association by:

$$\Psi_{M,A}^{\text{hist}} : \text{Sol}_M(D_M, \Theta_M) \longrightarrow \mathcal{H}_A^M. \quad (315)$$

where $\mathcal{H}_A^M$ denotes only the model-represented aspects of the physical history of A . The source is the

declared family of model realizations, not the domain-of-validity statement itself.

The existence of such an association alone does not establish complete representational identity:

$$\left[\Psi_{M,A}^{\text{hist}} : \text{Sol}_M(D_M, \Theta_M) \longrightarrow \mathcal{H}_A^M \right] \not\Rightarrow \mathcal{H}_A^M = \mathcal{H}_A. \quad (316)$$

Equality would require an independent argument for complete representational adequacy over every component relevant to the claim. Likewise,

$$\left[\Psi_{M,A}^{\text{hist}} : \text{Sol}_M(D_M, \Theta_M) \longrightarrow \mathcal{H}_A^M \right] \not\Rightarrow \lambda_M \equiv_{\text{type}} T_{\text{ITOF}}. \quad (317)$$

19.8 Valid models with different parameters

Two physical models may successfully represent different aspects of the same physical system or different systems M_1 and M_2 .

Their parameters may satisfy:

$$\lambda_{M_1} \neq \lambda_{M_2}. \quad (318)$$

Distinct model parameters do not imply distinct temporal referents:

$$\lambda_{M_1} \neq \lambda_{M_2} \not\Rightarrow \text{DistinctTemporalReferents}(M_1, M_2). \quad (319)$$

It indicates different representational constructions.

19.9 Formal reversibility within a non-reversed order

A physical model may admit:

$$\lambda_M \mapsto -\lambda_M. \quad (320)$$

This mathematical transformation does not reverse $\prec_C$.

Therefore:

$$\text{ModelInvariantUnder}(\lambda_M \mapsto -\lambda_M) \not\Rightarrow \text{CosmicOrderingReversed}. \quad (321)$$

Mathematical reversibility, physical recurrence, and non-reversal of the governing cosmic order remain distinct.

19.10 System-specific physical directionalities

A physical-system history may exhibit a directional pattern relative to a declared physical criterion without generating an additional temporal order. For qualified system A and criterion α , let

$$Y_{A,\alpha} : I_A \longrightarrow \mathcal{Y}_{A,\alpha} \quad (322)$$

be a declared physical or model-supported descriptor, and let

$$\preceq_{A,\alpha} \subseteq \mathcal{Y}_{A,\alpha} \times \mathcal{Y}_{A,\alpha} \quad (323)$$

be the comparison relation warranted for that criterion. No totality, metric, linearity, or universal cross-system meaning is assumed for $\preceq_{A,\alpha}$.

Define the criterion-indexed directionality descriptor:

$$\mathfrak{A}_{A,\alpha} := (\mathcal{Y}_{A,\alpha}, Y_{A,\alpha}, \preceq_{A,\alpha}). \quad (324)$$

For $J \subseteq I_A$, define alignment with the universal cosmic ordering on that domain by:

$$\text{ArrowAligned}_{A,\alpha}(J) \iff \forall r, s \in J, \quad r \prec_C s \implies Y_{A,\alpha}(r) \preceq_{A,\alpha} Y_{A,\alpha}(s). \quad (325)$$

Where the strict part of the criterion relation is needed, define:

$$u \prec_{A,\alpha}^{\text{phys}} v \iff u \preceq_{A,\alpha} v \wedge \neg (v \preceq_{A,\alpha} u). \quad (326)$$

A criterion-relative reversal over an ordered pair may then be represented by:

$$\text{CriterionReversal}_{A,\alpha}(r, s) \iff r \prec_C s \wedge Y_{A,\alpha}(s) \prec_{A,\alpha}^{\text{phys}} Y_{A,\alpha}(r). \quad (327)$$

Such a reversal concerns the selected physical criterion. It does not reverse the cosmic order:

$$\text{CriterionReversal}_{A,\alpha}(r, s) \not\Rightarrow s \prec_C r. \quad (328)$$

A conventional physical “arrow” is therefore admissible only as a criterion-indexed physical regularity:

$$\text{PhysicalArrow}_{A,\alpha}(J) \iff \text{ArrowAligned}_{A,\alpha}(J). \quad (329)$$

The designation is not a second meaning of time. The physical comparison relation and the universal cosmic order have different types:

$$\preceq_{A,\alpha} \not\equiv_{\text{type}} \prec_C. \quad (330)$$

Even perfect alignment over a declared domain does not transfer temporal identity:

$$\text{PhysicalArrow}_{A,\alpha}(J) \not\Rightarrow \preceq_{A,\alpha} \equiv_{\text{type}} \prec_C. \quad (331)$$

UCC requires actual system-specific physical change; it does not require one criterion to be monotonic for every system:

$$\text{UCC} \not\Rightarrow \exists \alpha \forall A \in \mathcal{U}_{\text{phys}}, \quad \text{PhysicalArrow}_{A,\alpha}(I_A). \quad (332)$$

Nor does a physical arrow require a metric on the identity range:

$$\text{PhysicalArrow}_{A,\alpha}(J) \not\Rightarrow \text{MetricOn}(J). \quad (333)$$

Thermodynamic, developmental, decay-statistical, memory- or record-related, computational, and other physical directionalities may be represented through $\mathfrak{A}_{A,\alpha}$ when the relevant physical model supplies a defined criterion and evidential support. Different directionalities may align, recur, plateau, or reverse relative to their own criteria while the universal earlier–later ordering remains fixed. The directionality descriptor is a defined application-level construction, not a new foundational temporal postulate.

20. Operational Metrics and Time

20.1 Operational metric layer

V40/F20 moves beyond the statement that a clock output is not time.

It asks how numerical quantities conventionally used to represent:

$$\begin{aligned} & \text{duration, elapsed units, frequency ratios, rates,} \\ & \text{synchronization differences, path-dependent intervals, and related metric outputs} \end{aligned} \quad (334)$$

are physically or mathematically constructed.

The governing answer is that such quantities require declared physical records, model quantities, calibration structures, comparison rules, or combinations of those ingredients. They are not extracted as a metric already contained in $(\mathcal{S}_C^{\text{tot}}, \prec_C)$.

20.2 Non-metricity as a type boundary

V40/F20 does not claim that bare earlier–later order generates differential equations, Hamiltonians, stochastic kernels, clock-response laws, or numerical intervals. Those belong to independently warranted physical-model layers. The connection to quantitative practice is instead typed: physical inputs are encoded into a declared model, the model dynamics constrain or generate admissible realizations, predicted physical quantities are mapped to records, and an operational construction maps those records together with calibration and comparison information to numerical outputs. Thus the absence of a canonical metric in T_{ITOF} is not repaired by silently inserting one into the temporal definition; quantitative scale enters only through the declared physical and operational architecture.

Accordingly,

$$\text{TemporalDefinition}_{\text{ITOF}} \not\Rightarrow \text{DynamicsDescriptorSpecified}(M; \mathcal{A}). \quad (335)$$

and successful application dynamics do not convert their evolution parameter or metric output into time.

Operational metric denotes a protocol-defined quantitative output used to express an interval, rate, ratio, synchronization difference, or related metric quantity. The term does not by itself assert that $\mathcal{Y}_P$ or $\mathcal{M}_P^{\text{op}}$ satisfies the axioms of a metric space. Where a genuine metric-space distance is required, non-negativity, separation, symmetry, the triangle inequality, the applicable domain, and the physical interpretation must be supplied independently.

20.3 General operational metric map

Let $\mathfrak{R}_P$ be a declared physical record domain associated with protocol P .

Let $\mathcal{K}_P$ contain the calibration, reference, normalization, unit, alignment, and comparison information required by the declared operational construction.

Define:

$$\mathcal{M}_P^{\text{op}} : \mathfrak{R}_P^n \times \mathcal{K}_P \longrightarrow \mathcal{Y}_P. \quad (336)$$

For records $r_1, \dots, r_n \in \mathfrak{R}_P$ and declared calibration bundle $c_P \in \mathcal{K}_P$, define:

$$m_P := \mathcal{M}_P^{\text{op}}(r_1, \dots, r_n; c_P). \quad (337)$$

The output:

$$m_P \in \mathcal{Y}_P \quad (338)$$

is an operational quantity.

It is not time (Eq. (453)).

20.4 Metric outputs and cosmic order

The ordered pair $(\mathcal{S}_C^{\text{tot}}, \prec_C)$ contains no foundationally defined numerical distance function. This is the application-level consequence of the order-representation non-metricity result in Eq. (38). A map of the form $d_C : \mathcal{S}_C^{\text{tot}} \times \mathcal{S}_C^{\text{tot}} \rightarrow \mathbb{R}$ may be introduced only as an additional mathematical or physical-model construction; it is not part of the definition of time.

Accordingly, an operational metric output does not by itself define a magnitude on the cosmic-stage order. A numerical difference between records belongs to the declared operational scale.

20.5 Model-derived metric quantities

Some scientifically useful metric quantities are obtained primarily from a mathematical or physical model rather than directly from record arithmetic.

Let:

$$\mu_M = \mathcal{G}_M(\mathcal{V}_M, \Theta_M) \quad (339)$$

be such a model-derived metric quantity.

By the Non-Transfer Principle it is not time either.

Where:

$$m_P \approx K_{P,M}(\mu_M) \quad (340)$$

successfully connects model quantity and operational output, the agreement warrants the declared quantitative association.

It does not make μ_M time:

$$m_P \approx K_{P,M}(\mu_M) \not\Rightarrow \mu_M \equiv_{\text{type}} T_{\text{ITOF}}. \quad (341)$$

20.6 Operational interval

For two ordered records r_1, r_2 , let:

$$N_P : \mathfrak{R}_P \longrightarrow \mathbb{R}_P \quad (342)$$

be a declared numerical reading map.

Define:

$$\Delta N_P := N_P(r_2) - N_P(r_1). \quad (343)$$

The quantity may conventionally be described as elapsed time or duration. Within ITOF it remains an operational quantity, not time.

Nor does a numerical interval establish an exact count of common cosmic stages. From $\Delta N_P = n$ alone, no finite cardinality of intervening or endpoint common stages follows. V40/F20 supplies no stage-count function, adjacency rule, or stage-identification-and-counting procedure from the bare strict order $(\mathcal{S}_C^{\text{tot}}, \prec_C)$; since change continues without stopping, no such procedure is available from records. This

Non-Transfer statement is kept in prose rather than introducing an otherwise unused stage-count predicate.

20.7 Operational physical rate

For measured physical quantity Q_A , define:

$$\Delta_P Q_A := \widehat{Q}_{A;P,M}(r_{A,2}) - \widehat{Q}_{A;P,M}(r_{A,1}). \quad (344)$$

Where $\Delta N_P \neq 0$, define:

$$\bar{v}_{Q_A|N}^P := \frac{\Delta_P Q_A}{\Delta N_P}. \quad (345)$$

This is a relation between a measured physical difference and a declared operational numerical interval.

It is not:

$$\bar{v}_{Q_A|N}^P \not\equiv_{\text{type}} \text{RateOfTime}. \quad (346)$$

20.8 Operational synchronization

Let two physical standard systems produce mapped outputs n_1 and n_2 .

Define:

$$d_{12}^P := \Gamma_{1,P}(n_1) - \Gamma_{2,P}(n_2). \quad (347)$$

For declared synchronization tolerance ϵ_{sync} :

$$\text{Synchronized}_{P,\epsilon_{\text{sync}}}(1,2) \iff |d_{12}^P| \leq \epsilon_{\text{sync}}. \quad (348)$$

This is an operational relation.

It neither creates nor defines CMA:

$$\text{Synchronized}_{P,\epsilon_{\text{sync}}}(1,2) \not\Rightarrow \text{CMA}. \quad (349)$$

Nor does failure of synchronization negate CMA:

$$\neg \text{Synchronized}_{P,\epsilon_{\text{sync}}}(1,2) \not\Rightarrow \neg \text{CMA}. \quad (350)$$

Clock-output agreement and common cosmic-stage unity remain different claims.

21. Signals, Records, and Observation

21.1 Physical actuality and observational access

A system-specific physical change may be actual whether or not it is accessible to a declared observer or apparatus.

For physical manifestation χ , record r , protocol P , model M , and threshold ϵ :

$$\text{PairwiseTypeDistinct}(\text{PhysReal}_A^+(s), \text{ManifestationAt}(A, \chi; s), \text{Detected}_{P,M,\epsilon}(A, \chi; r)). \quad (351)$$

Hence:

$$\text{PhysReal}_A^+(s) \not\Rightarrow \text{Detected}_{P,M,\varepsilon}(A, \chi; r). \quad (352)$$

And:

$$\neg \text{Detected}_{P,M,\varepsilon}(A, \chi; r) \not\Rightarrow \text{NC}_A^{\text{phys}}(s). \quad (353)$$

21.2 Access relations and common-stage realization

For $A, B \in \mathcal{S}_{\text{phys}}(s)$, CMA supplies objective common-stage co-presence. Under UCC, $\text{PhysReal}_A^+(s)$ and $\text{PhysReal}_B^+(s)$ also hold. The physical relations of interaction, signal accessibility, and observational accessibility remain separately typed: $\text{PhysicalInteraction}(A, B; s)$, $\text{SignalAccessible}(A, B; s)$, and

$$\text{ObservationallyAccessible}_{P,M}(B; A, s). \quad (354)$$

The first two non-entailments are fixed in Eqs. (78) and (79). Observational accessibility is likewise not supplied by CMA:

$$\text{CMA} \not\Rightarrow \forall s \in \mathcal{S}_C^{\text{tot}} \forall A, B \in \mathcal{S}_{\text{phys}}(s), \quad \text{ObservationallyAccessible}_{P,M}(B; A, s). \quad (355)$$

21.3 Signal delay within one common stage

If a signal originating from system B is not yet physically received by system A at s , this does not imply that B is absent from the common stage.

Thus:

$$A, B \in \mathcal{S}_{\text{phys}}(s) \wedge \text{SignalNotYetReceived}(A, B; s) \not\Rightarrow B \notin \mathcal{S}_{\text{phys}}(s). \quad (356)$$

Under UCC, delayed reception leaves system-specific change intact:

$$\text{UCC} \wedge A, B \in \mathcal{S}_{\text{phys}}(s) \wedge \text{SignalNotYetReceived}(A, B; s) \implies \text{PhysReal}_B^+(s). \quad (357)$$

Spatial and causal accessibility affect physical interaction and knowledge. They do not partition the common cosmic change stage.

21.4 Observation as a physical process

An observational arrangement consists of physical systems and physically realized factors.

Let $\mathcal{L}_P$ denote the declared family of target, apparatus, detector, record-bearing, observer, reference, calibration, communication, processing, and environmental systems entering protocol P .

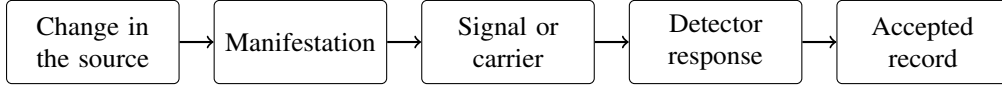
For every member of that physical-system family that is realized at s , UCC gives

$$\text{UCC} \wedge X \in \mathcal{L}_P \cap \mathcal{S}_{\text{phys}}(s) \implies \text{PhysReal}_X^+(s). \quad (358)$$

A sample or target, apparatus, detector, record-bearing system, observer, and laboratory, where each satisfies the governing physical-system criteria, are therefore all inside the same changing physical domain. A laboratory may itself be a qualified composite system while its constituents retain their own qualified histories. Selection of any of these systems as a reference, standard, or observer does not exempt it from UCC.

Thus no sample, observer, apparatus, or laboratory supplies a changeless standpoint outside the common cosmic extension.

21.5 Source-to-record physical chain



Every element is a physical system or a physical process, and each changes at every stage at which it is realized. The record is later than the change it reports and does not identify the stage of that change.

Figure 3: From a change in a source to an accepted record.

A physical observation may be schematically represented by:

$$\begin{aligned}
 \text{SourceManifestation} &\rightsquigarrow_{\text{phys}} \text{AccessiblePhysicalEffect} \\
 &\rightsquigarrow_{\text{phys}} \text{ApparatusDetectorInteraction} \\
 &\rightsquigarrow_{\text{phys}} \text{RecordFormation} \\
 &\rightsquigarrow_{\text{phys}} \text{PhysicalRecordAccess}.
 \end{aligned} \tag{359}$$

The physical links are changes and interactions of systems within the same cosmic succession; none is an operation performed from outside that succession. The source, apparatus, record-bearing system, observer, and relevant laboratory or environmental systems may contribute at different members of $\mathcal{S}_C^{\text{tot}}$, as represented by the physical support set below.

A subsequent operational reading and scientific inference may be represented by

$$\text{PhysicalRecordAccess} \longrightarrow \text{Reading} \longrightarrow \text{RestrictedScientificConclusion}. \tag{360}$$

The availability and access of a record are physical; numerical representation and scientific inference add model-dependent and inferential operations. No arrow or physical arrow in these chains denotes identity of source, record, stage, reading, or time.

21.6 Record type

For physical record r :

$$r \not\equiv_{\text{type}} \text{SourceManifestation}, \quad r \not\equiv_{\text{type}} s, \quad r \not\equiv_{\text{type}} T_{\text{ITOF}}. \tag{361}$$

A record may physically encode information about a source.

Information carriage does not erase the type distinction between: source, record, stage, time.

21.7 Physical acquisition support

For record $r \in \mathfrak{R}_P$, define:

$$J_r^{\text{phys}} := \{s \in \mathcal{S}_C^{\text{tot}} \mid \exists X \in \mathcal{L}_P \text{ PhysicalContributionToRecord}(X, s; r)\}. \tag{362}$$

A physically produced record satisfies:

$$\text{PhysicallyProducedRecord}(r) \implies J_r^{\text{phys}} \neq \emptyset. \quad (363)$$

The support need not be a singleton:

$$\left| J_r^{\text{phys}} \right| > 1 \quad (364)$$

is admissible.

Therefore:

$$\text{ReadableAt}(r; s_d) \not\Rightarrow J_r^{\text{phys}} = \{s_d\}. \quad (365)$$

21.8 Observation as a physically restricted projection

Let:

$$\mathfrak{A}_C^{P,M} \subseteq \{ \mathfrak{R}_C(s) \mid s \in \mathcal{S}_C^{\text{tot}} \} \quad (366)$$

denote only the physically accessible part of the common-stage physical-realization architecture relevant to protocol P and model M .

Define schematically:

$$\mathcal{O}_{P,M} : \mathfrak{A}_C^{P,M} \times \Upsilon_{P,M} \longrightarrow \mathfrak{R}_P. \quad (367)$$

Here $\Upsilon_{P,M}$ denotes the declared physical acquisition, transformation, calibration, and record-production conditions.

The definition of the observation map does not entail injectivity, observational completeness, or invertibility to common cosmic change stages. Let $\text{ObservationMapSpecified}_{P,M}$ denote that the declared map is well defined for the stated protocol and model. Then:

$$\text{ObservationMapSpecified}_{P,M} \not\Rightarrow \text{Injective}(\mathcal{O}_{P,M}), \quad (368)$$

$$\text{ObservationMapSpecified}_{P,M} \not\Rightarrow \text{SurjectiveOntoCompletePhysicalReality}(\mathcal{O}_{P,M}). \quad (369)$$

Thus:

$$\text{ObservationMapSpecified}_{P,M} \not\Rightarrow \text{RecordToCosmicChangeStageInverse}. \quad (370)$$

This construction formalizes the distinction between ontological population completeness and physically restricted observational access.

22. Change-Stage Restraint

22.1 Stage designation and epistemic identification

Each $s \in \mathcal{S}_C^{\text{tot}}$ is a formal stage expression of realized physical change within the common cosmic earlier–later succession. The physical realization and the earlier–later relation are objective within the governing theory; no additional stage entity or independently existing ordering-position entity is required.

Yet:

$$s \in \mathcal{S}_C^{\text{tot}} \not\Rightarrow \text{CosmicChangeStageObservationallyIdentified}(s). \quad (371)$$

The distinction is epistemic and does not make the cosmic ordering observer-dependent.

22.2 Positive observational warrant

Define:

$$\begin{aligned}
 \text{PositiveManifestationWitness}_{A;P,M,\epsilon}(\chi; r) &\iff \text{Detected}_{P,M,\epsilon}(A, \chi; r) \\
 &\quad \wedge \text{ValidSystemAttribution}_{P,M}(r; A) \\
 &\quad \wedge \text{PhysicalSourceRecordLink}_{P,M}(A, \chi; r) \\
 &\quad \wedge \text{AcceptedDifference}_{P,M,\epsilon}(r).
 \end{aligned} \tag{372}$$

Then:

$$\begin{aligned}
 &\text{PositiveManifestationWitness}_{A;P,M,\epsilon}(\chi; r) \\
 &\implies \text{Warrant}_{P,M} [\exists s \in I_A (\text{ManifestationAt}(A, \chi; s) \wedge \text{PhysReal}_A^+(s))].
 \end{aligned} \tag{373}$$

The existential witness is physically actual.

The record does not thereby identify which member of I_A it is. Under UCC, the investigated system continues to realize physical change at every member of its identity range, while the sample, detector, apparatus, record-bearing systems, observer, and laboratory — all physical systems of the universe — also continue to change. A reference frame that is only a coordinate construction is not a physical system and bears no record. This makes first detectability a threshold within ongoing physical change rather than its onset. Because change continues without stopping, observed or not, no physical system is a changeless anchor, and the observed change does not determine its stage or the place of that stage in the succession. The source–record architecture and finite physical access are the forms this takes in practice; they are not further conditions under which the stage could be identified.

22.3 Formal Change-Stage Restraint

Principle 22.1 (Change-Stage Restraint). A valid physical observation may warrant that a manifestation, physical difference, threshold crossing, recurrence, formation-related manifestation, ending-related manifestation, or ordered physical development is realized at some common cosmic change stage in a physical-system history.

The observation does not thereby identify that common cosmic change stage or its position in the complete universal ordering. The restraint is epistemic rather than ontological: the source, sample, detector, apparatus, record-bearing systems, observer, and laboratory are physical systems of the universe and are themselves changing under UCC, so no changeless external observer or record is available as a cosmic-stage label.

The positive existential warrant is already fixed by Eq. (373). The restraint concerns what that same validated witness does not identify:

$$\text{PositiveManifestationWitness}_{A;P,M,\epsilon}(\chi; r) \not\Rightarrow \text{CosmicChangeStageIdentified}_{P,M}(A, \chi), \tag{374}$$

and:

$$\text{PositiveManifestationWitness}_{A;P,M,\epsilon}(\chi; r) \not\Rightarrow \text{CosmicOrderPositionIdentified}_{P,M}(A, \chi). \tag{375}$$

22.4 The ground of change-stage restraint

The ground of the restraint is the postulate of change itself. Change continues in every physical system without stopping, whether observed or not; the sample, the apparatus, the observer, and the laboratory are physical systems of the universe and change with it. A changeless anchor would be a physical system of the universe that does not change at some stage of its identity range, $\text{ChangelessAnchor}(A) : \Longleftrightarrow A \in \mathcal{U}_{\text{phys}} \wedge \exists s \in I_A \text{NC}_A^{\text{phys}}(s)$. By UCC, no physical system is a changeless anchor:

$$\text{UCC} \implies \neg \exists A \in \mathcal{U}_{\text{phys}} \text{ChangelessAnchor}(A). \quad (376)$$

An observed change is itself part of the continuing change and marks no boundary outside it, and its record is a later change in a system that is itself changing. It therefore does not determine its stage, nor the place of that stage in the succession; this holds for an observed change for the same reason that it holds for an unobserved one.

The restraint is carried in practice by:

$$\begin{aligned} &\text{source--record separation,} \quad \text{finite physical access,} \\ &\text{absence of an external changeless measurement anchor,} \\ &\text{changing acquisition and record-bearing systems,} \\ &\text{possibly non-singleton record support,} \quad \text{model dependence,} \\ &\text{and stage--record type distinction.} \end{aligned} \quad (377)$$

22.5 First record and first change

Under UCC, every earlier member of the same identity range already expresses actual physical change realized in that physical system:

$$\text{UCC} \wedge s \in I_A \wedge I_A^{<s} \neq \emptyset \implies \forall q \in I_A^{<s}, \quad \text{PhysReal}_A^+(q). \quad (378)$$

Let $\text{FirstResolvedManifestation}_{P,M,\varepsilon}(A, \chi; r)$ mean only that r is the earliest record in the declared protocol order that resolves manifestation χ as attributable to A above the stated criterion. It does not encode a minimum of the physical-change history. Hence

$$\begin{aligned} &\text{FirstResolvedManifestation}_{P,M,\varepsilon}(A, \chi; r) \\ &\quad \Rightarrow \exists s \in I_A \left[\text{ManifestationAt}(A, \chi; s) \right. \\ &\quad \quad \left. \wedge \forall q \in I_A (q \prec_C s \Rightarrow \neg \text{PhysReal}_A^+(q)) \right]. \end{aligned} \quad (379)$$

A detection threshold concerns the changing source--acquisition--record system and the declared criterion. It does not establish a transition from physical stasis to physical change. A resolved manifestation warrants that the relevant physical condition was realized at some common cosmic change stage, but neither the member of $\mathcal{S}_C^{\text{tot}}$ nor its position in the universal ordering is thereby identified. The first resolved observation is therefore an observational threshold event, not an ontological onset marker for change.

22.6 Record order and source-development order

Let $r_1 \prec_P r_2$ be an order relation in a declared record domain.

Then:

$$r_1 \prec_P r_2 \not\Rightarrow \text{SourceDevelopmentEarlier}(A, \chi_1, \chi_2). \quad (380)$$

A physical source-order bridge is required.

Let:

$$\text{OrderBridge}_{A;P,M}(r_1, r_2; \chi_1, \chi_2) \quad (381)$$

denote such a warranted relation.

Then a record comparison may support:

$$\begin{aligned} \text{Warrant}_{P,M} \left[\exists s_1, s_2 \in I_A : s_1 \prec_C s_2 \right. \\ \quad \wedge \text{ManifestationAt}(A, \chi_1; s_1) \\ \quad \left. \wedge \text{ManifestationAt}(A, \chi_2; s_2) \right]. \end{aligned} \quad (382)$$

This still does not identify the pair of stages:

$$\text{Warrant}_{P,M}[\exists s_1, s_2 (\dots)] \not\Rightarrow \text{CosmicChangeStagePairIdentified}_{P,M}(A, \chi_1, \chi_2). \quad (383)$$

23. Clocks: Physical Systems, Not Time

23.1 Physical status of a clock

A clock is a physical system selected because a sufficiently reproducible, stable, controllable, or modelable part of its physical operation can generate ordered records and standardized numerical outputs. Modern atomic-clock comparisons provide high-precision physical record domains for such response analysis [36, 38, 51, 52, 53].

Thus:

$$\text{Clock}(C) \implies \text{PhysicalSystem}(C). \quad (384)$$

The clock possesses:

$$I_C = \{s \in \mathcal{S}_C^{\text{tot}} \mid \text{ExistsAs}(C, s)\}, \quad (385)$$

and under UCC:

$$C \in \mathcal{S}_{\text{phys}}(s) \implies \text{PhysReal}_C^+(s). \quad (386)$$

Under CRP:

$$\text{PhysReal}_C^+(s) \implies \mathcal{C}_C^{\text{act}}(s) \neq \emptyset. \quad (387)$$

Selection of a physical system as a standard does not remove it from physical change or causal realization.

23.2 Clock process, record, and reading

A clock involves at least three analytically distinct levels:

$$\text{ClockProcess}, \quad \text{ClockRecord}, \quad \text{ClockReading}. \quad (388)$$

The three objects are physical or operational parts of a clock model. None is the temporal referent T_{TOF} .

23.3 Clock-record map

Let $J \subseteq I_C$ denote a portion of the clock's physical history relevant to record production. Let $\Upsilon_{C,P}$ contain declared operating, environmental, interrogation, control, detector, transfer, and record-production conditions.

Define:

$$\mathcal{R}_{C,P} : (\mathcal{H}_C|_J, \Upsilon_{C,P}) \mapsto r_C. \quad (389)$$

This map is a physical/operational construction. It does not assign a rate to time.

23.4 Numerical clock reading

Define:

$$N_{C,P} : \mathfrak{R}_{C,P} \longrightarrow \mathbb{R}_P. \quad (390)$$

For $r_C \in \mathfrak{R}_{C,P}$, the protocol assigns the numerical reading

$$n_C = N_{C,P}(r_C). \quad (391)$$

This equation defines the reading as an output of the record map; it does not identify the reading with time.

Then:

$$n_C \not\equiv_{\text{type}} r_C, \quad n_C \not\equiv_{\text{type}} s. \quad (392)$$

23.5 Clock interval as a special operational metric

For two records $r_{C,1} \prec_P r_{C,2}$, define:

$$\Delta N_{C,P} := N_{C,P}(r_{C,2}) - N_{C,P}(r_{C,1}). \quad (393)$$

Then:

$$\Delta N_{C,P} \not\equiv_{\text{type}} \text{MagnitudeOf}(\mathcal{S}_C^{\text{tot}}, \prec_C). \quad (394)$$

The quantity is a special case of the operational metric architecture developed in Section 20.

23.6 Clock comparison

For clocks C_1, C_2 , map their readings into a declared comparison codomain:

$$d_{12}^{\text{obs}} := \Gamma_{1,12}(N_{C_1,P_1}(r_1)) - \Gamma_{2,12}(N_{C_2,P_2}(r_2)). \quad (395)$$

A resolved $d_{12}^{\text{obs}} \neq 0$ warrants a physical/operational difference under the declared comparison conditions. It establishes neither different cosmic extensions for C_1 and C_2 , nor a deformation of the cosmic ordering, nor different rates of time: the difference is a difference between the clocks, not a difference in time.

23.7 Clock synchronization and common-stage co-presence

Clock synchronization remains operational: $\text{Synchronized}_{P,\varepsilon}(C_1, C_2)$.

Objective co-presence at a stage is supplied by CMA (Eq. (75)). The two are distinct in type:

$$\text{Synchronized}_{P,\varepsilon} \not\equiv_{\text{type}} \text{CosmicCoPresence}_C. \quad (396)$$

Common-stage unity is not constructed by clock agreement.

23.8 Clock failure

Functional clock failure need not terminate numerical identity:

$$\text{ClockFailure}_P(C; s) \not\Rightarrow \text{End}_C(s). \quad (397)$$

If $s \in I_C$, then under UCC:

$$\text{ClockFailure}_P(C; s) \wedge s \in I_C \implies \text{PhysReal}_C^+(s). \quad (398)$$

Likewise:

$$\text{NoClockOutputAfter}_P(C; s) \not\Rightarrow \text{CosmicSuccessionStopsAt}(s). \quad (399)$$

23.9 Clock records under mechanical vibration

A clock is a physical system, not time; strong or sustained mechanical vibration can therefore alter its record. For an atomic or optical clock C , the record-producing chain comprises

$$\begin{aligned} \mathcal{K}_C = \{ & \text{atom or ion, interrogation laser, reference cavity, trap or lattice,} \\ & \text{servo lock, detector, electronics, comparison link} \}. \end{aligned} \quad (400)$$

Vibration acts on members of $\mathcal{K}_C$: on the length and therefore the resonance of the reference cavity that stabilizes the interrogation laser; on the position, motion, and confinement of the atoms or ions in the trap or lattice; on the servo lock; on the detector and readout; on connections and electronics; and on the signal path of a comparison between clocks. Each effect is a physical response of the physical system to a mechanical factor of the kind listed in Section 8. A declared vibration condition is

$$V = (S_a(f), [f_1, f_2], \hat{\mathbf{n}}, \text{CouplingPath}), \quad (401)$$

with acceleration spectral density S_a , frequency band, axis, and coupling path into C . The clock record under V is modelled as

$$y_C^{\text{obs}} = y_C^0 + \sum_k s_{k,C} + s_C^{\text{vib}}(V; \boldsymbol{\beta}_C) + \varepsilon_C, \quad (402)$$

where s_C^{vib} is the vibration contribution predicted by a declared response model with sensitivity coefficients $\boldsymbol{\beta}_C$ for the members of $\mathcal{K}_C$ (for example, the fractional frequency shift of the cavity per unit acceleration

along $\hat{\mathbf{n}}$), and the remaining terms are as in Eq. (671).

Definition 23.1 (Clock vibration-condition protocol). A test of clock C under vibration condition V and protocol P satisfies

$$\begin{aligned}
& \text{VibrationClockProtocol}(C, V, P) \\
& \implies \text{ConditionDeclared}(V) \wedge \text{ChainDeclared}(\mathcal{K}_C) \\
& \quad \wedge \text{SensitivityModelDeclared}(\beta_C) \\
& \quad \wedge \text{IndependentMotionRecord}(V) \wedge \text{InterleavedControl}(P) \\
& \quad \wedge \text{ProtocolFrozen}(P) \wedge \text{NoPostHocContributor}(P).
\end{aligned} \tag{403}$$

Here the motion record is taken by an accelerometer or equivalent sensor independent of C ; interleaved control alternates vibration-on and vibration-off intervals or compares C with an isolated reference clock; and no contributor is added to the record model after the result is inspected.

A record shift observed under V is attributed first to the response of the physical system and of its record-producing chain:

$$\text{VibrationRecordShift}(C; V, P) \not\Rightarrow \text{TimeChanged}, \tag{404}$$

consistent with the Generalized Non-Transfer Principle (Section 28). If the shift agrees with $s_C^{\text{vib}}(V; \beta_C)$ within declared uncertainty, the response model is supported on the tested domain. If a residual remains, the response model is restricted, and a further physical contributor may be proposed only with a new predeclared test; the residual is not assigned to time. If vibration breaks the lock or interrupts output, the case is clock failure (Eq. (397)): the clock continues to change under UCC, and absence of output does not mark a cosmic stage (Eq. (399)). The same reading applies to pressure, heat and direct solar exposure, shock, motion, and gravitational conditions: each acts on the physical system and its record chain, and a difference between clock records is a physical result in a physical system under declared conditions, not a transfer, change, or deformation of time.

24. Physical Response and Records

24.1 From clock response to typed application

V36/F16 developed clock-response modeling as an application-level construction. V40/F20 generalizes the same discipline to arbitrary admissible physical-system classes without promoting any application model into the temporal core. In this application vocabulary, a physical or operational “response” is a predicted or measured characterization of a realized or model-predicted physical effect; it is not a foundational intermediate entity between cause and change.

The governing typed chain is Eq. (114). For a declared system A , its independently warranted physical conditions, causal contributors, boundaries, and preparations enter the physical-input domain; the model-input bridge encodes them, the declared dynamical rule constrains or generates admissible model realizations according to its stated mathematical type, the model-output bridge yields predicted physical quantities, and the measurement bridge connects those quantities to records. Every step requires an independently specified relation of the correct type. No step is supplied by the definition of time, CMA, or UCC alone.

24.2 Application-level status

A temporal type claim is not a physical response model, and successful physical prediction does not make a model output time.

24.3 Physical-condition bundle

For system A_i and accepted comparison index k , let:

$$\mathcal{B}_{i,k} := \left(\widehat{X}_{i,k}, \widehat{Z}_{i,k}, \widehat{R}_{i,k}, \widehat{\Pi}_{i,k} \right), \quad (405)$$

where:

- (i) $\widehat{X}_{i,k}$ is the reconstructed system state relevant to the declared model;
- (ii) $\widehat{Z}_{i,k}$ is the declared local or environmental physical-condition bundle;
- (iii) $\widehat{R}_{i,k}$ contains relevant physical relations to other systems or reference structures;
- (iv) $\widehat{\Pi}_{i,k}$ contains applicable physical propagation, transfer, interaction- path, or comparison-path conditions that belong to the declared model-input specification. Acquisition, calibration, and record-alignment conditions belong to the separately typed measurement layer.

Additional model-specific variables may be introduced only where physically required. No component is automatically a coordinate of $\mathcal{S}_C^{\text{tot}}$.

24.4 Physical response function

Let:

$$\widehat{q}_{i,k}^M = \mathcal{Q}_{i,M}(\mathcal{B}_{i,k}; \theta_i) \quad (406)$$

be a predicted physical or operational response. Where atomic or optical physical-system models are used, independently derived sensitivity calculations can supply application-level coefficient provenance when physically warranted [54].

The model parameters:

$$\theta_i = (\theta_{i,1}, \dots, \theta_{i,p_i}) \quad (407)$$

must possess declared provenance:

$$\text{Prov}(\theta_{i,j}) = \mathcal{P}_{i,j}. \quad (408)$$

Admissible provenance may include:

$$\begin{aligned} &\text{independent physical derivation, independent measurement,} \\ &\text{construction specification, independent calibration,} \\ &\text{external physical constraint, or declared derivation-domain estimation.} \end{aligned} \quad (409)$$

24.5 Benchmark recovery and independent prediction

If: $\text{Prov}(\theta) = \text{BenchmarkAssigned}$, then:

$$\text{Prov}(\theta) = \text{BenchmarkAssigned} \not\Rightarrow \text{IndependentPrediction}(\theta). \quad (410)$$

Likewise:

$$\theta = \hat{\theta}(D_{\text{eval}}) \not\Rightarrow \text{IndependentPrediction}(D_{\text{eval}}). \quad (411)$$

A model may successfully recover an existing benchmark. Recovery and advance prediction remain distinct inferential statuses.

25. Predeclared Physical Tests

25.1 Four inferential levels

V40/F20 retains the hierarchy:

$$\text{Recovery} \longrightarrow \text{AdvancePrediction} \longrightarrow \text{ModelDiscrimination} \longrightarrow \text{FoundationalAssessment}. \quad (412)$$

The arrows indicate increasing inferential burden. They do not state automatic entailment. Recovery concerns whether a declared application model represents known records adequately within a specified domain. Advance prediction requires model form, parameter values or derivation rules, controls, uncertainty, and acceptance criteria to be fixed independently before the evaluation outcome is known. Model discrimination requires sufficiently separated rival predictions. Foundational assessment additionally requires identifiable logical attribution to the foundational commitments under test.

25.2 Protocol freeze

Let:

$$\mathfrak{P}^* := (\mathcal{S}, \mathcal{B}, \mathcal{Q}, \mathfrak{M}, \Theta, \mathcal{C}, \Sigma, \mathcal{E}, \mathcal{A}, \mathcal{F}, \mathcal{R}). \quad (413)$$

The components specify:

- (i) physical systems and system classes;
- (ii) physical-system boundaries and identity criteria;
- (iii) controlled and measured physical-condition bundles;
- (iv) application model and declared rival models;
- (v) model form and parameter provenance;
- (vi) positive and null-control channels;
- (vii) covariance, uncertainty, and bounded remainder structure;
- (viii) exclusions and data-quality rules;
- (ix) acceptance criteria;
- (x) failure criteria;
- (xi) replication specification.

Predictive status requires:

$$\text{ProtocolFrozen}(\mathfrak{P}^*) \implies \text{NoEvaluationOutcomeDependence}(\mathfrak{P}^*). \quad (414)$$

For any application whose claims depend on numerical physical-system identity, the system class, declared system boundary, and applicable identity criterion are part of the frozen protocol rather than post-evaluation

interpretive choices:

$$\begin{aligned}
& \text{ProtocolFrozen}(\mathfrak{P}^*) \wedge \text{IdentitySensitiveApplication}(\mathfrak{P}^*) \\
& \implies \text{OutcomeIndependentSystemClass}(\mathfrak{P}^*) \\
& \quad \wedge \text{OutcomeIndependentSystemBoundary}(\mathfrak{P}^*) \\
& \quad \wedge \text{OutcomeIndependentIdentityCriterion}(\mathfrak{P}^*).
\end{aligned} \tag{415}$$

Where formation, ending, or successor attribution is part of the tested claim, the corresponding formation, ending, and successor criteria must likewise be declared before evaluation. A post-evaluation revision of any such criterion is a revised protocol, not a retroactive rescue of the original test. The revised identity or boundary specification requires independent evaluation under a newly declared protocol. This constraint does not impose one universal identity criterion on all physical-system classes; it prevents outcome-dependent reclassification within a specific test.

25.3 Derivation and evaluation separation

Let D_{der} be the derivation domain and D_{eval} the evaluation domain.

Require:

$$D_{\text{der}} \cap D_{\text{eval}} = \emptyset. \tag{416}$$

But:

$$D_{\text{der}} \cap D_{\text{eval}} = \emptyset \not\Rightarrow \text{NoEvaluationLeakage}. \tag{417}$$

Outcome-sensitive model form, preprocessing, exclusions, covariance choices, thresholds, controls, remainder bounds, or model-selection rules can still produce leakage despite record-level separation.

25.4 Prediction separation

For rival models M_1, M_2 , let:

$$\hat{\mathbf{y}}^{M_1}, \quad \hat{\mathbf{y}}^{M_2} \tag{418}$$

be their predeclared evaluation predictions.

Define:

$$\Delta \hat{\mathbf{y}}_{12} := \hat{\mathbf{y}}^{M_1} - \hat{\mathbf{y}}^{M_2}. \tag{419}$$

A meaningful discrimination claim requires that the predicted separation be resolved relative to the declared combined uncertainty structure. Using the short predicate $\text{ResolvedSep}_{\Sigma_{12}}$ for that declared criterion:

$$\text{PredictionSeparation}(M_1, M_2; P, D) \implies \text{ResolvedSep}_{\Sigma_{12}}(\Delta \hat{\mathbf{y}}_{12}). \tag{420}$$

No universal numerical threshold is imposed by the foundation. The criterion belongs to the predeclared protocol.

25.5 Identifiability

A fitted model does not acquire predictive force merely because one parameter choice reproduces the observations.

Let:

$$J_D = \left[\frac{\partial \hat{y}_k^M}{\partial \theta_j} \right]_{k \in D} \quad (421)$$

be the local sensitivity matrix.

For positive-definite covariance:

$$W_D^T W_D = \Sigma_D^{-1}, \quad (422)$$

define:

$$X_D = W_D J_D. \quad (423)$$

A local identifiability criterion may require:

$$\text{Identifiable}_D(M) \iff \text{rank}(X_D) = p_M \wedge \text{cond}_2(X_D) \leq c_{\max}, \quad (424)$$

where the conditioning bound is declared before evaluation.

This is an application-level statistical criterion. It is not part of the definition of time.

26. Foundation-to-Observable Bridges

26.1 Foundational and empirical bridges

The local stage-change condition remains $\text{SCB}_C(s)$. It records the local conjunction of CMA common-stage co-presence and UCC complete system-specific actual-change coverage at member s . It is a foundational representation only and is not an empirical bridge. A foundational empirical bridge instead records the additional physical and observational premises required to derive a measurable consequence.

Therefore:

$$\text{SCB}_C \not\equiv_{\text{type}} \text{FoundationalEmpiricalBridge}. \quad (425)$$

26.2 Empirical bridge tuple

For foundational claim F , protocol P , and evaluation domain D , with any declared application-model family represented within B_F^{phys} by its physical-encoding, dynamical, and model-to-prediction premises, define the full empirical assessment tuple by:

$$\mathfrak{B}_F^{P,D} := \left(B_F^{\text{phys}}, B_F^{\text{obs}}, \mathcal{P}_F^{\text{aux}}, \Sigma_F, \mathcal{A}_F \right). \quad (426)$$

Here:

- (i) B_F^{phys} contains independently specified physical-encoding, dynamical, and model-to-prediction premises;
- (ii) B_F^{obs} contains independently specified acquisition, source-record, measurement, and reconstruction premises;
- (iii) $\mathcal{P}_F^{\text{aux}}$ contains additional independently warranted auxiliary assumptions;
- (iv) Σ_F contains the declared uncertainty and covariance architecture;
- (v) $\mathcal{A}_F$ contains the attribution conditions required to determine which premise class is actually challenged by an observed failure.

The tuple is methodological. Its first three entries refine the derivational core stated in Eq. (427); Σ_F and $\mathcal{A}_F$ govern evaluation and attribution rather than the logical content of the predicted observable itself. When B_F^{phys} , B_F^{obs} , or $\mathcal{P}_F^{\text{aux}}$ appears in a conjunction or entailment, the symbol denotes the conjunction of its declared propositional premises. The tuple $\mathfrak{B}_F^{P,D}$ itself is never used as a proposition.

It is not a physical object and not a component of time.

26.3 Foundational-to-observable derivation

A claimed observable consequence O_F must satisfy:

$$F \wedge B_F^{\text{phys}} \wedge B_F^{\text{obs}} \wedge \mathcal{P}_F^{\text{aux}} \vdash O_F. \quad (427)$$

The derivation itself must not be reconstructed after observing the outcome if advance predictive status is claimed.

Thus:

$$\text{AdvanceFoundationalPrediction} \implies \text{OutcomeIndependentSpecification} \left(\mathfrak{B}_F^{P,D}, O_F \right). \quad (428)$$

26.4 Observable failure and foundational scope

If the derivation of Eq. (427) holds and $\neg O_F$ is observed, then

$$\neg O_F \not\Rightarrow \neg F. \quad (429)$$

The failure may instead lie in:

$$B_F^{\text{phys}}, \quad B_F^{\text{obs}}, \quad \mathcal{P}_F^{\text{aux}}, \quad \Sigma_F, \quad \text{or their declared domain.} \quad (430)$$

26.5 Foundational Attribution Principle

Principle 26.1 (Foundational Empirical Attribution Principle). A failed or successful application-level observable warrants a conclusion about a foundational commitment only where the derivational path from foundation to observable is independently specified and the attribution of the result to the foundational difference is identifiable against bridge, auxiliary, acquisition, and uncertainty alternatives.

Formally:

$$\begin{aligned}
\text{FoundationalAttribution}(F; O, P, D) \implies & \text{FoundationToObservableDerivationDeclared} \\
& \wedge \text{OutcomeIndependentBridges} \\
& \wedge \text{ProtocolFrozen}(P) \\
& \wedge \text{NoEvaluationLeakage}(P, D) \\
& \wedge \text{ValidPhysicalSystemBoundaries} \\
& \wedge \text{ValidIdentityCriteriaWhereApplicable} \\
& \wedge \text{ValidAcquisitionSupport} \\
& \wedge \text{ValidCovariance} \\
& \wedge \text{PredictionSeparationIdentifiable} \\
& \wedge \text{AlternativeAttributionControlled}.
\end{aligned} \tag{431}$$

These conditions are necessary.

They are not claimed to be universally sufficient for every possible experimental domain. The principle is methodological and evidential: it constrains what may be warranted from a foundation-to-observable derivation. It adds no temporal component, ontological realization commitment, physical causal law, or independent empirical postulate.

26.6 Empirical status and prediction criterion

The existence of formal counterconditions to CMA, the UCC continuity condition, or other foundational commitments is distinct from the existence of a presently available finite experiment that uniquely identifies those counterconditions. Likewise, a foundational conflict with a rival temporal ontology is not by itself an experimental preference relation.

Therefore, where no independently warranted physical branch produces a resolved prediction separation attributable to the foundational difference, V40/F20 does not claim that experiment has already established empirical preference for ITOF over that rival ontology:

$$\neg \text{FoundationSpecificSeparation}_{P,D} \implies \neg \text{ExperimentalPreferenceEstablished}_{P,D}(I, R). \tag{432}$$

This is an epistemic-status statement, not a retreat from the formal contrary conditions. The current scientific burden is to construct an independently warranted physical bridge for which prediction separation and foundational attribution survive the declared uncertainty and bridge freedom.

At the present V40/F20 stage, the framework does not claim a unique quantitative observable residual derived from the temporal foundation alone. This limitation is stated explicitly because a foundation-specific prediction cannot be created by stipulation without adding prediction-relevant physical content. Any future claim of an ITOF-specific prediction must identify the responsible foundational premise, derive the physical consequence through independently warranted application physics, fix the measurement bridge before outcome-sensitive evaluation, compare the relevant rival on matched shared inputs, and show that the resulting observable separation survives uncertainty and admissible bridge freedom. A candidate effect that is merely appended as an optional interaction is a test of that interaction, not yet a test of ITOF's temporal ontology.

26.7 Foundational discrimination between two alternatives

For foundational alternatives F and F^* , a warranted discrimination claim requires independently specified observable consequences:

$$F \wedge B_F^{\text{phys}} \wedge B_F^{\text{obs}} \wedge \mathcal{P}_F^{\text{aux}} \vdash O_F, \quad (433)$$

$$F^* \wedge B_{F^*}^{\text{phys}} \wedge B_{F^*}^{\text{obs}} \wedge \mathcal{P}_{F^*}^{\text{aux}} \vdash O_{F^*}. \quad (434)$$

A necessary condition is:

$$\begin{aligned} & \text{Warrant}_{P,D} [\text{FoundationalDiscrimination}(F, F^*)] \\ \implies & \text{OutcomeIndependentSpecification} \left(\mathfrak{B}_F^{P,D}, \mathfrak{B}_{F^*}^{P,D} \right) \\ & \wedge \text{ProtocolFrozen}(P) \\ & \wedge \text{NoEvaluationLeakage}(P, D) \\ & \wedge \text{PredictionSeparationBeyondCombinedUncertainty} (O_F, O_{F^*}; P, D) \\ & \wedge \text{FoundationalAttributionIdentifiable} (F, F^*; P, D). \end{aligned} \quad (435)$$

Shared calibrations or systematic inputs are not prohibited where their dependence is explicitly represented in provenance and covariance.

26.8 Application-model and foundational discrimination

If two application models differ $M_1 \neq M_2$, and observation favours one: $\text{DiscriminationFavours}(M_1)$, the warranted conclusion is initially:

$$\text{Warrant} [\text{ApplicationModelSupportedOn}(M_1; D)]. \quad (436)$$

It does not follow that the foundational theory is thereby established. Application models may differ for reasons downstream of their foundations.

26.9 Revision after a failed prediction

Suppose model M_1 makes a predeclared advance prediction and fails. A later model M_2 may legitimately introduce a newly established physical contributor, improved response law, corrected boundary condition, or revised uncertainty structure.

That scientific revision does not alter the historical status of the original test:

$$\text{PostEvaluationRevision}(M_1 \rightarrow M_2) \not\Rightarrow \text{OriginalAdvancePredictionSucceeded}. \quad (437)$$

The revised model requires:

$$M_2 \longrightarrow D_{\text{new}} \quad (438)$$

for new predictive evaluation.

This prevents unrestricted auxiliary modification from making an application model empirically immune to failure.

26.10 Direct UCC countercondition

The direct physical contrary to UCC is $\neg \text{UCC}$ (Eq. (657)); by Eq. (90), it is exactly $\exists A \in \mathcal{U}_{\text{phys}} \exists s \in I_A : \neg \text{PhysReal}_A^+(s)$.

A null difference $D^{\text{obs}} = 0$ does not establish that contrary:

$$D^{\text{obs}} = 0 \not\Rightarrow \exists A \in \mathcal{U}_{\text{phys}} \exists s \in I_A, \quad \text{NC}_A^{\text{phys}}(s). \quad (439)$$

Positive physical warrant for $\text{NC}_A^{\text{phys}}(s)$ of the qualified persisting system at a stage would be required. A zero selected-variable result, criterion-relative stability, or failure to resolve change is not the same proposition.

26.11 CMA challenge condition

The governing contrary to CMA is a qualified system with a private stage or a private ordering of stages (Eq. (656)). Complete physical non-change of a realized qualified system is instead the direct contrary to UCC. Different physical states, different clock outputs, spatial separation, delayed signals, or different observational access do not themselves establish either kind of challenge.

Thus:

$$\text{DifferentPhysicalOutputs}(A, B) \not\Rightarrow \neg \text{CMA}. \quad (440)$$

Likewise:

$$\text{SignalDelay}(A, B) \not\Rightarrow \neg \text{CMA}. \quad (441)$$

A challenge to CMA must warrant a private stage or private ordering. A challenge to UCC must establish complete physical non-change of at least one realized qualified system at a member. These evidential targets are distinct.

26.12 Strong test condition

A strong discriminating application satisfies:

$$\begin{aligned}
 \text{StrongDiscriminatingTest} \implies & \text{ProtocolFrozen} \\
 & \wedge \text{IndependentPhysicalBridge} \\
 & \wedge \text{IndependentParameterProvenance} \\
 & \wedge \text{ValidPhysicalSystemBoundaries} \\
 & \wedge \text{ValidAcquisitionSupport} \\
 & \wedge \text{ValidCovariance} \\
 & \wedge \text{NoEvaluationLeakage} \\
 & \wedge \text{IdentifiableModel} \\
 & \wedge \text{PositiveDiscriminatingChannels} \\
 & \wedge \text{NullControlChannels} \\
 & \wedge \text{RivalPredictionSeparation} \\
 & \wedge \text{IndependentEvaluation} .
 \end{aligned} \tag{442}$$

Where replication is physically appropriate and claimed, `IndependentReplication` is added as a further condition.

The distinction between a formal contrary and a finite experimental procedure, and the limits of finite evidence for universal commitments, are stated in Section 48.

27. Application Bridge Structure

27.1 Five distinct levels

The V40/F20 bridge architecture consists of five distinct levels without collapsing their roles.

$$\begin{aligned}
 \text{Level I:} & \quad \text{FoundationalCommitment}, \\
 \text{Level II:} & \quad \text{FoundationalDefinedRepresentation}, \\
 \text{Level III:} & \quad \text{PhysicalEncodingDynamicsAndPrediction}, \\
 \text{Level IV:} & \quad \text{MeasurementAndRecordBridge}, \\
 \text{Level V:} & \quad \text{EmpiricalComparisonAndAttribution} .
 \end{aligned} \tag{443}$$

For example:

$$\text{CMA} \wedge \text{UCC} \implies \forall s \in \mathcal{S}_C^{\text{tot}} \text{SCB}_C(s) . \tag{444}$$

belongs to the foundational and defined-representation levels. The converse at each stage is only the local unpacking of the defined bridge into its CMA and UCC components; the bridge is not an independent foundational commitment.

Level III is the typed physical application chain formed by the model-input bridge, the declared dynamics, and the model-output bridge in Eq. (114). Level IV begins only when predicted physical quantities enter the measurement or observation bridge and are connected to records under a declared protocol. Thus a physical response law belongs to Level III, whereas a source–record or acquisition relation belongs to Level IV.

A model-discrimination or foundational-attribution claim belongs to Level V.

27.2 Worked instantiation: the no-asymptotic-closure expectation

The currently-complete-isolation criterion and its associated expectation (Section 5.7, Corollary 5.3) are a qualitative empirical commitment, not a numeric discriminant, and fall under the same level discipline:

- Level I: UCC,
- Level II: $\text{CCPI}_{M,G}(A,s)$ and the stagewise form of UCC (Eq. (87)),
- Level III: the declared M fixing which channels count as closed, at boundary and granularity G (Definition 5.2),
- Level IV: a certification protocol P for a named system, reporting either an identified channel or an upper bound on residual change, (445)
- Level V: treatment of a decreasing sequence of Level-IV bounds as adverse evidence against UCC, only where the Level-III and Level-IV premises are independently defended.

UCC does not determine which channel a Level-III model names (Eq. (446)). A Level-IV result bears on UCC only through Level V. Level IV can be executed on existing isolation experiments.

27.3 Application physics requires its own premises

The temporal definition does not by itself determine any specific physical dynamics, clock response, metric output, signal law, observation model, or experimental prediction,

$$\text{TemporalDefinition}_{\text{ITOF}} \not\Rightarrow \text{SpecificApplicationPhysics}, \quad (446)$$

and neither CMA nor UCC supplies a specific clock difference or a specific nonzero differential between systems. System specificity permits physically different responses; it does not manufacture a quantitative difference without an independently specified physical law.

27.4 Bridge closure before external-theory confrontation

Quantitative confrontation with an external physical theory requires the dependency chain:

$$\begin{aligned}
 \text{FoundationalDifference} &\longrightarrow \text{IndependentlySpecifiedPhysicalBridge} \\
 &\longrightarrow \text{DistinctAdvancePrediction} \\
 &\longrightarrow \text{PhysicalRecord} \\
 &\longrightarrow \text{ControlledComparison} \\
 &\longrightarrow \text{IdentifiableAttribution} .
 \end{aligned} \tag{447}$$

Without the second and third steps, a foundational disagreement does not become an empirical result. The generalized Non-Transfer Principle fixes the type boundary governing such external-theory comparisons.

28. Generalized Non-Transfer Principle

28.1 Scope

The Non-Transfer Principle prevents mathematical, representational, physical, and operational success from being converted into temporal identity without an independent identity argument. V40/F20 generalizes that discipline beyond clocks and relativistic quantities. Let q denote any mathematical, physical-model, operational, representational, geometrical, statistical, coordinate, record-derived, or comparison quantity.

Let $\text{MathematicallyConsistent}_M(q)$ state that q belongs to a mathematically consistent declared model M .

Let $\text{OperationalSuccess}_{P,M,D}(q)$ state that use of q contributes successfully to prediction, reconstruction, measurement, comparison, or calculation under protocol P , model M , and physical domain D .

Principle 28.1 (Generalized Non-Transfer Principle (NTP)). Mathematical consistency, physical applicability, and operational or predictive success do not transfer temporal identity to the object, parameter, relation, or quantity possessing those properties:

$$\boxed{\text{NTP : } \text{MathematicallyConsistent}_M(q) \wedge \text{OperationalSuccess}_{P,M,D}(q) \not\Rightarrow q \equiv_{\text{type}} T_{\text{ITOF}} .} \tag{448}$$

The principle protects the governing definition in Eq. (11).

28.2 Three separate transfers are prohibited

V40/F20 distinguishes three logically different transfer errors.

First:

$$\text{MathematicallyConsistent}_M(q) \not\Rightarrow \text{ActuallyPhysicallyRealized}(q). \tag{449}$$

Second:

$$\text{ActuallyPhysicallyRealized}(q) \not\Rightarrow q \equiv_{\text{type}} T_{\text{ITOF}}. \tag{450}$$

Third:

$$\text{OperationalSuccess}_{P,M,D}(q) \not\Rightarrow q \equiv_{\text{type}} T_{\text{ITOF}}. \tag{451}$$

These statements are not one transitive argument. They block different unjustified inferences. A mathematical object may lack physical realization. A physically real object may remain non-temporal. A predictively successful quantity may remain only the quantity defined by its model or measurement procedure.

28.3 Names and types

A quantity may historically contain the word “time” in its conventional name.

That linguistic fact does not determine its ontological type:

$$\text{NameContainsTime}(q) \not\Rightarrow q \equiv_{\text{type}} T_{\text{ITOF}}. \quad (452)$$

Temporal classification depends on the construction and role of q and on an independent identity argument relative to the governing definition of T_{ITOF} . Terminological convention cannot supply that identity argument.

28.4 Model-parameter Non-Transfer

The basic model-parameter non-transfer statement is already fixed in Eq. (310). Even predictive success does not supply temporal identity (Eq. (310)). A parameter may successfully order a solution, label model states, parameterize a path, or predict physical records. Those roles do not make it the universal cosmic extension.

28.5 Operational-metric Non-Transfer

For operational metric quantity m_P :

$$m_P = \mathcal{M}_P^{\text{op}}(r_1, \dots, r_n; c_P) \not\Rightarrow m_P \equiv_{\text{type}} T_{\text{ITOF}}. \quad (453)$$

Higher precision likewise does not transfer type:

$$\text{Precision}(m_P) \rightarrow \text{VeryHigh} \not\Rightarrow m_P \equiv_{\text{type}} T_{\text{ITOF}}. \quad (454)$$

28.6 Coordinate Non-Transfer

For coordinate map:

$$\zeta : \mathcal{E}_{\text{phys}} \longrightarrow \mathbb{R}^n, \quad (455)$$

the coordinate representation of event e is not the event:

$$e \not\equiv_{\text{type}} \zeta(e). \quad (456)$$

Likewise, a coordinate component used to label model evolution remains type-distinct from time:

$$x^0 \not\equiv_{\text{type}} T_{\text{ITOF}}. \quad (457)$$

28.7 Geometrical Non-Transfer

Let $(\mathcal{M}, g)$ be a mathematical manifold–metric structure used in an external or application model.

Then:

$$\text{GeometricalRepresentation}(\mathcal{M}, g) \not\Rightarrow (\mathcal{M}, g) \equiv_{\text{type}} T_{\text{ITOF}}. \quad (458)$$

Even if the geometrical model successfully predicts physical records:

$$\text{OperationalSuccess}_{P,M,D}(\mathcal{M}, g) \not\Rightarrow (\mathcal{M}, g) \equiv_{\text{type}} T_{\text{ITOF}}. \quad (459)$$

28.8 Physical-history Non-Transfer

A physical history is not time (Eq. (210)). The restricted ordering $\prec_C|_{I_A}$ is the order component of the physical history and does not create an independent private time. In the governing ontology:

$$\forall A \in \mathcal{U}_{\text{phys}}, \quad \neg \text{PrivateTimeOf}(A). \quad (460)$$

28.9 Physical-realization-profile Non-Transfer

The complete-population common-stage physical-realization profile remains outside the definition of time by Eq. (169). The restriction remains necessary because V40/F20 expands the theory of physical realization.

The expanded realization architecture does not identify time with the cosmic physical totality or with any complete physical-reality profile:

$$T_{\text{ITOF}} \not\equiv_{\text{type}} \mathcal{U}_C^{\text{phys}}, \quad T_{\text{ITOF}} \not\equiv_{\text{type}} \text{CompletePhysicalRealityProfile}. \quad (461)$$

The cosmic physical totality is physical ontology; a realization profile is a typed physical representation; time denotes the ordered extension of realized change. None is retyped as another.

The temporal architecture and the physical-realization architecture remain integrated but type-distinct.

29. Relativistic Temporal Identifications

29.1 Foundational point of disagreement

Relativistic theories possess substantial calculational and predictive success in experimentally tested physical domains [5, 6, 28, 31]. V40/F20 treats those successes as successes of the corresponding physical and geometrical models within the domains in which their empirical warrant is established; the associated foundational questions concerning time remain separate [32, 33].

ITOF rejects identification of time with coordinate time, metric interval, proper-time functional, frame-dependent simultaneity relation, spacetime metric, foliation parameter, cosmological coordinate parameter, or clock output. The disagreement concerns temporal identity and is foundational.

Two questions must remain separate:

$$\text{DoesRelativisticModelPredictPhysicalRecordsSuccessfully?} \quad (462)$$

and:

$$\text{IsRelativisticModelQuantityIdenticalWithITOFTime?} \quad (463)$$

The first is an empirical and quantitative question. The second is definitional and ontological.

Hence:

$$\text{RelativisticPredictionSuccessful} \not\Rightarrow \text{RelativisticTemporalQuantity} \equiv_{\text{type}} T_{\text{ITOF}}. \quad (464)$$

29.2 Foliation and the common stage domain

A relativistic spacetime model may employ a foliation $\{\Sigma_\lambda\}_{\lambda \in L}$ when such a construction is independently admissible for the declared model and domain. V40/F20 does not identify any leaf Σ_λ , foliation parameter λ , coordinate-time function, or Cauchy slicing with a common cosmic change stage merely because that mathematical structure is useful. A foliation is a structure inside a declared spacetime representation. By contrast, $\mathcal{S}_C^{\text{tot}}$ is one cosmic-stage domain for all qualified physical-system identities, and CMA makes every system's realization succession a segment of it. Neither is constructed from a foliation, coordinate chart, or synchronization convention.

Accordingly, relating a relativistic spacetime representation to ITOF cosmic-stage expressions requires an independently declared cross-representation bridge assigning the relevant physically realized manifestations to members of $\mathcal{S}_C^{\text{tot}}$. Such a bridge is not supplied by a Lorentz transformation, coordinate convention, synchronization rule, metric tensor, or foliation alone, and it is not inferred from the empirical success of those constructions. The existence of a usable foliation in a particular relativistic model therefore neither establishes CMA nor turns that foliation into $\mathcal{S}_C^{\text{tot}}$. CMA supplies no spacetime-to-stage map that records could identify. Because every system realized at a stage has its state there, CMA and UCC together fix, for each stage, the states of all systems realized at it, and CMA entails that a frame-independent relation of common-stage co-presence holds among them. No record or signal determines which events of a spacetime model stand in that relation (Change-Stage Restraint). ITOF thus belongs to the class of ontologies with an objective but empirically undetectable simultaneity relation; it identifies no frame or foliation as realizing that relation, postulates no medium, and under identical physics is empirically equivalent to special relativity. This equivalence concerns records; it does not qualify the commitment that time is global and encompasses the whole universe. Whatever association σ of events with stages is considered must respect the causal order strictly: no contribution passes from a later stage to an earlier change, and an influence from one event reaches a distinct event only at a later stage (Proposition 8.1, Eq. (136)):

$$e_1 \leq_{\text{causal}} e_2 \wedge e_1 \neq e_2 \implies \sigma(e_1) \prec_C \sigma(e_2), \quad (465)$$

so that no two distinct events assigned to one stage are causally connected: no timelike or null curve joins them. The strict clause is a commitment of ITOF on any admissible association, not a consequence of relativity. The association of stages with events is undetermined by experiment, not absent.

This architecture does not convert ITOF into presentism. The derived reference-stage prefix introduced earlier is only an order-relative subset of the full stage totality; it does not define a moving present, generated frontier, second mode of stage existence, or privileged hypersurface identifiable in a spacetime model. Neither the definition of time nor CMA postulates a temporal ether, rest medium, preferred inertial frame, velocity field, or material carrier.

The foundational conflict with CMA is stated in Section 32.4; it concerns temporal ontology, cannot be removed by a change of coordinates or synchronization convention, and is distinct from UCC's actual-change burden. Relativistic equations may nevertheless be used as independently warranted application-level physical models; their calculational or empirical success does not transfer temporal identity to a coordinate, metric quantity, proper-time functional, or spacetime foliation.

29.3 Relativistic quantity family

Let:

$$\mathcal{Q}_{\text{rel}} := \left\{ \begin{array}{l} x_F^\mu, t_F, g_{\mu\nu}, ds^2, \tau[\gamma, g], \Sigma_\lambda, \sim_F, \\ J^+(p), J^-(p), t_{\text{cos}}, t_{\text{age}}, \\ \text{ClockOutput}, \text{SynchronizationOutput} \end{array} \right\}. \quad (466)$$

These objects perform different mathematical, geometrical, physical-model, or operational roles. Their common inclusion in $\mathcal{Q}_{\text{rel}}$ does not make them one type.

The governing ITOF conclusion is:

$$\forall q \in \mathcal{Q}_{\text{rel}}, \quad q \not\equiv_{\text{type}} T_{\text{ITOF}}. \quad (467)$$

In particular:

$$t_F \not\equiv_{\text{type}} T_{\text{ITOF}}, \quad (468)$$

$$g_{\mu\nu} \not\equiv_{\text{type}} T_{\text{ITOF}}, \quad (469)$$

$$ds^2 \not\equiv_{\text{type}} T_{\text{ITOF}}, \quad (470)$$

$$\tau[\gamma, g] \not\equiv_{\text{type}} T_{\text{ITOF}}, \quad (471)$$

$$\Sigma_\lambda \not\equiv_{\text{type}} s, \quad s \in \mathcal{S}_{\text{C}}^{\text{tot}}, \quad (472)$$

$$\text{ClockOutput} \not\equiv_{\text{type}} T_{\text{ITOF}}. \quad (473)$$

No successful calculation changes these type relations.

The Generalized Non-Transfer Principle (Eq. (448)) applies to every $q \in \mathcal{Q}_{\text{rel}}$ without a relativistic exception: physical gravitational systems, paths, clocks, signals, and matter distributions may be real while the metric that represents their relations remains a model quantity, and terms such as coordinate time, proper time, time dilation, or cosmic time do not settle the ontological question (Eq. (452)).

30. Coordinates and Temporal Invariance

30.1 Physical event and coordinate assignment

Let $\mathcal{E}_{\text{phys}}$ be a declared family of physically realized events or manifestations.

For chart or frame F , let:

$$\zeta_F : \mathcal{E}_{\text{phys}} \longrightarrow \mathbb{R}^4. \quad (474)$$

For $e \in \mathcal{E}_{\text{phys}}$, the coordinate tuple is:

$$x_F^\mu(e) = \zeta_F(e). \quad (475)$$

The physical manifestation is not its coordinates:

$$e \not\equiv_{\text{type}} \zeta_F(e). \quad (476)$$

Likewise:

$$\mathcal{U}_C^{\text{phys}} \not\equiv_{\text{type}} (\mathcal{M}, g). \quad (477)$$

A spacetime manifold and metric may represent physical relations in an application model; they are not identical with the cosmic physical totality represented.

30.2 Coordinates and common stages

Suppose:

$$\text{ManifestationAt}(A, \chi; s), \quad s \in I_A. \quad (478)$$

A relativistic model may assign:

$$\zeta_F(e) = (x_F^0, x_F^1, x_F^2, x_F^3). \quad (479)$$

Accordingly, the coordinate component remains type-distinct from both the common cosmic-stage member and the ITOF temporal referent:

$$x_F^0 \not\equiv_{\text{type}} s. \quad (480)$$

and $x_F^0 \not\equiv_{\text{type}} T_{\text{ITOF}}$ (Eq. (468)).

A coordinate value may be operationally associated with a physical event. Even when a coordinate component is chosen so that its ordering agrees with $\prec_C$ on a declared domain, it remains an order representation in the sense of Eq. (37). Its numerical intervals are therefore not fixed by the bare cosmic order.

It does not become the common cosmic-stage designation or the ordering position that designation represents.

30.3 Different meanings of invariance

V40/F20 explicitly distinguishes:

$$\text{PairwiseDefDistinct}(\text{InvariantCosmicOrdering}, \text{LorentzInvariance}, \text{GeneralCovariance}). \quad (481)$$

Invariant Cosmic Ordering means that $\prec_C$ is the one universal earlier-later ordering of the common stages of change, invariant in the sense of Definition 2.1: a non-metric succession that is non-reversed, with no stage empty of change or static.

Lorentz invariance concerns transformation properties under Lorentz transformations. General covariance concerns admissible coordinate representation of physical laws. Neither defines T_{ITOF} . Therefore Lorentz invariance does not make a quantity time, and general covariance of a model does not make the model define time.

30.4 Coordinate transformations and cosmic order

A special-relativistic transformation may contain:

$$t' = \gamma \left(t - \frac{vx}{c^2} \right), \quad \gamma = \frac{1}{\sqrt{1 - v^2/c^2}}. \quad (482)$$

The transformation relates coordinate assignments. It does not transform $(\mathcal{S}_C^{\text{tot}}, \prec_C)$.

Thus:

$$t \neq t' \not\Rightarrow \text{ITOFTimeTransformed}. \quad (483)$$

More generally:

$$\text{CoordinateTransform}(F \rightarrow F') \not\Rightarrow \text{Transform}(\mathcal{S}_C^{\text{tot}}, \prec_C). \quad (484)$$

Different coordinate assignments do not generate different cosmic extensions.

31. Metric Geometry and Proper Time

31.1 Metric interval

In a relativistic model:

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu. \quad (485)$$

The expression defines a geometrical model quantity under the adopted metric structure; neither ds^2 nor $g_{\mu\nu}$ is T_{ITOF} (Eq. (467)). Metric success therefore does not establish temporal identity.

31.2 Metric dependence on physical or coordinate variables

A metric may be represented as:

$$g_{\mu\nu} = g_{\mu\nu}(x). \quad (486)$$

It does not follow that:

$$g_{\mu\nu} = g_{\mu\nu}(x) \not\Rightarrow T_{\text{ITOF}} = T_{\text{ITOF}}(x). \quad (487)$$

ITOF does not define time as a field whose value changes from one spacetime location to another.

31.3 Curvature

General-relativistic geometry may possess:

$$R^\rho{}_{\sigma\mu\nu} \neq 0. \quad (488)$$

This geometrical result does not curve time:

$$R^\rho{}_{\sigma\mu\nu} \neq 0 \not\Rightarrow \text{ITOFTimeCurved}. \quad (489)$$

The ordered pair $(\mathcal{S}_C^{\text{tot}}, \prec_C)$ is not assigned a curvature tensor by the definition of time.

31.4 Einstein field equation

A general-relativistic application may employ:

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}. \quad (490)$$

V40/F20 does not deny the mathematical content or empirically warranted physical use of such equations

[6, 28]. The type conclusion is unchanged: success of the field equations on a domain does not make $g_{\mu\nu}$ time. The equation relates geometrical and matter-energy model quantities. It does not define the ITOF temporal referent.

31.5 Proper-time functional

For timelike path γ :

$$\tau[\gamma, g] = \frac{1}{c} \int_{\gamma} \sqrt{-g_{\mu\nu} dx^{\mu} dx^{\nu}}. \quad (491)$$

The quantity depends on γ and g .

Therefore:

$$\tau = \tau[\gamma, g]. \quad (492)$$

It is not T_{ITOF} (Eq. (471)). Different path-dependent values satisfy:

$$\tau[\gamma_1, g] \neq \tau[\gamma_2, g]. \quad (493)$$

That difference does not establish different temporal extensions:

$$\tau[\gamma_1, g] \neq \tau[\gamma_2, g] \not\Rightarrow \text{DistinctTemporalReferents}(\gamma_1, \gamma_2). \quad (494)$$

They establish different values of the declared metric functional.

31.6 Proper time along a system's path

For physical system A represented by a worldline or path γ_A , the proper-time functional $\tau[\gamma_A, g]$ is not the restriction $\prec_C|_{I_A}$.

Thus:

$$\tau[\gamma_A, g] \not\equiv_{\text{type}} \prec_C|_{I_A}. \quad (495)$$

Accordingly, the proper-time functional is not a private temporal extension belonging to the system. The system has a physical history within the one common cosmic ordering. It does not possess a separate temporal extension.

31.7 Clock agreement with proper-time calculation

A physical clock output may satisfy:

$$N_{C,P} \approx K_{P,M}(\tau[\gamma, g]) \quad (496)$$

within the warranted domain of a relativistic model.

The conclusion is:

$$\text{QuantitativeAssociationSupported}(N_{C,P}, \tau[\gamma, g]). \quad (497)$$

It is not:

$$N_{C,P} \approx K_{P,M}(\tau[\gamma, g]) \not\Rightarrow \tau[\gamma, g] \equiv_{\text{type}} T_{\text{ITOF}}. \quad (498)$$

The relation is therefore an example of successful model-to-record association without ontological transfer.

32. Simultaneity, Lorentzian Structure, and the Common Stage

32.1 Frame-dependent simultaneity

Let:

$$e_1 \sim_F e_2 \quad (499)$$

denote simultaneity assigned according to relativistic frame, chart, and synchronization structure F .

Different admissible frames may satisfy:

$$\exists e_1, e_2, F, F', \quad e_1 \sim_F e_2 \wedge \neg(e_1 \sim_{F'} e_2). \quad (500)$$

For the standard Lorentz transformation along one spatial axis,

$$\Delta t' = \gamma \left(\Delta t - \frac{v \Delta x}{c^2} \right). \quad (501)$$

Hence two spatially separated events satisfying $\Delta t = 0$ in one inertial coordinate system generally satisfy

$$\Delta t' = -\gamma \frac{v \Delta x}{c^2} \neq 0 \quad (502)$$

when $v \Delta x \neq 0$. V40/F20 therefore does not dispute the frame-dependence of relativistic coordinate simultaneity. The foundational issue is instead whether that representational fact exhausts the ontology of temporal ordering and co-realization.

The relation $\sim_F$ is a relativistic representational relation.

It is not:

$$\sim_F \not\equiv_{\text{type}} \text{CosmicCoPresence}_C. \quad (503)$$

32.2 Co-presence and synchronization

Clock synchronization neither creates nor replaces the formal cosmic-stage domain, and co-presence is not obtained from that domain alone. It follows from CMA (Eq. (75)), which is stated through realization successions, not through signal exchange, clock agreement, coordinate equality, Einstein synchronization, frame choice, or hypersurface construction.

Thus a change of synchronization convention does not change co-presence, and a change of coordinate assignment does not change the common cosmic change stage at which a system is realized.

32.3 Lorentz symmetry without a temporal ether

In a Minkowski representation a Lorentz transformation acts on spacetime coordinates or event representations, for example

$$x'^\mu = \Lambda^\mu_\nu x^\nu, \quad \Lambda^\top \eta \Lambda = \eta. \quad (504)$$

No ITOF rule identifies this matrix action with an action on the formal cosmic-stage domain $\mathcal{S}_C^{\text{tot}}$ or derives from it a map that replaces the governing order $\prec_C$. The Lorentz transformation changes the relativistic representation assigned to events; it does not, by type alone, transform the ITOF ordered pair. This is the domain distinction already expressed by Eq. (484).

The common-stage ontology also introduces no material or spatial ether. T_{ITOF} contains no spatial

coordinate, velocity field, rest-medium variable, or dynamical substrate. Neither $\mathcal{S}_C^{\text{tot}}$ nor CMA selects a preferred inertial frame (Eqs. (523) and (524)). Any preferred-frame dynamics, measurable anisotropy, or velocity-dependent new coupling must therefore enter as an additional physical hypothesis with its own empirical burden; it is not contained in CMA or in the definition of time.

Common-stage identity is therefore neither recast as Einstein synchronization nor secured by a hidden rest medium. The disagreement is localized: Lorentz covariance and relativity of coordinate simultaneity remain model facts, whereas denial of every objective universal common stage is the stronger ontological claim treated in Section 32.4.

32.4 Direct foundational conflict

A relativistic representation containing frame-dependent simultaneity does not by that mathematical fact alone negate the definition of time or CMA.

The direct foundational conflict is exact and is not softened by coordinate terminology: any ontological interpretation that denies a frame-independent universal common cosmic-stage co-realization for the complete then-realized qualified physical-system population is incompatible with CMA. In ITOF terms, such an interpretation assigns the qualified systems frame- or worldline-relative orderings of their realizations, that is, private orderings in the sense of Eq. (656). The contradiction is supplied by CMA, not by the definition of $\mathcal{S}_C^{\text{tot}}$ or by UCC. This ontological incompatibility does not by itself negate the mathematical consistency, Lorentz covariance, or empirical success of relativistic physical models; empirical discrimination requires an independently warranted physical-to-observable difference.

Let:

$$\text{NoUniversalCommonStageOntology} \quad (505)$$

denote that stronger claim.

Then the conflict is with CMA:

$$\begin{aligned} & [\forall s \in \mathcal{S}_C^{\text{tot}}, \quad \text{CosmicCoPresence}_C(\mathcal{S}_{\text{phys}}(s); s)] \wedge \text{NoUniversalCommonStageOntology} \\ & \implies \perp. \end{aligned} \quad (506)$$

Equivalently, at stage-relative level, the fixed global-stage consequence cannot coexist with its denial:

$$\begin{aligned} & [\forall s \in \mathcal{S}_C^{\text{tot}} : \text{CosmicCoPresence}_C(\mathcal{S}_{\text{phys}}(s); s)] \\ & \wedge [\exists s \in \mathcal{S}_C^{\text{tot}} : \neg \text{CosmicCoPresence}_C(\mathcal{S}_{\text{phys}}(s); s)] \implies \perp. \end{aligned} \quad (507)$$

This is a genuine foundational incompatibility of the two asserted ontologies. It is not removed by reinterpreting common-stage identity as an operational synchronization convention, because CMA is an ontological common-stage co-presence commitment within ITOF, not a clock procedure.

Time is global and encompasses the whole universe. There is one time for the entire universe, the one succession of the common stages of change on which every physical system of the universe, near or at the greatest distance, realizes its change; no region, system, frame, observer, or worldline has a time of its own. The geometric reading of relativity has no such time: it assigns a proper time to each worldline and a coordinate time to each chart, and a global time function, where a spacetime admits one, is one choice among infinitely many. ITOF affirms what that reading denies. The many proper and coordinate times are retained as physical or model quantities of clocks and charts, not as times (Non-Transfer Principle). The empirical equivalence of ITOF with special relativity under identical physics concerns records and does

not weaken this commitment, which is ontological and is held without reservation. In logical type, the co-presence of spacelike-separated realizations at one common stage is the relation the literature calls absolute simultaneity; ITOF states this commitment openly, as the content of one global time. Under Lorentz-covariant dynamics no experiment selects the partition into common stages [29, 31]. The position is close to the dynamical, or neo-Lorentzian, reading of special relativity [29, 31, 30], with two differences: ITOF posits no ether and identifies no preferred inertial frame, and its common stages are fixed by the realization successions of the physical systems, not by a medium.

32.5 The empirical status of the conflict

Foundational contradiction does not by itself produce a measurable separation.

Empirical discrimination requires the bridge architecture established earlier:

$$\begin{aligned} &\text{FoundationalConflict} \wedge \text{IndependentPhysicalBridges} \wedge \text{SeparatedPredictions} \\ &\quad \wedge \text{ValidObservation} \wedge \text{IdentifiableAttribution} . \end{aligned} \tag{508}$$

Conceptual disagreement alone therefore does not constitute experimental refutation.

32.6 The Rietdijk–Putnam argument

The Rietdijk–Putnam argument [24, 25] runs as follows. (R1) For an observer, the events simultaneous with the observer’s here-now in the observer’s rest frame are real for that observer. (R2) The relation “real for” is transitive and is the same for every observer. (R3) Two co-located observers in relative motion have different simultaneity hypersurfaces. From (R1)–(R3) it follows that every event, including events in an observer’s causal future, is real for that observer.

ITOF denies (R1). Co-presence is fixed by CMA through realization successions (Eq. (75)); it is not fixed by any observer’s coordinate simultaneity (Eqs. (500) and (396)):

$$x_F^0(e_1) = x_F^0(e_2) \not\Rightarrow \exists s \in \mathcal{S}_C^{\text{tot}} : e_1, e_2 \text{ are realized at } s. \tag{509}$$

Without (R1) the argument has no premise connecting the relativity of simultaneity to co-presence. ITOF does not adopt presentism either: $\mathcal{S}_C^{\text{tot}}$ is one ordered domain, not a moving present, and the argument’s conclusion is not a thesis ITOF must refute. What ITOF asserts — one common succession, strictly ordered and never reversed — is not addressed by (R1)–(R3), because the argument contains no premise about the order of realization. The cost of this position is stated in Section 32.4: the common stage is not identified with any model-selected foliation, yet it induces an objective partition of the realizations of the qualified systems into common stages, and no record selects it.

33. Common Stages and Signal Access

Relativistic causal domains represent causal accessibility within the declared spacetime model. They remain distinct from common-stage incidence and co-presence under CMA and from the general physical source–signal–record architecture of Section 40.

33.1 Common stages and causal propagation

For $A, B \in \mathcal{S}_{\text{phys}}(s)$, CMA gives objective common-stage co-presence for the complete stage population. That co-realization gives neither instantaneous causal influence between A and B , nor instantaneous signal transfer, nor mutual observational access.

Common-stage co-realization is thus separate from causation, signalling, and observational access. CMA is not a hidden superluminal interaction postulate.

33.2 Relativistic causal domains

For modeled event p :

$$J^+(p), \quad J^-(p) \quad (510)$$

represent causal-accessibility domains within the adopted spacetime model.

They are not:

$$J^\pm(p) \not\equiv_{\text{type}} \mathcal{S}_C^{\text{tot}}. \quad (511)$$

Nor:

$$J^\pm(p) \not\equiv_{\text{type}} \mathcal{C}_C. \quad (512)$$

Causal accessibility and universal ordering therefore remain distinct. They are related by one condition: any association σ of events with stages preserves the causal order strictly (Eq. (465)), so that every event of $J^+(p)$ other than p is assigned to a stage later than the stage of p .

34. Foliations and the Common Stage

34.1 Mathematical foliation

Let:

$$\mathfrak{F} = \{\Sigma_\lambda\}_{\lambda \in \Lambda} \quad (513)$$

be a mathematical foliation where such a construction is defined [28, 34].

A hypersurface Σ_λ is not automatically a common cosmic change stage (Eq. (472)). Likewise, the foliation parameter λ is not time.

34.2 Global time functions and ITOF ontology

If a mathematical or relativistic model possesses:

$$t_{\text{glob}} : \mathcal{M} \longrightarrow \mathbb{R}, \quad (514)$$

its existence does not establish:

$$\exists t_{\text{glob}} : \mathcal{M} \rightarrow \mathbb{R} \not\Rightarrow \text{ActuallyPhysicallyRealized}(\mathcal{S}_C^{\text{tot}}, \prec_C). \quad (515)$$

The model construction and ITOF temporal ontology remain different claims.

34.3 CMA and relativistic foliations

Conversely:

$$\text{CMA} \not\Rightarrow \exists! \mathfrak{F} \text{ ExactlyRepresents } (\mathcal{S}_C^{\text{tot}}, \prec_C). \quad (516)$$

V40/F20 does not identify a coordinate foliation with the common cosmic change-stage totality.

Any proposed association

$$\Sigma_\lambda \leftrightarrow s \quad (517)$$

is an additional model-level hypothesis requiring independent physical justification; CMA does not supply that association.

34.4 Cross-representation burden and Lorentzian extra structure

Special relativity makes simultaneity of spatially separated events frame-dependent under Lorentz transformations [5, 28]. V40/F20 does not deny that result and does not derive CMA from Lorentzian geometry. To compare CMA with a relativistic spacetime $(\mathcal{M}, g)$, an application must introduce an additional association

$$\Phi_M : \mathcal{S}_C^{\text{tot}} \rightarrow \mathcal{P}(\mathcal{M}), \quad s \mapsto \Phi_M(s), \quad (518)$$

where $\Phi_M(s)$ denotes the event set, hypersurface, or other spacetime representation proposed for stage s . Neither the Lorentzian metric nor CMA alone supplies Φ_M . This is a cross-type representation bridge, not a type identity: the ITOF stage remains a member of the formal cosmic-stage domain, while its image is a geometric object inside the declared spacetime model. In particular,

$$s \not\equiv_{\text{type}} \Phi_M(s), \quad T_{\text{ITOF}} \not\equiv_{\text{type}} (\mathcal{M}, g), \quad t_F \not\equiv_{\text{type}} T_{\text{ITOF}}. \quad (519)$$

Equality of a coordinate-time label inside a chart is therefore not a definition of common-stage co-presence, and common-stage co-presence does not require equal spatial coordinates for distinct systems.

If the images $\Phi_M(s)$ are taken to form physically distinguished hypersurfaces, the application has added structure beyond the bare Lorentzian model:

$$(\mathcal{M}, g) \mapsto (\mathcal{M}, g, \Phi_M). \quad (520)$$

Globally hyperbolic spacetimes can admit smooth Cauchy foliations, but the existence of such foliations does not select one as the physically realized ITOF stage representation [34]. A physically distinguished slicing can therefore not be smuggled into the framework as a consequence of Lorentzian geometry.

The empirical burden is explicit. If observable predictions depend on the added association, its symmetry properties and consequences require independent testing:

$$\text{PredictionDependsOn}(\Phi_M) \implies \text{IndependentEmpiricalTestRequired}(\Phi_M). \quad (521)$$

If observable predictions do not depend on it, CMA alone supplies no empirical discrimination from the relativistic application:

$$\neg \text{PredictionDependsOn}(\Phi_M) \implies \neg \text{EmpiricalDiscriminationFromCMAAlone}. \quad (522)$$

CMA is an additional ontological commitment relative to standard Lorentzian spacetime structure; it is not a theorem of special or general relativity and is not made compatible by renaming a coordinate slicing. Observational compatibility in a declared domain means only that the complete application, including any Φ_M , preserves the tested relativistic predictions within their empirical warrant. A future bridge that makes the common-stage association physically discriminating must face the corresponding Lorentz-symmetry and experimental constraints.

34.5 The question of a preferred inertial frame

Co-presence under CMA does not itself define a preferred inertial frame:

$$[\forall s \in \mathcal{S}_C^{\text{tot}}, \text{CosmicCoPresence}_C(\mathcal{S}_{\text{phys}}(s); s)] \not\Rightarrow \text{PreferredInertialFrame}. \quad (523)$$

Likewise:

$$T_{\text{ITOF}} \not\equiv_{\text{type}} \text{PreferredVelocityField}. \quad (524)$$

Any claim of:

$$\begin{aligned} &\text{preferred motion, measurable anisotropy, modified propagation,} \\ &\text{preferred dynamical frame, or frame-specific physical law} \end{aligned} \quad (525)$$

would be an additional physical hypothesis.

Such a hypothesis requires:

$$\text{IndependentPhysicalModel} \wedge \text{IndependentObservableConsequences} \wedge \text{EmpiricalEvaluation}. \quad (526)$$

It cannot be inferred merely from the existence of CMA.

35. Relativistic Clock Records and Temporal Identity

35.1 Special-relativistic interval relation

A standard special-relativistic relation may be represented as:

$$\Delta\tau = \frac{\Delta t}{\gamma}. \quad (527)$$

Within V40/F20, this equation relates declared relativistic model quantities; it is not an equation for deformation or dilation of the ITOF temporal referent. Thus:

$$\Delta\tau \neq \Delta t \not\Rightarrow \text{ITOFTimeDilated}. \quad (528)$$

The conventional phrase “time dilation” may continue to identify this standard relativistic class of calculation. ITOF rejects only the ontological inference that the entity denoted by time is literally dilated.

35.2 Separated-clock histories

Let C_A and C_B be two physical clock systems with:

$$\mathcal{H}_{C_A} = \left(I_{C_A}, \prec_C|_{I_{C_A}}, X_{C_A}, \Delta_{C_A}^{\text{phys}} \right), \quad (529)$$

$$\mathcal{H}_{C_B} = \left(I_{C_B}, \prec_C|_{I_{C_B}}, X_{C_B}, \Delta_{C_B}^{\text{phys}} \right). \quad (530)$$

Their physical histories may differ in:

$$\begin{aligned} & \text{motion,} \quad \text{gravitational environment,} \quad \text{thermal conditions,} \\ & \text{electromagnetic interactions,} \quad \text{mechanical conditions,} \quad \text{control,} \\ & \text{interrogation,} \quad \text{signal transfer,} \quad \text{and other physical variables.} \end{aligned} \quad (531)$$

A later comparison may yield:

$$d_{AB}^{\text{obs}} = \Gamma_A(N_A) - \Gamma_B(N_B) \neq 0. \quad (532)$$

The warranted direct conclusion is:

$$\text{DifferentPhysicalClockRecords}(C_A, C_B). \quad (533)$$

The record difference does not establish unequal amounts of ITOF time:

$$d_{AB}^{\text{obs}} \neq 0 \not\Rightarrow [\text{LessTimeFor}(C_A) \vee \text{MoreTimeFor}(C_B)]. \quad (534)$$

35.3 CMA and UCC in the separated-clock case

Where $C_A, C_B \in \mathcal{S}_{\text{phys}}(s)$, CMA gives objective common-stage co-presence:

$$\text{CosmicCoPresence}_C(\mathcal{S}_{\text{phys}}(s); s), \quad (535)$$

Under UCC,

$$\text{PhysReal}_{C_A}^+(s) \wedge \text{PhysReal}_{C_B}^+(s). \quad (536)$$

UCC expresses the uninterrupted continuity of those system-specific changes throughout the respective realized identity ranges.

The clocks therefore share one common cosmic change stage while realizing different system-specific physical histories and possibly different clock outputs.

35.4 Gravitational clock comparison

A weak-field benchmark may contain:

$$\frac{\Delta v}{v} \simeq \frac{\Delta \Psi}{c^2}. \quad (537)$$

Within its warranted approximation domain, this is a relation among physical or model quantities associated with clock response under different gravitational conditions.

It is not a dilation of time:

$$\frac{\Delta v}{v} \neq 0 \not\Rightarrow \text{ITOFGravitationalTimeDilation}. \quad (538)$$

V40/F20 classifies $\frac{\Delta v}{v}$ as a physical or operational clock-response difference. The records fix only the difference between clocks at different gravitational potentials, compared through a signal path; how that difference divides between the two clocks is not fixed by records, as the stages themselves are not (Change-Stage Restraint). To the extent tested, the response to the potential is the same for all clocks (local position invariance); it is a difference of rate, not a varying action, and so does not conflict with the statement that a uniform gravitational field alone produces no local change in a freely falling system. A constitution-dependent part would be the subject of the clock hypothesis H_{CR} (Section 51.2). The model used to predict that difference may be relativistic or another independently specified physical response model. Neither model acquires temporal identity through successful recovery.

35.5 GPS and integrated relativistic operations

Navigation systems, including GPS-class systems, may combine [35]:

$$\begin{aligned} &\text{satellite systems, physical clocks, orbital models, signal propagation,} \\ &\text{receivers, coordinate assignments, synchronization conventions,} \\ &\text{relativistic corrections, calibration, and record processing.} \end{aligned} \quad (539)$$

If: $\text{NavigationError} \leq \epsilon_{\text{nav}}$, then $\text{GPSOperationalSuccess}$ may be warranted within the declared domain.

It does not follow that the coordinate t_{GPS} is time. GPS success is evidence for the adequacy of the integrated physical, geometrical, signal, coordinate, clock, correction, and record architecture within its validated application domain. It does not determine the ontological definition of time.

36. Cosmological Parameters and Temporal Identity

36.1 Cosmological coordinate parameter

A relativistic cosmological model may employ:

$$ds^2 = -c^2 dt_{\text{cos}}^2 + a^2(t_{\text{cos}}) d\Sigma_k^2. \quad (540)$$

The parameter t_{cos} belongs to the declared cosmological model. Even where it orders a useful family of model hypersurfaces, t_{cos} is not time.

36.2 Model-derived cosmological age

A cosmological model may calculate:

$$t_{\text{age}} = \int_{a_i}^{a_0} \frac{da}{aH(a; \Omega_i, \dots)}. \quad (541)$$

This is a model-derived quantitative magnitude. It does not enumerate the members of $\mathcal{S}_C^{\text{tot}}$. Computing t_{age} therefore does not count common cosmic change stages, and t_{age} is not time.

36.3 Cosmic origin and cosmological model origin

The Cosmic Origin commitment `CosmicOrigin` remains logically distinct from: `RelativisticModelOriginParameter`.

Thus:

$$\text{CosmicOrigin} \not\equiv_{\text{def}} \text{RelativisticCosmologicalBoundary}. \quad (542)$$

Agreement or disagreement between a physical cosmological model and the foundational origin postulate requires an independently developed bridge. No identity follows from similar language such as “beginning”, “age”, or “cosmic time”.

37. ITOF–Relativity Physical Bridges

37.1 Ontological difference and empirical comparison

The foundational disagreement between ITOF and relativistic temporal identification must not be weakened by an ontological merger. At the same time, a physical theory cannot obtain quantitative force merely by declaring a different ontology. V40/F20 therefore distinguishes ontological identification from empirical comparison. The bridge is an empirical-comparison architecture, not an ontological merger of temporal definitions.

37.2 Cosmic stages and spacetime geometry

The definition: $T_{\text{ITOF}} = (\mathcal{S}_C^{\text{tot}}, \prec_C)$ does not itself derive: $g_{\mu\nu}$, ds^2 , $\tau[\gamma, g]$, $J^\pm(p)$, Σ_λ .

The definition of time therefore does not entail relativistic spacetime geometry.

Likewise, neither foundational commitment supplies the corresponding relativistic mathematical structure:

$$\text{CMA} \not\Rightarrow \text{RelativisticMetricStructureSpecified}, \quad (543)$$

$$\text{UCC} \not\Rightarrow \text{ProperTimeFunctionalSpecified}. \quad (544)$$

No mathematical projection from the temporal definition to relativistic geometry is part of the definition of time.

37.3 Empirical recovery without ontological recovery

Validity of ITOF does not entail recovery of a relativistic temporal ontology. Such a requirement would erase the foundational disagreement before testing it. What may be required in a physical domain is empirical recovery or discrimination of observed physical records.

Thus:

$$\text{PhysicalCompetitionOn}(D) \implies \text{ObservableRecoveryOrDiscriminationOn}(D), \quad (545)$$

not `TemporalOntologyIdentity`. Observable model discrimination therefore does not by itself establish an identity claim about the temporal ontology.

37.4 Two independent application branches

Let F_I denote the relevant ITOF foundational commitments.

Let M_I be an independently specified physical application model consistent with those commitments.

Let M_R be the declared relativistic comparison model.

The ITOF branch is:

$$F_I \wedge M_I \wedge B_I^{\text{phys}} \wedge \mathcal{P}_I \vdash \hat{\mathbf{y}}^I. \quad (546)$$

The relativistic branch is:

$$M_R \wedge B_R^{\text{phys}} \wedge \mathcal{P}_R \vdash \hat{\mathbf{y}}^R. \quad (547)$$

Both predictions must then be related to one declared empirical comparison space through their own warranted observation and acquisition bridges.

37.5 Common observable space

For the vector-valued comparison developed below, let

$$\mathcal{Y}_{\text{obs}}^{P,D} \subseteq \mathbb{R}^{m_{P,D}}, \quad m_{P,D} \in \mathbb{N}_{>0}, \quad (548)$$

be the common empirical output space in which the rival predictions are actually compared. Vector subtraction is therefore defined in the ambient space $\mathbb{R}^{m_{P,D}}$. Where a protocol has non-vector-valued outputs, it must supply a separately declared comparison functional; the vector and inverse-covariance formulas below then apply only after a warranted embedding into such a numerical comparison space.

Define:

$$\Pi_I^{P,D} : \widehat{\mathcal{Y}}_I \longrightarrow \mathcal{Y}_{\text{obs}}^{P,D}, \quad (549)$$

$$\Pi_R^{P,D} : \widehat{\mathcal{Y}}_R \longrightarrow \mathcal{Y}_{\text{obs}}^{P,D}. \quad (550)$$

Then:

$$\mathbf{y}_I^{P,D} = \Pi_I^{P,D}(\hat{\mathbf{y}}^I), \quad (551)$$

$$\mathbf{y}_R^{P,D} = \Pi_R^{P,D}(\hat{\mathbf{y}}^R). \quad (552)$$

The common empirical codomain permits comparison. It does not create ontological identity between the theories.

37.6 Observable comparison bridge

Define the comparison architecture:

$$\mathfrak{B}_{I:R}^{P,D} := \left(B_I^{\text{phys}}, B_R^{\text{phys}}, \Pi_I^{P,D}, \Pi_R^{P,D}, \mathcal{P}_I, \mathcal{P}_R, \Sigma_{I:R} \right). \quad (553)$$

This is the V40/F20 ITOF–relativistic observable comparison bridge.

Its status is:

$$\text{Status}\left(\mathfrak{B}_{I:R}^{P,D}\right) = \text{ApplicationLevelEmpiricalComparisonArchitecture}. \quad (554)$$

The bridge compares physical predictions. It is not a temporal-identity merger, an ontological merger, a definition of time, or an identity map between ITOF time and a relativistic temporal quantity.

37.7 Bridges require more than coordinate names

Coordinate assignment alone does not supply a physical association with a common cosmic change stage.

Likewise $t_F(e) = t_0$ does not identify the stage:

$$t_F(e) = t_0 \not\Rightarrow \text{CosmicChangeStageIdentified}(e). \quad (555)$$

Any claimed physical association between observable data and common cosmic change-stage realization requires a separately declared association bridge.

37.8 Physical association burden

For protocol P and model M :

$$\text{CommonCosmicChangeStageDataClaim}_{P,M} \implies \text{DeclaredPhysicalAssociationBridge}_{P,M}. \quad (556)$$

Let $\mathcal{Q}_{P,M}^{\text{assoc}}$ be the set of physically applicable association components selected from:

$$\begin{aligned} &\text{source attribution,} \quad \text{propagation/path model,} \quad \text{detector interaction,} \\ &\text{record formation,} \quad \text{reconstruction,} \quad \text{calibration,} \\ &\text{system identification,} \quad \text{uncertainty characterization.} \end{aligned} \quad (557)$$

Then:

$$\begin{aligned} \text{DeclaredPhysicalAssociationBridge}_{P,M} \implies &\text{ApplicabilitySetFixedIndependently}_{P,M}\left(\mathcal{Q}_{P,M}^{\text{assoc}}\right) \\ &\wedge \forall q \in \mathcal{Q}_{P,M}^{\text{assoc}}, \quad \text{DeclaredAndWarranted}_{P,M}(q). \end{aligned} \quad (558)$$

A component may be omitted where it is physically inapplicable. Its omission must not be chosen post hoc to absorb a failed prediction or unresolved attribution.

37.9 Recovery bridge

Suppose the ITOF application model is constructed to recover an established relativistic prediction on benchmark domain D_{rec} .

Let the two application branches be projected through their independently specified observation maps into the common benchmark observable space:

$$\mathbf{y}_{I,\text{rec}}^{P,D_{\text{rec}}} = \Pi_I^{P,D_{\text{rec}}}(\hat{\mathbf{y}}_{\text{rec}}^I), \quad (559)$$

$$\mathbf{y}_{R,\text{rec}}^{P,D_{\text{rec}}} = \Pi_R^{P,D_{\text{rec}}}(\hat{\mathbf{y}}_{\text{rec}}^R). \quad (560)$$

A recovery condition may then be stated in that common empirical codomain:

$$\left\| \mathbf{y}_{I,\text{rec}}^{P,D_{\text{rec}}} - \mathbf{y}_{R,\text{rec}}^{P,D_{\text{rec}}} \right\|_{\Sigma_{I:R}^{-1}} \leq \epsilon_{\text{rec}}. \quad (561)$$

The comparison norm, covariance, and threshold must be declared in advance.

Successful recovery warrants:

$$\text{ITOFApplicationRecoversBenchmarkOn}(D_{\text{rec}}). \quad (562)$$

It does not establish that the ITOF temporal ontology is the relativistic one.

37.10 Recovery and discrimination

If the common-observable predictions satisfy:

$$\mathbf{y}_I^{P,D} \approx \mathbf{y}_R^{P,D} \quad (563)$$

within the declared combined uncertainty, the two application models may be empirically indistinguishable on that domain.

Thus benchmark recovery neither confirms ITOF foundationally nor establishes the relativistic temporal identification. Recovery establishes quantitative adequacy of the tested application chain on the declared benchmark domain.

37.11 Discriminating prediction

For a genuine quantitative confrontation, define:

$$\Delta_{I:R}^{P,D} := \mathbf{y}_I^{P,D} - \mathbf{y}_R^{P,D}. \quad (564)$$

A necessary discrimination condition is:

$$\text{ResolvedPredictionSeparation}_{I:R} \implies \left\| \Delta_{I:R}^{P,D} \right\|_{\Sigma_{I:R}^{-1}} > \eta_*, \quad (565)$$

where $\eta_* > 0$ is a predeclared protocol threshold appropriate to the comparison.

The foundation does not assign one universal numerical value to η_* .

37.12 Bridge symmetry at the comparison level

Empirical comparison should not permit one model to receive unexamined bridge freedom denied to the other.

Thus:

$$\text{FairModelComparison}_{I:R} \implies \text{BridgeRequirementsAppliedByDeclaredRole}. \quad (566)$$

This does not require identical physical premises for two different models.

It requires that:

$$\begin{aligned}
& \text{each necessary bridge be declared,} \\
& \text{each parameter have provenance,} \\
& \text{each uncertainty contribution be represented,} \\
& \text{and no model receive outcome-dependent auxiliary freedom.}
\end{aligned} \tag{567}$$

37.13 Bridge-robust prediction separation

A single pair of bridge choices can display prediction separation while other independently admissible bridge choices remove it. Foundation-sensitive comparison therefore requires the residual bridge freedom to be represented explicitly rather than absorbed into one preferred application map.

Let

$$\mathbb{B}_I^{P,D} \neq \emptyset, \quad \mathbb{B}_R^{P,D} \neq \emptyset \tag{568}$$

be the independently specified admissible bridge classes for the ITOF and relativistic application branches. Membership in those classes must be fixed by outcome-independent admissibility conditions:

$$\text{AdmissibleBridgeClasses}_{I:R}(P,D) \implies \text{OutcomeIndependentMembershipRule}(\mathbb{B}_I^{P,D}, \mathbb{B}_R^{P,D}). \tag{569}$$

Residual bridge freedom is present when at least one branch admits more than one independently acceptable bridge realization:

$$\text{ResidualBridgeFreedom}_{I:R}(P,D) \iff \left| \mathbb{B}_I^{P,D} \right| > 1 \vee \left| \mathbb{B}_R^{P,D} \right| > 1. \tag{570}$$

For $b_I \in \mathbb{B}_I^{P,D}$ and $b_R \in \mathbb{B}_R^{P,D}$, let

$$d_{I:R}^{P,D}(b_I, b_R) := \left\| \mathbf{y}_I^{P,D}(b_I) - \mathbf{y}_R^{P,D}(b_R) \right\|_{\Sigma^{-1}(b_I, b_R)}. \tag{571}$$

The covariance entering the norm must include the declared shared and branch-specific uncertainty contributions applicable to that bridge pair. Where the inverse-covariance norm in Eq. (571) is used, the applicable covariance must be positive definite on the evaluated observable subspace:

$$\forall b_I \in \mathbb{B}_I^{P,D} \forall b_R \in \mathbb{B}_R^{P,D}, \quad \Sigma(b_I, b_R) \succ 0. \tag{572}$$

If a domain requires a singular covariance treatment, the protocol must replace the inverse norm by a predeclared mathematically valid alternative rather than silently applying an undefined inverse.

Define the bridge-robust separation margin:

$$\delta_{I:R}^{P,D} := \inf_{\substack{b_I \in \mathbb{B}_I^{P,D} \\ b_R \in \mathbb{B}_R^{P,D}}} d_{I:R}^{P,D}(b_I, b_R). \tag{573}$$

For a predeclared threshold $\eta_\star > 0$, define:

$$\text{RobustBridgeSeparation}_{I:R}(P,D; \eta_\star) \iff \delta_{I:R}^{P,D} > \eta_\star. \tag{574}$$

This condition states that every independently admissible bridge pair preserves a resolved prediction separation. It is stronger than separation obtained from one selected bridge pair and remains a necessary, not sufficient, condition for a foundation-sensitive inference whenever unresolved bridge freedom is present.

Accordingly:

$$\begin{aligned} & \text{ResidualBridgeFreedom}_{I:R}(P, D) \wedge \text{Warrant}_{P,D} [\text{FoundationalDiscrimination}(F_I, F_R)] \\ & \implies \text{RobustBridgeSeparation}_{I:R}(P, D; \eta_\star). \end{aligned} \quad (575)$$

If

$$\delta_{I:R}^{P,D} \leq \eta_\star, \quad (576)$$

then admissible bridge freedom can eliminate the predeclared separation. The comparison may still discriminate particular application realizations, but that separation alone does not isolate the foundational difference.

37.14 Foundational discrimination between ITOF and relativity

A result favouring M_R rejects or restricts the ITOF application model on D and leaves the type assignments of Eq. (467) unchanged. A failure of M_I is an application failure, not a refutation of the temporal definition, CMA, or UCC (Eq. (659)). Agreement of both models with the data establishes their empirical adequacy on D , not the identity of T_{ITOF} with $\tau[\gamma, g]$ or of co-presence with $\sim_F$: empirical equivalence on a finite domain is not ontological identity.

A genuinely foundational discrimination between an ITOF commitment F_I and a declared rival foundational proposition F_R carries the burden of Eq. (435) with $F = F_I$ and $F^* = F_R$. Where residual bridge freedom remains, Eq. (575) adds the bridge-robust separation requirement. If the observable separation can be removed by an independently admissible bridge variation while the foundational commitments are held fixed, the result does not isolate the foundational difference.

37.15 Bridge claim boundary

The admissible V40/F20 bridge claim is:

ITOF and a relativistic physical model may be brought into direct quantitative comparison only after each has been connected independently to the same observable domain through explicit physical, acquisition, calibration, and uncertainty structures. Agreement establishes bounded empirical adequacy of the respective application model; disagreement establishes model-level discrimination where resolved. A foundational conclusion requires the observed separation to be independently traceable to the foundational difference itself; where residual bridge freedom exists, that separation must remain resolved across the independently admissible bridge classes. The comparison bridge does not identify coordinate time, metric interval, proper time, simultaneity convention, spacetime geometry, or clock output with the entity denoted by time in ITOF.

38. Special- and General-Relativistic Phenomena

This section states, phenomenon by phenomenon, what ITOF retains from special and general relativity and what it denies. Every quantitative relativistic result is retained. What is denied is only the identification

of a relativistic model quantity with time and the attribution of a physical effect to time.

38.1 The relativistic phenomenon bridge

Definition 38.1 (Relativistic phenomenon bridge). For a relativistic phenomenon Φ observed under protocol P ,

$$\mathfrak{B}_\Phi := (\mathcal{K}_\Phi, \mathcal{C}_\Phi, M_\Phi, q_\Phi, \Pi_\Phi, \text{Rec}_\Phi), \quad (577)$$

where $\mathcal{K}_\Phi \subseteq \mathcal{U}_{\text{phys}}$ is the set of physical systems whose records constitute the data (clocks, unstable particles, sources, receivers, detectors, links, test masses, gyroscopes); $\mathcal{C}_\Phi$ is the declared set of physical conditions and causal contributors (motion relative to the apparatus, gravitational relation, medium, link and environmental conditions); M_Φ is the relativistic model (Lorentz-covariant dynamics, or the Einstein field equations with a matter model); q_Φ is the model quantity used (x^0 , $\tau[\gamma, g]$, $g_{\mu\nu}$, ds^2 , a redshift, or a strain); Π_Φ maps model quantities and conditions to predicted records; and Rec_Φ is the set of records obtained.

The bridge is required to be inclusive, so that nothing in the data falls outside it, and exclusive, so that nothing outside physics enters it.

Inclusion conditions: record closure (J1), contributor closure (J2), and quantitative retention (J3).

$$(J1) \quad \text{Data}_\Phi \subseteq \text{Records}(\mathcal{K}_\Phi), \quad (578)$$

$$(J2) \quad \text{Contributors}(\text{Rec}_\Phi) \subseteq \mathcal{K}_\Phi \cup \mathcal{C}_\Phi, \quad (579)$$

$$(J3) \quad \text{Rec}_\Phi \approx_{\sigma_P} \Pi_\Phi(q_\Phi; \mathcal{C}_\Phi). \quad (580)$$

Exclusion conditions: non-identity (M1), non-contribution (M2), non-transfer (M3), and common-stage retention (M4).

$$(M1) \quad q_\Phi \not\equiv_{\text{type}} T_{\text{ITOF}}, \quad (581)$$

$$(M2) \quad T_{\text{ITOF}} \notin \text{Contributors}(\text{Rec}_\Phi), \quad (582)$$

$$(M3) \quad (J3) \not\Rightarrow q_\Phi \equiv_{\text{type}} T_{\text{ITOF}}, \quad (583)$$

$$(M4) \quad A, B \in \mathcal{K}_\Phi \cap \mathcal{S}_{\text{phys}}(s) \implies \text{CosmicCoPresence}_C(\{A, B\}; s) \wedge \text{PhysReal}_A^+(s) \wedge \text{PhysReal}_B^+(s). \quad (584)$$

In (J3), $\approx_{\sigma_P}$ denotes agreement within the declared uncertainty of P . In (J2), contributors are of the three classes fixed by CRP: internal structure of a physical system, influencing physical systems, and non-system physical factors.

Proposition 38.2 (Inclusion and exclusion of the phenomenon bridge). Let Φ be a relativistic phenomenon with an admissible phenomenon bridge,

$$\text{AdmissiblePhenomenonBridge}(\Phi) : \iff (J1) \wedge (J2) \wedge (J3). \quad (585)$$

Then every quantitative relativistic temporal result of Φ is retained as a relation among records of physical physical systems under declared conditions, and (M1)–(M4) hold.

Proof. (J1)–(J3) are the admissibility conditions and are not inferred from one another; (J1) is satisfiable

because every observable is a record produced by a physical system (Section 40), and (J2) requires that the declared contributors include every contributor that CRP assigns to the records. (M1) is Proposition 43.4 applied to q_Φ . (M2) holds because time is not a causal contributor (Eq. (314)). (M3) is the Generalized Non-Transfer Principle (Section 28). (M4) follows from Eq. (75) and UCC, since $\mathcal{K}_\Phi \subseteq \mathcal{U}_{\text{phys}}$.

The bridge is an application-level empirical bridge. It retains every relativistic prediction: under identical physical-to-observable specifications, ITOF and a relativistic temporal ontology yield the same predictions (Eq. (706)). The phenomena listed are those read explicitly through the bridge. Its function is to fix, for each phenomenon, what the measured quantity is a property of.

38.2 Lorentz transformations as a symmetry of record assignment

ITOF does not derive the Lorentz transformations from $(\mathcal{S}_C^{\text{tot}}, \prec_C)$, which carries no metric, rate, or dynamics. They follow from physical properties of the physical systems by which coordinates are assigned. An inertial laboratory L is a composite qualified system of rods and clocks; it assigns to a record-bearing event the values (t, x) , with x from rod comparison and t from clock records synchronized by two-way light signals. For two laboratories L and L' in uniform relative motion with velocity v along x , assume:

- (H) *Homogeneity*: the map between their assignments is linear after choice of a common origin.
- (I) *Isotropy*: no spatial direction is distinguished.
- (P) *Relativity principle*: the dynamical laws governing the physical systems have the same form in every inertial laboratory, and the maps form a group.
- (O) *Record-order preservation*: the order of the records of any one physical system is the same in every laboratory's assignment.
- (C) *Continuity*: the map depends continuously on v and reduces to the identity at $v = 0$.

Premises (H), (I), (P), and (C) fix the map up to one universal constant K ; this is the derivation first given by Ignatowsky [7] and analysed in [31]:

$$x' = \gamma_K(v)(x - vt), \quad t' = \gamma_K(v)(t - Kvx), \quad \gamma_K(v) = (1 - Kv^2)^{-1/2}. \quad (586)$$

Derivation. By (H) the map is linear. The origin of L' is a physical system at rest in L' and has $x = vt$ in L 's assignment, so $x' = \gamma(v)(x - vt)$ for some coefficient $\gamma(v)$, which is positive, because the two assignments orient the spatial axis alike and, by (C), γ varies continuously from $\gamma(0) = 1$. By (P), with the reciprocity of relative velocity that it implies [37], the inverse map has the same form with velocity $-v$, and by (I) the coefficient does not depend on the direction of motion, $\gamma(-v) = \gamma(v)$; hence $x = \gamma(v)(x' + vt')$. Eliminating x' between the two relations gives

$$t' = \gamma(v)(t - K(v)vx), \quad K(v) := \frac{\gamma(v)^2 - 1}{\gamma(v)^2 v^2}, \quad (587)$$

that is, $\gamma(v) = (1 - K(v)v^2)^{-1/2}$. Write the map as $M(v) = \gamma(v) \begin{pmatrix} 1 & -v \\ -K(v)v & 1 \end{pmatrix}$ acting on (x, t) . By the group property in (P), the composite $M(v_2)M(v_1)$ is again of this form, so its two diagonal entries are equal:

$$1 + K(v_1)v_1v_2 = 1 + K(v_2)v_1v_2. \quad (588)$$

Since v_1 and v_2 are arbitrary, $K(v_1) = K(v_2)$: K is one universal constant, which gives Eq. (586). For $K > 0$ the maps are defined for $|v| < K^{-1/2}$, and $K^{-1/2}$ is an invariant speed. $\square$

If $K < 0$, the maps are rotations of the (t, x) plane, and composition within the group yields a map that reverses the order of a single physical system's records, contrary to (O); hence $K \geq 0$. $K = 0$ gives the Galilean map. The measured isotropy of the two-way speed of light under rotation of the apparatus [8, 9], is consistent with the Ignatowsky form, and the measured frequency relations of moving ions [10], which test the moving-clock factor directly, fix $K = 1/c^2$:

$$x' = \gamma(x - vt), \quad t' = \gamma\left(t - \frac{vx}{c^2}\right), \quad \gamma = \left(1 - \frac{v^2}{c^2}\right)^{-1/2}. \quad (589)$$

Two consequences follow. A clock at rest in L' , with $x = vt$, has records $t' = t/\gamma$ in L 's assignment: the moving-clock relation is a relation between the records of two physical laboratories. Equality of t' differs from equality of t : relativity of simultaneity is a difference in which record-bearing events receive equal coordinate values (Section 32.1).

Premises (H), (I), (P), (O), (C) and the light-speed data concern physical systems and records only; none refers to $\prec_C$, CMA, or UCC. Hence

$$T_{\text{ITOF}}, \text{CMA}, \text{UCC} \not\Rightarrow \text{Eq. (589)}, \quad \text{Eq. (589)} \not\Rightarrow \neg \text{CMA}. \quad (590)$$

The first holds because the derivation uses physical premises that the temporal core does not supply. The second holds because the transformations constrain coordinate values assigned from records, whereas CMA constrains realization successions; an interpretation that retains Lorentz-covariant dynamics together with a frame-independent common succession is empirically equivalent to special relativity [31]. Premise (O) is the record-level counterpart of the non-reversal of $\prec_C$: orthochronous Lorentz maps never reverse the order of a single physical system's records.

38.3 Special-relativistic phenomena

Table 1: Special-relativistic phenomena under the phenomenon bridge.

Phenomenon	Records and representative tests	Model quantity	ITOF reading
Invariance and isotropy of the speed of light	Interferometer and rotating optical-cavity frequency records [8, 9]	c in Lorentz-covariant dynamics	A property of electromagnetic propagation and of the cavity and rods; retained in full. It fixes $K = 1/c^2$ in Eq. (586). It is not a property of T_{ITOF} .
Moving-clock frequency relation	Transition frequencies of fast ions in a storage ring [10]	γ, τ	Frequencies of moving ions relative to laboratory records; the relation of Eq. (589). The ion has no private time.
Lifetime of moving unstable particles	Decay records of muons in a storage ring [11]	$\gamma\tau_0$	Decay is a physical process of the muon; its decay distribution under its motion state relative to the apparatus agrees with $\gamma\tau_0$. See Section 38.4.

Phenomenon	Records and representative tests	Model quantity	ITOF reading
Transported clocks	Clock records after transport by aircraft or in relative motion [12, 39]	$\tau[\gamma, g]$	Different accumulated clock records along different histories between common stages (Section 35.2).
Relativity of simultaneity	Coordinate values assigned by synchronization	x^0	Frame-dependent equality of coordinate values, not of stages (Section 32.1).
Length contraction	No isolated direct measurement; enters through Lorentz-covariant dynamics of the constituents of rods	L_0/γ	A relation among rod records of physical systems in relative motion, explained by the covariant dynamics of their constituents [31]; not a property of space or time.

38.4 Unstable particles

Muons circulating in a storage ring at $\gamma \approx 29.3$ decay with a laboratory-recorded mean lifetime $\gamma\tau_0$, and the decay rate depends on speed but not on the very large centripetal acceleration [11]. In ITOF, the decay of a muon is a physical change of the muon; the laboratory's decay-time records are records of detectors and clocks. The relation between them is fixed by the Lorentz-covariant dynamics of the decay process under the muon's motion relative to the apparatus. The result is retained in full. It does not state that the muon had less time: the muon and the laboratory are co-present at every common stage of their shared existence, and each changes at each such stage (Eq. (584)). What differs is the amount of the muon's internal change between two common stages, as recorded by the laboratory.

38.5 Differential ageing

Two systems that separate and reunite, including two clocks or two living organisms, may display different accumulated change. In ITOF, each system has its own physical history and accumulated change, and both histories run through the same common stages:

$$I_A \cap I_B \supseteq [s_1, s_2]_{\prec_C} \wedge \text{Accumulated}_A(s_1, s_2) \neq \text{Accumulated}_B(s_1, s_2) \Rightarrow \text{FewerStages}(A) \vee \text{PrivateTime}(A). \quad (591)$$

Here $[s_1, s_2]_{\prec_C}$ is the set of stages from separation to reunion. Biological ageing is accumulated physical change of the organism; a smaller accumulation along one history is a smaller amount of change between the same common stages, not a smaller share of time. The relativistic model computes that amount through $\tau[\gamma, g]$; ITOF retains the computation and denies only that τ is time.

38.6 General-relativistic phenomena

Table 2: General-relativistic phenomena under the phenomenon bridge.

Phenomenon	Records and representative tests	Model quantity	ITOF reading
Gravitational frequency shift	Gamma-ray resonance over a tower [13]; space-borne maser [14]; eccentric satellite clocks [15]; optical clocks over 33 cm and across a millimetre-scale sample [39, 51]	$g_{00}, \Delta\Phi/c^2$	Transition frequencies of physical systems under different gravitational relations, compared through a signal path (Section 35.4); not a difference in the amount of time.
Satellite navigation	Integrated clock, orbit, and signal records [35]	$\tau, g_{\mu\nu}$	Operational success of an integrated physical model (Section 35.5); success does not transfer temporal identity.
Deflection of light	Astrometric and radio-interferometric positions [27]	null geodesics of $g_{\mu\nu}$	Deviation of a signal path under a gravitational relation (Section 40.8).
Signal delay near a mass	Round-trip radio-link records to a spacecraft [16]	Shapiro delay	Longer round-trip record of a signal propagating near a mass; a propagation condition (Eq. (613)), not a delay of time.
Perihelion advance	Planetary ranging and astrometry [27]	orbit in $g_{\mu\nu}$	Orbital dynamics of a physical system in a gravitational relation; no temporal content.
Geodetic precession and frame dragging	Gyroscope spin-axis records in Earth orbit [17]	g_{0i} , connection	Precession of gyroscopes; the rotation of the Earth is a contributor to the frame-dragging part. Neither is a property of time.
Gravitational waves	Interferometer strain records [18]	$h_{\mu\nu}$	A propagating gravitational disturbance acting on test masses and on the light paths that read them; not a ripple of time.
Cosmological stretching of light curves	Supernova light-curve widths at redshift z [19]	$(1+z)$, scale factor	The received record sequence is stretched by propagation in the cosmological model; the change of the source is not thereby slowed (Section 40.5).

Phenomenon	Records and representative tests	Model quantity	ITOF reading
Horizons	No record from within a horizon reaches an exterior receiver	coordinate divergence of t	See Section 38.7.
Closed timelike curves	None observed	solutions such as [20, 21]	Excluded as a reversal of the succession of change (Section 38.8).

38.7 Horizons and coordinate divergence

In the exterior Schwarzschild chart, the coordinate t of a system falling toward the horizon diverges, and signals it emits reach a distant receiver with unbounded delay and redshift. In the same model, the proper-time functional along the falling worldline to the horizon is finite. ITOF reads the divergence as a property of the chart and of signal access to the distant receiver:

$$\lim t_{\text{Schw}} = \infty \not\Rightarrow \text{ChangeStops}(A), \quad (592)$$

consistent with Eq. (603). The falling system continues to change under UCC. The statement “time stops at the horizon” is therefore not an ITOF statement and is not a statement of the relativistic model’s own proper-time account either.

38.8 The succession of change is never reversed

A journey into the past, as some relativistic solutions are read, would require a physical system to realize its changes in an order that runs against the cosmic order, a later change of its own preceding an earlier one. No stage goes backward: a stage is the formal expression of a change realized in the succession of change. CMA identifies each system’s own earlier–later order with the cosmic order, and Strict Cosmic Ordering makes that order asymmetric. Hence

$$\boxed{\text{CMA} \wedge \text{StrictTotalOrder}(\mathcal{S}_C^{\text{tot}}, \prec_C) \implies \neg \exists A \in \mathcal{U}_{\text{phys}} \exists x, y \in \mathcal{W}_A : x \triangleleft_A y \wedge y \prec_C x.} \quad (593)$$

Proof. By CMA, $\triangleleft_A = \prec_C|_{\mathcal{W}_A}$, so $x \triangleleft_A y$ gives $x \prec_C y$; together with $y \prec_C x$ this contradicts the asymmetry of the strict total order (Eq. (24)). $\square$

The succession of change is never reversed: no physical system of the universe realizes its changes in an order that runs against the cosmic order. Four cases follow.

1. *Closed timelike curves.* Some solutions of the Einstein field equations contain them [20]. A closed timelike curve in a solution is a geometric object of the representation; by itself it establishes no reversal of the ITOF order. What ITOF excludes is any physical realization in which a system realizes its changes in an order that runs against the cosmic order, the excluded pair of Eq. (593). Hence no physical realization of a closed timelike curve can reverse the succession of change of a system. Therefore

$$\neg \exists A \in \mathcal{U}_{\text{phys}} : \text{RealizedOnClosedTimelikeCurve}(A) \wedge \text{ReversedSuccession}(A). \quad (594)$$

Here $\text{ReversedSuccession}(A)$ is the pair excluded by Eq. (593). With the strict causal order of any association of events with stages (Eq. (465)), a closed causal curve admits no assignment of its events to stages at all, since each of its events would have to lie at a stage later than its own; a region of a spacetime model containing closed causal curves therefore has no admissible association with the stages, and the curve has no physical realization in ITOF.

2. *Wormhole and warp-drive constructions.* Traversable-wormhole solutions proposed as time machines [21] and warp-drive metrics [22] require energy conditions to be violated by the assumed matter. Their mathematical consistency does not establish physical realization (Definition 43.6). Whatever physics may establish about such configurations as spatial connections or transport, their use to reverse the succession of change of a system is excluded by Eq. (593).
3. *Consistency paradoxes.* Paradoxes of the grandfather type presuppose a reversal of the succession of change. Since the presupposition is excluded, ITOF requires no consistency condition on histories to avoid them.
4. *Travel into the future.* A system that has accumulated less change between two common stages than another (Eq. (591)) has not traveled into the future of the other: both pass through the same stages, and neither reaches a stage before the other. A process that reproduces an earlier state is a new later change, not a reversal (Eq. (649)).

Within general relativity the physical realizability of closed timelike curves is itself open, with a conjecture that physical processes prevent their formation [23]. Eq. (593) is a definite ITOF commitment: an established physically realized reversal of the succession of change would contradict CMA or Strict Cosmic Ordering.

39. ITOF–Relativity Boundary

The type-level conclusion is Eq. (467), supported quantity by quantity by Proposition 43.4. None of the governing commitments — the definition of time, CMA, UCC, and CRP — is replaced by a coordinate, metric, proper-time, foliation, synchronization, or clock construction. Three levels are kept apart:

$$\begin{aligned} \text{FoundationalTemporalIdentity} &\not\equiv_{\text{def}} \text{RelativisticRepresentation}, \\ \text{RelativisticRepresentation} &\not\equiv_{\text{def}} \text{PhysicalRecord}, \\ \text{PhysicalRecordAgreement} &\not\equiv_{\text{def}} \text{TemporalIdentity}. \end{aligned} \tag{595}$$

The foundational disagreement is direct; its empirical comparison proceeds only through the bridges of Section 37, and no identity or merger between the competing temporal identifications is asserted.

39.1 Points of conflict and what decides them

ITOF retains every established quantitative result of special and general relativity. It does so by construction: ITOF alters no relativistic equation, parameter, or prediction, and the phenomenon bridge carries each model result unchanged to the records; what it rejects concerns the identification of model quantities with time, not their values. It rejects the geometric reading of time that usually accompanies them, and affirms against it one global time for the whole universe. Table 3 states each point of conflict, the position of ITOF, and the evidence that would bear on it. The rows are not of one kind: some conflicts are decided by observation, and some are decided by the type of the quantities involved.

Table 3: Points of conflict between ITOF and the geometric reading of relativity.

Point	Geometric reading	ITOF	What decides
Extent of time	Many times: a proper time for each worldline and a coordinate time for each chart or frame; no time common to the whole universe	One global time encompassing the whole universe: the common stages of change of all physical systems, wherever they are	The type of the quantities and CMA: proper and coordinate times are quantities of clocks and charts (NTP); evidence of a private stage or ordering would refute CMA
What time is	A dimension of a four-dimensional manifold, read by coordinate time and proper time	The invariant succession of the common stages of change; coordinates and proper time are model quantities	The type of the quantities: model success does not transfer temporal identity (NTP)
Simultaneity	No frame-independent relation of simultaneity exists	All physical systems realized at a stage are co-present there (CMA); this is a frame-independent relation, not a synchronization, and no record selects it	No signal-based procedure decides it; evidence of a private stage or ordering would refute CMA
Clock shifts	Clocks read proper time; shifts are properties of spacetime paths and are universal	Shifts are physical responses of each clock to motion and to the gravitational factor	Observation: a constitution-dependent shift would refute universality; a null result decides neither reading (Section 51.2)
Block universe	The relativity of simultaneity is taken to imply that all events are equally real	The succession is fixed and non-reversed; the argument treats coordinate simultaneity as ontological	The type of the premise: coordinate simultaneity is a relation among coordinate assignments
Reversal of the succession of change	Solutions with closed timelike curves are admitted	The succession of change is never reversed: no physical system realizes its changes in an order that runs against the cosmic order	Observation: a physical causal loop, in which a system contributes to a change of its own that is earlier than the contribution, would refute ITOF (Eq. (593))
Spacetime	A physical entity whose curvature is gravity	A representation of the gravitational relation among physical systems	The type of the quantities; every established quantitative result is retained

Two rows can be decided by observation. In the row on clock shifts the metric theories of gravity, and with them the geometric reading of clock time, require universality, which is the Einstein equivalence principle, and ITOF does not; ITOF admits a hypothesis, H_{CR} , under which universality fails, and a positive result would refute the equivalence principle and with it the geometric reading, while a null result constrains H_{CR} and leaves both readings standing. The minimal field model of H_{CR} is already constrained below its withdrawal threshold by the weak-equivalence-principle bound (Section 51.5), so a positive

clock result would require a model that evades that bound. In the row on reversal of the succession of change the exclusion is made by ITOF alone: general relativity admits solutions with closed timelike curves [20, 21], whereas ITOF excludes any physical reversal; no such reversal has been observed, and the exclusion agrees with the chronology protection conjecture. A reversal would not be established by identifying stages, which records do not do (Change-Stage Restraint), but by a physical causal loop: a system contributing to a change of its own that its records show to be earlier than the contribution [23]. The remaining rows concern what kind of thing a quantity is. There ITOF holds its position: a model quantity that predicts records correctly is a successful model quantity, not time. The dynamical reading of relativistic effects, in which the behaviour of rods and clocks is explained by their physical constitution and dynamics rather than by the geometry of spacetime [31], shows that this position is compatible with the full quantitative content of the theory.

40. Signals and Remote Physical Access

Signals and remote records are treated as physical source–propagation–receiver chains within the common cosmic ordering. The earlier relativistic causal-domain section used only the subset of these distinctions required to separate common-stage realization from model-specific causal accessibility.

40.1 Signals are physical processes

A signal relation contains physically realized systems, fields, interactions, or other physically admissible carriers and factors.

For a declared source–receiver chain Γ , the physical sequence may be represented schematically as:

$$\begin{aligned} \text{SourceChange} \rightsquigarrow_{\text{phys}} \text{Emission} \rightsquigarrow_{\text{phys}} \text{Propagation} \\ \rightsquigarrow_{\text{phys}} \text{ReceiverInteraction} \rightsquigarrow_{\text{phys}} \text{RecordFormation}. \end{aligned} \quad (596)$$

Every physical-system identity participating in the chain remains governed by the same common cosmic ordering.

Where a participating entity A is independently qualified as a physical system and $A \in \mathcal{S}_{\text{phys}}(s)$, UCC gives $\text{PhysReal}_A^+(s)$. The physical signal chain therefore belongs to the system-specific physical realization architecture. It is not a temporal transport chain.

40.2 Record-lag decomposition

A declared operational record lag may be represented as:

$$\begin{aligned} L_{\Gamma}^{\text{rec}} = L_{\Gamma}^{\text{emit}} + L_{\Gamma}^{\text{prop}} + L_{\Gamma}^{\text{path}} \\ + L_{\Gamma}^{\text{interaction}} + L_{\Gamma}^{\text{detect}} + L_{\Gamma}^{\text{process}}. \end{aligned} \quad (597)$$

Every term in this expression is an operationally or physically defined quantity under the declared signal model. A positive lag $L_{\Gamma}^{\text{rec}} > 0$ implies neither multiple temporal referents nor a delayed cosmic change stage. The delay belongs to the physical and operational chain.

40.3 Signals carry energy and records, not time

For a physical signal $S : A \rightarrow B$, V40/F20 retains:

$$\text{SignalPropagation}(S) \not\Rightarrow \text{TimeTransported}(A \rightarrow B). \quad (598)$$

Likewise, the arrival of a signal at B is not the arrival of time at B .

A signal may transport:

$$\begin{aligned} &\text{energy, momentum, information-bearing physical variation,} \\ &\text{or another physically warranted quantity,} \end{aligned} \quad (599)$$

depending on the applicable physical theory.

It does not transport the universal cosmic extension.

40.4 Remote source and receiver

Let A_S be a remote source system and A_D a detector or receiving system.

A record r_D received by A_D may be physically attributable to an earlier source manifestation $\text{ManifestationAt}(A_S, \chi_S; s_S)$. The record remains:

$$r_D \not\equiv_{\text{type}} \chi_S, \quad (600)$$

and:

$$r_D \not\equiv_{\text{type}} s_S. \quad (601)$$

A valid physical source–record bridge may warrant:

$$\text{Warrant}_{P,M} [\exists s_S \in I_{A_S} \text{ ManifestationAt}(A_S, \chi_S; s_S)]. \quad (602)$$

It does not thereby identify that member of $\mathcal{S}_C^{\text{tot}}$.

40.5 Remote change proceeds independently of access

Suppose the detector receives at common cosmic change stage s_D a record associated with source manifestation at some $s_S \prec_C s_D$. The record-arrival stage is not the source stage.

Nor does delayed access imply delayed physical participation by the remote system:

$$\text{RemoteAccessDelayed}(A_S, A_D) \not\Rightarrow \text{RemotePhysicalChangeDelayed}(A_S). \quad (603)$$

If both identities are realized at a later current common cosmic change stage a , that is, $A_S, A_D \in \mathcal{S}_{\text{phys}}(a)$, then CMA supplies their objective common-stage co-presence at a , while UCC requires their respective actual physical changes:

$$\text{UCC} \wedge A_S, A_D \in \mathcal{S}_{\text{phys}}(a) \implies \text{PhysReal}_{A_S}^+(a) \wedge \text{PhysReal}_{A_D}^+(a). \quad (604)$$

UCC states the corresponding uninterrupted system-specific continuity throughout each realized identity range.

The arrival of an older record at A_D does not place the presently realized source identity in a private past time, and a propagation delay, however large, neither divides the common stage nor gives the remote system a different time.

40.6 Successive remote records

Let two source manifestations χ_1 and χ_2 belong to the same source identity A_S .

Suppose a warranted physical reconstruction establishes:

$$\exists s_1, s_2 \in I_{A_S}, \quad s_1 \prec_C s_2, \quad (605)$$

with:

$$\text{ManifestationAt}(A_S, \chi_1; s_1) \wedge \text{ManifestationAt}(A_S, \chi_2; s_2). \quad (606)$$

Let the reconstructed record separation satisfy:

$$\Delta_{\text{arr}} = \Delta_{\text{src}} + \Delta_{\text{prop}}. \quad (607)$$

Here Δ_{src} is an operational representation of source-development separation under the declared reconstruction model, while Δ_{prop} contains differential path, propagation, lensing, medium, source-motion, detector, and reconstruction contributions where physically applicable.

If: $|\Delta_{\text{prop}}| \leq \epsilon_{\text{prop}}$, then:

$$|\Delta_{\text{arr}} - \Delta_{\text{src}}| \leq \epsilon_{\text{prop}}. \quad (608)$$

This may warrant relative source development without identifying the stage pair:

$$\begin{aligned} & \text{Warrant}_{P,M} [\exists s_1, s_2 \in I_{A_S} (s_1 \prec_C s_2)] \\ & \Rightarrow \text{CosmicChangeStagePairIdentified}_{P,M}(A_S, \chi_1, \chi_2). \end{aligned} \quad (609)$$

40.7 Light and radiation

A radiation pulse, photon-qualified entity, excitation, beam, field object, or other radiation-model object belongs to $\mathcal{U}_{\text{phys}}$ only if it independently satisfies the applicable physical-system identity criterion.

Thus:

$$\text{RadiationModelObject}(\ell) \Rightarrow \text{PhysicalSystem}(\ell). \quad (610)$$

Where $\ell \in \mathcal{U}_{\text{phys}}$ and $\ell \in \mathcal{S}_{\text{phys}}(s)$, UCC gives:

$$\text{UCC} \wedge \ell \in \mathcal{S}_{\text{phys}}(s) \Rightarrow \text{PhysReal}_{\ell}^+(s). \quad (611)$$

Propagation, scattering, attenuation, interference, refraction, lensing, spectral change, path deviation, polarization change, and detector interaction remain physical phenomena.

Therefore:

$$\text{OpticalPathDeviation}(\ell) \Rightarrow \text{TimeBent}, \quad (612)$$

and:

$$\text{RadiationArrivalDelay}(\ell) \Rightarrow \text{TimeDelayed}. \quad (613)$$

40.8 Observed deflection of light

An observed deflection of light is a difference between the propagation direction, or the reconstructed propagation path, of a physical signal ℓ at a receiver and a reference direction or path, stated relative to declared physical reference systems $\mathcal{S}_{\text{ref}}$ and a declared reconstruction procedure P :

$$\text{ObservedDeflection}(\ell; \mathcal{S}_{\text{ref}}, P) := \angle(\hat{\mathbf{k}}_R^{\text{rec}}, \hat{\mathbf{k}}_R^{\text{ref}}) \Big|_{\mathcal{S}_{\text{ref}}, P}. \quad (614)$$

It is a property of the signal's physical propagation path or of its reconstruction. It is not a deformation of the light itself, as if the radiation were an elastic body that bends:

$$\text{ObservedDeflection}(\ell; \mathcal{S}_{\text{ref}}, P) \not\Rightarrow \text{IntrinsicDeformation}(\ell). \quad (615)$$

Nor is it evidence that time, or a temporal fabric, has bent (Eq. (612)). Within ITOF the expression “bending of time” is a type error rather than a false empirical claim: $T_{\text{ITOF}} = (\mathcal{S}_{\text{C}}^{\text{tot}}, \prec_{\text{C}})$ carries no direction, curvature, or spatial structure (Eq. (11)), so no property of a propagation path is a property of T_{ITOF} . Time neither bends with light nor travels inside it; light is a physical signal with a path and propagation conditions.

A deflection is attributed only to declared physical contributors. The contributor families relevant to a signal path are

$$\begin{aligned} \text{DeflectionAttribution}(\ell) \implies \emptyset \neq \mathcal{C}_{\ell} \subseteq \{ &\text{Medium, Gravitational,} \\ &\text{MotionRotation, ScatteringReflectionRefraction,} \\ &\text{TransmissionReconstruction} \}, \end{aligned} \quad (616)$$

namely: a material medium and its refractive conditions (air, water, glass, plasma); the mass distribution or gravitational relation represented in the declared physical model; motion or rotation of the source, the receiver, the deflecting body, the medium, or the reference system; scattering, reflection, or refraction at physical boundaries; and the transmission conditions of the path between source and receiver together with the reconstruction model. Rotation is a contributor in some cases — where the deflecting body, the medium, or the reference system rotates — and is not the explanation of every deflection:

$$\text{ObservedDeflection}(\ell; \mathcal{S}_{\text{ref}}, P) \not\Rightarrow \mathcal{C}_{\ell} = \{\text{MotionRotation}\}. \quad (617)$$

Gravitational deflection is retained as a quantitative result of the applicable relativistic model [6, 28], confirmed by astrometric and radio-interferometric observation [27]. ITOF attributes it to the physical gravitational relation between the signal and the deflecting mass distribution as represented in that model. The model represents the path as a null geodesic of a curved metric; by the Non-Transfer Principle and Proposition 43.4, curvature of the model geometry is not curvature of time, and the predictive success of the representation does not transfer temporal identity to it. ITOF does not dispute any measured deflection value; it specifies what the measured quantity is a property of.

40.9 Remote Records in Physical Realization

For a source stage s_S , the source system belongs to $\mathfrak{R}_{\text{C}}(s_S)$. At the later detector-record stage s_D , the detector and record-producing systems belong to $\mathfrak{R}_{\text{C}}(s_D)$. The physical source–record chain therefore connects physical realizations across the invariant order.

It does not identify the two stage-relative profiles:

$$s_S \prec_C s_D \not\Rightarrow \mathfrak{R}_C(s_S) = \mathfrak{R}_C(s_D). \quad (618)$$

Nor does it require a universal deterministic map from the earlier complete profile to the later complete profile. The physical propagation model supplies only the dependencies warranted for the particular source–signal–receiver system.

41. Quantum Records and System Identity

41.1 Mathematical-form-neutral treatment

V40/F20 does not adopt one interpretation of quantum mechanics as part of the definition of time. Quantum mathematical structures enter through the mathematical-form-neutral physical-model architecture defined in Section 19. The formal time definition remains that of Eq. (11).

41.2 When quantum model objects are physical systems

A state vector $|\psi\rangle$, density operator ρ , operator $\hat{O}$, path amplitude, probability distribution, entanglement relation, or superposition notation is not automatically a numerical physical-system identity.

Their model status must be distinguished from the physical-system identities they may represent.

41.3 Quantum model objects and time

The generalized Non-Transfer Principle gives:

$$|\psi\rangle \not\equiv_{\text{type}} T_{\text{ITOF}}, \quad \rho \not\equiv_{\text{type}} T_{\text{ITOF}}, \quad \hat{O} \not\equiv_{\text{type}} T_{\text{ITOF}}. \quad (619)$$

A parameter appearing in a quantum evolution equation remains governed by the model-parameter Non-Transfer rule.

For example, where:

$$i\hbar \frac{\partial}{\partial \lambda} |\psi(\lambda)\rangle = \hat{H} |\psi(\lambda)\rangle, \quad (620)$$

the formal role of λ is fixed by the declared quantum model.

Its occurrence as an evolution parameter does not alter the governing type assignment: λ is not time.

41.4 Joint quantum states and system number

A joint quantum state q_{AB} does not by itself fix the number of physical systems it represents.

A physically warranted classification may involve:

$$\begin{aligned} &\text{two or more independently qualified systems,} \\ &\text{one composite system,} \\ &\text{a composite together with independently qualified subsystems,} \\ &\text{or another physically justified identity architecture.} \end{aligned} \quad (621)$$

The hierarchical composition relation $A \triangleleft_{\kappa,s} B$ may be used only where the physical identity and composition criteria justify it. Quantum-state notation alone does not decide that relation.

41.5 Entanglement and temporal type

An entanglement relation does not by itself establish a private time or a second cosmic ordering:

$$\text{Entangled}_M(A, B) \not\Rightarrow \text{PrivateTime}(A, B), \quad (622)$$

$$\text{Entangled}_M(A, B) \not\Rightarrow \text{SecondCosmicOrdering}. \quad (623)$$

Where $A, B \in \mathcal{S}_{\text{phys}}(s)$, entanglement classification neither supplies nor removes the common stage: CMA makes the represented qualified population co-present at the shared member, while UCC requires the respective system-specific physical changes and their continuation without stasis throughout each realized identity range.

41.6 Quantum measurement

Let a quantum measurement arrangement contain physical source or sample, apparatus, interaction, detector, environment, record-bearing, observer, and laboratory or reference systems. Where those entities satisfy the governing physical-system criteria, each has its own identity-bounded history in the one cosmic succession and is subject to UCC at every stage at which it remains realized. Their stage-relative realizations belong to:

$$\mathfrak{R}_C(s). \quad (624)$$

No measurement-system component is assigned a changeless standpoint outside the physical process merely because it functions as an observer, detector, reference, or laboratory standard.

A detector outcome r_Q is a physical record. Like every record, it is not time. A probability $P(o|\psi, M)$ is a model quantity, not time.

41.7 Physical transformation versus representational update

If terminology such as “collapse” denotes an actual physical transformation of a qualified physical system, then:

$$\text{PhysicalCollapse}_M(A; s) \implies \text{PhysReal}_A^+(s) \quad (625)$$

where the applicable physical interpretation and system attribution are independently warranted.

If the same terminology instead denotes a change in state assignment, conditional description, information, or statistical representation, then the change belongs to the representational level. Therefore a change of collapse notation changes neither the identity of a physical system nor the cosmic ordering.

41.8 Delayed-choice and quantum-eraser records

Delayed-choice and quantum-eraser experiments provide concrete record-level contexts in which later measurement settings or later correlation classifications must be distinguished from retroactive physical alteration [55, 56, 57]. A delayed measurement setting or later correlation classification does not retroactively reverse the universal cosmic ordering.

Likewise:

$$\text{DelayedChoiceRecord}(r) \not\Rightarrow \exists \prec'_C \neq \prec_C. \quad (626)$$

A later record may alter the scientifically warranted description assigned to an earlier process. It does not make a later common cosmic change stage earlier.

41.9 Quantum correlations and causal attribution

Observed quantum correlations are physical-record relations whose theoretical interpretation depends on the declared quantum model. Their existence does not by itself identify a specific physical causal mechanism or an instantaneous causal signal. CMA does not supply such a mechanism either. The physical causal interpretation must remain independently warranted.

42. Higher-Dimensional Representations

42.1 Mathematical dimension and physical realization

Let $\mathcal{M}_n$ be an n -dimensional mathematical manifold, embedding space, state space, configuration space, phase space, or coordinate representation.

Its mathematical consistency may satisfy $\text{MathematicallyConsistent}(\mathcal{M}_n)$. It does not follow that:

$$\text{MathematicallyConsistent}(\mathcal{M}_n) \not\Rightarrow \text{AllDimensionsPhysicallyReal}(\mathcal{M}_n). \quad (627)$$

The physical interpretation of dimensions is an additional model question.

42.2 Extra coordinate dimensions and time

For coordinate component x^j , V40/F20 retains:

$$x^j \not\equiv_{\text{type}} T_{\text{ITOF}}. \quad (628)$$

An additional coordinate dimension therefore does not add a time:

$$\text{AdditionalCoordinateDimensionInModel} \not\Rightarrow \text{AdditionalCosmicTimeExists}. \quad (629)$$

Nor does a model containing several time-like coordinates establish several ITOF temporal extensions merely from its mathematical signature:

$$\text{MultipleTimelikeCoordinatesInModel} \not\Rightarrow \text{MultipleITOFTemporalExtensions}. \quad (630)$$

42.3 State-space dimension and the one succession

A high-dimensional state space Ω_A may be required to represent the physical state of system A . Its dimension does not determine the cardinality or order type of $\mathcal{S}_C^{\text{tot}}$.

Thus:

$$\dim(\Omega_A) = n \not\Rightarrow |\mathcal{S}_C^{\text{tot}}| = n. \quad (631)$$

The same distinction applies to: Ξ_A , $\mathcal{V}_P$, $\mathcal{L}_{AB,P}$, and other application-level spaces.

42.4 Fixed coordinates and continuing change

For $s_1, s_2 \in I_A$ with $s_1 \prec_C s_2$, selected coordinate equality:

$$x_P(A; s_1) = x_P(A; s_2) \quad (632)$$

does not establish:

$$x_P(A; s_1) = x_P(A; s_2) \not\Rightarrow X_A(s_1) = X_A(s_2). \quad (633)$$

Under UCC, the selected coordinate equality leaves the governing actual-change consequence unchanged:

$$x_P(A; s_1) = x_P(A; s_2) \wedge s_2 \in I_A \wedge \text{UCC} \implies \text{PhysReal}_A^+(s_2). \quad (634)$$

A system can remain at the same selected spatial coordinate while undergoing physical change.

42.5 General representation rule

For any mathematical representation $\mathcal{R}_M(A)$, V40/F20 adopts:

$$\text{Represents}_M(\mathcal{R}_M(A), A) \not\Rightarrow \mathcal{R}_M(A) \equiv_{\text{type}} A. \quad (635)$$

Likewise, representing time-related records does not make a quantity time.

This rule unifies the treatment of:

$$\begin{aligned} &\text{coordinates, state vectors, metrics, proper-time functionals,} \\ &\text{higher-dimensional spaces, clock readings, statistical estimators,} \\ &\text{and model-evolution parameters.} \end{aligned} \quad (636)$$

43. Geometrized Time and the Commitments of Relativity

43.1 Purpose and method

For each relativistic temporal quantity, this section states which governing ITOF commitment the quantity fails to satisfy. Because $\prec_C$ is itself defined as a strict total, representation-invariant order (Eq. (11)), the arguments below identify commitment distinctions rather than premises independent of that definition; they are not offered as a derivation of non-identity from relativity alone. Where an argument compares an event ordering on a relativistic manifold with the stage ordering $\prec_C$, the comparison presupposes an independently declared cross-representation bridge of the kind required in Section 6 and is not itself a supplied instance of such a bridge. Two such distinctions, each stated as premises and a conclusion, together with type considerations, establish in one proposition the non-identity with T_{ITOF} of each relativistic geometric temporal quantity, including global time functions and cosmological time. A third distinction concerns the eternalist interpretation only and is not used in that proposition.

Argument 43.1 (Total order versus boost-relative order). **Premise 1.** By the governing definition of $\prec_C$ and the invariance of the earlier–later ordering, $\prec_C$ is a strict, asymmetric total order on $\mathcal{S}_C^{\text{tot}}$ that is invariant under every admissible representation: no representation, coordinate assignment, or description converts $s \prec_C s'$ into $s' \prec_C s$, and no representation assigns distinct stages an order-independent status.

Premise 2. In a relativistic model with Lorentzian signature, a designated coordinate $x^0 = ct$ transforms under a boost as

$$x'^0 = \gamma(x^0 - \frac{v}{c}x^1), \quad \gamma = (1 - v^2/c^2)^{-1/2}, \quad (637)$$

so that the value of x'^0 for a fixed event depends on the spatial coordinate x^1 and on the boost parameter v . The temporal coordinate is thereby a component of a vector transformed by the Lorentz group together with the spatial components.

Premise 3. The order that relativistic physics does preserve is narrower than the order $\prec_C$ requires. The orthochronous subgroup preserves the sign of x^0 -separation only for pairs of events that are timelike or lightlike separated. For spacelike-separated events, the sign of Δx^0 is not preserved: there exist boosts under which $\Delta x^0 > 0$ becomes $\Delta x^0 < 0$, and the standard relativity-of-simultaneity result asserts exactly this. Hence the x^0 -ordering is a frame-dependent partial preservation, defined on a causally connected subset of event pairs.

Conclusion. ITOF requires a single relation invariant for every pair of distinct stages (Premise 1). Relativistic physics preserves an order-theoretic fact only for causally connected event pairs, and that fact is boost-reversible for spacelike-separated pairs (Premises 2 and 3): what relativity secures is a frame-independent partial causal order on events, not a frame-independent total order. This is a difference in the strength of commitment, not a discovery that relativity contradicts $\prec_C$ on some shared domain where both are defined: $\prec_C$ is a stage relation for which no relativistic quantity is, by itself, a supplied representation. Consequently x^0 , or any event-ordering fact recoverable from a relativistic model, is not type-identical with $\prec_C$: identifying the two would import ITOF's stronger total-order commitment into a domain where standard relativistic ontology commits only to the weaker partial causal order. This conclusion grants, and does not depend on denying, that the orthochronous Lorentz subgroup preserves time orientation for causally connected pairs.

Argument 43.2 (Intra-stage and inter-stage relations). **Premise 1.** By CMA, the qualified systems realized at a stage s are co-present at that one stage (Eq. (75)). Spatial relations among physical systems — separation, configuration, relative position — hold among systems realized together; each is borne by a stage population $\mathcal{S}_{\text{phys}}(s)$, not by a pair of distinct stages.

Premise 2. $\prec_C$ relates distinct stages; it holds between no two systems as members of one stage population.

Premise 3. In a Lorentzian representation, x^0 and x^i are components of one coordinate tuple on the event manifold, interconverted by Lorentz transformations (Eq. (637)); the representation assigns them one homogeneous type.

Conclusion. ITOF distinguishes in type the relation that orders stages from the relations that hold within a stage; the Lorentzian representation does not. x^0 is therefore not a representation of $\prec_C$ that preserves this distinction, and $x^0 \not\equiv_{\text{type}} T_{\text{ITOF}}$. The conclusion depends on CMA and is a commitment distinction, not a result derived from relativity alone. It does not concern the metrology of length and time standards, which are operationally linked through the defined speed of light, and it does not deny the predictive content of the representation.

Argument 43.3 (Constitution-criterion conflict). This argument states a conflict between two constitution criteria for a totality of stage-like elements. It does not classify ITOF as presentist, growing-block, or any other tensed metaphysical position, and, per Section 6, it does not depend on whether NTCS_C holds.

Premise 1. By the common-stage condition, membership of $s \in \mathcal{S}_C^{\text{tot}}$ is fixed by the criterion that s is a common stage of the physical systems of the universe, at which, by UCC, every one of them changes (Eq. (104)). This membership criterion is stated without reference to, and holds independently of, whether

$\mathcal{S}_C^{\text{tot}}$ is order-isomorphic to a bounded or an unbounded total order: it fixes what makes a candidate element a member, not how many members the succession has.

Premise 2. The geometric formalism of relativistic spacetime, as a mathematical structure (a manifold M with a Lorentzian metric g), does not by itself assert a constitution criterion for the points of M . The eternalist interpretation adds to the formalism a distinct membership criterion: a point of M is a member of the completed manifold in virtue of its location in the fixed geometric structure, independently of any realization-based criterion applied to it.

Conclusion. The formalism and the eternalist interpretation are distinguished. Membership in $\mathcal{S}_C^{\text{tot}}$ is fixed by a realization criterion (Premise 1); membership in the eternalist manifold is fixed by a structural-location criterion (Premise 2). These are different constitution criteria regardless of the order type of either totality, so an identification of $\mathcal{S}_C^{\text{tot}}$ with the eternalist manifold would conflate two distinct membership criteria rather than merely restate one of them in different notation. The conflict is with the eternalist interpretation, not with the formalism itself, and it is not a claim that later cosmic stages fail to exist prior to some privileged present, a claim this framework does not make. A relativistic model interpreted without a completed-manifold commitment is not addressed by this argument, and no claim is made that the operational or predictive content of the formalism is false. An eternalist reading may also adopt a realization criterion for the points of M , in which case the distinction lapses; for this reason the argument is not used in Proposition 43.4.

Proposition 43.4 (Geometrized-time non-identity). For every relativistic geometric temporal quantity $q \in \{x^0, T, t_{\text{cos}}, g_{\mu\nu}, ds^2, \tau[\gamma, g], R^\rho{}_{\sigma\mu\nu}, 1+z, h_{\mu\nu}\}$, where T is a global time function and t_{cos} the cosmological time of a homogeneous model,

$$q \not\equiv_{\text{type}} T_{\text{ITOF}}, \quad (638)$$

by Arguments 43.1 and 43.2 and by the type considerations given for each quantity.

Proof. The derivation is given quantity by quantity, because the quantities fail different tests.

Coordinate time x^0 . It fails the invariance-domain test of Argument 43.1 and the intra-/inter-stage type distinction of Argument 43.2.

Global time function T and cosmological time t_{cos} . A globally hyperbolic spacetime admits smooth global time functions [34], and a homogeneous cosmological model distinguishes the proper time of comoving observers. Each induces a total preorder on events that is not reversed by boosts, so Argument 43.1 does not apply to it. Each fails as T_{ITOF} for other reasons. It is real-valued and metric, whereas $\prec_C$ carries no magnitude (Eq. (24)). It exists only in models satisfying stated global conditions, whereas T_{ITOF} is not conditional on a spacetime model. A global time function is not unique, since increasing reparametrizations and inequivalent foliations also qualify, and cosmological time is distinguished only within a homogeneous model, whereas $\prec_C$ is one designated order. The level sets of such a function are natural candidates for a representation bridge from events to stages; adopting one is additional application structure (Section 6), not an identity.

Metric $g_{\mu\nu}$ and curvature $R^\rho{}_{\sigma\mu\nu}$. These are tensor fields on M . They are not orderings of any set of stages, so they have no domain of order-invariance to compare with $\prec_C$.

Interval ds^2 . It is boost-invariant, so Argument 43.1 does not apply to it as stated. It fails as a candidate for T_{ITOF} for a different reason: it is a signed quadratic quantity that takes a positive, zero, or negative value, and it does not supply an earlier–later relation between distinct stages at all.

Proper-time functional $\tau[\gamma, g]$. It is defined only along timelike worldlines γ , takes path-dependent values for the same pair of events, and is realized operationally as a clock record of one system; it supplies neither one order for all stage pairs nor an order of stages at all.

Redshift $1 + z$ and *strain* $h_{\mu\nu}$. The first is a ratio of received to emitted signal frequencies, the second a dimensionless perturbation of model geometry recorded by detectors. Both are real-valued record or model quantities; T_{TOF} is an ordered pair, not a number or a field, so both are type-distinct from it.

Remark 43.5. Arguments 43.1–43.3 state structural, type, and interpretive distinctions. They do not derive the Lorentz transformations or any relativistic quantitative prediction, and they do not license inferring quantitative disagreement with a successful relativistic model from the foundational disagreement alone.

43.2 Dimensional reading of time and higher-dimensional spacetime

The claim that time is a geometric dimension has three separable parts, and the arguments above bear on them differently.

Definition 43.6 (Physical-dimension admission). A dimension of a mathematical representation $\mathcal{M}_n$ is admitted as physically realized only where an independently warranted physical criterion of realization for that dimension is supplied: a verification procedure or physical interaction signature that identifies the dimension in physical systems and does not consist in the representation's own mathematical consistency. Accordingly, $\text{MathematicallyConsistent}(\mathcal{M}_n) \not\Rightarrow \text{AllDimensionsPhysicallyReal}(\mathcal{M}_n)$.

Proposition 43.7 (Status of time as a geometric dimension). Let x^0 be the temporal coordinate of a relativistic representation $\mathcal{M}_4$.

- (a) x^0 is admitted as a coordinate of the representation, and relativistic models that use it are not thereby denied operational or predictive content.
- (b) $x^0 \not\equiv_{\text{type}} T_{\text{TOF}}$ (Proposition 43.4). The claim that ITOF time is a dimension of the geometric manifold is therefore not adopted.
- (c) The representation assigns x^0 and the spatial coordinates one homogeneous type, whereas ITOF distinguishes in type the relation that orders stages from the relations that hold within a stage (Argument 43.2). The homogeneity of the representation therefore does not establish that time is a dimension of the same kind as space; no association of x^0 or of its level surfaces with stages is assumed.

Proof. (a) is a statement of what is granted. (b) is Proposition 43.4. (c) follows from Argument 43.2: the homogeneity is a property of the representation, and the type distinction is a commitment of ITOF; neither is derived from the other.

Remark 43.8 (Boundary of the claim). Proposition 43.7 does not assert that additional spatial dimensions of Kaluza–Klein or string-theoretic representations do or do not exist. Their status is governed by Definition 43.6 and by independent physical evidence, not by ITOF. What ITOF fixes is that any such dimension, and any additional timelike coordinate, leaves T_{TOF} and the single stage domain $\mathcal{S}_C^{\text{tot}}$ unchanged (equations (629), (630) and (631)).

43.3 Temporal deformation predicates and their carriers

$T_{\text{TOF}} = (\mathcal{S}_C^{\text{tot}}, \prec_C)$ is a set with a strict total order. It carries no metric, connection, curvature, direction in a space, dimension, or signature. Predicates defined only on such structures are therefore not false of time

but inapplicable to it:

$$\text{IllTyped}(P; T_{\text{ITOF}}) \quad \text{for} \quad (639)$$

$$P \in \{\text{Curved, Warped, Dilated, Contracted, Stretched, Compactified, Bent}\}.$$

Three further predicates are well typed but excluded by governing commitments: $\text{Reversed}(T_{\text{ITOF}})$ by Strict Cosmic Ordering, $\text{Multiplied}(T_{\text{ITOF}})$, that is, several times, by CMA, and TraversedBackward by Eq. (593).

Each deformation predicate used in relativistic language has a physical or representational carrier, and is reassigned to it:

$$\begin{aligned} \text{Curved, Warped} &\longmapsto (g_{\mu\nu}, R^{\rho}{}_{\sigma\mu\nu}), (M_D, g_{AB}), \\ \text{Dilated} &\longmapsto \Delta\tau[\gamma_1, \gamma_2; g], \Delta N_{C_1 C_2}, \\ \text{Contracted} &\longmapsto L_0/\gamma, \\ \text{Stretched} &\longmapsto (1+z), a, \\ \text{Compactified} &\longmapsto \text{coordinate dimensions of } M_D, \\ \text{Bent} &\longmapsto \text{ObservedDeflection}(\ell; \mathcal{S}_{\text{ref}}, P). \end{aligned} \quad (640)$$

The carriers are, in order: the model geometry representing the gravitational relation; worldline functionals and the clock records of physical systems; rod records of physical systems in relative motion; the received record sequence and the cosmological scale factor; representational coordinate dimensions; and signal paths (Section 40.8). For every carrier b in Eq. (640), no carrier predicate alters the stages of the universe or their order:

$$P(b) \not\Rightarrow \text{Altered}(\mathcal{S}_C^{\text{tot}}, \prec_C). \quad (641)$$

It extends Eq. (489) and the type boundary of Proposition 43.4 to every carrier.

43.4 Spacetime as representation and the gravitational relation

A spacetime $(M, g_{\mu\nu})$ is a mathematical representation of physical relations among physical systems and fields. The gravitational relation that the metric represents is physically real: it belongs to the gravitational family of physical factors (Section 8), it contributes to change, and its propagating disturbances are recorded by detectors (Table 2). What ITOF does not admit is a physical entity composed of space and time, a “fabric” of which time is a component:

$$\begin{aligned} &\text{Represents}((M, g), \text{GravitationalRelation}) \wedge \text{PhysicalFactor}(\text{GravitationalRelation}) \\ &\not\Rightarrow T_{\text{ITOF}} \in \text{Components}(\text{PhysicalEntity}). \end{aligned} \quad (642)$$

The geometric representation of gravitation is retained in full as application physics; only the reading of time as one of its components is excluded.

43.5 Temporal geometry and the definition of time

Proposition 43.9 (Non-admission of temporal geometry). No geometric structure is admitted in ITOF as a physical property of time:

$$\boxed{\forall G \in \{\text{metric, curvature, dimension, signature, warping}\} : \neg \text{PhysicalPropertyOf}(G, T_{\text{ITOF}}).} \quad (643)$$

Proof. Three independent grounds apply. (i) By type: each listed structure requires structure that T_{ITOF} does not carry (Eq. (639)). (ii) By admission: a geometric dimension is physically realized only under an independent realization criterion (Definition 43.6); for time as a dimension none is available that does not consist in the consistency of the representation (Proposition 43.7). (iii) By physical content: under the phenomenon bridge, every record that a temporal-geometric reading accounts for is accounted for as a relation among physical systems, signals, and the gravitational relation (Proposition 38.2, Eq. (640)); neither the temporal-geometric reading nor the ITOF common-stage reading adds a record-level correlate to those, and by the Generalized Non-Transfer Principle the predictive success of the geometry does not confer one. The difference between the two readings is ontological and is decided by type, not by records.

Ground (iii) is an argument of non-transfer: the records do not require a geometry of time, and its predictive success does not transfer to a physical property of time. The records equally do not establish the common stages, which ITOF adopts by definition and by CMA, not by inference from records. Within ITOF the proposition rests on grounds (i) and (ii); ground (iii) blocks only the converse inference from predictive success to a geometry of time. The proposition does not deny the mathematical consistency of relativistic geometry, its predictive success, the reality of the gravitational relation, or the possibility that independent physical evidence establishes an additional spatial dimension. It denies that any of these makes geometry a property of time.

44. Reading the Relativistic Equations

The relativistic equations of this part are compact, and their force depends on reading each one in the same four steps: what it states; which relativistic temporal reading it answers; why it holds in ITOF; and what it leaves standing, including what would count against ITOF. This section applies those steps to the principal equations in order of their dependence.

1. Coordinate time is not time (Eqs. (468), (480)).

Statement. The coordinate x^0 of a chart is not T_{ITOF} . *Reading answered.* In ordinary relativistic language the time coordinate of an inertial frame is “the time” in that frame. *Why it holds.* x^0 is a value assigned to events by a chart; different charts assign different values to the same events, while T_{ITOF} is one designated order that no choice of chart changes. A quantity that changes with the chart cannot be the order that does not. *Retained.* Every use of x^0 in calculation. *Against ITOF.* Nothing about x^0 could count against ITOF, because the claim concerns type, not value.

2. Proper time is not time (Eqs. (491), (471), (494)).

Statement. The proper-time functional $\tau[\gamma, g]$ along a worldline is not T_{ITOF} , and two worldlines with different values of τ between the same events do not have two times. *Reading answered.* Relativity is

commonly read as saying that each system carries its own time, measured by its proper time. *Why it holds.* τ is a number computed along one path; two paths between the same two events give two numbers. These numbers measure the amount of a clock's internal change along each path, not two orders of stages: both clocks pass through the same common stages (Eq. (584)). *Retained.* The values of τ and their agreement with clock records. *Against ITOF.* A physical system with a private ordering of stages would count against CMA; a difference in τ is not one.

3. Relativity of simultaneity (Eqs. (500), (503)).

Statement. Equality of coordinate time in one frame differs from that in another, and neither is co-presence at a common stage. *Reading answered.* Since observers disagree about which distant events are simultaneous, there is no fact of the matter about a universal “now.” *Why it holds.* Coordinate simultaneity is fixed by a synchronization convention between clocks; it is a relation among records. Co-presence is fixed by CMA through realization successions (Eq. (70)). The disagreement of conventions is a disagreement about records, and it does not reach realization. *Retained.* Every simultaneity convention and its use. *Against ITOF.* None of the disagreements of conventions; only a warranted private ordering of realization.

4. The direct conflict (Eqs. (506), (507)).

Statement. An interpretation that denies a frame-independent common stage contradicts CMA. *Reading answered.* The view that relativity itself establishes the absence of a common stage. *Why it holds.* Such an interpretation assigns each system an ordering of its realizations relative to a frame or worldline, that is, a private ordering, which is the contrary of CMA (Eq. (656)). *Retained.* Relativistic dynamics, which do not contain that interpretation. *Against ITOF.* The conflict is ontological; it becomes empirical only when a bridge from events to stages predicts a record that the competitor does not (Eq. (706)).

5. The phenomenon bridge (Eqs. (577)–(584)).

Statement. Every relativistic phenomenon is read through its physical systems, conditions, model, model quantity, prediction map, and records; (J1)–(J3) include all data and all contributors and retain every quantitative result; (M1)–(M4) exclude time as model quantity and as contributor. *Reading answered.* That the success of relativistic predictions confirms the temporal reading of their quantities. *Why it holds.* The data of every relativistic test are records of physical systems, and the contributors are physical; the temporal reading adds no record and no contributor. *Retained.* Every prediction. *Against ITOF.* A record that could not be attributed to any physical system or physical contributor — none is known.

6. Lorentz transformations (Eqs. (586)–(590)).

Statement. The transformations follow from homogeneity, isotropy, the relativity principle, and order preservation of each physical system's records, with $K = 1/c^2$ fixed by experiment; the temporal core neither yields them nor is refuted by them. *Reading answered.* That the transformations are a property of time and space themselves. *Why it holds.* Every premise concerns rods, clocks, and records; none mentions $\prec_C$, CMA, or UCC. The moving clock relation $t' = t/\gamma$ is a relation between the records of two laboratories. *Retained.* The transformations in full. *Against ITOF.* A demonstration that the premises cannot be satisfied without a frame-relative order of realization.

7. Differential ageing (Eq. (591)).

Statement. Two systems that separate and reunite may accumulate different amounts of change, without either having fewer stages or a private time. *Reading answered.* The twin who travels “experiences less

time.” *Why it holds.* Both twins pass through the same stages between separation and reunion; what differs is the amount of their own change, as ageing is the accumulated change of an organism. *Retained.* The computed difference, through τ . *Against ITOF.* Nothing in the size of the difference; only a private ordering.

8. Horizons (Eq. (592)).

Statement. The divergence of a coordinate does not stop the change of a falling system. *Reading answered.* “Time stops at the horizon.” *Why it holds.* The divergence belongs to one chart and to the delay of signals reaching a distant receiver; in the same model the falling system’s proper time remains finite, and under UCC it continues to change. *Retained.* The geometry of the solution. *Against ITOF.* None from the divergence; it is not a record of the falling system.

9. No reversal of the succession of change (Eqs. (593), (594)).

Statement. The succession of change is never reversed: no physical system realizes its changes in an order that runs against the cosmic order, and no stage goes backward. *Reading answered.* Closed timelike curves, wormhole or warp-drive time machines, and journeys into the past. *Why it holds.* By CMA a system’s own earlier–later order is the cosmic order; by Strict Cosmic Ordering that order is asymmetric; a reversal would require both orders at once. *Retained.* The solutions as mathematics. *Against ITOF.* A physically established reversal of the succession of change would contradict ITOF directly: a record warranting that the order of realization of a system ran against the cosmic order — for example, a system that meets its own earlier history on a closed path.

10. Deformation predicates (Eqs. (639)–(641)).

Statement. Curved, warped, dilated, contracted, stretched, compactified, or bent are not predicates of time; each belongs to a definite carrier. *Reading answered.* “Time is curved,” “time dilates,” “space-time is warped.” *Why it holds.* T_{ITOF} is an ordered set without metric, connection, or dimension, so these predicates do not apply to it; the measurements behind them are of model geometry, clocks, rods, signals, and received light. *Retained.* Every measured curvature effect, dilation relation, and stretching. *Against ITOF.* None, because the claim is about type.

11. Spacetime and temporal geometry (Eqs. (642), (643)).

Statement. Spacetime is a representation of the gravitational relation, and no metric, curvature, dimension, signature, or warping is a physical property of time. *Reading answered.* That time is the fourth dimension of a physical entity. *Why it holds.* By type; by the dimension-admission criterion, because no realization criterion for time as a dimension exists apart from the consistency of the representation; and by physical content, because every record that the geometric reading explains is explained by physical systems, signals, and the gravitational relation. *Retained.* The gravitational relation as a physical factor and its geometric representation as a tool. *Against ITOF.* An independent physical criterion showing a dimension of time realized beyond the representation.

12. Non-identity of the whole family (Proposition 43.4).

Statement. None of x^0 , a global time function, cosmological time, the metric, the interval, proper time, or curvature is time. *Reading answered.* That some relativistic quantity, if not coordinate time, must be the real time, for example cosmological time. *Why it holds.* Cosmological time and global time functions are boost-invariant, but they are metric, conditional on a model, and not unique; T_{ITOF} is none of these. *Retained.* Their use as representation bridges from events to stages. *Against ITOF.* None from the

identification question; bridges remain empirical hypotheses.

13. The Rietdijk–Putnam argument (Eq. (509)).

Statement. Equal coordinate time does not imply realization at a common stage. *Reading answered.* That relativity forces a block universe because what is real for an observer is fixed by its simultaneity hypersurface. *Why it holds.* The argument’s first premise identifies co-presence with frame simultaneity; ITOF denies that premise, and nothing in the argument addresses the order of realization. *Retained.* The relativity of simultaneity. *Against ITOF.* The cost is stated: no record selects the common stage.

14. Light deflection (Eqs. (614)–(617)).

Statement. Deflection is a property of a signal path or of its reconstruction, attributed to declared contributors, of which rotation is one. *Reading answered.* “Light bends because space-time is curved,” and “gravity bends time.” *Why it holds.* The measured quantity is an angle between directions relative to reference systems; it is a property of a path. *Retained.* The measured deflection and its gravitational prediction. *Against ITOF.* None from the angle itself.

Summary.

In each case the relativistic quantity, its value, and its prediction are retained, and only one step is refused: the step from the quantity to time. The refusal rests on type, on the governing axioms, or on the absence of any record that the temporal reading adds. Where ITOF makes a claim that physics could contradict — a private ordering, a reversal of the succession of change, a physically realized dimension of time — the claim is stated as such.

45. Foundational Scope and Claim Boundary

45.1 Limits of the foundation

Time, the common-stage condition, CMA, UCC, CRP, and the non-termination hypothesis do not by themselves specify a Hamiltonian, field equation, constitutive law, transition probability, universal change magnitude, clock response, signal law, or observable residual. Such quantities require independently warranted physical and measurement structures. Absence of an observed difference is not proof that physical change has ceased. A clock test of an application hypothesis such as H_{CR} does not test the governing commitments: its result, positive or null, leaves the definition of time, CMA, and UCC standing. The target, apparatus, record-bearing systems, observer, and laboratory are within the changing physical domain; an observed manifestation is produced and accessed through an internal physical chain and does not by itself identify the stage of the change it reports.

45.2 Formal contraries and empirical procedures

$$\text{FormalCountercondition}(F) \not\equiv_{\text{def}} \text{DirectFiniteExperimentFor}(F). \quad (644)$$

A formal contrary states what would contradict a commitment; an empirical procedure specifies how physical evidence could warrant that contrary. The first does not guarantee the second. For CMA no present procedure is available: no record selects a stage, so a private stage could not be identified by records alone, and CMA is exposed formally, through the architecture in which it stands, not by a present experiment. For UCC the procedure is certified isolation (Section 5.7). For the non-reversed order the procedure is the observation of a physical causal loop (Eq. (593)).

45.3 Universal commitments and finite evidence

For a universal foundational statement F ,

$$\begin{aligned} \text{FinitePositiveObservations} &\not\Rightarrow \text{DeductiveProof}(F), \\ \text{FiniteNullObservation} &\not\Rightarrow \text{PhysicalCounterexample}(F). \end{aligned} \tag{645}$$

The inferential force of an observation depends on what it actually establishes.

45.4 Clocks in relative motion that never meet

For two inertial clocks in relative motion that never meet, CMA makes them co-present at every common stage at which both are realized, so the counts that each has realized at such a stage are physical facts, and so is their relation. No record decides that relation: records do not identify stages (Change-Stage Restraint), and no signal fixes the association of stages with distant events. The reciprocal relation of their coordinate descriptions concerns records and coordinate assignments. This undecidability is the cost of objective co-presence without a preferred frame, and ITOF states it rather than removing it. When the clocks are brought together, the comparison is local (Proposition 8.1) and decides the difference of their counts.

46. Core Commitments and Logical Status

The governing commitments are:

- (1) **Temporal referent and stage meaning.** $T_{\text{ITOF}} = (\mathcal{S}_C^{\text{tot}}, \prec_C)$. A written stage symbol designates an member of the formal cosmic-stage domain; that member of the formal cosmic-stage domain is the formal expression of the physical change of all physical systems of the universe realized there and its place within the one universal earlier–later cosmic succession. Neither notation nor the member of the formal cosmic-stage domain is an independently existing physical object; its type boundary is that of the Cosmic Stage Definition (Section 2.3).
- (2) **Designated objective orientation, strict ordering, and non-reversal of the governing cosmic succession.** $\prec_C$ denotes the governing earlier–later relation. Strict Cosmic Ordering requires that designated relation to be a strict total order. A later realization remains later even if its declared physical state equals or recurs to an earlier state; state recurrence is not stage recurrence.
- (3) **Scientific openness of complete cosmic extent.** V40/F20 does not assert whether the complete future succession terminates or is unlimited. Non-termination (Eq. (17)) is a revisable cosmological hypothesis, used only as an explicit premise, and not a constituent of temporal constitution.
- (4) **One common succession and Cosmic Moment Axiom.** One universal formal domain of cosmic stages is adopted. The identity ranges $I_A \subseteq \mathcal{S}_C^{\text{tot}}$ and stage populations record identity-stage incidence; they do not establish objective co-presence. CMA states that every system’s realization succession is a segment of the one common succession, which excludes system-private stages and orderings and yields objective co-presence of the complete then-realized population at each stage. UCC independently requires every qualified system in that population to realize its own actual change there. No synchronization construction or private-stage identification is introduced.
- (5) **Universal Change Continuity.** UCC requires $\text{PhysReal}_A^+(s)$ for every qualified A and every $s \in I_A$. Its continuity means absence of complete physical-system stasis throughout the realized identity range; it is non-metric and does not itself select the system’s dynamical law. UCC and CMA are logically independent (Proposition 5.4).

- (6) **Cosmic physical totality, systems, factors, and granularity.** The physical universe denotes $\mathcal{U}_C^{\text{phys}}$, the physical totality of system identities and physically realized physical factors; it is neither a physical container nor a single physical-system identity. Physical-system status is objective, while application-level individuation is fixed relative to a physically warranted class and organizational level. Simple systems need not be composite. Composite qualification requires physically warranted interconnection and coherence; ending or failure of a constituent does not by itself end the composite identity.
- (7) **Identity and lifecycle.** Identity-Realization Convexity, AFB, PIECP, conditional successor attribution, and optional UEIE retain distinct scopes. AFB constrains the least member of an identity range within the common cosmic-stage domain; it neither introduces a private stage nor marks the onset of physical change. AFB and UEIE are not derived from the governing temporal/CMA realization core; UEIE applies only when universal eventual identity ending is explicitly adopted. A terminal identity stage is the end of that identity range, not automatically a terminal cosmic stage. Identity ending does not itself require a successor. Where an ending transformation physically produces a genuinely new identity, the direct-successor relation fixes the required production, formation, and numerical-distinction conditions; absorption by a pre-existing persisting identity can instead end the absorbed system without creating a successor.
- (8) **Physical causation.** CRP separately requires actual physical causal contributors for actual physical change, and every contributor is realized at the stage of the change to which it contributes (Proposition 8.1) and an external influence reaches the system by contact or through a physical pathway (Eq. (136)). Time, ordering, stage unity, and UCC are not causal-source classes.
- (9) **Observation and empirical discipline.** The sample or target, apparatus, detector, record-bearing system, observer, and laboratory are physical systems of the universe, and under UCC they continue changing throughout their realized identity ranges. The observation chain is therefore internal to the same cosmic succession and supplies no changeless external stage marker. Clock readings, proper-time functionals, coordinates, and metric intervals are physical or mathematical operational constructions, not the ITOF temporal referent. Prediction separation requires independently warranted physical provenance; ontological difference alone does not manufacture a residual.

47. Integrated Dependency Architecture

47.1 Temporal branch

The constructional dependency is

$$\langle \mathcal{S}_C^{\text{tot}}, \prec_C \rangle \overset{\text{definition}}{\rightsquigarrow} T_{\text{ITOF}}, \quad (646)$$

with temporal constitution as defined in Eq. (22). The designated earlier–later semantics is fixed independently of the strict-order axiom. The explicit earlier–later pair supplies only temporal non-degeneracy; it does not imply unlimited continuation. The common-stage condition together with UCC makes every stage a stage of change of all physical systems realized there, without supplying a dynamical law. Cosmic non-termination is a separate revisable cosmological hypothesis.

47.2 Physical-system, population, CMA, and UCC branches

At the governing ontic level,

$$\langle \text{PhysicalSystem}, \text{ExistsAs} \rangle \overset{\text{dep}}{\rightsquigarrow} \langle \mathcal{U}_{\text{phys}}, I_A, \mathcal{S}_{\text{phys}}(s) \rangle. \quad (647)$$

The temporal constitution of the stages then yields CSPP as a population corollary. The definition of time fixes one formal cosmic-stage domain; CMA states that every system's realization succession is a segment of it, which yields objective co-presence. UCC states complete system-specific actual-change realization systemwise across identity ranges; by the stage-population definition the same UCC content can be re-indexed stagewise. That quantifier conversion concerns UCC only and does not derive CMA; it is shown in Appendix C.

47.3 Causal branch

The UCC condition states physical-change actuality but does not type or supply causal contributors. CRP is separate:

$$\text{UCC} \wedge \text{CRP} \implies \forall A \in \mathcal{U}_{\text{phys}} \forall s \in I_A, \quad \mathcal{C}_A^{\text{act}}(s) \neq \emptyset. \quad (648)$$

No temporal symbol, CMA relation, or UCC predicate is thereby promoted into a physical causal source.

47.4 Identity and lifecycle branch

Identity qualification precedes application-level persistence, formation, ending, and successor attribution. For a protocol P , admissible application requires the prospective conditions of Eq. (193); a specific attribution additionally requires Eq. (195). AFB fixes the least member of each identity range within the common cosmic-stage domain. Under UCC, actual physical change is realized at that member and at every other member of the range. Ending together with UCC therefore implies actual physical-change realization at the ending boundary. Optional UEIE remains independent of UCC and is not part of the governing core; ending does not by itself entail a direct successor; successor attribution is conditional on genuine new-identity production, while optional UEIE independently determines whether every qualified identity ends.

47.5 Application and observation branch

A physical prediction depends on declared model inputs, laws, parameter provenance, and model-output bridges. Observation additionally depends on acquisition, calibration, comparison, and uncertainty structures. Therefore failure of an application model does not by itself reject the ITOF foundation. A foundation-level conclusion requires an identifiable bridge from the targeted foundational statement to the failed observable. Under identical complete physical-to-observable specifications, ontological difference alone produces no prediction separation.

47.6 Direct derivations under the current architecture

Exact or equivalent state recurrence does not change the governing order:

$$r \prec_C s \wedge X_A(r) = X_A(s) \implies r \neq s \wedge \neg(s \prec_C r). \quad (649)$$

A physical trajectory may reverse a variable, recur, cycle, or reconstruct a previously realized state description; such a process is a new later dynamical change, not a reversal of the succession. From the

common-stage condition and the postulate of change,

$$\mathfrak{T}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \implies \text{CSPP}, \quad \mathfrak{T}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \wedge \text{UCC} \implies \forall s \in \mathcal{S}_C^{\text{tot}} \text{ RealizedChangeStage}_C(s). \quad (650)$$

Order asymmetry (Eq. (26)), complete-population change coverage under $\mathfrak{T}_C \wedge \text{UCC}$ (Eq. (105)), and the conditional results under non-termination (no greatest stage and an infinite stage domain, Eqs. (821)–(822)) are stated with their premises where cited. These derivations supply no Hamiltonian, causal law, metric scale, or observable beyond their declared premises.

48. Core Counterconditions

48.1 Scope and countercondition discipline

The direct contraries of the core foundational commitments are distinguished from identity-level, causal, formation, ending, application-model, and empirical failure conditions, which retain their separately typed definitions.

Three levels must remain distinct:

$$\text{LogicalNegation}(P) \not\equiv_{\text{def}} \text{PhysicalFailureRealization}(P) \not\equiv_{\text{def}} \text{EmpiricalNonConfirmation}(P). \quad (651)$$

Failure to detect a predicted quantity is not by itself the logical negation of a foundational commitment.

48.2 Contraries and bearing evidence

Table 4 lists, for each governing commitment, its direct contrary, the findings that do not amount to that contrary, and the kind of evidence that bears on it.

Table 4: Governing commitments, their direct contraries, and the evidence that bears on them.

Commitment	Direct contrary	Not a contrary	Bearing evidence
Temporal constitution	An empty stage domain, a failure of strict total order, a stage that is not a common stage, or no earlier–later pair	A coordinate relabeling that preserves the designated earlier–later relation	Formal analysis of the stage domain
Non-reversal (Strict Cosmic Ordering with CMA)	A physical system whose own order of realization reverses the cosmic order on its range, $x \triangleleft_A y$ with $y \prec_C x$: a reversal of the succession of change	Recurrence of a state, a place, or a selected variable	A physically established reversal of the succession of change, along a closed timelike curve or otherwise
Cosmic Origin	A succession without a least member: for every stage an earlier one	Evidence of physical change before a stage hitherto taken as first, which places the first stage earlier	Cosmological evidence locates the earliest established change; it does not by itself decide the postulate

Commitment	Direct contrary	Not a contrary	Bearing evidence
Non-termination (revisable hypothesis)	A greatest stage	Absence of density, adjacency, or metric continuity; an apparently static observational condition	Cosmological evidence on the complete extent of cosmic change
CSPP (derived)	A stage at which no physical system is realized	A region or record without detected systems	Failure of common-stage semantics, not a separate test
CMA	A physical system with a private stage or a private ordering of stages	Different states, records, clock readings, signal delays, spatial separation, or absence of interaction	Formal contrary; no present experimental procedure, because no record selects a stage
UCC	A realized physical system with complete physical non-change at a stage of its identity range	Non-detection, constancy of selected variables, model stationarity, or a stable record	Certified isolation with a sequence of decreasing bounds on residual change
CRP	An actual change with no actual physical contributor	An unresolved or stochastic cause	Physical analysis of the change and its contributors
Stage-local causation and influence through a pathway	An actual change with a physical contributor not realized at the stage of that change, or an established influence on a system that reaches it through no physical pathway	Correlations, or records received in an order different from the order of their sources	Physical causal analysis of the contributing chain
Strict causal order of stages	Two distinct, causally connected events assigned to one stage, or an effect assigned to a stage earlier than its source	Coordinate simultaneity, or an association of events with stages that records leave undetermined	Physical causal analysis of signal and influence chains
Identity-Realization Convexity	An identity realized at two stages but not at a stage between them	A gap in the records of the system	Identity criteria applied to the physical history
AFB	A realized identity range without a least member	An unresolved formation stage	Physical evidence on formation
PIECP	An ending to which no actual contributor contributes specifically	Failure to resolve that contributor experimentally	Physical analysis of the ending transformation
UEIE (optional)	A qualified identity with no ending over the full theoretical scope	A long-lived system that has not yet ended	Not testable by finite observation; adopted only as an optional commitment

Commitment	Direct contrary	Not a contrary	Bearing evidence
H _{CR} (declared application hypothesis)	A constitution-dependent clock response whose pattern, sign, or coefficient violates (P1)–(P3); restriction at $ k_\alpha < 10^{-9}$ and withdrawal at $ k_\alpha < 10^{-10}$, each at 95% confidence	A clock shift explained by a declared systematic contributor	Comparisons of clocks of different constitution over a change of gravitational potential; in a declared field model, equivalence-principle tests

48.3 Temporal-extension countercondition

Failure of temporal constitution is

$$\neg \mathfrak{T}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \quad (652)$$

and, by definition, occurs if the stage domain is empty, the designated relation fails to be a strict total order, at least one member is not a common stage of the physical systems of the universe, or the domain contains no nontrivial earlier–later pair:

$$\begin{aligned}
& \neg \mathfrak{T}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \\
& \iff [\mathcal{S}_C^{\text{tot}} = \emptyset] \vee \neg \text{StrictTotalOrder}(\mathcal{S}_C^{\text{tot}}, \prec_C) \\
& \quad \vee \exists s \in \mathcal{S}_C^{\text{tot}} \neg \text{CommonStage}_C(s) \\
& \quad \vee \neg \exists r \in \mathcal{S}_C^{\text{tot}} \exists t \in \mathcal{S}_C^{\text{tot}} (r \prec_C t).
\end{aligned} \quad (653)$$

A relabeling or coordinate transformation does not constitute reversal of the governing order when it preserves Eq. (30).

48.4 Contrary to the non-termination hypothesis

Where the conditional cosmological premise is under consideration, Strict Cosmic Ordering makes its direct contrary the existence of a greatest stage:

$$\begin{aligned}
& \text{StrictTotalOrder}(\mathcal{S}_C^{\text{tot}}, \prec_C) \implies \left[\neg \text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \right. \\
& \quad \left. \iff \exists g \in \mathcal{S}_C^{\text{tot}} \forall t \in \mathcal{S}_C^{\text{tot}} (t = g \vee t \prec_C g) \right].
\end{aligned} \quad (654)$$

This is not itself a failure of temporal constitution. Nor is either side established merely by a finite observational gap, failure to receive a signal, lack of a record, or non-detection of a selected observable.

48.5 Countercondition to the derived CSPP population principle

$$\neg \text{CSPP} \iff \exists s \in \mathcal{S}_C^{\text{tot}} : \mathcal{S}_{\text{phys}}(s) = \emptyset. \quad (655)$$

Because the temporal constitution requires every stage to be a common stage of the physical systems of the universe (Eq. (15)), $\neg \text{CSPP}$ is a failure of the governing stage semantics rather than an independent foundational countercondition.

48.6 Countercondition to CMA

The direct formal contrary to CMA is a qualified system with a private stage or a private ordering of stages:

$$\neg \text{CMA} \iff \exists A \in \mathcal{U}_{\text{phys}} : \neg \left[\mathcal{W}_A \subseteq \mathcal{S}_C^{\text{tot}} \wedge \triangleleft_A = \prec_C|_{\mathcal{W}_A} \right]. \quad (656)$$

This contrary is distinct from complete physical non-change of a realized system, which is the direct contrary to UCC.

48.7 Countercondition to UCC

$$\neg \text{UCC} \iff \exists A \in \mathcal{U}_{\text{phys}} \exists s \in I_A : \text{NC}_A^{\text{phys}}(s). \quad (657)$$

This means that a qualified identity remains realized at s while the UCC actual physical-change condition fails for that physical system. It does not imply that the cosmic succession terminates:

$$\neg \text{UCC} \not\Rightarrow \neg \text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C). \quad (658)$$

Nor does non-detection of change establish $\text{NC}_A^{\text{phys}}(s)$.

48.8 Application failure and the core

Failure of a declared application model warrants rejection or restriction of that model on the tested domain. It does not automatically negate temporal admissibility, CSPP, CMA, UCC, or CRP:

$$\text{ApplicationModelRejectedOrRestricted}(M, D) \not\Rightarrow \text{ITOFFoundationRejected}. \quad (659)$$

A foundation-level conclusion requires an independently warranted and identifiable dependency chain from the targeted foundational premise to the failed observable.

A formal contrary states what would contradict a commitment; an empirical procedure states how physical evidence may warrant that contrary. The first does not guarantee the second, and the absence of a simple finite test does not remove the formal contrary of UCC or of any other universal commitment. Finite positive observations do not prove a universal commitment, and a finite null observation is not a physical counterexample to it. The governing discipline is:

Scientific inference propagates only through explicitly declared logical dependency, a typed physical application chain, observational support, uncertainty structure, and warranted evidential scope.	(660)
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49. Mass-Defect and Clock-Response Program

49.1 Status and physical provenance

The mathematical-form-neutral dynamics and bridge architecture admits physical models whose governing laws have independent physical provenance. A quantitative atomic-clock response branch instantiates that architecture based on the internal-energy mass defect and weak gravitational coupling. The branch is

denoted Ω_{MD} and has the status

$$\text{Status}(\Omega_{\text{MD}}) = \text{ApplicationLevelPhysicalModelBranch}. \quad (661)$$

The branch is a physical model instantiation, not itself a measurement bridge. Its independently specified inputs enter the model-input layer, its Hamiltonian or response law belongs to the dynamics layer, its calculated fractional shifts belong to the prediction domain, and comparison with experimental records occurs only through the declared measurement and empirical-assessment layers. It is not derived from the temporal definition, CMA, or UCC. Its physical input is independently sourced from mass-energy equivalence, atomic transition physics, and the equality of inertial and gravitational mass in the weak-field model used below. Mass-defect formulations of atomic-clock shifts have been developed independently in the atomic-clock literature [40, 41].

Accordingly,

$$\Omega_{\text{MD}} \not\equiv_{\text{type}} T_{\text{ITOF}}. \quad (662)$$

The program predicts physical clock-transition quantities; comparison with record differences belongs to the declared measurement and empirical-assessment layers. It does not redefine the entity denoted by time.

For application-level derivability statements below, let $\Gamma_{40}^{\text{fund}}$ denote the conjunction of the governing V40/F20 foundational commitments actually invoked by the declared application. This premise shorthand is distinct from the framework-level tuple $\mathfrak{F}_{40}$ defined in Eq. (7) and from all application-specific physical assumptions. If a narrower premise set is used, its scope must be declared explicitly rather than inferred from the symbol.

49.2 Two-level clock physical system and mass-defect relation

Consider a clock physical system with internal states $|g\rangle$ and $|e\rangle$, unperturbed energies $E_g^{(0)}$ and $E_e^{(0)}$, and unperturbed angular transition frequency

$$\hbar\omega_0 = E_e^{(0)} - E_g^{(0)}. \quad (663)$$

Let the corresponding rest masses be M_g and M_e . Mass-energy equivalence gives

$$M_e - M_g = \frac{\hbar\omega_0}{c^2}. \quad (664)$$

The difference is a physical mass defect associated with the different internal energies of the same clock physical system. It is not a difference of times or cosmic stages.

49.3 Weak gravitational physical-response law

Let $\phi(\mathbf{r})$ be a weak classical gravitational potential over the declared experimental domain, with $|\phi|/c^2 \ll 1$, defined relative to a declared fixed reference-potential convention for the adopted weak-field model. Only potential differences enter the operational clock-comparison predictions; no undeclared absolute potential zero is assigned physical significance here. Under equality of inertial and gravitational mass, the physical energy assigned to internal state $j \in \{g, e\}$ is

$$E_j(\phi) = M_j c^2 + M_j \phi = M_j c^2 \left(1 + \frac{\phi}{c^2} \right). \quad (665)$$

Using Eq. (664), the transition frequency becomes

$$\omega(\phi) = \frac{E_e(\phi) - E_g(\phi)}{\hbar} = \omega_0 \left(1 + \frac{\phi}{c^2} \right). \quad (666)$$

For two locations $\mathbf{r}_1$ and $\mathbf{r}_2$, define the model fractional response relative to the unperturbed transition frequency by

$$y_{12}^{\text{MD}} := \frac{\omega(\phi_1) - \omega(\phi_2)}{\omega_0} = \frac{\phi_1 - \phi_2}{c^2}. \quad (667)$$

This is a physical transition-frequency relation. No proper-time functional, metric interval, clock-defined time, or stage-count magnitude occurs in its derivation. The benchmark observable is conventionally reported relative to a local clock frequency rather than ω_0 ; within the retained weak-field order, replacing the denominator by that local reference changes only terms beyond c^{-2} and therefore does not alter the benchmark predictions below.

For a sufficiently small vertical separation Δh , assume that the declared local potential profile is twice differentiable on the interval between h and $h + \Delta h$. Define the signed local potential gradient

$$g_h(h) := \frac{\partial \phi}{\partial h}(h), \quad (668)$$

which has dimensions of acceleration. Taylor's theorem gives, for some ξ between h and $h + \Delta h$,

$$\phi(h + \Delta h) - \phi(h) = g_h(h) \Delta h + \frac{1}{2} \frac{\partial^2 \phi}{\partial h^2}(\xi) (\Delta h)^2. \quad (669)$$

The sign of g_h is fixed by the declared vertical coordinate. Where the quadratic remainder is negligible on the stated domain, the retained leading local prediction is

$$y_h^{\text{MD}} = \frac{g_h \Delta h}{c^2}, \quad \kappa_h^{\text{MD}} := \frac{y_h^{\text{MD}}}{\Delta h} = \frac{g_h}{c^2}. \quad (670)$$

The coefficient is not fitted to the clock outcome in the benchmark protocol; it is fixed by the independently supplied local potential gradient and the exact SI value of c .

49.4 Record model and independently controlled systematics

A measured clock comparison generally contains physical contributions beyond the weak gravitational response. For a declared protocol P , write

$$y_{12}^{\text{obs}} = y_{12}^{\text{MD}} + \sum_{k=1}^K s_{k,12} + \epsilon_{12}, \quad (671)$$

where $s_{k,12}$ denotes a separately characterized differential physical systematic contribution and ϵ_{12} denotes the residual stochastic record term under the declared acquisition model. Depending on the clock class, the systematic family may include Zeeman, Stark, black-body-radiation, density, lattice, motional, vibration (Section 23.9), link, and calibration contributions. The membership of that family and the associated correction and uncertainty models are protocol- and physical-system-specific.

A benchmark claim using a corrected published result requires

$$\begin{aligned} \text{BenchmarkAdmissible} \implies & \text{InputsExternallySpecified} \\ & \wedge \text{SystematicCorrectionsDeclared} \\ & \wedge \text{UncertaintyDeclared}. \end{aligned} \quad (672)$$

No unreported adjustment of g_h , Δh , or the coefficient in Eq. (670) is permitted after inspection of the target clock result.

49.5 Benchmark A: 0.33-m aluminium-ion clock comparison

Status: the clock result below is an externally reported measurement; the V40/F20 comparison value is calculated from independently supplied published inputs under the declared weak-field model.

Chou et al. reported a height change of $\Delta h_A = 0.33$ m and a measured fractional frequency change

$$y_A^{\text{obs}} = (4.1 \pm 1.6) \times 10^{-17} \quad (673)$$

in a comparison of two $^{27}\text{Al}^+$ optical clocks [39].

Using only the published nominal local value $g_{h,A} = 9.80 \text{ ms}^{-2}$ for the upward height coordinate, the height change, and the exact value of c , Eq. (670) gives

$$y_A^{\text{MD}} = \frac{(9.80)(0.33)}{c^2} = 3.5983 \times 10^{-17}. \quad (674)$$

Using the published quoted uncertainty as the benchmark standard deviation, the nominal standardized residual is

$$z_A := \frac{y_A^{\text{obs}} - y_A^{\text{MD}}}{1.6 \times 10^{-17}} = 0.314. \quad (675)$$

This is a published-input consistency benchmark, not a reconstruction of the raw clock record or its full covariance.

49.6 Benchmark B: millimetre-scale strontium clock gradient

Status: the observed gradients below are externally reported measurements, while the comparison value is a model calculation from the independently reported local gravitational acceleration and exact c .

Bothwell et al. reported a local vertical gravitational acceleration $a_B = -9.796 \text{ ms}^{-2}$ for the coordinate convention of their vertically oriented ^{87}Sr optical-lattice-clock sample and a predicted weak-field fractional frequency gradient of approximately $-1.09 \times 10^{-19} \text{ mm}^{-1}$ [51]. Equation (670) gives directly

$$\kappa_B^{\text{MD}} = \frac{a_B}{c^2} (10^{-3} \text{ m/mm}) = -1.08995 \times 10^{-19} \text{ mm}^{-1}. \quad (676)$$

The same work reports a corrected campaign gradient

$$\kappa_{B,1}^{\text{obs}} = -9.8(2.3) \times 10^{-20} \text{ mm}^{-1} \quad (677)$$

and a corrected synchronous two-region determination

$$\kappa_{B,2}^{\text{obs}} = -1.28(27) \times 10^{-19} \text{ mm}^{-1}. \quad (678)$$

The corresponding nominal standardized residuals are

$$z_{B,1} = \frac{\kappa_{B,1}^{\text{obs}} - \kappa_B^{\text{MD}}}{2.3 \times 10^{-20}} = 0.478. \quad (679)$$

$$z_{B,2} = \frac{\kappa_{B,2}^{\text{obs}} - \kappa_B^{\text{MD}}}{2.7 \times 10^{-20}} = -0.704. \quad (680)$$

The two reported determinations are not combined here as statistically independent measurements. Each is used only as a separate consistency check against the physical-response prediction with its response coefficient fixed by externally supplied physical inputs.

49.7 Cross-system benchmark meaning

The aluminium-ion and strontium benchmarks involve different atomic clock physical systems, different apparatuses, and different local gravitational fields. Under the mass-defect response law, physical-system independence concerns the response coefficient conditional on the same local physical potential gradient. For a physical-system class A realized at location $\mathbf{r}$,

$$\kappa_h^{(A)}(\mathbf{r}) = \frac{g_h(\mathbf{r})}{c^2} \quad (681)$$

for every physical-system class to which the stated physical assumptions apply. Thus the law does not require numerically identical gradients in laboratories with different g_h ; it requires the same fractional response per unit local potential difference. The published benchmark values above are consistent with that conditional physical-system independence relation at their quoted precision.

This result warrants only the bounded claim

$$\text{MassDefectClockResponseBenchmarkRecovered}(D_{\text{Al}^+}, D_{\text{Sr}}). \quad (682)$$

It does not establish UCC, CMA, the ITOF temporal definition, or any universal claim outside the tested physical domains.

49.8 Benchmark recovery and relativistic discrimination

The leading weak-field relation in Eq. (667) coincides with the standard gravitational clock-shift relation through the retained order c^{-2} . Let the superscript (2) denote the prediction truncated consistently through that order. On the same physical inputs and benchmark domain,

$$\mathbf{y}_{\text{MD}}^{(2),P,D} = \mathbf{y}_R^{(2),P,D}. \quad (683)$$

No equality of uncalculated higher-order terms follows from this relation. Consequently, recovery of the benchmark does not discriminate between ITOF and relativity at the foundational level. The quantitative importance of $\mathfrak{Q}_{\text{MD}}$ is different: it supplies an independently sourced physical route from atomic internal-energy structure and external physical conditions to clock records without identifying the record difference with a difference in T_{ITOF} .

49.9 Hamiltonian physical-system extension for confined-ion motion

The weak-field scalar benchmark can be extended to confined-ion motion without altering the temporal definition. For this purpose V40/F20 adopts, as an independently sourced application model, the leading internal–external Hamiltonian structure derived for a charged composite clock physical system in external electromagnetic and weak gravitational fields [41]. In the notation used here, the relevant decomposition is

$$\hat{H} = \hat{H}_{\text{com}} + \hat{H}_{\text{int}} + \hat{H}_{\text{at-emf}} + \hat{H}_{\text{metric}} + \hat{H}_{\text{MD}}. \quad (684)$$

The diagonal mass-defect coupling between center-of-mass and internal degrees of freedom is

$$\hat{H}_{\text{MD}} = \left(M\phi(\hat{\mathbf{R}}) - \frac{\hat{\mathbf{P}}^2}{2M} \right) \otimes \frac{\hat{H}_{\text{int}}^{(0)}}{Mc^2}. \quad (685)$$

Here M is the physical-system rest mass used in the external Hamiltonian, $\hat{\mathbf{R}}$ is its center-of-mass position, $\hat{\mathbf{P}}$ is the mechanically coupled center-of-mass momentum, and $\hat{H}_{\text{int}}^{(0)}$ is the unperturbed internal Hamiltonian. In the stationary nondegenerate internal-state regime treated by the cited derivation, the metric term has no diagonal energy contribution at the retained order; the leading diagonal internal–external clock coupling is then carried by Eq. (685).

Define the external kinematic–gravitational coupling operator

$$\hat{K}_{\text{ext}} := \phi(\hat{\mathbf{R}}) - \frac{\hat{\mathbf{P}}^2}{2M^2}. \quad (686)$$

For a two-level transition satisfying Eq. (663), first-order diagonal perturbation theory in c^{-2} gives the instantaneous fractional transition response

$$y_H(t) = \frac{1}{c^2} \text{Tr}_{\text{ext}} \left[\rho_{\text{ext}}(t) \hat{K}_{\text{ext}} \right]. \quad (687)$$

For interrogation interval $[0, T]$, the corresponding cycle-averaged branch is

$$\bar{y}_H(T) := \frac{1}{Tc^2} \int_0^T \text{Tr}_{\text{ext}} \left[\rho_{\text{ext}}(t) \hat{K}_{\text{ext}} \right] dt. \quad (688)$$

This expression contains the gravitational contribution through $\phi(\hat{\mathbf{R}})$ and the motional second-order contribution through $\hat{\mathbf{P}}^2$. It is an application-level perturbative physical response formula. If internal–external entanglement or additional relativistic terms are non-negligible in a selected experiment, the corresponding full Hamiltonian evolution must replace this reduced first-order expression.

49.10 Hamiltonian content and residuals

The independently derived full trapped-ion Hamiltonian framework cited above provides the external–internal relativistic dynamics in electromagnetic and weak gravitational fields and is applied to Paul-trap effects including secular motion, micromotion, excess micromotion, and trap imperfections [41]. Within that broader framework, Eq. (685) is the retained leading diagonal internal–external mass-defect coupling under the stated approximation; the isolated displayed $\hat{H}_{\text{MD}}$ term must not be read as, by itself, encoding every trap, field, micromotion, or imperfection contribution of the full derivation. The cited framework recovers the established relativistic frequency-shift content in its domain and does not thereby supply an

additional ITOF-specific residual. Earlier mass-defect analyses had considered additional trapped-clock contributions [40]; those proposals are not promoted here to governing V40/F20 predictions.

Accordingly, the V40/F20 temporal core together with the established physical Hamiltonian does not supply an independently nonzero additional residual:

$$\left[\Gamma_{40}^{\text{fund}} \wedge \text{BaseHamiltonianSpecified} \left(\hat{H}_{\text{base}} \right) \right] \not\Rightarrow \delta y_X \neq 0, \quad (689)$$

where $\hat{H}_{\text{base}}$ denotes the independently warranted standard Hamiltonian for the declared physical system and apparatus. This is a dependency boundary, not a claim that every possible physical extension must have zero residual.

49.11 Hamiltonian benchmark C: reconstructed secular-motion shift

This benchmark reconstructs a published systematic correction from published modal inputs; it is neither an independent measurement nor an advance ITOF prediction.

A direct modal benchmark is supplied by the 2025 NIST $^{27}\text{Al}^+$ quantum-logic clock [42]. Its supplemental evaluation reports six secular modes with mode-specific fractional frequency shift per motional quantum s_α , mean occupation $\bar{n}_\alpha$, and uncertainty $\sigma_{\bar{n},\alpha}$. For the reported modal model, define

$$y_{\text{sec}}^{\text{modal}} := \sum_{\alpha=1}^6 s_\alpha \left(\bar{n}_\alpha + \frac{1}{2} \right). \quad (690)$$

The factor $1/2$ retains the zero-point motional contribution. The published inputs are:

Mode	ν_α [MHz]	s_α [10^{-19}]	$\bar{n}_\alpha$	$\sigma_{\bar{n},\alpha}$	$s_\alpha(\bar{n}_\alpha + 1/2)$ [10^{-19}]
Axial COM	2.16	-0.95	8.22	0.48	-8.2840
Axial STR	3.75	-1.42	4.50	0.19	-7.1000
X COM	4.22	-1.77	5.68	0.49	-10.9386
X STR	3.48	-6.48	6.69	0.51	-46.5912
Y COM	5.37	-1.42	4.31	0.14	-6.8302
Y STR	4.75	-6.53	4.84	0.24	-34.8702

Therefore,

$$y_{\text{sec}}^{\text{modal}} = -114.6142 \times 10^{-19}. \quad (691)$$

Using only the reported occupation-number uncertainties and the published modal coefficients, the corresponding propagated uncertainty is

$$\sigma_{\text{sec}}^{(\bar{n})} = \left[\sum_{\alpha=1}^6 (s_\alpha \sigma_{\bar{n},\alpha})^2 \right]^{1/2} = 3.80135 \times 10^{-19}. \quad (692)$$

Rounding to the precision of the published clock evaluation gives

$$y_{\text{sec}}^{\text{modal}} = -(114.6 \pm 3.8) \times 10^{-19}, \quad (693)$$

which reproduces the reported secular-motion correction. This is a reconstruction of the published modal systematic model, not an independent experimental confirmation and not a foundational ITOF–relativity

discrimination.

49.12 Independent nonstandard Hamiltonian residual family

A genuinely new residual requires an independently specified physical interaction beyond $\hat{H}_{\text{base}}$. Let

$$\hat{H}_{\text{test}} := \hat{H}_{\text{base}} + \lambda_X \hat{O}_X, \quad (694)$$

where $\hat{O}_X$ is a physically typed operator and λ_X has independent physical provenance. Their dimensions must be declared for each candidate so that $\lambda_X \hat{O}_X$ has units of energy. Thus the normalization of λ_X is not a free notational choice that can be changed after confronting data. In the perturbative diagonal regime, define

$$D_X(t) := \text{Tr}_{\text{ext}} \left[\rho_{\text{ext}}(t) (\langle e | \hat{O}_X | e \rangle - \langle g | \hat{O}_X | g \rangle) \right]. \quad (695)$$

After the internal-state matrix elements are taken, the bracketed difference in Eq. (695) is an operator on the external motional state space. The external trace therefore gives the state-dependent transition-energy contribution per unit λ_X . The induced cycle-averaged fractional residual is then

$$\delta y_X(T) = \frac{\lambda_X}{\hbar \omega_0 T} \int_0^T D_X(t) dt. \quad (696)$$

No advance prediction follows unless the operator, coupling, physical-system state, apparatus parameters, domain, and acquisition bridge are fixed independently of the evaluation outcome. In particular,

$$\Gamma_{40}^{\text{fund}} \not\Rightarrow \lambda_X \neq 0. \quad (697)$$

The ITOF temporal ontology therefore cannot be used as a substitute for the missing physical derivation of a new interaction.

Let y_{base} denote the prediction derived from $\hat{H}_{\text{base}}$ in the same declared protocol. For a rival prediction y_R , model-level resolved separation requires

$$|y_{\text{base}} + \delta y_X - y_R| > \eta_*, \quad (698)$$

with the combined uncertainty structure and admissible bridge class fixed before evaluation. A foundational conclusion additionally requires the attribution and bridge-robust conditions of Section 26 and Section 37.

49.13 Forward quantum-motional test domain

Status: the numerical effects discussed here are externally sourced forward physical-model predictions used as a test domain for the bridge architecture; they are not derived from the temporal ontology.

Recent trapped-ion theory provides a further application domain in which the external motional state is genuinely quantum rather than a classical trajectory surrogate [43]. For a harmonically trapped clock physical system, let

$$\epsilon_m := \frac{\hbar \omega_m}{Mc^2}, \quad (699)$$

where ω_m is the motional angular frequency. The cited Hamiltonian model predicts, for the motional ground state,

$$y_{\text{vSODS}} = -\frac{\epsilon_m}{4}, \quad (700)$$

and for a squeezed motional state with squeeze parameter r , to the stated leading order,

$$y_{\text{sqSODS}} \simeq -\frac{\epsilon_m}{4} \cosh(2r). \quad (701)$$

The same model predicts a motion–clock entanglement signature in the Ramsey visibility. In its leading small-parameter form,

$$\mathcal{V} \simeq 1 - \frac{(\epsilon_m \omega_0 T)^2}{16} \sinh^2(2r). \quad (702)$$

For the $^{27}\text{Al}^+$ parameter example analyzed in the cited work, a 20-MHz trap, one-second evolution, and $r = 2.26$ give a predicted visibility of approximately 0.93, while the magnitude of the squeezing-associated fractional frequency shift is approximately 3.8×10^{-17} . These are external physical-model predictions and constitute a forward experimental domain for the V40/F20 bridge architecture.

Observation of such quantum-motional effects would test the corresponding Hamiltonian model. It would not by itself identify the proper-time quantity used in that model with the entity denoted by time in ITOF.

49.14 Quantitative claim boundary

The program now contains a weak-field gravitational branch, a trapped-ion Hamiltonian physical-system branch, a modal reconstruction of a published secular-motion correction, and a forward quantum-motional application domain. None supplies a nonzero ITOF-specific interaction coefficient. The governing quantitative status is therefore

$$\begin{aligned} & \text{QuantitativePhysicalBridgeSpecified} \\ & \wedge \text{HamiltonianPhysicalSystemBranchSpecified} \\ & \wedge \text{BenchmarkRecoveryDemonstrated} \\ & \wedge \text{PublishedMotionalBenchmarkReconstructed} \\ & \wedge \neg \text{ITOFSpecificResidualDerived} \\ & \wedge \neg \text{FoundationSpecificPredictionSeparationDemonstrated}. \end{aligned} \quad (703)$$

The distinction between quantitative physical adequacy and foundational discrimination is preserved. A separating hypothesis that is declared rather than derived is stated in Section 51.

50. Predictive Separation Boundary

50.1 Claim boundary

The quantitative program has established physical benchmark recovery and a Hamiltonian physical-system branch, but neither result supplies a nonzero ITOF-specific residual. The next question is therefore narrower: under what conditions can a physically testable prediction differ from a rival prediction while the V40/F20 temporal definition remains unchanged?

Candidate interactions remain subject to the stated physical and inferential constraints. A candidate does not become a governing V40/F20 postulate merely because it would produce a measurable difference.

50.2 Non-separation under identical physics

Using the governing-premise shorthand $\Gamma_{40}^{\text{fund}}$ fixed in Section 49, let two application branches I and R be defined on the same evaluation domain D . For each branch $J \in \{I, R\}$, define the complete physical-to-observable specification

$$\begin{aligned} \mathfrak{S}_J^{P,D} := & \left(\text{PhysicalTarget}_J, \text{StatePreparation}_J, \text{PhysicalParameters}_J, \text{SystemBoundaries}_J, \right. \\ & \mathcal{B}_J^{\text{in}}, \text{Dyn}_J, \mathcal{B}_J^{\text{out}}, \text{AuxiliaryPhysicalPremises}_J, \\ & \left. \mathcal{B}_{J;P,D}^{\text{obs}}, \text{AcquisitionModel}_J, \text{Calibration}_J, \text{UncertaintyModel}_J \right). \end{aligned} \quad (704)$$

The temporal ontological interpretation is not a component of $\mathfrak{S}_J^{P,D}$. Define

$$\text{SamePhysicalSpecification}_{P,D}(I, R) \iff \mathfrak{S}_I^{P,D} = \mathfrak{S}_R^{P,D}. \quad (705)$$

The predicate therefore holds only when every declared component relevant either to the predicted record or to its empirical evaluation is held fixed across the typed encoding–dynamics–prediction–measurement chain. $\mathbf{y}_J^{P,D}$ denotes the declared predicted observable object: a numerical/vector prediction in a deterministic branch, a probability law or other distributional record object in a stochastic branch, or the declared quantum measurement-statistics object in a quantum branch. Equality of these objects does not assert identity of separately realized stochastic samples or individual measurement outcomes.

Proposition 50.1 (Physical-Prediction Non-Separation). If the only difference between the two branches is the temporal ontological interpretation while $\text{SamePhysicalSpecification}_{P,D}(I, R)$ holds, then no observable prediction separation follows from that ontological difference alone:

$$\text{SamePhysicalSpecification}_{P,D}(I, R) \implies \mathbf{y}_I^{P,D} = \mathbf{y}_R^{P,D}. \quad (706)$$

Consequently,

$$\Delta_{I;R}^{P,D} = 0, \quad \delta_{I;R}^{P,D} = 0, \quad (707)$$

where the second equality applies to the bridge-robust separation margin when the admissible bridge classes contain no physically distinct prediction branch.

Proof. By Eq. (705), the two branches have identical physical target, state preparation, physical parameters, system boundaries, model-input bridge, model dynamics, model-output bridge, auxiliary physical premises, measurement bridge, acquisition model, calibration, and uncertainty model on (P, D) . The identical dynamical and prediction chain evaluated on identical physical inputs therefore gives the same pre-observable prediction in both branches. Applying the identical measurement and acquisition specification gives the same declared predicted observable object—including the same probability law or quantum outcome-statistics object when the bridge is non-deterministic—so $\mathbf{y}_I^{P,D} = \mathbf{y}_R^{P,D}$. This equality is not an assertion that two independent stochastic realizations must return the same sample. Hence $\Delta_{I;R}^{P,D} = 0$. If the admissible bridge classes contain no physically distinct prediction branch, every admissible bridge pair yields zero prediction distance, so the infimum defining $\delta_{I;R}^{P,D}$ is also zero.

This is a dependency proposition. It does not add a dynamical law or assert empirical equivalence between ITOF and every relativistic physical theory.

By contraposition of Eq. (706), an observable prediction separation requires a difference in the complete

physically operative specification:

$$\mathbf{y}_I^{P,D} \neq \mathbf{y}_R^{P,D} \implies \mathfrak{S}_I^{P,D} \neq \mathfrak{S}_R^{P,D}. \quad (708)$$

For a claimed novel physical prediction, the differing component must also be prediction-relevant and independently warranted. This condition is necessary, not sufficient. The V40/F20 temporal definition, CMA, and UCC do not by themselves specify such an additional physically operative difference.

50.3 Minimal stage-referenced preferred-frame candidate

A direct attempt to connect objective common-stage realization to a measurable clock response is to introduce, at application level, a physically specified preferred-stage rest frame. V40/F20 does not identify such a frame with the cosmic microwave background or with any coordinate system. For screening only, let $\mathbf{V}_n$ denote the laboratory velocity relative to a separately specified candidate stage-referenced frame and let $\hat{\mathbf{p}}$ be the physical-system momentum relative to the laboratory apparatus.

For a nonrelativistic physical system in this application-level screening model, define

$$\hat{\mathbf{v}}_n := \mathbf{V}_n + \frac{\hat{\mathbf{p}}}{M}. \quad (709)$$

For a spin-independent, parity-even response constructed only from this relative physical-system velocity and the scalar internal clock energy, the leading nonconstant rotational scalar is parameterized by

$$\hat{H}_{\text{SR}}^{(2)} := \xi_2 \hat{H}_{\text{int}}^{(0)} \frac{\hat{\mathbf{v}}_n^2}{c^2}. \quad (710)$$

Here ξ_2 is a dimensionless physical coupling. It is not fixed by the time definition:

$$\Gamma_{40}^{\text{fund}} \not\Rightarrow (\xi_2 \neq 0). \quad (711)$$

Expanding Eq. (710) gives

$$\hat{H}_{\text{SR}}^{(2)} = \xi_2 \hat{H}_{\text{int}}^{(0)} \left[\frac{V_n^2}{c^2} + \frac{2\mathbf{V}_n \cdot \hat{\mathbf{p}}}{Mc^2} + \frac{\hat{\mathbf{p}}^2}{M^2 c^2} \right]. \quad (712)$$

This decomposition separates a preferred-frame kinematic term, a motion-frame cross term, and a quantum or classical motional-energy term.

50.4 Phenomenological non-uniqueness of the quadratic candidate

A clock-frequency response proportional to V_n^2/c^2 belongs to the same phenomenological class as preferred-frame and Lorentz-symmetry-violation clock tests. Robertson–Mansouri–Sexl clock comparisons already constrain a quadratic time-dilation-violation coefficient at the level $|\alpha| \lesssim 1.1 \times 10^{-8}$ in the normalization used in that test framework [48]. Optical-clock comparisons also constrain orientation-dependent electron-sector Lorentz-violation coefficients at levels reaching approximately 10^{-21} for the reported combinations [49], and more general matter-gravity clock comparisons constrain additional SME coefficient combinations [50].

Therefore Eq. (710) is not a unique ITOF signature. Let $\alpha_{\text{vio}}^{\text{RMS}}$ denote the quadratic time-dilation-violation coefficient in the convention used for the clock-network bound of Ref. [48]. Under the conditional

normalization

$$\xi_2 = \alpha_{\text{vio}}^{\text{RMS}}, \quad (713)$$

the existing clock-network constraint gives the screening bound

$$|\xi_2| \lesssim 1.1 \times 10^{-8}. \quad (714)$$

This is a conditional phenomenological mapping, not an identification of ITOF with the RMS framework and not a claim that ITOF selects the preferred frame used in that analysis. The cited RMS result directly constrains the corresponding leading observable quadratic preferred-frame response under this declared normalization. Extending the same ξ_2 to the motion-frame cross term and the motional $\hat{\mathbf{p}}^2$ term is a model assumption of the screened candidate Hamiltonian, not a separately measured operator-level bound. The quantum-motional estimates below are therefore conditional projections of that candidate under the stated shared-coefficient normalization.

50.5 Conditional quantum-motional scale

For one harmonic motional mode of angular frequency ω_m , the ground state satisfies

$$\left\langle \frac{\hat{\mathbf{p}}^2}{M^2} \right\rangle_0 = \frac{\hbar \omega_m}{2M}. \quad (715)$$

The corresponding magnitude of the quadratic stage-referenced quantum-motional fractional response is bounded by

$$|\delta y_{\text{SR},0}^{(2)}| \leq |\xi_2| \frac{\hbar \omega_m}{2Mc^2}. \quad (716)$$

For a squeezed state with squeeze parameter r , the phase-averaged momentum variance introduces the factor $\cosh(2r)$, giving

$$|\delta y_{\text{SR},\text{sq}}^{(2)}| \leq |\xi_2| \frac{\hbar \omega_m}{2Mc^2} \cosh(2r). \quad (717)$$

Using $^{27}\text{Al}^+$, $\omega_m = 2\pi \times 20\text{MHz}$, $r = 2.26$, and the conditional bound in Eq. (714), the numerical screening values are

$$|\delta y_{\text{SR},0}^{(2)}| \lesssim 1.81 \times 10^{-26}, \quad (718)$$

and

$$|\delta y_{\text{SR},\text{sq}}^{(2)}| \lesssim 8.31 \times 10^{-25}. \quad (719)$$

Thus squeezing does not make this already constrained quadratic candidate a competitive source of a new clock-frequency residual at present optical-clock precision. The conclusion concerns the explicitly screened candidate, not every possible physical extension.

50.6 Higher-order preferred-stage scalar candidates

A formally possible next term is

$$\hat{H}_{\text{SR}}^{(4)} := \xi_4 \hat{H}_{\text{int}}^{(0)} \left(\frac{\hat{\mathbf{v}}_n^2}{c^2} \right)^2. \quad (720)$$

Such a term is not adopted as a prediction. The absence of the lower-order coefficient ξ_2 while $\xi_4 \neq 0$ requires an independent symmetry, selection rule, or microscopic mechanism. V40/F20 supplies none. Moreover, higher-order preferred-frame matter couplings belong generically to broader Lorentz-violation

effective-field-theory searches, where operators of multiple mass dimensions and background tensors are already classified [44], rather than constituting a signature unique to ITOF. The quartic term is therefore retained only as a classification example and is not promoted to the predictive branch.

50.7 Coherence and predictive warrant

A proposed residual depending directly on a state functional such as $\rho_{\text{off-diagonal}}$, a variance, or an expectation value inside the Hamiltonian would in general introduce state-dependent nonlinear dynamics unless it is derived from a state-independent operator and an independently specified physical interaction. Accordingly, a desired quantum-only residual does not by itself yield an admissible linear Hamiltonian interaction. If a term is instead written as an ordinary linear operator, for example through quadratic motional operators associated with an apparatus phase reference, its physical coefficient and phase reference require independent provenance. Such a term is then a generic physical interaction and does not become ITOF-specific by being evaluated on a squeezed state.

50.8 Stage change and complete-population coupling

A different proposal would couple a local system directly to a functional of the complete common-stage population or of $\mathfrak{R}_C(s)$. A schematic expression would be

$$\hat{H}_A^{\text{pop}}(s) = g_A F(\mathfrak{R}_C(s)) \hat{O}_A. \quad (721)$$

CMA does not entail this interaction. Adopting it would add a new physical coupling law connecting one system to information about the complete population, whereas V40/F20 explicitly separates common-stage co-realization from physical interaction, signal accessibility, and causal determination. Such a law would therefore require a separately specified physical mediator or nonlocal dynamics and its own no-signalling, conservation, and causal analysis. It is not a minimal predictive consequence of the present framework.

50.9 Differential structure for foliation couplings

A metric application could introduce a smooth stage-association scalar and a unit timelike normal, then construct expansion, shear, acceleration, or extrinsic-curvature tensors. V40/F20 itself does not require a differentiable stage parameter, a metric on $\mathcal{S}_C^{\text{tot}}$, adjacency, or topology. Consequently, terms depending on derivatives of a foliation field are not derivable from the bare temporal ordered pair. In particular, the definition of time specifies no foliation-derivative structure. The unprovided structures include $\nabla_\mu n_\nu$, $K_{\mu\nu}$, θ_n , and $\sigma_{\mu\nu}$. They remain possible structures of an independently supplied spacetime model, but using them as a new physical interaction would constitute a substantially larger extension than the minimal clock-response program examined here.

50.10 Result of the minimal predictive search

The candidate screening produces the following bounded result:

$$\begin{aligned} & \text{PhysicalPredictionNonSeparationEstablished} \\ & \wedge \text{QuadraticPreferredStageCandidateClassified} \\ & \wedge \text{QuadraticQuantumEnhancementInsufficientUnderExistingBound} \\ & \wedge \text{HigherOrderCandidateNotIndependentlyMotivated} \\ & \wedge \text{StateFunctionalShortcutRejected} \\ & \wedge \text{PopulationWideCausalCouplingNotDerivedFromCMA} \\ & \wedge \text{DifferentiableFoliationCouplingNotDerivedFromBareOrder} \\ & \wedge \neg \text{UniqueITOFSpecificHamiltonianOperatorDerived} . \end{aligned} \tag{722}$$

This is a formal dependency-boundary result. It identifies where a genuinely new prediction must enter: through an independently warranted physical postulate or microscopic mechanism that changes the physical application model while remaining consistent with the established benchmark limits. No such mechanism is manufactured from temporal ontology alone. Section 51 declares one such hypothesis at application level.

51. Where the Geometric Reading Can Be Tested: The Declared Clock-Response Hypothesis

This part states an application hypothesis, H_{CR} . It is not a commitment of ITOF, and its test bears on the Einstein equivalence principle and the geometric reading of clock time, not on the governing commitments of ITOF (Section 51.1).

51.1 Why universality of clock response is the point of contact

In the geometric reading of relativity, an ideal clock reads the proper time along its worldline. The gravitational and kinematic shifts of clock frequencies are then properties of spacetime paths, and they must be the same for every ideal clock, whatever its constitution. Universality of the clock response is constitutive of that reading.

In ITOF, a clock is a physical system whose selected transition responds to the physical factors acting on it. The weak-field shift follows from the mass defect of the clock transition and from the equality of inertial and gravitational mass of its internal energy (Section 49). Universality is therefore a physical fact about how the internal energy of every kind of clock couples to the gravitational factor. It is not a consequence of the definition of time, and it is open to test. A confirmed dependence of the gravitational clock response on the constitution of the clock would contradict the Einstein equivalence principle, which every metric theory of gravity, and with it the geometric reading of clock time, requires, while ITOF would accommodate it as a physical response of the clocks concerned. A null result would not decide between the two readings, because universality is compatible with ITOF, which derives neither the sign nor the size of the dependence. The test is therefore asymmetric: it can refute the Einstein equivalence principle, and it can refute the hypothesis stated below; its bearing on the governing commitments is stated in the claim boundary (Section 45).

51.2 The declared clock-response hypothesis

Definition 51.1 (Constitution-dependent clock response, H_{CR}). The fractional response of a clock of kind X to a difference $\Delta\phi$ of the gravitational potential is

$$\frac{\Delta v_X}{v_X} = (1 + \beta_X) \frac{\Delta\phi}{c^2}, \quad \beta_X = K_{\alpha,X} k_\alpha, \quad (723)$$

where $K_{\alpha,X} = \partial \ln v_X / \partial \ln \alpha$ is the sensitivity of the clock transition to the electromagnetic coupling, calculated independently from atomic structure, and $k_\alpha = (c^2/\alpha) d\alpha/d\phi$ is one coefficient common to all clocks. H_{CR} asserts $k_\alpha \neq 0$.

H_{CR} is an application hypothesis admitted within ITOF and not derived from it. Its form is the standard parametrization of a violation of local position invariance used in the experimental literature [38]. It is not derived from the definition of time, CMA, or UCC, and its failure would leave them untouched (Section 50). Its physical content is that the electromagnetic part of the internal energy of a clock responds to the gravitational factor differently from the rest. Analogous terms for other sectors of the internal energy can be added in the same form; they are not asserted here.

For two clocks X and Y compared at one place while the potential changes, H_{CR} gives

$$\Delta \ln \frac{v_X}{v_Y} = (K_{\alpha,X} - K_{\alpha,Y}) k_\alpha \frac{\Delta\phi}{c^2}, \quad (724)$$

whereas the geometric reading with a universal response requires zero.

The hypothesis is consistent with every established quantitative result of relativity, because the departure from a universal response that it predicts lies within present bounds. It differs from general relativity in a prediction that experiment has not yet decided. Under H_{CR} , the gravitational premise of the mass-defect branch holds for the electromagnetic part of the internal energy only up to the factor $1 + K_{\alpha,X} k_\alpha$; the universal branch is the limit $k_\alpha = 0$. Comparisons of clocks of one kind at two heights test that factor as a whole, and at the present bound it differs from unity by less than 3×10^{-7} for any clock with $|K_{\alpha,X}| \leq 6$, far below the uncertainty of the height benchmarks.

51.3 Predictions fixed before evaluation

The hypothesis makes three predictions whose form is fixed before any evaluation data are examined.

- (P1) *Pattern*. For any two clock pairs compared under the same change of potential, the ratio of their responses is fixed by atomic structure alone:

$$\frac{\Delta \ln(v_X/v_Y)}{\Delta \ln(v_Z/v_W)} = \frac{K_{\alpha,X} - K_{\alpha,Y}}{K_{\alpha,Z} - K_{\alpha,W}}. \quad (725)$$

- (P2) *Sign*. Once the sign of k_α is fixed by one pair, the sign of the response of every other pair is fixed by the sign of $K_{\alpha,X} - K_{\alpha,Y}$.
- (P3) *One coefficient*. The value of k_α obtained from the annual variation of the solar potential, from clocks at different heights, and from clocks in orbit is the same within uncertainty.

The sensitivities used here are $K_{Cs} = 2.83$ for the caesium hyperfine transition, $K_{Sr} = 0.06$ for the strontium optical transition, and $K_{E2} = 1.00$ and $K_{E3} = -5.95$ for the quadrupole and octupole transitions of $^{171}\text{Yb}^+$ [45].

51.4 Present bound and design sensitivity

Over the year, the eccentricity $e \simeq 0.0167$ of the orbit of the Earth modulates the solar potential at the clocks with amplitude

$$\frac{\Delta\phi_\odot}{c^2} \simeq e \frac{GM_\odot}{c^2 r_\oplus} \simeq 1.65 \times 10^{-10}. \quad (726)$$

Comparisons of the two Yb^+ transitions with each other and with caesium over this modulation give $k_\alpha = (14 \pm 11) \times 10^{-9}$ [38], compatible with zero; caesium–rubidium fountain comparisons constrain other combinations of sector coefficients [36].

For the pair E3/Sr, with $K_{\text{E3}} - K_{\text{Sr}} = -6.01$, Eq. (724) predicts an annual modulation of the frequency ratio with amplitude $9.9 \times 10^{-10} |k_\alpha|$: about 1.4×10^{-17} at the central value above and below 3.6×10^{-17} at its two-standard-deviation upper limit. A comparison that resolves this amplitude to 1×10^{-18} over a year is sensitive to $|k_\alpha| \simeq 1 \times 10^{-9}$. Comparisons of clocks at different heights are far less sensitive to this coefficient: one metre of height gives $g\Delta h/c^2 \simeq 1.1 \times 10^{-16}$, so the differential effect is smaller than the solar modulation by a factor of about 10^6 per unit k_α .

51.5 A minimal field model and the equivalence-principle bound

A field model of H_{CR} must state what acts on the clocks. In the minimal model a light scalar field, which ITOF types as a physical factor, couples to the electromagnetic interaction with strength d_e and to matter universally, in the dilaton parametrization of Damour and Donoghue [46]. The field is sourced by the masses of the Sun and the Earth and reaches the clocks and the test bodies where they are. The clocks and the test bodies are physical systems made of matter, and the field, like every other physical factor acting on them, changes their own physical condition: in a clock, its transition frequency; in a test body, its free fall. A shift of a clock frequency is a change of the clock, not of time.

In this model the fine-structure constant at a clock varies with the Newtonian potential U of the sources as $\delta\alpha/\alpha = -D_e U/c^2$, with $D_e = d_g^* d_e$, where d_g^* is the universal dilaton charge of the source; since the gravitational potential is $\phi = -U$, $k_\alpha = D_e$; and two bodies A and B of different composition fall with the Eötvös parameter

$$\eta_{AB} \simeq D_e [Q'_e]_{AB} + D_{\hat{m}} [Q'_{\hat{m}}]_{AB}, \quad Q'_e \simeq 7.7 \times 10^{-4} \frac{Z(Z-1)}{A^{4/3}}, \quad (727)$$

where $[Q]_{AB} = Q_A - Q_B$, Z and A are the atomic and mass numbers, and $D_{\hat{m}}$ is the coupling of the non-electromagnetic sector [46]. H_{CR} is a hypothesis of the electromagnetic sector, so its minimal model has $D_{\hat{m}} = 0$. For titanium and platinum, taken as pure elements, $[Q'_e]_{\text{Ti,Pt}} \simeq -2.0 \times 10^{-3}$, and the MICROSCOPE result $\eta(\text{Ti,Pt}) = [-1.5 \pm 2.3 (\text{stat}) \pm 1.5 (\text{syst})] \times 10^{-15}$ [47], with the uncertainties combined in quadrature, gives

$$k_\alpha = D_e = (0.7 \pm 1.3) \times 10^{-12}, \quad |k_\alpha| < 3.4 \times 10^{-12} \text{ (95\%)}. \quad (728)$$

This is about 10^4 times stronger than present clock comparisons and below the withdrawal threshold of Section 51.6. At this bound the annual amplitude of the E3/Sr ratio would be about 3×10^{-21} , beyond any planned clock comparison. The clock programme of Section 51.4 is therefore not decisive for the minimal field model at present or planned sensitivity; it bears on the phenomenological form of H_{CR} and on field models that evade the equivalence-principle bound.

Consequently, the weak-equivalence-principle bound places k_α in the minimal field form of H_{CR} below the withdrawal threshold; the withdrawal condition was declared for clock comparisons, and the bound

is stated here without changing it. H_{CR} remains open only as a phenomenological hypothesis about the response of clocks, or in a field model in which a non-electromagnetic coupling cancels the titanium–platinum signal; such a cancellation depends on composition, is constrained by tests with other pairs of materials [27], and no such model is specified here. Extending H_{CR} to the other dimensionless constants, the electron-to-proton mass ratio and the quark masses, through transition-dependent sensitivities, as V34/F14 proposed for its double-ratio target, does not escape the bound: in the same model their couplings enter η_{AB} directly. The kinematic channel of that target, a species-dependent response to motion, belongs to the preferred-frame and Lorentz-symmetry class whose clock bounds are stated in Section 50.4. Schiff’s conjecture, that a consistent theory obeying the weak equivalence principle obeys the full principle [27], makes a model with non-universal clock response and no composition-dependent free fall unlikely. The conditions of refutation and withdrawal below continue to apply to clock comparisons, and a field model proposed for H_{CR} must satisfy Eq. (728). None of this bears on the definition of time, CMA, or UCC. That the clocks respond universally is, in ITOF, a matter of observation about physical systems, and the present observations, through this model, support it.

51.6 Conditions of refutation and withdrawal

H_{CR} is refuted if a constitution-dependent clock response is established whose pattern violates Eq. (725) beyond the combined uncertainty, whose sign differs between pairs, or whose coefficient differs between independent determinations. Its withdrawal is staged by attainable sensitivity. It is restricted to $|k_\alpha| < 1 \times 10^{-9}$ when predeclared comparisons establish that bound at 95% confidence without a signal, which requires a resolution of the annual amplitude of about 1×10^{-18} ; it is withdrawn in the electromagnetic sector when they establish $|k_\alpha| < 1 \times 10^{-10}$, which requires about 1×10^{-19} . Either outcome concerns H_{CR} only. The definition of time, CMA, and UCC are not tested by it, and the confrontation with the geometric reading of clock time stated above does not depend on it.

A confirmed signal satisfying (P1)–(P3) would not by itself establish ITOF. It would establish that clock readings are not universal measures of proper time, which ITOF admits and the geometric reading excludes; attribution to H_{CR} would further require that the signal be predicted in sign and pattern before evaluation and that it outperform other non-universal models.

52. Physical Research Program

Quantum fluctuation and entanglement program.

Future work may apply ITOF’s existing type discipline to quantum fluctuation models and entangled physical systems by fixing the physical-system boundary, identifying which attributions of system-specific change are warranted by the applicable quantum dynamics, and separating physical correlations from detector records and reconstruction. This program does not modify the quantum state, Hamiltonian, Born rule, or entanglement correlations by definition. Any ITOF-specific observable difference would require an independently specified physical interaction or bridge that changes a prediction relative to an otherwise identical physical model.

52.1 Foundational completion and open physics

V40/F20 develops a foundational temporal and physical-realization architecture and now includes the domain-specific quantitative mass-defect clock-response branch of Section 49. That benchmark branch does not amount to a complete dynamics of all physical phenomena. Specifying the foundational

architecture does not specify a complete physical theory of nature. In particular, the governing temporal definition (Eq. (11)) does not determine one universal law of system-specific physical change. Likewise, the complete-population common-stage physical-realization profile

$$\mathfrak{R}_C(s) = (\mathcal{S}_{\text{phys}}(s), \mathfrak{X}_C(s), \mathfrak{D}_C(s), \mathfrak{G}_C(s)) \quad (729)$$

does not supply one universal equation transforming one such profile into another.

52.2 Open Problem 1: Domain-specific dynamics

For a declared class of physical systems $\mathcal{A}$ not already covered by the mass-defect clock-response benchmark, or for physical effects beyond that branch's declared validity domain, a major application problem is to derive or independently warrant a physical model

$$M_{\mathcal{A}} \quad (730)$$

with a sufficiently explicit typed application chain connecting system-specific physical inputs to model realizations, predictions, and records.

The required route is:

$$\begin{aligned} \text{DeclaredPhysicalSystems} &\longrightarrow \text{TypedPhysicalInputs} \\ &\longrightarrow \text{ModelEncoding} \\ &\longrightarrow \text{PhysicalDynamics} \\ &\longrightarrow \text{AdvancePrediction} \\ &\longrightarrow \text{MeasurementAndAcquisition} \\ &\longrightarrow \text{PhysicalRecord}. \end{aligned} \quad (731)$$

The response law must be established independently of the ITOF temporal definition. No equation is accepted merely because it produces a desired interpretation of time.

52.3 Open Problem 2: Realization across system levels

The hierarchy relation

$$A \triangleleft_{\kappa, s} B \quad (732)$$

makes cross-level questions explicit without answering them universally.

Future physical work may investigate:

$$\begin{aligned} &\text{how subsystem change contributes to composite change,} \\ &\text{how composite constraints affect constituent change,} \\ &\text{how causal contributions are redistributed under changing boundaries,} \\ &\text{and how new numerical identities emerge from physical reorganization.} \end{aligned} \quad (733)$$

Any quantitative cross-level rule requires its own physical derivation. Composition alone is insufficient.

52.4 Open Problem 3: Population transformation

The stage-pair population descriptor

$$\mathfrak{P}_C^{\text{pop}}(r, s) \quad (734)$$

provides a general identity-level classification of persistence, formation, ending, and intermediate-only realization.

Future work may connect these sets to specific physical models of:

$$\begin{aligned} &\text{formation, decay, fusion, fission, reorganization,} \\ &\text{biological formation and ending, astrophysical transformation,} \\ &\text{chemical transformation, and other identity-changing physical processes.} \end{aligned} \quad (735)$$

No universal law of population conservation, one-to-one successorship, or successor nonemptiness is presupposed. An actual ending may produce zero, one, or several direct successors according to the physically warranted transformation and identity criteria.

52.5 Open Problem 4: Domain-specific directionality

The criterion-indexed descriptor $\mathfrak{A}_{A,\alpha}$ permits physical “arrows” to be studied without identifying them with time. Domain-specific applications must determine which state variables and comparison relations are physically warranted, whether alignment holds over a stated domain, and whether plateaus, recurrence, or criterion-relative reversals occur. No universal thermodynamic, developmental, decay-statistical, memory, record, or computational arrow is inferred from UCC alone.

52.6 Open Problem 5: Operational metrics

V40/F20 defines the general operational architecture

$$m_P = \mathcal{M}_P^{\text{op}}(r_1, \dots, r_n; c_P). \quad (736)$$

A major future task is to classify physically important metric constructions according to:

$$\begin{aligned} &\text{record source, calibration, comparison rule, model dependence,} \\ &\text{physical sensitivity, systematic effects, uncertainty, and predictive role.} \end{aligned} \quad (737)$$

The purpose is not to eliminate metric science.

It is to identify precisely what each metric measures or represents without transferring that quantity into the definition of time. The order-representation result in Eq. (38) further requires that any claimed metric interval specify the additional physical or mathematical structure that fixes its scale beyond bare earlier–later order.

52.7 Open Problem 6: Physical-system-specific residual physics

The quantitative program in Section 49 now includes both weak-field gravity and an independently sourced trapped-ion Hamiltonian branch. It also reconstructs the published 2025 six-mode secular-motion correction. These results show that clock-system motion and confinement can be treated quantitatively without redefining time, but the established Hamiltonian does not itself generate an ITOF-specific residual.

Any stronger physical-system-specific program must therefore identify a physical interaction beyond the declared base Hamiltonian and specify

$$\mathfrak{M}_C^X = \left(\text{ClockSystemBoundary}, \hat{H}_{\text{base}}, \lambda_X \hat{O}_X, \text{StatePreparation}, \right. \\ \left. \text{ParameterProvenance}, \text{AcquisitionModel}, \right. \\ \left. \text{UncertaintyStructure}, \text{PredictionCriterion} \right). \quad (738)$$

The additional operator and coupling must be physically derived or independently warranted. A nonzero value may not be inferred from the ITOF temporal definition, CMA, UCC, or disagreement with a rival temporal ontology.

The quantum-motional branch of Eqs. (700)–(702) provides a near-term experimental domain for testing internal–external quantum clock dynamics while preserving this attribution boundary. The minimal candidate screening in Section 50 additionally shows that the simplest quadratic preferred-stage clock coupling is neither unique to ITOF nor rescued by squeezed-state enhancement under the existing clock-network bound. A stronger residual therefore requires a physically new mechanism rather than a relabeling of an already constrained preferred-frame coefficient.

52.8 Open Problem 7: Prediction separation

A foundation-sensitive empirical program requires a domain D^* in which independently specified ITOF and relativistic application branches remain separated after the admissible bridge freedom has been propagated. In the notation of Section 37, the target condition is:

$$\delta_{I:R}^{P,D^*} > \eta_*, \quad (739)$$

with the bridge classes, covariance construction, and threshold fixed independently of the evaluation outcome. Such a separation creates empirical discriminatory potential that cannot be removed merely by choosing another already-admissible bridge realization.

Without it, foundational disagreement yields no observable discrimination. The declared hypothesis H_{CR} (Section 51.2) supplies one candidate domain: comparisons of clocks of different constitution over a change of gravitational potential. Its realization at the required sensitivity remains one of the principal physical tasks of the framework.

52.9 Open Problem 8: Attribution to foundational commitments

Even where an ITOF-admissible application model and a relativistic model make distinct predictions, further work is required to determine whether the difference originates in:

a foundational temporal commitment,
 a physical response law,
 a parameter choice,
 an approximation,
 a measurement bridge,
 or another auxiliary physical assumption.

(740)

Therefore an observable separation between models does not by itself identify a foundational attribution. The attribution problem is a distinct stage of theory testing.

52.10 Open Problem 9: Empirical access to global stages

V40/F20 contains two distinct empirical burdens. UCC can be challenged by positive physical warrant that any physical system of the universe is completely physically non-changing at a member of its identity range:

$$\exists A \in \mathcal{S}_{\text{phys}}(s) \text{ NC}_A^{\text{phys}}(s). \quad (741)$$

Because CMA and UCC are independent commitments, such a warranted counterinstance refutes UCC only; it does not by itself refute CMA. CMA is challenged only by a warranted private stage or private ordering (Eq. (656)); whether such a finding is empirically accessible is a separate question. Coordinate disagreement, clock-rate differences, signal delay, frame-dependent synchronization, or finite observational silence do not by themselves challenge either burden.

52.11 Open Problem 10: Class-specific identity

Empirical tests of CMA, AFB, UEIE, persistence, ending, and population transformation require domain-specific physical-system and numerical-identity criteria. Future work must construct physically warranted class-specific profiles

$$\mathfrak{Q}_{\mathcal{K}}^{\text{id}} = (\kappa_{\text{sys}}, \kappa_{\text{boundary}}, \kappa_{\text{id}}, \kappa_{\text{persist}}, \kappa_{\text{form}}, \kappa_{\text{end}})_{\mathcal{K}} \quad (742)$$

that distinguish continued numerical identity, functional alteration, component replacement, formation of a new identity, ending of an old identity, and successor production. For a given protocol these criteria must satisfy the prospective admissibility discipline of Eq. (193); V40/F20 does not supply one universal empirical identity criterion for all physical-system classes.

52.12 Open Problem 11: Complete cosmological extent

Equation (17) defines a possible non-terminating cosmological extension condition, but V40/F20 does not assert that the actual universe satisfies it. The scientific problem is first to determine what physically warranted evidence or cosmological theory could bear on whether realized physical change has a greatest future stage at all. Only if a specific non-termination hypothesis is adopted does the further question arise of whether a complete physical bridge can connect that hypothesis to discriminating observables or predictions.

A genuine empirical discriminator requires a complete physical-to-observable specification $\mathfrak{P}$ such that

$$P_{\text{TOF}}(\mathcal{O} \mid \mathfrak{P}) \neq P_{\text{alt}}(\mathcal{O} \mid \mathfrak{P}). \quad (743)$$

If the complete physical specification is identical and yields the same observable distribution, the ontological difference alone does not generate a test:

$$P_{\text{TOF}}(\mathcal{O} \mid \mathfrak{P}) = P_{\text{alt}}(\mathcal{O} \mid \mathfrak{P}) \implies \neg \text{PredictionSeparation}_{\mathfrak{P}}. \quad (744)$$

No temporal definition, stage symbol, CMA, or UCC supplies the required physical coupling or observable map by itself. Likewise, non-detection of change is not cessation of physical change. A finite observational gap, insensitive observable, threshold limitation, or unmeasured degree of freedom cannot be promoted into proof that the cosmic succession has stopped.

52.13 Limits of the research program

An open problem is neither a current failure of ITOF nor a problem already solved by the foundational definition.

53. Conclusion

V40/F20 defines time as the invariant universal cosmic extension: the objective, fixed, and non-reversed succession of the common stages of physical change of all physical systems in the universe (Eq. (11)). Invariance means that the succession is non-reversed and that no stage in it is empty of change or static. The numerals of the Ordinal Succession convention are a formal expression of that fixed succession and are not added; stage 0 is the beginning of the stages of change, at the formation and genesis of the universe. A stage expresses the change realized at it; it is not a container. Time is one throughout the universe; it does not cause physical change, and physical change does not produce it.

CMA states the unity of the stages of change for all physical systems of the universe: every one of them realizes its changes on the one common succession, with no private stage or private ordering, so that all of them realized at a stage are objectively co-present there (Eq. (72)). UCC, the postulate of change, states that physical change continues without interruption in every physical system of the universe, without exception, at every member of its identity range (Eq. (83)). The two are logically independent, and their conjunction is the full content of the cosmic moment: no stage of the universe is empty, static, or private (Eq. (104)). Co-presence is not synchronization, signal access, coordinate equality, interaction, or causal mechanism.

The universe expresses the totality of physical systems and physical factors; it is neither a container nor one system. Physical change has three classes of causal contributors — the internal structure and properties of the system, influencing physical systems, and non-system physical factors — which act together and combine qualitatively; the realized effect depends on the responsiveness of the receiving system and is supportive or adverse only relative to a declared criterion. Each system has its own physical history through the same common stages; at its ending, the retained result of its accumulated change and its final change are realized together at one stage, and the ending need not produce a successor.

The succession has a first stage, adopted as the Cosmic Origin postulate on the evidence of an early hot and dense state. Its non-termination remains a revisable hypothesis, because current evidence establishes neither a terminal stage nor an unbounded future; the symbol ∞ is therefore conditional.

Clocks, observers, apparatus, records, and laboratories are physical systems of the universe and change under UCC. A difference between their records is a physical result in physical systems under declared conditions, not a change, transfer, or deformation of time. Clock readings, proper-time functionals, coordinates, metric intervals, and geometric dimensions do not become time through successful application, and every established quantitative relativistic result is retained as a relation among records of physical systems. Conversely, time, CMA, UCC, and the non-termination hypothesis supply no Hamiltonian, coupling, or observable residual: under identical complete physical-to-observable specifications, ontological difference alone creates no prediction separation, while UCC is exposed to evidence through its countercondition, complete physical non-change, under the same channel physics that standard theory already tests. A separation enters only through a declared physical hypothesis; ITOF admits the constitution-dependent clock response H_{CR} , an application hypothesis under which the gravitational response of a clock depends on its constitution, a dependence that the geometric reading of clock time excludes (Section 51.2).

The governing V40/F20 core is therefore

$$\begin{aligned}
T_{\text{ITOF}} &= (\mathcal{S}_C^{\text{tot}}, \prec_C) \quad \text{subject to} \quad \mathfrak{T}_C(\mathcal{S}_C^{\text{tot}}, \prec_C), \\
\text{CSPP} &\iff \forall s \in \mathcal{S}_C^{\text{tot}} : \mathcal{S}_{\text{phys}}(s) \neq \emptyset \quad (\text{derived from } \mathfrak{T}_C), \\
\text{CMA} &\iff \forall A \in \mathcal{U}_{\text{phys}} : \mathcal{W}_A \subseteq \mathcal{S}_C^{\text{tot}} \wedge \triangleleft_A = \prec_C|_{\mathcal{W}_A}, \\
\text{UCC} &\iff \forall A \in \mathcal{U}_{\text{phys}} \forall s \in I_A : \text{PhysReal}_A^+(s).
\end{aligned} \tag{745}$$

Every stage has physical content because it is a common stage of the physical systems of the universe at which every one of them changes (Eq. (104)); scientific attribution of a particular realization remains subject to independent physical warrant. Strict ordering and the nontrivial earlier–later pair provide order structure and non-degeneracy. Independently sourced physics supplies dynamics, causal attribution, and empirical bridges.

A. Statement-Status and Dependency Register

Defined constructions and their types are given in Appendix B.

Table 5: Logical status and direct role of principal V40/F20 statements and constructions.

Item	Status	Direct dependency or role
$\mathcal{S}_C^{\text{tot}}$	Primitive formal cosmic-stage domain	Formal domain of the common stages of the physical systems of the universe in the one universal cosmic succession. A stage expresses the change realized at it; it is not a container, and neither a written stage symbol nor the member it designates is a further physical or ontic stage object behind that change.

Item	Status	Direct dependency or role
One-global-stage domain architecture	Foundational formal architecture	One formal cosmic-stage domain; every I_A is its restriction. Exclusion of private per-system successions, followed by mapping or synchronization, is the content of CMA, not of the domain definition, strict ordering, synchronization, clock agreement, or coordinate choice.
$\prec_C$	Primitive ordering relation with governing semantic designation	The one objective earlier–later relation on $\mathcal{S}_C^{\text{tot}}$. Its earlier–later orientation is designated by ITOF semantics; Strict Cosmic Ordering constrains that designated relation rather than selecting it over its inverse.
Strict Cosmic Ordering	Foundational axiom	Requires $\prec_C$ to be a strict total order on $\mathcal{S}_C^{\text{tot}}$; yields asymmetry and total comparability but does not itself supply the semantic orientation.
NonTerminating CosmicSuccession _C	Revisable cosmological hypothesis	Requires every stage to have a later stage. It is non-metric and order-theoretic, but V40/F20 does not assume that the complete future satisfies it; all results using it are conditional.
Temporal-extension admissibility	Defined temporal-admissibility condition	Requires a nonempty formal cosmic-stage domain, Strict Cosmic Ordering, every member a common stage of the physical systems of the universe, and a nontrivial earlier–later pair. The last requirement excludes a succession-free singleton but neither asserts nor denies a greatest future stage. Temporal constitution neither entails CMA nor entails UCC.
Order-representation non-metricity	Derived mathematical result	Any supplied order representation remains non-unique under strictly increasing reparameterization; the ordering alone does not determine a canonical scalar interval magnitude.

Item	Status	Direct dependency or role
T_{ITOF}	Governing definition	$T_{\text{ITOF}} := \mathcal{E}_C := (\mathcal{S}_C^{\text{tot}}, \prec_C)$: the invariant universal cosmic extension, the objective, fixed, and non-reversed succession of the common stages of physical change of all physical systems in the universe; one throughout the universe. It is not a container, physical stage object, or causal agent. Unlimited future extent is not built into the definition.
Ordinal Succession	Representation convention (Definition 2.2)	$0 \prec_C 1 \prec_C 2 \prec_C 3 \prec_C 4 \prec_C \dots \infty$ (conditional): stage 0 is the beginning of the stages of change, at the formation and genesis of the universe, with no date fixed for that beginning; the numerals are a formal expression of the fixed succession of the stages and are not added; no stage, named or lying between two named stages, is empty of change or static; ∞ is not a stage and is conditional.
CosmicOrigin	Independent cosmological postulate, anchored in the observed early hot and dense state, which does not by itself establish a first stage	$\mathcal{S}_C^{\text{tot}}$ has one unique least member, the stage at which change in the universe begins, with the formation and genesis of the universe. Its contrary is established evidence of systems realized earlier. Non-termination neither entails nor is entailed by it.
$\text{CosmicCoPresence}_C(P; s)$	Defined ontological relation (Eq. (70))	Each member of P realizes s as a member of the one common succession, with no private stage or ordering. Stronger than population membership; not synchronization, signal access, interaction, or coordinate equality.
CSPP	Derived population principle	Records the consequence $\mathcal{S}_{\text{phys}}(s) \neq \emptyset$ for every $s \in \mathcal{S}_C^{\text{tot}}$, because temporal constitution requires every stage to be a common stage of the physical systems of the universe (Eq. (15)). It is not an additional independent postulate.

Item	Status	Direct dependency or role
CMA	Independent governing foundational axiom	Every qualified system's realization succession is a segment of the one common succession: no private stage or ordering. Yields objective co-presence of the complete then-realized population at every stage. It does not assert complete all-system change; that burden belongs to UCC.
UCC	Independent foundational physical postulate	Physical change continues without interruption in every physical system of the universe, without exception, throughout its realized identity range. Equivalently, for every member $s \in \mathcal{S}_C^{\text{tot}}$, every qualified system whose identity range contains s realizes actual physical change. UCC is not the non-termination hypothesis and supplies no universal scalar rate or magnitude.
Complete physical non-change	Defined qualitative contrary predicate	Equivalent to $\neg \text{PhysReal}_A^+(s)$ for $s \in I_A$. Application of this contrary requires positive physical warrant under the applicable theory/model and declared system boundary and granularity that no physically constitutive change admissible to the claim is realized at that pair. Selected-observable equality or finite non-detection is insufficient. A warranted instance is the direct change countercondition to UCC; it is not by itself a countercondition to CMA.
Δ_A^{phys}	Typed physical-change map	$\Delta_A^{\text{phys}} : I_A^\Delta \rightarrow \Xi_A$; preserves system-specific change content and countermodel typing.
$\text{GCN}_C(s)$	Defined stage-relative null predicate	Holds exactly when $\mathcal{B}_\Delta(s) = \emptyset$. Excluded at every stage by UCC together with the common-stage condition (Eq. (108)); under UCC every then-realized qualified physical system changes there. It does not denote a universal numerical zero.
$X_A : I_A \rightarrow \Omega_A$	Defined physical-state map	System-specific physical state realized at each member of I_A .
CRP	Independent foundational physical postulate	Requires nonempty actual physical causal realization for every actual system-specific physical change.

Item	Status	Direct dependency or role
Stage-local causation	Consequence of the causal typing	Every actual physical contributor to a change is realized at the stage of that change; its physical content lies in the typing conditions of influencing systems and factors, which carry the stated contrary (Eq. (133)); no contribution passes from one stage to another.
Influence through a pathway	Typing condition of external influence	An external influence, from a near or a distant system or factor, contributes to the change of a system as it reaches the system, by contact or through a physical pathway (Eq. (136)).
CMA–UCC–CRP stage-relative realization consequence	Derived consequence	Under temporal constitution together with CMA, UCC, and CRP, every stage is nonempty, satisfies the local Stage-to-Change condition, and has nonempty actual causal realization for every qualified member; no additional realization predicate is introduced.
Cross-Level Non-Transfer	V40 physical/type principle	Composition alone does not transfer state, physical-change content, causal determination, or numerical identity across system levels.
Identity-Realization Convexity	Independent foundational identity postulate	Prevents an internal gap in one numerical identity range.
AFB	Independent identity postulate	Requires one unique least member for every qualified identity range within the single common cosmic-stage domain; does not introduce a private stage or a change-onset claim.
$\Omega_{\mathcal{K}}^{\text{id}}$	V40/F20 class-indexed application-admissibility formalization	Six-component current profile governing system class, boundary, numerical identity, persistence, formation, and ending criteria where relevant; not a universal identity criterion and not a temporal component.
Historical Physical Accumulation	Historical designation	Earlier actually realized system-specific physical change; not an arithmetic sum or causal-source class.
Present Cumulative Physical Resultant	Defined present-resultant predicate	States that retained or transformed earlier effects remain physically embodied in the present developed condition.

Item	Status	Direct dependency or role
$\text{End}_A(e)$	Defined identity-ending predicate	Physical identity-ending transformation at the final member of numerical identity A .
PIECP	Independent ending-specific causal postulate	Requires at least one actual causal contributor to contribute specifically to the identity-ending transformation.
UEIE	Optional universal lifecycle postulate	Requires eventual identity ending together with nonempty strict pre-ending identity history. Its quantifier ranges over the governing ontic physical-system totality $\mathcal{U}_{\text{phys}}$. Empirical attribution of ending within any declared class still requires an independently warranted class-specific numerical-identity criterion; no universal empirical identity criterion is supplied.
$\text{SuccAt}(A, B; e)$	Defined direct-successor relation	New numerical identity B is physically produced through the ending transformation of A at e .
$\mathfrak{S}^+(A, e)$	Defined successor family	Direct successors physically produced through the ending of A at e ; the set may be empty when the ending produces no new qualified identity.
Cross-system comparison maps	Application-level defined constructions	Map system-specific physical quantities into a declared common comparison space without identifying the underlying physical quantities.
Mathematical-form-neutral dynamics	Application architecture	Uses a typed internal dynamics descriptor and separates physical encoding, dynamics, model-to-prediction mapping, and measurement. It permits independently warranted deterministic, stochastic, quantum, field, geometrical, or other model classes without defining one universal dynamics.

Item	Status	Direct dependency or role
Change-Stage Restraint	Epistemic principle	Observation may warrant manifestation at some actual common cosmic change stage without identifying the stage or its place in the global order. The source, apparatus, record-bearing systems, observer, and laboratory/reference systems remain within the changing physical domain; UCC contributes this physical non-stasis but does not alone prove non-invertibility of an observation map.
Foundational empirical bridge	V40 methodological bridge architecture	Records the independently specified physical, observational, auxiliary, uncertainty, and attribution conditions connecting a foundational commitment to an observable and to any subsequent foundation-sensitive inference.
Foundational Empirical Attribution Principle	Methodological inferential principle	Restricts foundational inference to cases with independent bridges, frozen protocol, identifiable prediction separation, valid uncertainty, and controlled alternative attribution.
$\mathfrak{Q}_{MD}$	Application-level quantitative physical-model branch	Independently sourced mass-defect and trapped-ion clock-response program used for benchmark recovery and forward physical modeling; not a temporal component and not by itself a foundation-specific prediction.
Same physical specification	Defined application-comparison predicate	Holds exactly when the complete physically operative target-to-observable specifications $\mathfrak{S}_I^{P,D}$ and $\mathfrak{S}_R^{P,D}$ are equal; temporal ontological interpretation is not a component of that tuple.
Physical-Prediction Non-Separation under Identical Physical-to-Observable Specification	Derived dependency/identifiability proposition	From equality of the complete physical-to-observable specifications, identical prediction rules and observable maps yield identical predicted observables. The result is a dependency boundary, not a new dynamical law.
NTP	Foundational type principle	Mathematical consistency, physical applicability, and predictive or operational success do not by themselves transfer temporal identity.

Item	Status	Direct dependency or role
Mutual independence of CMA and UCC (Prop. 5.4)	Derived result, by explicit countermodel	Each countermodel satisfies every other governing postulate; neither axiom is recoverable from the other.
No change-void stage (Eq. (104))	Derived result, from UCC with the common-stage condition	Stagewise content of UCC; nonempty population is supplied by the common-stage condition.
Arguments 43.1–43.3 and Prop. 43.4	Commitment distinction; derived result	Distinguish $\prec_C$ from relativistic geometric temporal quantities, including global time functions and cosmological time, by invariance domain, intra-/inter-stage type, or quantity type; the constitution-criterion argument concerns the eternalist interpretation only.
Dimension-admission criterion (Def. 43.6, Prop. 43.7)	Foundational type criterion / derived result	Blocks inference from mathematical consistency of a coordinate or higher dimension to its physical reality; applied to x^0 and to higher-dimensional geometric representations.

B. Governing Symbol and Type Register

Table 6: Core V40/F20 notation and governing meanings.

Symbol	Type	Meaning
T_{ITOF}	Temporal referent	Time in ITOF V40/F20.
$\mathcal{E}_C$	Temporal referent	The same one universal non-metric cosmic extension denoted by T_{ITOF} .
$\mathcal{S}_C^{\text{tot}}$	Formal cosmic-stage domain	Formal domain of the common stages of the physical systems of the universe in the one universal cosmic succession. Under UCC every member is a stage of change of all physical systems realized there; membership does not analytically entail CMA or UCC.
$\prec_C$	Strict order	Designated governing objective earlier–later relation; strict-order properties are imposed separately.

Symbol	Type	Meaning
l	Order-representation map	Optional injective representation of the cosmic order in a declared ordered label domain; its labels and numerical intervals are not time.
$\text{NonTerminatingCosmicSuccession}_C$	Conditional cosmological condition	If adopted for a cosmological model, every cosmic stage has a later stage; formally this is absence of a greatest member. V40/F20 does not assume that the complete future satisfies this condition.
s_C^0	Boundary symbol	Unique least cosmic stage, fixed by Cosmic Origin.
$\mathcal{U}_C^{\text{phys}}$	Cosmic physical totality	Physical universe as the typed ontological totality of physical-system identities and physically realized physical factors; not a physical container and not one numerical physical-system identity.
$\mathfrak{F}_{\text{phys}}$	Physical-factor totality	Physically realized physical-factor reality, type-distinct from numerical physical-system identity; every factor has stage support in $\mathcal{S}_C^{\text{tot}}$, while actual influence on a particular system is represented separately.
$\text{FactorRealizedAt}(F, s)$	Stage-relative factor realization	Records physical realization of non-system factor F at s , separately from any warranted causal-influence relation.
$\mathfrak{F}_{\text{phys}}(s)$	Stage-relative physical-factor population	Physical factors realized at stage s , irrespective of whether they influence a particular system.
$\mathcal{U}_C^{\text{phys}}(s)$	Stage-relative cosmic physical totality	Typed union of the physical-system population and physical-factor population realized at s ; not a container or a physical-system identity.
$\mathfrak{F}_{\text{phys}}^{\text{inf}}$	Influencing physical-factor domain	Those members of the physical-factor totality that actually influence at least one realized system–stage pair; attribution of a particular influence requires applicable physical warrant.
$\mathcal{U}_{\text{phys}}$	Physical-system totality	Governing totality of objectively realized physical-system identities having at least one realized member in $\mathcal{S}_C^{\text{tot}}$. Application schemes Ω select warranted subdomains for identification, tracking, or testing but do not create this totality.

Symbol	Type	Meaning
I_A	Identity range	Members of $\mathcal{S}_C^{\text{tot}}$ at which numerical identity A is physically realized. It is an identity-bounded restriction of the one domain, not a private time.
I_A^Δ	Actual-change subset	Members of I_A at which actual system-specific physical change is realized. Under UCC it equals I_A .
$\mathcal{S}_{\text{phys}}(s)$	Population	Complete qualified physical-system population realized at s . It is obtained from memberwise identity-stage incidence.
$\mathfrak{T}_C$	Foundational-definition symbol	Temporal constitution, $\text{TemporalConstitution}_C$: the defining predicate of Eq. (22), fixing a nonempty, strictly ordered, non-degenerate domain of common stages of the physical systems of the universe. Abbreviated for legibility in long equations; not itself CMA, UCC, or CSPP.
CSPP	Derived-principle symbol	Cosmic Change-Stage Population Principle; a consequence of the revised the common-stage condition, retained as a useful named population result.
CMA	Axiom symbol	Cosmic Moment Axiom (Eq. (72)).
UCC	Foundational postulate symbol	Universal Change Continuity; the independent system-specific physical-change postulate requiring actual physical change throughout every realized identity range.
CommonChange $\text{StageRole}_C(s)$	Defined stage-role predicate	Full-theory role-name for a common stage of the universe whose population is co-present under CMA and fully covered by UCC.
$\text{PhysReal}_A^+(s)$	Physical relation	Actual system-specific physical change realized by A at s . Attribution requires independent physical warrant under the applicable theory/model and a declared system boundary and granularity; stage membership or detection alone does not supply that warrant.
Ξ_A	Change-content type	System-specific codomain for physical-change content.
$\Delta_A^{\text{phys}}(s)$	Physical-change content	System-specific physical content of change for an actual-change pair.

Symbol	Type	Meaning
$\mathcal{B}_\Delta(s)$	Population subset	Change-realizing members of the stage-relative population. Its equality with the entire population at every s is equivalent to UCC.
$\mathcal{D}_C(s)$	Dependent profile	System-indexed family of physical-change contents.
$\text{SCB}_C(s)$	Defined foundational bridge	Defined local conjunction of co-presence at the stage and UCC complete-population actual-change coverage. At every stage it is equivalent to $\text{CMA} \wedge \text{UCC}$ under the domain condition; it is not an axiom, cause, synchronization rule, or observation bridge.
Ω_A	Physical state space	Declared state space appropriate to system A .
$X_A(s)$	Physical state	State of system A realized at s .
$\mathfrak{X}_C(s)$	V40 state profile	Complete-population dependent family of system-specific physical states.
$\mathfrak{C}_A(s)$	Causal profile	Internal physical contributors and external physical-influence sources. The external set contains influencing physical systems and influencing physical factors; each source retains its physical type.
$\mathcal{C}_A^{\text{ext}}(s)$	Defined external-influence set	External physical-influence sources applicable to physical system A at s , formed by the union of influencing physical systems and influencing physical factors.
System-specific external response	Application-level characterization	Characterizes, where physically warranted, the magnitude, amount or extent, type, direction, or result of physical change actually realized under a declared external-influence attribution. It is prose-level application terminology, not an intermediate causal layer, universal response variable, causal-source class, or temporal law.
Criterion-relative external impact	Application-level classification	Supportive/beneficial, adverse/harmful, mixed, or neutral impact is assigned only relative to a declared physical or functional criterion; unresolved is an epistemic status rather than an additional physical impact type.
$\mathcal{C}_A^{\text{act}}(s)$	Actual causal set	Union of the actual physical causal contributors for the change of A at s .
$\mathfrak{G}_C(s)$	V40 causal profile	Population-indexed family of actual causal sets.

Symbol	Type	Meaning
$\mathfrak{R}_C(s)$	V40 realization profile	Population, physical-state, physical-change, and causal-realization architecture at common cosmic change stage s . It does not become a temporal object.
$\mathfrak{R}_C^{[M]}(s)$	Relational augmentation	Model-relative enrichment of the complete-population realization profile by additional independently warranted physical relations. It changes no temporal identity and claims no exhaustive physical description.
$A \triangleleft_{\kappa,s} B$	Composition relation	Qualified physical-system identity A is physically realized as a proper constituent or subsystem of B under criterion κ at s . The relation does not itself provide cross-level dynamics.
$\mathfrak{K}_C(s)$	Composition profile	Collection of warranted stage-relative constituent relations.
f_A	Formation boundary	Unique least member of I_A under AFB within the common cosmic-stage domain; not a private stage or a marker for the beginning of physical change.
e_A	Ending boundary	Identity-ending member where an ending exists.
$\mathcal{H}_A$	History representation	Identity domain, restricted common order, state map, and physical-change-content map. It is not a private time.
$\mathcal{P}_{r,s}$	Population set	Identities realized at both r and s .
$\mathcal{N}_{r \rightarrow s}$	Population set	Identities absent at r and realized at s .
$\mathcal{L}_{r \rightarrow s}$	Population set	Identities realized at r and absent at s .
$\mathcal{T}_{r,s}$	Population set	Identities realized only at one or more members strictly between selected endpoints r and s .
$\text{Cmp}_{AB,P}(s)$	Comparison output	Mapped comparison of declared system-specific physical-change quantities.
$\mathfrak{A}_{A,\alpha}$	Physical-directionality descriptor	Criterion-indexed triple $(\mathcal{Y}_{A,\alpha}, Y_{A,\alpha}, \preceq_{A,\alpha})$ used to represent a physically warranted directional regularity over I_A . It may align with the cosmic order without becoming that order or a second time.

Symbol	Type	Meaning
$\text{ArrowAligned}_{A,\alpha}(J)$	Directionality predicate	The selected physical descriptor is nondecreasing according to its declared criterion relation over $J \subseteq I_A$; not a second temporal ordering.
λ_M	Model parameter	Declared evolution or representation parameter of application model M ; not automatically time.
$\mathcal{M}_P^{\text{op}}$	Operational map	Maps records and calibration structures to an operational metric quantity. Its output remains type-distinct from time.
r	Physical record	Physically produced record in an acquisition chain.
J_r^{phys}	Physical support set	Common cosmic change stages whose physical realizations contribute to production of record r .
$\mathfrak{P}^*$	Test protocol	Predeclared quantitative test architecture.
$\mathfrak{B}_F^{P,D}$	Empirical bridge tuple	Physical, observational, auxiliary, uncertainty, and attribution conditions connecting foundational commitment F to empirical evaluation.
NTP	Type principle	Generalized Non-Transfer Principle.
$\mathcal{Q}_{\text{rel}}$	External quantity family	Declared relativistic quantities and representations examined for temporal nonidentity.
$\mathfrak{B}_{I:R}^{P,D}$	Comparison bridge	ITOF–relativistic observable comparison architecture.
$\delta_{I:R}^{P,D}$	Robust separation margin	Infimum common-observable prediction separation over independently admissible bridge classes for the two comparison branches.

C. Formal Models and Dependencies

C.1 Logical status of formal model constructions

Formal model constructions test satisfiability, definitional conservativity, and declared logical dependencies; they are not empirical cosmological models or microscopic dynamics. For commitments Γ and proposition P ,

$$\text{Model}[\Gamma \wedge \neg P] \implies \Gamma \not\models P. \quad (746)$$

Conversely, the existence of a formal model does not make it physically realized.

C.2 Typed realization-core signature

Use the primitive typed language

$$\begin{aligned}\Sigma_{40}^{\text{primitive}} &:= \langle P, S_C, U_{\text{phys}}; \prec_C, \triangleleft, \text{ExistsAs}, \text{PhysReal}^+ \rangle, & S_C &\subseteq P, \\ \prec_C &\subseteq S_C \times S_C, & \triangleleft &\subseteq U_{\text{phys}} \times P \times P, \\ \text{ExistsAs} &\subseteq U_{\text{phys}} \times P, & \text{PhysReal}^+ &\subseteq U_{\text{phys}} \times P.\end{aligned}\tag{747}$$

Here $\mathcal{W}_A = \{x \in P \mid \text{ExistsAs}(A, x)\}$ and $\triangleleft_A$ is the section of $\triangleleft$ at A . The objects I_A , I_A^Δ , $\mathcal{S}_{\text{phys}}(s)$, $\mathcal{B}_\Delta(s)$, $\text{CommonStage}_C(s)$, $\text{RealizedChangeStage}_C(s)$, and $\text{CosmicCoPresence}_C(P; s)$ are defined constructions. Identity-stage incidence determines which qualified identities are represented at s ; co-presence additionally requires that each realization succession be a segment of $(\mathcal{S}_C^{\text{tot}}, \prec_C)$, which CMA asserts for every system.

C.3 Domain admissibility

$$\text{DomainAdmissible}_{40} \iff \forall A \in \mathcal{U}_{\text{phys}} \exists s \in \mathcal{S}_C^{\text{tot}} \text{ExistsAs}(A, s).\tag{748}$$

This enforces the definition of $\mathcal{U}_{\text{phys}}$ and is not an additional physical postulate.

C.4 Governing realization-core model

A governing V40/F20 realization-core model satisfies

$$\begin{aligned}\mathfrak{M} \models \mathfrak{G}_{40}^{\text{core}} &\iff \text{DomainAdmissible}_{40} \wedge \mathfrak{T}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \\ &\wedge \text{CMA} \wedge \text{UCC}.\end{aligned}\tag{749}$$

CSPP follows from the temporal constitution of the stages and is therefore not an independent core conjunct. UCC is an independent physical postulate and is therefore included explicitly alongside CMA in the governing realization core. The typed realization-core signature intentionally omits the separate physical-factor module; any fuller model that instantiates members of $\mathfrak{F}_{\text{phys}}$ must also satisfy the stage-support requirement in Eq. (50). This does not add physical factors to CMA or UCC quantification. Non-terminating cosmic succession is absent from the governing core: it may be added as a conditional cosmological premise in a stronger model. CRP, identity, lifecycle, observation, composition, and application modules retain their separate statuses.

Proposition C.1 (Governing-core expansion). Under Eq. (22),

$$\begin{aligned}\mathfrak{M} \models \mathfrak{G}_{40}^{\text{core}} &\iff \text{DomainAdmissible}_{40} \wedge [\mathcal{S}_C^{\text{tot}} \neq \emptyset] \wedge \text{StrictTotalOrder}(\mathcal{S}_C^{\text{tot}}, \prec_C) \\ &\wedge \forall s \in \mathcal{S}_C^{\text{tot}} \text{CommonStage}_C(s) \\ &\wedge \exists r \in \mathcal{S}_C^{\text{tot}} \exists t \in \mathcal{S}_C^{\text{tot}} (r \prec_C t) \wedge \text{CMA} \wedge \text{UCC}.\end{aligned}\tag{750}$$

C.5 Historical status of realization-core elements

The V40/F20 realization core is governed by the present definitions and commitments. Earlier versions are relevant only as developmental history.

C.6 A joint-satisfiability witness

Let

$$\mathcal{S}_C^{\text{tot}} = \mathbb{N}_0, \quad m \prec_C n \iff m < n. \quad (751)$$

Then $\mathcal{S}_C^{\text{tot}} \neq \emptyset$ and Strict Cosmic Ordering holds. This particular witness also satisfies the stronger optional condition

$$\forall n \in \mathbb{N}_0 \exists m \in \mathbb{N}_0 (n < m), \quad (752)$$

so $\text{NTCS}_C(\mathbb{N}_0, <)$ holds in the witness even though non-termination is not required by the governing core, and Cosmic Origin holds with $s_C^0 = 0$.

Let

$$\mathcal{U}_{\text{phys}} = \{A_0, A_1, A_2, \dots\}, \quad I_{A_k} = \{k, k+1\}. \quad (753)$$

Every range is convex with $f_{A_k} = k$ and $e_{A_k} = k+1$. Assign the relevant ending transformation so that $\text{End}_{A_k}(k+1)$ holds. At stage n ,

$$\mathcal{S}_{\text{phys}}(n) = \begin{cases} \{A_0\}, & n = 0, \\ \{A_{n-1}, A_n\}, & n \geq 1, \end{cases} \quad \mathcal{S}_{\text{phys}}(n) \neq \emptyset, \quad (754)$$

so CSPP holds. Set the realization successions to

$$\mathcal{W}_{A_k} = I_{A_k}, \quad \triangleleft_{A_k} = <|_{I_{A_k}}, \quad (755)$$

so CMA holds and, by Eq. (75), $\text{CosmicCoPresence}_C(\mathcal{S}_{\text{phys}}(n); n)$ holds at every n . Assign complete system-specific actual change by

$$\forall k \forall n \in I_{A_k}, \quad \text{PhysReal}_{A_k}^+(n). \quad (756)$$

This assignment satisfies CMA and UCC as separate conditions; both are jointly satisfiable with the temporal and population core, and

$$\forall n \in \mathbb{N}_0, \quad \mathcal{B}_\Delta(n) = \mathcal{S}_{\text{phys}}(n) \neq \emptyset. \quad (757)$$

This witness is a consistency construction, not a proposed physical cosmology.

For the causal and lifecycle extensions used below, choose for every realized pair (A_k, n) one explicitly internal physical contributor $c_{k,n}$:

$$\mathcal{C}_{A_k}^{\text{int}}(n) = \{c_{k,n}\}, \quad \mathcal{C}_{A_k}^{\text{infl-sys}}(n) = \emptyset, \quad \mathcal{C}_{A_k}^{\text{infl-factor}}(n) = \emptyset, \quad (758)$$

so that

$$\mathcal{C}_{A_k}^{\text{act}}(n) = \{c_{k,n}\}. \quad (759)$$

This supplies a fully typed witness for the causal-source union; it is only one consistency assignment and does not privilege internal causation in physical applications. Assign

$$\text{PhysicallyContributes}(c_{k,n}; \Delta_{A_k}^{\text{phys}}(n)). \quad (760)$$

CRP is therefore satisfied. At the ending member assign

$$\text{PhysicallyContributes}(c_{k,k+1}; \text{IdentityEndingTransformation}(A_k; k+1)), \quad (761)$$

so PIECP holds. The ranges $I_{A_k} = \{k, k+1\}$ are convex, have least member k , and contain the strict pre-ending member k before $e_{A_k} = k+1$; thus Identity-Realization Convexity, AFB, and the optional UEIE extension are jointly satisfiable in the same witness.

C.7 Stagewise and systemwise forms of UCC

The conversion between the stagewise and systemwise forms of UCC uses the common stage domain and the stage-population definition

$$A \in \mathcal{S}_{\text{phys}}(s) \iff [A \in \mathcal{U}_{\text{phys}} \wedge s \in I_A]. \quad (762)$$

UCC's stagewise clause is

$$\forall s \in \mathcal{S}_C^{\text{tot}} \forall A \in \mathcal{S}_{\text{phys}}(s) : \text{PhysReal}_A^+(s), \quad (763)$$

and re-indexing the same identity-stage pairs gives

$$\forall A \in \mathcal{U}_{\text{phys}} \forall s \in I_A : \text{PhysReal}_A^+(s), \quad (764)$$

which is the systemwise form of UCC. This re-indexing establishes only the equivalence of two formulations of UCC; it does not yield CMA (Proposition 5.4).

C.8 State and change profiles in the consistency witness

For each A_k , let:

$$\Omega_{A_k} = \mathbb{N}_0 \quad (765)$$

and define:

$$X_{A_k}(n) = n + k. \quad (766)$$

Let:

$$\Xi_{A_k} = \mathbb{N}_0 \times \{k\} \quad (767)$$

This codomain keeps the change content explicitly system-typed in the consistency model.

Define the corresponding change-content map by

$$\Delta_{A_k}^{\text{phys}}(n) = (n, k). \quad (768)$$

Then Eq. (757) supplies the complete change-realizing population at every n .

The state profile:

$$\mathfrak{X}_C(n) = (A_k \mapsto n+k)_{A_k \in \mathcal{S}_{\text{phys}}(n)} \quad (769)$$

is well defined.

The change profile:

$$\mathfrak{D}_C(n) = (A_k \mapsto (n, k))_{A_k \in \mathcal{S}_{\text{phys}}(n)} \quad (770)$$

is well defined.

The causal-realization profile:

$$\mathfrak{G}_C(n) = (A_k \mapsto \{c_{k,n}\})_{A_k \in \mathcal{S}_{\text{phys}}(n)} \quad (771)$$

is well defined.

Hence:

$$\mathfrak{R}_C(n) = (\mathcal{S}_{\text{phys}}(n), \mathfrak{X}_C(n), \mathfrak{D}_C(n), \mathfrak{G}_C(n)) \quad (772)$$

exists at every n . Therefore the witness satisfies, at every n , the nonempty population, local stage-change, and nonempty causal-realization conditions of Eq. (170). No additional temporal object or realization predicate is introduced.

C.9 Optional successor links in the joint witness

The consistency witness does not require successor production. One admissible extension may nevertheless assign, for selected k ,

$$\text{PhysicalProductionLink}(A_k, A_{k+1}; k+1) \quad (773)$$

and therefore

$$\text{SuccAt}(A_k, A_{k+1}; k+1). \quad (774)$$

Because $f_{A_{k+1}} = k+1$, such a $B = A_{k+1}$ is a genuinely new direct successor in that selected extension. The same base witness remains admissible without any such assignment, demonstrating that successor production is not a universal lifecycle requirement.

The principal witness therefore tests simultaneous satisfiability of

$$\begin{aligned} &\text{StrictTotalOrder}(\mathbb{N}_0, <), \quad \text{NTCS}_C(\mathbb{N}_0, <), \quad \text{CSPP}, \\ &\text{CMA}, \quad \text{UCC}, \quad \text{CRP}, \quad \text{IdentityRealizationConvexity}, \\ &\text{AFB}, \quad \text{UEIE}, \quad \text{PIECP}, \end{aligned} \quad (775)$$

together with the complete V40/F20 physical-realization profile construction.

The construction is only a satisfiability witness. Its countable population, two-member identity ranges, state assignments, and any optional successor links are not proposed as a physical cosmology.

C.10 Profile coverage and state plurality

Consider two qualified systems A and B realized at the same stage s .

Let:

$$\Omega_A = \mathbb{R}, \quad \Omega_B = \mathbb{R}^3. \quad (776)$$

Assign:

$$X_A(s) = 1, \quad X_B(s) = (0, 1, 2). \quad (777)$$

The complete state profile:

$$\mathfrak{X}_C(s) = (A \mapsto 1, B \mapsto (0, 1, 2)) \quad (778)$$

is well defined.

Yet:

$$\Omega_A \neq \Omega_B. \quad (779)$$

Therefore:

$$\text{CompleteStateProfileCoverage} \not\vdash \text{OneUniversalPhysicalStateSpace}. \quad (780)$$

C.11 Change coverage and system-specific codomains

Let:

$$\Xi_A = \mathbb{R}, \quad \Xi_B = \mathbb{R}^2. \quad (781)$$

Assign actual change to both systems.

Then:

$$\mathcal{B}_\Delta(s) = \mathcal{S}_{\text{phys}}(s) = \{A, B\} \quad (782)$$

may hold while $\Xi_A \neq \Xi_B$.

Thus:

$$\mathcal{B}_\Delta(s) = \mathcal{S}_{\text{phys}}(s) \not\vdash \exists \Xi_{\text{univ}} \forall X \in \mathcal{S}_{\text{phys}}(s), \quad \Xi_X = \Xi_{\text{univ}}. \quad (783)$$

C.12 Independence of composition and cross-level change identity

Let:

$$A \triangleleft_{\kappa, s} B. \quad (784)$$

Assign:

$$\mathfrak{E}_A = \mathbb{R}, \quad \mathfrak{E}_B = \mathbb{R}^3. \quad (785)$$

Under UCC both systems change.

Nevertheless:

$$\Delta_A^{\text{phys}}(s) \not\equiv_{\text{type}} \Delta_B^{\text{phys}}(s). \quad (786)$$

Hence:

$$A \triangleleft_{\kappa,s} B \not\models \Delta_A^{\text{phys}}(s) \equiv_{\text{type}} \Delta_B^{\text{phys}}(s). \quad (787)$$

C.13 Independence of composition and cross-level causal determination

Consider two typed structures $\mathfrak{M}_1$ and $\mathfrak{M}_2$ with the same:

$$A, \quad B, \quad s, \quad A \triangleleft_{\kappa,s} B, \quad X_A(s), \quad X_B(s), \quad \Delta_A^{\text{phys}}(s). \quad (788)$$

Let the structures differ only in the admissible causal realization assigned to B :

$$\mathcal{C}_{B,1}^{\text{act}}(s) \neq \mathcal{C}_{B,2}^{\text{act}}(s). \quad (789)$$

Both may satisfy CRP.

Therefore the composition relation alone does not determine the composite causal profile:

$$A \triangleleft_{\kappa,s} B \not\models \mathcal{C}_B^{\text{act}}(s) = F_{\kappa}(\mathcal{C}_A^{\text{act}}(s)). \quad (790)$$

Any such F_{κ} requires additional physical premises.

C.14 Independence of co-realization and interaction

Let $A, B \in \mathcal{S}_{\text{phys}}(s)$ and retain CMA.

Assign:

$$\neg \text{PhysicalInteraction}(A, B; s). \quad (791)$$

This does not violate CMA.

Hence:

$$\text{CMA} \not\models \text{UniversalPairwisePhysicalInteraction}. \quad (792)$$

Likewise assign:

$$\neg \text{SignalAccessible}(A, B; s). \quad (793)$$

Then:

$$\text{CMA} \not\models \text{UniversalInstantaneousSignalAccessibility}. \quad (794)$$

C.15 Population transformation without adjacent stages

Take:

$$0 \prec_C 1 \prec_C 2. \quad (795)$$

Compare the nonadjacent endpoints:

$$r = 0, \quad s = 2. \quad (796)$$

The sets:

$$\mathcal{P}_{0,2}, \quad \mathcal{N}_{0 \rightarrow 2}, \quad \mathcal{L}_{0 \rightarrow 2}, \quad \mathcal{T}_{0,2} \quad (797)$$

remain well defined.

Therefore:

$$\text{PopulationTransformationDescriptorDefined}(r, s) \not\models \text{Adjacent}(r, s). \quad (798)$$

C.16 Independence of population transformation and population motion

The pairwise descriptor is constructed entirely from correctly typed identity-domain membership statements of the form

$$A \in \mathcal{U}_{\text{phys}}, \quad u \in \mathcal{S}_C^{\text{tot}}, \quad v \in I_A, \quad (799)$$

with v instantiated by the selected endpoints or, where required by $\mathcal{T}_{r,s}$, by an intermediate common cosmic change stage.

No motion predicate occurs in its definition.

Thus:

$$\text{Defined}(\mathfrak{P}_C^{\text{pop}}(r, s)) \not\models \text{PopulationMovesFrom}(r, s). \quad (800)$$

C.17 Independence of successorship and population conservation

The direct-successor definition constrains only those candidate relations that are actually asserted. It neither requires every ending to have a successor nor requires every later entrant to be a successor, and it imposes no one-to-one correspondence between departing and newly realized populations. Therefore

$$\text{Defined}(\text{SuccAt}) \not\models \text{PopulationConservationLaw}. \quad (801)$$

An ending may produce several successors, one successor, or none, while independently formed systems may enter the later population without being successors of an identity that ended in the selected interval.

C.18 Independence of operational metrics and temporal identity

Consider two physically admissible calibration conventions:

$$m_P = \mathcal{M}_P^{\text{op}}(r_1, r_2; c_P), \quad (802)$$

$$m'_P = 2m_P. \quad (803)$$

The two representations may encode the same ordered physical records under different unit scales. The universal cosmic ordering is unchanged.

Thus:

$$m_P \neq m'_P \not\Rightarrow \text{DifferentTemporalReferents}(P, P'). \quad (804)$$

Successful construction does not establish identity either:

$$\text{OperationalMetricSuccessfullyConstructed} \not\vdash m_P \equiv_{\text{type}} T_{\text{ITOF}}. \quad (805)$$

C.19 Independence of model success and temporal identity

Let one application model use parameter λ and an equivalent reparameterization use:

$$\lambda' = 2\lambda. \quad (806)$$

Suppose both representations predict exactly the same physical observables after the corresponding transformation of the model equations.

Then:

$$\text{Success}(\lambda) \wedge \text{Success}(\lambda'). \quad (807)$$

Operational success alone cannot identify both distinct numerical parameters with the same temporal referent.

Therefore:

$$\text{SuccessfulEvolutionParameter} \not\vdash \text{TemporalIdentity}. \quad (808)$$

C.20 Non-injective observation

Let:

$$s_0 \prec_C s_1 \prec_C s_2 \prec_C s_3 \quad (809)$$

belong to I_A .

Define:

$$\mathcal{O}_{P,\varepsilon} : I_A \longrightarrow \{0, 1\} \quad (810)$$

with:

$$\mathcal{O}_{P,\varepsilon}(s) = \begin{cases} 0, & \text{Response}_P(A; s) < \varepsilon, \\ 1, & \text{Response}_P(A; s) \geq \varepsilon. \end{cases} \quad (811)$$

Suppose:

$$\mathcal{O}_{P,\varepsilon}(s_0) = \mathcal{O}_{P,\varepsilon}(s_1) = 0 \quad (812)$$

and:

$$\mathcal{O}_{P,\varepsilon}(s_2) = \mathcal{O}_{P,\varepsilon}(s_3) = 1. \quad (813)$$

Then the map is non-injective.

Therefore:

$$\mathcal{O}_{P,\varepsilon}(s) = 1 \not\Rightarrow \text{CosmicChangeStageIdentified}(s). \quad (814)$$

This is one form in which Change-Stage Restraint appears in records; its ground is that change continues without stopping.

C.21 State reconstruction and stage identification

Suppose:

$$\widehat{X}_{A;P,M}(r) = X^*. \quad (815)$$

If:

$$\exists s_1, s_2 \in I_A, \quad s_1 \neq s_2, \quad X_A(s_1) = X_A(s_2) = X^*, \quad (816)$$

then a unique reconstruction of the selected state does not identify a unique cosmic change stage. State recurrence and cosmic-stage identity remain distinct.

C.22 Model failure and foundational failure

Suppose $M_1 \neq M_2$ and

$$\text{DiscriminationFavours}(M_1). \quad (817)$$

Let both models contain application-level bridge assumptions not deductively fixed by their respective foundational commitments.

Then model discrimination establishes:

$$\text{ApplicationModelSupportOrRestriction} \quad (818)$$

without logically isolating a foundational premise.

Therefore:

$$\text{ModelDiscrimination} \not\vdash \text{FoundationalAttribution}. \quad (819)$$

The additional attribution burden of Section 26 is therefore non-redundant.

C.23 Current principal modular non-entailments

The identity, lifecycle, causal, application, and representation modules remain separated unless an explicit dependency is stated. Every retained formal non-derivability claim requires a corresponding witness or admissible modular extension. Ordinary non-transfer claims use $\not\Rightarrow$ rather than $\not\vdash$.

C.24 Current direct derivations

V40/F20 also preserves genuine derivations.

From strict total ordering:

$$r \prec_C s \implies \neg(s \prec_C r). \quad (820)$$

From Non-Terminating Cosmic Succession:

$$\text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \implies \nexists g \in \mathcal{S}_C^{\text{tot}} \text{ Greatest}_{\prec_C}(g). \quad (821)$$

Because unlimited future extent is not part of temporal constitution, infinity of the stage domain follows only conditionally when the additional cosmological non-termination hypothesis is adopted:

$$\begin{aligned} &\mathfrak{I}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \\ &\wedge \text{NTCS}_C(\mathcal{S}_C^{\text{tot}}, \prec_C) \implies \text{Infinite}(\mathcal{S}_C^{\text{tot}}). \end{aligned} \quad (822)$$

From AFB and the UCC:

$$\text{AFB} \wedge \text{UCC} \implies \forall A \in \mathcal{U}_{\text{phys}}, \quad \text{FormationChange}_A(f_A). \quad (823)$$

This derived statement concerns physical change of A at its identity-range boundary only. It does not order that change ahead of or behind the changes of other qualified systems sharing the same common cosmic stage.

From ending and UCC, the ending stage is a stage of actual change of the ending system (Eq. (234)).

From UCC and CRP:

$$\text{UCC} \wedge \text{CRP} \implies \forall A \in \mathcal{U}_{\text{phys}} \forall s \in I_A, \quad \mathcal{C}_A^{\text{act}}(s) \neq \emptyset. \quad (824)$$

From CSPP, CMA, and UCC:

$$\text{CSPP} \wedge \text{CMA} \wedge \text{UCC} \implies \forall s \in \mathcal{S}_C^{\text{tot}}, [\mathcal{S}_{\text{phys}}(s) \neq \emptyset \wedge \text{CosmicCoPresence}_C(\mathcal{S}_{\text{phys}}(s); s) \wedge \mathcal{B}_\Delta(s) = \mathcal{S}_{\text{phys}}(s)] . \quad (825)$$

From temporal constitution, CMA, UCC, and CRP, Eq. (170) supplies the corresponding nonempty stage-relative population, local stage-change condition, and nonempty causal realization for every member. This identifies the causal completion of the governing common-stage realization without adding a new independent universal postulate or realization predicate.

D. Governing Equation Reference

The following register locates the principal equations of V40/F20. Their logical status is given in the Statement-Status and Dependency Register.

Table 7: Principal governing equations of V40/F20.

Role	Reference
Definition of time	Eq. (11)
Governing earlier–later designation	Eq. (23)
Strict Cosmic Ordering	Eq. (24)
Non-Terminating Cosmic Succession	Eq. (17)
Temporal-extension admissibility	Eq. (22)
Order-representation non-metricity	Eqs. (37)–(38)
Cosmic physical totality	Eqs. (48)–(59)
Physical-system totality	Eq. (56)
Common stage and stage of change	Eqs. (15), (16)
Noticed(A, s), Measured $_{P,M,\varepsilon}(A, s)$	Eq. (85)
Recognizes $_O(m; r)$	Eq. (85)
Components(T_{TOF})	Eq. (9)
Invariance and its relation to UCC	Eqs. (9), (10)
Responsiveness profile $\text{RespProf}_A(s)$	Eq. (138)
Realization succession ($\mathcal{W}_A, \triangleleft_A$)	Eq. (61)
Identity-realization range	Eq. (62)
Stage-relative population	Eq. (63)
Stage-relative cosmic physical totality	Eqs. (49)–(64)
CSPP	Eq. (67)
CMA	Eq. (72)
UCC	Eq. (83)
Actual-change subset	Eq. (81)

Role	Reference
Complete-population change coverage	Eq. (103)
System-change profile	Eq. (112)
Local stage-change condition	Eq. (110)
State profile	Eq. (122)
CRP	Eq. (148)
Causal-realization profile	Eq. (153)
Complete physical-realization profile	Eq. (160)
Relationally augmented realization profile	Eq. (168)
Hierarchical constituent relation	Eq. (173)
Class-indexed identity-qualification profile	Eqs. (192)–(193)
Physical history	Eq. (209)
Identity ending	Eq. (231)
PIECP	Eq. (243)
UEIE	Eq. (250)
Direct successor	Eq. (257)
Endpoint-persistent population	Eq. (266)
Later-endpoint entrant population	Eq. (269)
Earlier-endpoint departing population	Eq. (272)
Intermediate-only identities	Eq. (278)
System-specific physical directionality	Eqs. (324)–(330)
Operational metric map	Eq. (336)
Change-Stage Restraint	Eqs. (373), (374), and (375)
Generalized Non-Transfer Principle	Eq. (448)
Relativistic temporal nonidentity	Eq. (467)
ITOF–relativistic comparison bridge	Eq. (553)
Bridge-robust separation margin	Eq. (573)
Foundational discrimination burden	Eq. (435)
Constitution-dependent clock response H_{CR}	Eqs. (723)–(725)

E. Framework Identity and Extension Boundary

E.1 Identity-preserving conditions

A physical extension or application presented as V40/F20-admissible preserves the temporal identity fixed by Eq. (11): the designated earlier–later meaning, Strict Cosmic Ordering, and the common-stage semantics of stages. It preserves CMA, UCC, and the identity-range and stage-population definitions that keep common-stage co-presence distinct from system-specific physical-change actuality; CSPP remains a derived consequence of temporal admissibility. It preserves the conditional direct-successor criterion rather than imposing universal successor production. If non-termination is adopted, it remains a separate cosmological premise with the exact meaning of Eq. (17). It preserves the type distinctions among time, the cosmic physical totality, the common stage, physical system, state, change, factor, causal contributor,

history, record, operational metric, coordinate, model parameter, and model geometry, and in particular the causal-source boundary of Eq. (314). An application may refine the physical content of $\mathfrak{R}_C(s)$ or add model-relative relations through $\mathfrak{R}_C^{[M]}(s)$; neither is reinterpreted as time (Eq. (169)), and neither requires expansion of the temporal ordered pair.

E.2 What may vary

Subject to physical warrant, explicit typing, parameter provenance, and appropriate empirical evaluation, V40/F20 permits variation in:

$$\begin{aligned}
 &\text{SystemClass, SystemBoundary, IdentityCriterion,} \\
 &\text{CompositionCriterion, StateSpace, ChangeContentType,} \\
 &\text{PhysicalDynamics, CausalModel, ComparisonMap,} \\
 &\text{SignalModel, ObservationModel, ClockResponseModel,} \\
 &\text{OperationalMetric, ExperimentalProtocol.}
 \end{aligned} \tag{826}$$

No single application model is permanently built into the definition of time.

E.3 What would constitute a foundational revision

The following substitutions would alter the governing identity of V40/F20 rather than constitute ordinary application-level extension:

$$\begin{aligned}
 T_{\text{ITOF}} &\longrightarrow \text{ClockOutput,} \\
 T_{\text{ITOF}} &\longrightarrow \text{CoordinateTime,} \\
 T_{\text{ITOF}} &\longrightarrow \text{MetricInterval,} \\
 T_{\text{ITOF}} &\longrightarrow \text{ProperTimeFunctional,} \\
 T_{\text{ITOF}} &\longrightarrow \text{PhysicalRealizationProfile,} \\
 \mathfrak{U}_C^{\text{phys}} &\longrightarrow \text{PhysicalContainer,} \\
 \mathfrak{U}_C^{\text{phys}} &\longrightarrow \text{PhysicalSystemIdentity,} \\
 \text{OneCommonCosmicStageTotality} &\longrightarrow \text{IndependentPerSystemTimes,} \\
 \text{PhysicalCausation} &\longrightarrow \text{TimeAsCauseOfChange,} \\
 \text{HistoricalPhysicalAccumulation} &\longrightarrow \text{FourthPhysicalCausalSource.}
 \end{aligned} \tag{827}$$

Removal or alteration of a governing axiom, constitutive condition, or derived definition that fixes the V40/F20 architecture—including Strict Cosmic Ordering, common-stage semantics, the non-container cosmic physical-totality distinction, governing CMA, or the UCC continuity condition—would constitute a foundational revision rather than an admissible application-level extension. Changing the definition of the optional Non-Terminating Cosmic Succession predicate would likewise revise its declared cosmological module, but a finite-extent application is not excluded merely for not assuming that optional condition.

E.4 Admissible extension condition

Let E be a proposed extension.

Define the structural admissibility burden:

$$\begin{aligned} \text{AdmissibleExtension}_{40}(E) \implies & \text{TemporalCorePreserved}(E) \\ & \wedge \text{CommonStageArchitecturePreserved}(E) \\ & \wedge \text{CMAUCCDependencyPreserved}(E) \\ & \wedge \text{PhysicalTypingExplicit}(E) \\ & \wedge \text{IdentityCriteriaExplicitWhereUsed}(E) \\ & \wedge \text{CausalTypingPreserved}(E) \\ & \wedge \text{NonTransferPreserved}(E) \\ & \wedge \text{ProvenanceDeclared}(E). \end{aligned} \tag{828}$$

Where E produces an empirical prediction:

$$\text{PredictiveExtension}_{40}(E) \implies \text{AdmissibleExtension}_{40}(E) \wedge \text{PredeclaredEmpiricalProtocol}(E). \tag{829}$$

Where foundational discrimination is claimed, the stronger attribution burden also applies.

F. Historical-Critical Status of V40/F20

F.1 Immediate predecessor and reference basis

The immediate predecessor and the archive record are identified in Section 1.3; the archive permits older definitions, dependencies, and formulations to be distinguished from the present governing theory. The reference basis comprises:

$$\begin{aligned} & \text{ImmediatePredecessor}, \\ & \text{ConsolidatedHistoricalITOFRecord}, \\ & \text{ExternalScientificLiterature}. \end{aligned} \tag{830}$$

The first supplies provenance, not current governing authority; the second preserves historical traceability; the third supplies external scientific and mathematical context. No earlier ITOF version overrides a governing V40/F20 statement merely by historical priority, and external scientific literature is not cited as authority for the definition of time; it is used where external physical models, measurements, mathematical constructions, experimental records, or competing interpretations are discussed.

F.2 Positions retained from earlier versions

The following positions are retained from V38/F18 [2] and V39/F19 [1]; where the basis of a position changed, the change is stated.

- **Successor closure.** V28/F8 and V29/F9 treat an ending as not necessarily producing a successor; V30/F10 through V34/F14 state that an ending necessarily produces one; V35/F15 replaced that commitment by conditional successor attribution. An identity ending does not by itself entail a direct successor, and absorption without a newly formed successor identity is admissible (Section 15.5). This position is closer to V28/F8 and V29/F9 than to V30/F10 through V34/F14.
- **Stage population.** A stage-population condition first appears in V26/F6 as the nonempty-population conjunct of the Cosmic Moment Axiom and in V27/F7 as a separate condition. From V34/F14 through V37/F17 it was an independent postulate (CSPP). V38/F18 derived it from its stage condition, which required actual change in at least one qualified system. In V39/F19 a stage was characterized as a populated common stage; V40/F20 adds to the common-stage condition that change is realized at the stage (Eq. (15)), so that CSPP and the absence of a stage empty of change follow from the common-stage condition (Section 4.2), while the change of all systems realized at each stage follows from UCC (Eq. (104)).
- **Cosmic non-termination.** V28/F8 and V29/F9 leave a possible cosmic ending open. Non-termination was derived in V33/F13 from the population content of CMA with the cumulative eventual-ending postulate (CPCES) and Necessary Successor Closure, and in V34/F14 from CSPP, UEIE, the Actual Formation Boundary, and Necessary Successor Closure; V35/F15 through V37/F17 stated it as a direct commitment; V38/F18 made it an optional cosmological condition. It is conditional in V40/F20 (Section 3), with the evidential justification in Section 3.4, which recovers the open treatment of V28/F8 and V29/F9.

The developmental history of the definition of time, UCC, the Non-Transfer Principle, and the quantitative test architecture is documented in the project archive [4].

F.3 Positions established in V39/F19 and retained

The following were established in V39/F19 [1] and are retained in V40/F20:

- **Realization-succession form of CMA** (Eqs. (61)–(75)). Each system’s own realization succession is a primitive, and CMA states that it is a segment of the one common succession. Objective co-presence is defined from this condition rather than left as an uninterpreted relation, and CMA acquires a direct contrary: a private stage or private ordering.
- **Mutual independence of CMA and UCC** (Proposition 5.4). V38/F18 gave a countermodel to the entailment of CMA by UCC using an uninterpreted co-presence relation; both directions are now proved by countermodels that satisfy every other governing postulate.
- **The common-stage condition and the theorem of stages of change** (retained, with the common-stage condition revised in V40/F20) (Eqs. (15), (16), (104)): every stage is a common stage of the physical systems of the universe at which change is realized, and, under the postulate of change, a stage of change of every one of them. The common-stage condition again refers to realized change, as in V38/F18, since a stage is the formal expression of a change realized within the unceasing chain of change; that change does not stop in any system realized at a stage is stated dynamically by UCC.
- **Exclusion of empty, change-null, static, and private stages** (retained, with the exclusions reassigned in V40/F20) (Eq. (104), Eq. (107)): a stage without systems or without realized change is excluded by the common-stage condition, a stage at which a realized system does not change by UCC, and private stages by CMA.
- **Uninterrupted change** (Eq. (86)): UCC together with Identity-Realization Convexity excludes both a member of an identity range without change and a gap in the range.

- **Evidential justification of conditional non-termination** (Section 3.4).
- **Relativistic commitment distinctions and a general non-identity proposition** (Section 43), covering global time functions and cosmological time.
- **Observed deflection of light** (Section 40.8): a path or reconstruction property of a physical signal, attributed to declared physical contributors, with rotation as one contributor among several; “bending of time” is a type error.
- **Relativistic phenomenon bridge** (Definition 38.1, Proposition 38.2) with inclusion conditions (J1)–(J3) and exclusion conditions (M1)–(M4), applied phenomenon by phenomenon to special and general relativity (Section 38); a record-level derivation of the Lorentz transformations that uses no premise about T_{TOF} , CMA, or UCC; a reply to the Rietdijk–Putnam argument; the exclusion of any reversal of the succession of change, along closed timelike curves or through wormhole or warp-drive time machines (Eq. (593)); the reassignment of temporal deformation predicates to their carriers; the reading of spacetime as representation of the gravitational relation; the non-admission of temporal geometry (Proposition 43.9); and the reading of horizons and differential ageing. Its experimental anchors — Pound–Rebka, Vessot, Hafele–Keating, the CERN muon ring, the twin-clock case, and satellite navigation — go back to V19, V23/F3, and V33/F13.
- **The meaning of invariance** (Section 2): the extension is a non-metric succession and invariance is the fixed and non-reversed succession of the change realized through its stages, never interrupted by a static or empty stage, stated by the Ordinal Succession convention $0 \prec_C 1 \prec_C 2 \prec_C 3 \prec_C 4 \prec_C \dots \infty$ (conditional), whose numerals express only the fixed succession of the stages and are not added. The account draws on V14 (the ordinal picture), V23/F3 (preservation by representations as a consequence of invariance, not a constituent), V24/F4 (fixity of the succession while what it orders changes), V25/F5–V26/F6 (no interchange of stages; distinction from Lorentz invariance), and V31/F11–V32/F12 (no stopping and no static condition), which is restored while the stronger requirement, that every system change, remains with UCC.
- **Cosmic Origin adopted** (Section 3.2): the first stage, optional since V35/F15, is adopted as a postulate anchored in, but not established by, observational evidence, while non-termination remains a revisable hypothesis; the first stage is distinguished from a model singularity and from the age assigned in cosmological time.
- **Reading the relativistic equations** (Section 44): each principal relativistic equation is read for what it states, the temporal reading it answers, why it holds, what it retains, and what would count against ITOF.
- **Pathways, influence profile, responsiveness, and response classes** (Sections 8.7–8.11). These sections restore, in corrected form, material developed in early versions: system resistance as cohesion, coherence, and integrity relative to an influence (V16); the characteristics of an influence — intensity, mode, exposure, coupling — (V17); the same influence being supportive for one system, adverse for another, and bounded for a third (V18); and engagement, thresholds, stability as maintained change, resistance and adaptation, and living and non-living response organization (V22). In the present form the realized response is the change itself rather than a state produced by a separate operator, with the responsiveness profile counted in the internal basis, and thresholds are criterion-relative rather than values of a universal scalar measure of engagement.
- **Clock vibration-condition protocol** (Section 23.9, Definition 23.1). Clock sensitivity to vibration and other environmental conditions was stated qualitatively in V20 (failure under vibration belongs to the clock’s physical structure) and listed among bearer-condition variables in V31/F11 and among controlled perturbations in V35/F15; it is now a declared protocol with a record model, an independent motion record, interleaved control, and a no-post-hoc rule.

- **A dimension-admission criterion** (Definition 43.6, Proposition 43.7).
- **A currently-complete physical isolation criterion** (Definition 5.2, Corollary 5.3), with the bounded, cumulative form of evidence against UCC and the ground-state case.

F.4 Revisions in V40/F20

- **Ordinal Succession** (Definition 2.2). The numerals are a formal expression of the succession: the stages follow one another as the numerals follow one another, in a fixed order, and the numerals are not added. Stage 0 is the beginning of the stages of change, at the formation and genesis of the universe, with no date fixed for that beginning. No stage, named or lying between two named stages, is empty of change or static. The numerals do not enumerate every stage, so the convention neither asserts nor denies an immediate successor.
- **One time throughout the universe** (Definition 2.1): there is no time in space that differs from time on Earth.
- **Stage and universe are expressions, not containers.** A stage expresses the change realized at it; it is not a container that holds change. The universe expresses the totality of physical systems and physical factors; it is not a container that holds them.
- **The isolated-eigenstate case** (Section 5.7): the exclusion rests on the changing and irregular action of the influencing systems and factors on the system, not on the bare presence of a coupling.
- **Cosmic Origin** (Section 3.2): the postulate is anchored in the established early hot and dense state, which does not by itself establish a first stage; its contrary is a succession without a least member.
- **Lorentz transformations** (Section 38.2): the derivation from homogeneity, isotropy, and the relativity principle is attributed to Ignatowsky.
- **Invariance for every physical system** (Eqs. (9), (10)): the invariance predicate states the change of every physical system of the universe at every stage; invariance is the fixed and non-reversed succession of the unceasing change that UCC states dynamically; the predicate is derivable from temporal constitution and UCC, but invariance is not produced by them, and UCC keeps its independent status.
- **Objective co-presence stated** (Section 32.4): the common stages induce an objective partition of realizations, in logical type absolute simultaneity, selected by no record and tied to no medium or preferred inertial frame.
- **Declared clock-response hypothesis** (Section 51): an application hypothesis under which the gravitational response of a clock depends on its constitution, with predictions, a present bound, and conditions of refutation and withdrawal fixed in advance, and an analysis of its minimal field model, which the weak-equivalence-principle bound constrains below the withdrawal threshold; it extends the double-ratio target of V32/F12 by a coupling law.
- **The common-stage condition** (Eq. (15)): a stage is characterized as populated and as the expression of realized change, so that no stage is empty of change; UCC states dynamically that change does not stop in any system realized at the stage, and invariance is the fixed and non-reversed succession of that unceasing change, not produced by the premises from which its predicate is derived (Eq. (10)).
- **Stage-local causation** (Proposition 8.1): every actual physical contributor to a change is realized at the stage of that change; this states the causal-order constraint of V24/F4 as a consequence of the causal typing, without a separate postulate.
- **Ordinal Succession** is stated as a representation convention (Definition 2.2); its substantive clauses are the Cosmic Origin postulate, invariance, and the conditional non-termination hypothesis.
- **Change-Stage Restraint** (Section 22): the restraint named Exact-Change-Stage Restraint in

V38/F18 is named Change-Stage Restraint: no stage of a change, and no place of that stage in the succession, is identified, exactly or approximately, because change continues without stopping, observed or not; the earlier-later relation that a physical ordering bridge warrants between two changes places neither of them in the succession.

- **Foundational scope and claim boundary** (Section 45) are stated again in compact form from V39/F19.
- **Influence through pathways and joint influence** (Eq. (136)): an external influence, near or distant, contributes to the change of a system as it reaches the system, by contact or through a physical pathway; influences act jointly and qualitatively, under conditions that include an environment differing from place to place; and the variation of a physical factor, as distinct from a condition of a physical system, such as the temperature of a medium, which is a state of that system, is not counted as change in the sense of UCC and does not constitute a stage, since a factor has no structural constitution and no identity range of its own and enters through the change that its joint action produces in physical systems.
- **Points of conflict with relativity** (Section 39.1) and **contraries of each commitment** (Section 48.2) are stated in single tables.

Earlier ITOF versions remain documentary and developmental evidence. Their definitions, axioms, postulates, principles, and claims are authoritative for V40/F20 only insofar as they are explicitly retained in Section F.2 or restated without qualification elsewhere in this document.

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