Invariant Temporal Ordering Framework V23/F3: Universal Temporal Meaning and the Systemwise Realization of Physical Change

Youssry Ghandour

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Abstract

Version 23/F3 of the Invariant Temporal Ordering Framework (ITOF) constructs realized change without presupposing stages and derives stages only after change is established, while treating the physically warranted prior–later relation as primitive. Its formal vocabulary is built from physical systems, identity-valid occurrences, complete realized conditions, and explicit warrants for ordered-pair assignment, representation, and measurement. The universe occurrence domain is primitive; system occurrence domains are its identity-scoped restrictions. Realized change is ordered physical non-identity of complete conditions, and a stage is derived only after such change is established.

The universal postulate applies to physically admissible systems with a nontrivial identity extension. On every realized identity-preserving history chain, each occurrence whose identity continues is followed by a later occurrence with a physically non-identical complete condition. The formulation permits finite plateaus, equilibrium, recurrence, stationary selected observables, and temporary stability, while admitting an exact conditional countermodel: an admissible system and realized identity-preserving history chain on which the complete condition remains physically identical throughout a later identity-open continuation.

ITOF distinguishes temporal meaning T_{ITOF} from the formal representation $\mathfrak{T}_{\mathrm{ITOF}} = (\mathbb{O}_{\mathrm{phys}}, \prec)$. The latter is a strict partial-order structure with explicitly stated axioms; admissible re-expression is defined by bijective order and occurrence-attribution preservation. Time in ITOF is the universe-wide descriptive expression of the continuing, non-reversing extension of physically realized prior–later succession across the identity-preserving histories of admissible physical systems throughout the universe. It specifies neither the physical content, magnitude, rate, mechanism, nor cause of change, and it is not a system, factor, field, force, clock, coordinate, metric component, signal, or causal participant.

The empirical program separates ontological scope from methodological admissibility, and domain anchoring from theory discrimination. Measurement estimates and ideal representations may share a numerical codomain while retaining different provenance and inferential status. Local-change, intervention, stationarity, and model-comparison protocols must declare identifiability, nuisance structure, covariance rank, decision rules, and uncertainty. Relativity remains a validated

domain application: ITOF preserves its quantitative relations while applying an independent type and attribution discipline to their interpretation.

Contents

Keywords: physical change; sustained succession; prior–later order; invariant temporal ordering; physically realized condition; physical history; engagement; empirical instantiation; discriminating tests; counterexample classes; measurement; clocks; proper time; relativity; non-transfer; domain-level testability.

1. The Foundational Problem: Change, Order, and Temporal Misattribution

Foundational definition. Every admissible identity-extended physical system undergoes sustained realized change. Within the sustained-change postulate, this realization analytically entails prior–later succession and the continuing, non-reversing extension of the succession of its physically realized occurrences and derived stages. Time in ITOF is the universe-wide descriptive expression of the continuing, non-reversing extension of physically realized prior–later succession across the identity-preserving histories of admissible physical systems throughout the universe. It specifies neither the physical content, magnitude, rate, mechanism, nor cause of change.

Governing scope. *Universal in meaning and scope, systemwise in physical realization, and independent of the specific content of change.*

Universe-wide temporal meaning is compatible with partial cross-system comparability.

Universal scope permits heterogeneous content, mechanism, magnitude, and rate.

Meaning of invariant. ITOF separates the intrinsic non-reversal of the physical prior–later order from fidelity under re-expression. The relation $\prec$ is irreflexive and transitive; asymmetry, and hence physical non-reversal, follows. Let

$$\Phi = (\phi_O, \phi_S), \qquad \phi_O : \mathbb{O}_{\text{phys}} \to \mathbb{O}'_{\text{phys}}, \qquad \phi_S : \mathbb{S}^{\mathcal{U}}_{\text{phys}} \to \mathbb{S}^{\mathcal{U}\prime}_{\text{phys}}$$

be bijections between two admissible representations of the same ontology. Then

$$\begin{aligned} \text{OrderFaithful}(\Phi) \ :\Longleftrightarrow\ & \text{Bij}(\phi_O) \wedge \text{Bij}(\phi_S) \\ & \wedge\ \forall o_1, o_2 \in \mathbb{O}_{\text{phys}} : [o_1 \prec o_2 \Longleftrightarrow \phi_O(o_1) \prec' \phi_O(o_2)] \\ & \wedge\ \forall A \in \mathbb{S}^{\mathcal{U}}_{\text{phys}} : \phi_O[\mathbb{O}_A] = \mathbb{O}'_{\phi_S(A)}. \end{aligned}$$

The biconditional preserves both order and incomparability; the attribution clause prevents a re-expression from moving an occurrence to a different system merely by relabelling. The clause is read relative to the fixed system specifications: a transformation that changes a system boundary or identity criterion is not an admissible re-expression of the same ontology. This representational condition neither creates the realized order nor implies a preferred frame, universal clock value, or total order over physically unrelated occurrences.

ITOF begins where physical attribution must begin: with the constituted bearer of change. A system has structure, internal relations, properties, processes, capacities, boundaries, and a realized history; it may also engage with other systems and with non-system physical factors. These conditions govern how change is physically realized. ITOF does not relocate change into time: each physically realized change remains attributable to the constituted system and its physical history, including any actual engagement. Time expresses the continuing prior–later succession of those realizations without entering their causal inventory.

The universal commitment is

$$\forall A \in \mathbb{S}^{\mathcal{U}}_{\text{phys}}, \qquad \text{SustainedChange}(A). \tag{1}$$

It states, first for one arbitrary system and then by quantification over the declared domain $\mathbb{S}^{\mathcal{U}}_{\text{phys}}$, that every admissible identity-extended physical system is excluded from an absolutely changeless mode of existence while that fixed identity specification remains applicable. Applicability does not depend on the system's type, scale, complexity, apparent stability, or on the magnitude, rate, visibility, utility, or outcome of its change. The manner in which change is realized remains system-specific because it depends on the system's constitution, internal processes, boundaries, and actual external engagements. Sections 6 and 23 develop a positive evidential case from resolved physical histories across distinct scales and methods. Section 24 then separates four empirical anchoring and specialization tests from a fifth model-discrimination test, and states an explicit counterexample class. Finite observation supplies systemwise evidence that can substantially support, restrict, or challenge the physical claims through which the postulate is applied.

For the arbitrary system A, sustained physical change analytically entails prior–later succession and the continuation of that succession while the identity of A remains applicable. These are not additional empirical hypotheses or physical causes; they articulate the ordered extension already contained in sustained physical realization. Universe-wide temporal meaning is obtained by applying the same systemwise construction throughout the admissible identity-extended domain $\mathbb{S}^{\mathcal{U}}_{\text{phys}}$, not by merging system histories into one countable global sequence.

The framework separates the physical realization from every mode of access to it. A physical occurrence belongs to the realized system; a stage is derived only after change is established, while the reference domain Ξ_A belongs to analysis, intervention, representation, or measurement. A justified reference may locate a selected stage, but it neither creates the stage nor generates its order. Physically realized conditions, ideal representations, measured estimates, selected-condition differences, and histories therefore remain distinct typed objects.

V23/F3 establishes a typed architecture connecting constituted systems, physical occurrences, derived stages, continuing succession, history, measurement, and domain specialization without replacing established physical dynamics. Domain theories—continuous, discrete, stochastic, quantum, causal, computational, geometric, or hybrid—supply the applicable variables, laws, probability structures, and closure. ITOF fixes the temporal meaning, object types, physical bearers, and attribution rules under which those results are interpreted.

Physics describes change through states, fields, trajectories, amplitudes, distributions, equations of motion, clock readings, coordinates, signals, and geometric structures. These resources are indispensable, but predictive precision does not by itself settle the ontology assigned to every symbol. A coordinate can organize a model without acting on the modeled system, and a clock can realize a numerical interval without detecting an independently acting temporal substance.

The admissibility of any cross-category physical attribution is governed by the bridge criteria stated in Section 22.3; inherited terminology alone cannot settle competing accounts of temporal or spacetime ontology [14, 15, 16].

Relativity is treated as a major application rather than the source of the definition. Coordinate time, proper time, invariant intervals, causal structure, redshift, and clock comparison retain their established mathematical and empirical roles [1, 2, 3, 5, 6]. ITOF contributes an independent attribution architecture: it identifies the type and bearer of each defined quantity, preserves the validated relativistic relation, and evaluates any additional temporal-physical ontology by the same bridge and testing requirements applied elsewhere in physics.

The paper proceeds from ontology and universal physical change to stage order, analytical reference, realized condition, engagement, realization, measurement, clocks, light propagation, relativity, non-transfer, and empirical specialization. The appendices consolidate the type system, governing relations, historical inheritance, and revision audit.

2. Methodological Architecture and Claim Discipline

ITOF is a foundational framework, not a universal substitute for domain dynamics. Classical, relativistic, quantum, stochastic, statistical, biological, computational, or hybrid models supply the variables, equations, probability laws, boundary conditions, calibration functions, and rejection criteria required for a particular application. ITOF's governing role is architectural: it constrains the types and bearers of the objects employed and the inferences licensed by successful calculation and measurement. The separation of ontology, representation, formal structure, and empirical interpretation is consistent with established methodological distinctions in the philosophy and foundations of science [12, 13, 17].

2.1 Claim classes

Every substantive statement is assigned primarily to one class, with its own governing question and standard of assessment:

Class	Governing question	Primary standard of assessment
Ontological	What counts as a system, factor, occurrence, derived stage, condition, history, representation, or temporal description?	Type coherence and category consistency
Structural	Which typed relations may hold among those objects?	Formal validity and domain adequacy
Operational	How are references, measurements, clocks, coordinates, calibrations, and comparisons constructed?	Explicit procedure, calibration, and uncertainty
Empirical	What is predicted, observed, compared, supported, restricted, or rejected?	Reproducible evidence and model comparison

No class inherits the evidential status of another automatically: operational success does not establish a unique ontology; an ontological distinction does not calculate an observable; a structural relation is not by itself a mechanism; and a residual does not identify its own cause.

2.2 Rules of formal construction

1. Every symbol has one primary type and definition.
2. Physical occurrences and derived stages selected for analysis are distinct from analytical references $\xi \in \Xi_A$.
3. The complete realized condition $X_A(o)$ is distinct from an ideal representation and from a measured estimate.
4. A relation is promoted to a function only when its domain establishes existence and uniqueness.
5. Internal constitution and external engagement are not counted twice.
6. Influencing systems retain system identity; non-system physical factors retain their own type.
7. A history is not replaced by a selected-condition difference.
8. A clock register, numerical reading, clock-defined duration, coordinate time, and proper-time functional remain distinct types.
9. The temporal definition is stated for one arbitrary system and universalized by quantification over $\mathbb{S}^{\mathcal{U}}_{\text{phys}}$; a second system is introduced only for a relational problem.
10. A displayed equation must define an object, fix a type, state a governing constraint, or support a quantitative test.
11. Cross-category physical inference requires a typed bridge law and testable consequences.
12. Superseded historical equations remain historical and cannot override the active formalism.

Formal Constraint 2.1. No symbolic inflation. Symbolic form is not evidence of derivation. A definition introduces notation; it does not prove that nature implements the defined mapping. A logical implication does not become a causal law unless causal content is independently supplied.

2.3 Controlled inheritance and empirical restraint

V23/F3 inherits only earlier concepts compatible with the present ontology: system-conditioned realization, decomposition of environment, separation of history from selected-condition difference, descriptive use of response, measurement discipline, non-transfer, and domain-level testing. Current canonical definitions govern over earlier wording.

ITOF preserves established observations and validated quantitative relations without inheriting every interpretation attached to their terminology. A reproducible experiment establishes the measured quantities and their dependence under stated conditions. A further ontological conclusion requires a further argument.

A satisfactory specialization must maintain type consistency, preserve known empirical results, state what is universal and what is domain-specific, define observables and uncertainty, and expose its assumptions to comparison or rejection. Length is justified only when it establishes a distinction, removes an ambiguity, or supplies a usable protocol.

3. Canonical Ontology, Types, and Symbol Discipline

The normative symbol table is given in Appendix A. The foundational order of construction is

$$\begin{aligned}
&\mathbb{O}_{\mathrm{phys}} \text{ primitive}, \qquad A \in \mathbb{S}_{\mathrm{phys}}, \qquad \mathrm{Spec} : \mathbb{S}_{\mathrm{phys}} \to \mathbb{S}^{\mathrm{phys}}_{\mathrm{spec}}, \\
&\mathrm{Spec}(A) = (\partial A, \mathcal{I}_A), \qquad \mathrm{AnalysisSpec}(A, \mathscr{D}, \mathcal{P}) = (\mathrm{Spec}(A), \mathscr{D}, \mathcal{P}), \\
&\mathbb{O}_A := \{o \in \mathbb{O}_{\mathrm{phys}} : \mathrm{OccurrenceOf}_A(o)\}, \\
&X_A : \mathbb{O}_A \to \mathbb{X}^{\mathrm{full}}_A, \qquad \prec \subseteq \mathbb{O}_{\mathrm{phys}} \times \mathbb{O}_{\mathrm{phys}}, \qquad \lhd_A := \prec \cap (\mathbb{O}_A \times \mathbb{O}_A), \\
&\mathrm{AdmissibleSystem}(A), \qquad \mathrm{AdmissibleAnalysis}(A, \mathscr{D}, \mathcal{P}), \qquad \mathrm{IdentityExtended}(A), \\
&\mathbb{S}^{\mathcal{U}}_{\mathrm{phys}} := \{A \in \mathbb{S}_{\mathrm{phys}} \mid \mathrm{AdmissibleSystem}(A) \wedge \mathrm{IdentityExtended}(A)\}, \\
&\xi \in \Xi_A, \qquad \mathrm{Locates}_A(\xi, o), \qquad \mathbf{x}_{A,\mathscr{D}}[\xi] = \Pi_{A,\mathscr{D}}(X_A(o)), \\
&\mathfrak{R}_A \subseteq \mathbb{X}^{\mathrm{full}}_A \times \mathbb{E}^0_{A,\mathrm{ext}} \times \mathbb{X}^{\mathrm{full}}_A \times \mathbb{H}_A.
\end{aligned} \tag{2}$$

The occurrence domain is primitive with respect to both system restriction and the change definition. An occurrence is a concrete physical realization; $\mathbb{O}_A$ contains precisely those occurrences attributable to A while the declared identity criterion of A applies. No second identity-activity predicate is introduced as a filter on $\mathbb{O}_A$; identity applicability is already built into the system restriction and is extended only through the chain conditions defined below.

A system belongs to the universal postulate domain under one fixed physical specification that it ontically instantiates. Let $\mathbb{S}^{\mathrm{phys}}_{\mathrm{spec}}$ denote the domain of physical system specifications, and declare

$$\mathrm{Spec} : \mathbb{S}_{\mathrm{phys}} \longrightarrow \mathbb{S}^{\mathrm{phys}}_{\mathrm{spec}}, \qquad \mathrm{Spec}(A) := (\partial A, \mathcal{I}_A), \tag{3}$$

where the boundary and identity criterion belong to the physical specification of the system. Ontic system admissibility is independent of whether the specification has already been documented, measured, or judged methodologically adequate:

$$\begin{aligned}
&\mathrm{OnticallyInstantiates} : \mathbb{S}_{\mathrm{phys}} \times \mathbb{S}^{\mathrm{phys}}_{\mathrm{spec}} \longrightarrow \{\mathrm{true}, \mathrm{false}\}, \\
&\mathrm{AdmissibleSystem}(A) :\Longleftrightarrow \mathrm{OnticallyInstantiates}(A, \mathrm{Spec}(A)).
\end{aligned} \tag{4}$$

Here $\mathrm{OnticallyInstantiates}(A, \mathrm{Spec}(A))$ states that A physically instantiates the specified boundary and the identity-bearing organization to which $\mathcal{I}_A$ refers. The criterion is part of the formal specification, not an additional physical object. Evidence may warrant or fail to warrant this attribution, but the evidence does not constitute the physical system or its identity. Methodological admissibility is stated separately. Let $\mathbb{S}^{\mathrm{an}}_{\mathrm{spec}}$ be the domain of analysis specifications and define

$$\mathrm{AnalysisSpec}(A, \mathscr{D}, \mathcal{P}) := (\mathrm{Spec}(A), \mathscr{D}, \mathcal{P}) \in \mathbb{S}^{\mathrm{an}}_{\mathrm{spec}}, \tag{5}$$

where $\mathcal{P}$ denotes the declared observational, intervention, or comparison protocol. Then

$$\begin{aligned} \text{OutcomeIndependent} : \mathbb{S}^{\text{an}}_{\text{spec}} &\longrightarrow \{\text{true}, \text{false}\}, \\ \text{AdmissibleAnalysis}(A, \mathscr{D}, \mathcal{P}) :&\Longleftrightarrow \text{AdmissibleSystem}(A) \\ &\quad \wedge \text{OutcomeIndependent}\big(\text{AnalysisSpec}(A, \mathscr{D}, \mathcal{P})\big). \end{aligned} \tag{6}$$

A materially different physical boundary or identity criterion requires an explicitly respecified system token. A different domain or protocol requires a separately declared analysis. Neither the system specification nor the analysis specification may be changed after observing the outcome merely to force change, constancy, continuation, or failure.

$$\text{IdentityExtended}(A) :\Longleftrightarrow \exists o_0, o_1 \in \mathbb{O}_A : \ o_0 \lhd_A o_1. \tag{7}$$

$$\mathbb{S}^{\mathcal{U}}_{\text{phys}} := \{A \in \mathbb{S}_{\text{phys}} \mid \text{AdmissibleSystem}(A) \wedge \text{IdentityExtended}(A)\}\,. \tag{8}$$

Ontic instantiation requires the specified boundary and identity-bearing physical organization to be realized by the system itself; it is not a judgment of evidential defensibility. Outcome independence belongs instead to the declared analysis and protects empirical attribution from post-outcome redefinition. A physical entity with no nontrivial identity extension may be represented as an occurrence, event, transfer, or factor within the history of an admissible encompassing system, but it is not itself a bearer to which the sustained-change predicate is applied.

The following universe-domain coverage postulate states an explicit ontological commitment: every occurrence admitted into $\mathbb{O}_{\text{phys}}$ is attributable to at least one admissible identity-extended system, without requiring the occurrence itself to be such a system. It is not a second definition of $\mathbb{O}_{\text{phys}}$:

$$\mathbb{O}_{\text{phys}} = \bigcup_{A \in \mathbb{S}^{\mathcal{U}}_{\text{phys}}} \mathbb{O}_A. \tag{9}$$

The union is conceptual and does not assume finite or countable enumeration, simultaneity, or total comparability. The global order is explicitly a strict partial order:

$$\begin{gathered} \forall o \in \mathbb{O}_{\text{phys}} : \ \neg(o \prec o), \\ \forall o_1, o_2, o_3 \in \mathbb{O}_{\text{phys}} : \big[(o_1 \prec o_2) \wedge (o_2 \prec o_3)\big] \Longrightarrow o_1 \prec o_3. \end{gathered} \tag{10}$$

Asymmetry follows from irreflexivity and transitivity.

The ontological complete-condition domain $\mathbb{X}^{\text{full}}_A$ contains the physically realized conditions of A; it is not defined as a quotient of descriptions. Raw domain descriptions belong instead to $\widetilde{\mathbb{X}}^{\text{full}}_A$. Let $\sim^{\text{phys}}_A$ identify gauge-, coordinate-, and representation-redundant descriptions that denote the same physical condition. It is required to be an equivalence relation on the raw-description space:

$$\begin{gathered} \forall \widetilde{X} \in \widetilde{\mathbb{X}}^{\text{full}}_A : \ \widetilde{X} \sim^{\text{phys}}_A \widetilde{X}, \\ \forall \widetilde{X}_1, \widetilde{X}_2 \in \widetilde{\mathbb{X}}^{\text{full}}_A : \ \widetilde{X}_1 \sim^{\text{phys}}_A \widetilde{X}_2 \Longrightarrow \widetilde{X}_2 \sim^{\text{phys}}_A \widetilde{X}_1, \\ \forall \widetilde{X}_1, \widetilde{X}_2, \widetilde{X}_3 \in \widetilde{\mathbb{X}}^{\text{full}}_A : \ \big(\widetilde{X}_1 \sim^{\text{phys}}_A \widetilde{X}_2 \wedge \widetilde{X}_2 \sim^{\text{phys}}_A \widetilde{X}_3\big) \Longrightarrow \widetilde{X}_1 \sim^{\text{phys}}_A \widetilde{X}_3. \end{gathered} \tag{11}$$

The corresponding formal full-state model space and its semantic denotation map are

$$\begin{gathered}\mathbb{M}_A^{\mathrm{full}} := \widetilde{\mathbb{X}}_A^{\mathrm{full}} / \sim_A^{\mathrm{phys}}, \qquad \mathrm{Den}_A : \mathbb{M}_A^{\mathrm{full}} \longrightarrow \mathbb{X}_A^{\mathrm{full}}, \\ \mathbf{m}_A : \mathbb{O}_A \rightharpoonup \mathbb{M}_A^{\mathrm{full}}, \\ o \in \mathrm{Dom}(\mathbf{m}_A) \Longrightarrow \exists \widetilde{X} \in \widetilde{\mathbb{X}}_A^{\mathrm{full}} : \Big[\mathbf{m}_A(o) = [\widetilde{X}]_{\sim_A^{\mathrm{phys}}} \wedge \mathrm{Den}_A(\mathbf{m}_A(o)) = X_A(o)\Big]. \end{gathered} \tag{12}$$

Thus $X_A(o)$ is fixed for every occurrence by the ontological occurrence-to-condition map, while $\mathbf{m}_A(o)$ is defined only on those occurrences for which a declared formal, redundancy-controlled full-state representative is supplied. The relation $\equiv_{\mathrm{phys}}$ compares denoted physical conditions, not raw coordinates, gauge representatives, or finite measurement projections. For an extended relativistic system, an occurrence may be a covariantly specified distributed, hypersurface-indexed, or spacetime-region realization; the specialization must declare the construction and any residual foliation dependence without treating coordinate or gauge change as physical change.

Formal Constraint 3.1. Equality, equivalence, and non-entailment conventions.

- $:=$ introduces a definition.
- $=$ denotes equality within one declared numerical, set-theoretic, functional, or coordinate type.
- $X_A(o_1) \equiv_{\mathrm{phys}} X_A(o_2)$ and $X_A(o_1) \not\equiv_{\mathrm{phys}} X_A(o_2)$ denote physical identity and physical non-identity of complete realized conditions.
- $\mathbf{x}_1 \cong_{\mathscr{D}} \mathbf{x}_2$ and $\mathbf{x}_1 \ncong_{\mathscr{D}} \mathbf{x}_2$ denote equivalence and non-equivalence under a declared representation-domain criterion; representational equivalence need not imply physical identity.
- $Y \equiv_{\mathrm{type}} Z$ and $Y \not\equiv_{\mathrm{type}} Z$ denote identity or non-identity of ontological/formal type.
- $P \not\models Q$ is used only as semantic non-entailment relative to the explicitly stated definitions and premises. No proof-theoretic claim is intended. Where no formal premise class is declared, the prose formulation "does not by itself warrant" is preferred.

Formal Constraint 3.2. Reserved distinctions.

$$\begin{gathered}\xi \not\equiv_{\mathrm{type}} o, \qquad X_A(o) \not\equiv_{\mathrm{type}} \mathbf{x}_{A,\mathscr{D}}[\xi], \qquad X_A(o) \not\equiv_{\mathrm{type}} \widehat{\mathbf{x}}_{A,\mathscr{D}}^{(M)}[\xi], \\ \delta_{A,\mathscr{D}}^{[\alpha,\beta]} \not\equiv_{\mathrm{type}} \mathcal{H}_A[\xi_\alpha, \xi_\beta], \qquad T_{\mathrm{ITOF}} \not\equiv_{\mathrm{type}} \mathfrak{T}_{\mathrm{ITOF}}, \\ T_{\mathrm{ITOF}} \not\equiv_{\mathrm{type}} t_C, \qquad T_{\mathrm{ITOF}} \not\equiv_{\mathrm{type}} D_C, \qquad T_{\mathrm{ITOF}} \not\equiv_{\mathrm{type}} \tau[\gamma, g], \qquad T_{\mathrm{ITOF}} \not\equiv_{\mathrm{type}} G_C. \end{gathered} \tag{13}$$

A finite representation may be sufficient for a declared task without becoming identical to the complete realized condition. A stage is introduced only after realized change has been defined; later use of a stage symbol therefore abbreviates a derived occurrence classification rather than a primitive ontology.

4. Physical Ontology: Systems, Factors, Boundaries, and Participation

Bearer principle. Physical change belongs to a physically constituted system. A coordinate, reading, model variable, or temporal description is not substituted for that bearer.

4.1 Physical systems and constitution

A physical system is a physically constituted organization distinguished under a specified physical boundary and identity criterion whose physical basis and role are stated. Its identity is carried by that organization, not by a coordinate location or an empty label. It has a structural constitution, properties, internal relations, processes, and—where applicable—multiple connected components or sub-systems. Systems can range from minimally constituted forms to weakly, moderately, or extensively organized systems. The boundary may be material, field-theoretic, causal, functional, or spatial, provided its physical basis and role are declared. Thus

$$A \in \mathbb{S}_{\text{phys}}. \tag{14}$$

A schematic constitution is

$$\Theta_A = \langle \text{Comp}_A, \text{Rel}_A, \text{Prop}_A, \text{Org}_A, \text{Cap}_A \rangle . \tag{15}$$

The relevant domain supplies the detailed ontology. ITOF requires the target of attribution to have a declared physical basis and an identity criterion explicit enough for the claim made.

An internal process is counted within the system whenever the adopted boundary includes the structures that realize it:

$$\text{InternalTo}(Y, A) \Longrightarrow Y \subseteq \text{ConstitutionOrProcess}(A). \tag{16}$$

The inclusion sign is schematic where the domain does not use a literal set ontology. Its function is to prevent the same physical contribution from being counted both internally and externally.

4.2 Physical factors and influencing systems

Within a declared analysis, $\mathbb{F}_{\text{phys}}$ denotes non-system physical factors admitted into the engagement account, such as physically specified fields, fluxes, transfers, radiation, pressures, or other non-system influences recognized by the relevant domain. A numerical value, unexplained residual, contextual label, or mere name is not itself a factor. Admission requires a physically specified bearer or process, a path to the target, and domain relevance:

$$\text{AdmissibleFactor}(f; A, \mathscr{D}) \Longrightarrow [f \in \mathbb{F}_{\text{phys}} \wedge \text{DefinedPath}(f \to A) \wedge \text{DomainRelevance}_{\mathscr{D}}(f, A)] . \tag{17}$$

The active ontology keeps the system role and the non-system-factor role disjoint within one declared attribution account $\mathscr{A}$. Let $\mathbb{S}^{(\mathscr{A})}_{\text{phys}}$ and $\mathbb{F}^{(\mathscr{A})}_{\text{phys}}$ denote the role-assigned classes in that account. Then

$$\mathbb{S}^{(\mathscr{A})}_{\text{phys}} \cap \mathbb{F}^{(\mathscr{A})}_{\text{phys}} = \varnothing. \tag{18}$$

The disjointness is scoped to the stated boundary and classification of $\mathscr{A}$: the same participant is not counted simultaneously as a full system and as a non-system factor in one attribution. A bearer may be modeled as a full physical system in another analysis with a different declared boundary, provided that the reclassification is explicit and does not duplicate its physical contribution. This is a distinction of role assignment within an account, not a denial of causal capacity. If $B \in \mathbb{S}_{\text{phys}}^{(\mathscr{A})}$ influences A, it remains a system in that account:

$$B \in \mathbb{S}_{\text{phys}}^{(\mathscr{A})} \wedge \text{Influences}(B, A; [\alpha, \beta]) \Longrightarrow B \notin \mathbb{F}_{\text{phys}}^{(\mathscr{A})}. \tag{19}$$

A system may generate or mediate a distinct field, flux, transfer, radiation process, or other factor; both may be recorded when the evidence requires both. The system identity and the influencing role must not be conflated.

4.3 Boundaries and environment

The physical boundary of a system follows from the extent of its constituted organization, components, internal relations, and the identity criterion under which it is treated as one system:

$$\partial A \longmapsto (\text{Internal}(A), \text{External}(A)). \tag{20}$$

An analysis then declares which physically constituted system, sub-system, branch, or composite is under study. That declaration selects the target and the scope of access; it does not create the system, its constitution, or its physical boundary. A test may focus on one branch or sub-system, or may combine multiple components and branches to provide a broader representation of the whole system. The scope of the test determines the scope of the warranted conclusion and must not be confused with the full physical extent of the system. Selecting a sub-system changes the declared target of analysis rather than the physical boundary of the larger system. No classification may duplicate or erase an actual physical influence.

The environment is a descriptive context rather than one cause. A record may be written

$$\text{Env}_{A,\mathscr{D}} = \langle \mathcal{S}_{A,\text{env}}, \mathcal{F}_{A,\text{env}}, \mathcal{M}_{A,\text{env}}, \mathcal{C}_{A,\text{env}} \rangle, \tag{21}$$

where the entries denote surrounding systems, candidate factors, media or pathways, and contextual constraints. Presence is not engagement:

$$\text{PresentInEnvironment}(Y, A) \not\models \text{Coupled}(Y, A; [\alpha, \beta]). \tag{22}$$

Physical attribution begins only after the coarse environmental description has been decomposed into typed participants and supported couplings.

5. Universal Sustained Change and System-Specific Realization

Universal sustained-change postulate. Every admissible identity-extended physical system undergoes sustained realized change on each realized identity-preserving history chain. The postulate is non-vacuous and identity-bounded. It does not assert topological continuity, order density, differentiability, a real-valued universal parameter, or detectable variation at every arbitrarily selected scale.

5.1 Physical occurrences and prior–later order

For each selected system A, $\mathbb{O}_A$ is the domain of physical occurrences attributable to A. The system-restricted prior–later relation is

$$\lhd_A := \prec \cap (\mathbb{O}_A \times \mathbb{O}_A). \tag{23}$$

It is irreflexive, asymmetric, and transitive on physically warranted pairs. It is not assumed to compare every pair of occurrences, and its restriction to A is not an independent local time.

5.2 Non-circular realized change and derived stages

For $o_\alpha, o_\beta \in \mathbb{O}_A$, realized physical change is defined by

$$\mathrm{Change}_A(o_\alpha, o_\beta) \ :\Longleftrightarrow \ \big(o_\alpha \lhd_A o_\beta\big) \wedge \big(X_A(o_\alpha) \not\equiv_{\mathrm{phys}} X_A(o_\beta)\big). \tag{24}$$

The occurrence domain and order relation are not defined through Change_A; hence the definition does not presuppose the change it characterizes. Equation (24) is an endpoint-resolved condition-change predicate: it states that the two selected occurrences differ physically. It does not imply that no change occurred within a physical history whose selected endpoints are physically equivalent; cyclic or recurrent process change is represented by the intervening physical history. Difference without order describes alternatives, while order without physical non-identity does not by itself establish endpoint condition change.

A stage is derived only after Equation (24) is available:

$$\mathrm{StageOf}_A(o) \ :\Longleftrightarrow \ o \in \mathbb{O}_A \wedge \exists o' \in \mathbb{O}_A : \ \big[\mathrm{Change}_A(o, o') \vee \mathrm{Change}_A(o', o)\big]. \tag{25}$$

Thus no countermodel or null preparation is forced to contain "stages of change" before change has been established. In later sections the symbol s may be used for an occurrence already certified by Equation (25); it is never a primitive alternative to o.

For expository use, minimum prior–later succession is the same nontrivial identity extension already defined in Equation (7):

$$\mathrm{PriorLaterSuccession}(A) \ :\Longleftrightarrow \ \mathrm{IdentityExtended}(A). \tag{26}$$

This is an explicit alias, not a second independent predicate. The existence of at least one endpoint-resolved condition change is stated separately:

$$\mathrm{EndpointChangeExists}(A) \ :\Longleftrightarrow \ \exists o_\alpha, o_\beta \in \mathbb{O}_A : \ \mathrm{Change}_A(o_\alpha, o_\beta). \tag{27}$$

This separation keeps bare order, endpoint-resolved physical difference, and process change within an intervening history as distinct claims.

5.3 Identity-bounded, branch-complete, and non-vacuous sustained change

Because every member of $\mathbb{O}_A$ is already attributable to the fixed identity specification Spec(A), identity-preserving realized chains can be defined directly on the occurrence order. Let

$$\begin{aligned}\mathrm{Chain}_A(C) :\Longleftrightarrow\ & C \subseteq \mathbb{O}_A \wedge C \neq \varnothing \\ & \wedge \forall o_1, o_2 \in C :\ \big[o_1 = o_2 \vee o_1 \lhd_A o_2 \vee o_2 \lhd_A o_1\big].\end{aligned} \tag{28}$$

Mathematical maximality and physical realization are distinct. Define

$$\mathrm{MaximalChain}_A(C) :\Longleftrightarrow \mathrm{Chain}_A(C) \wedge \neg\exists C' \subseteq \mathbb{O}_A : \big[C \subsetneq C' \wedge \mathrm{Chain}_A(C')\big]. \tag{29}$$

The ontological predicate RealizedHistoryChain$_A(C)$ states that C is one physically realized identity-preserving history rather than a maximal comparable subset generated only by spatial incomparability or incomplete formal ordering:

$$\mathrm{RealizedHistoryChain}_A(C) \Longrightarrow \big[C \subseteq \mathbb{O}_A \wedge \mathrm{Chain}_A(C)\big]. \tag{30}$$

Empirical or model-based licensing is separate. Define the evidential predicate

$$\mathrm{HistoryLicensed}_{A,\mathscr{D},\mathcal{P}} : 2^{\mathbb{O}_A} \longrightarrow \{\mathrm{true}, \mathrm{false}\}. \tag{31}$$

When HistoryLicensed$_{A,\mathscr{D},\mathcal{P}}(C)$ holds, the declared domain and protocol provide adequate causal continuity, record linkage, localization, trajectory, or equivalent evidence for attributing C as a realized history chain. The license warrants the attribution within that analysis; it neither defines the ontological predicate nor makes absence of a present license imply absence of a physical history. The family used by the sustained-change postulate is therefore

$$\mathfrak{C}_A^{\mathrm{id}} := \{C \subseteq \mathbb{O}_A \mid \mathrm{MaximalChain}_A(C) \wedge \mathrm{RealizedHistoryChain}_A(C)\}\,. \tag{32}$$

Every member of $\mathfrak{C}_A^{\mathrm{id}}$ consists of realized occurrences attributable to the same fixed system specification. Mathematical maximal chains that arise only from incomparability or incomplete ordering are not promoted automatically to physical-history branches. If physical branching is realized, every maximal realized identity-preserving branch is evaluated separately; experimental access to a branch additionally requires the corresponding domain license.

Identity continuation is defined without using change:

$$\mathrm{IdOpen}_A(o; C)\ :\Longleftrightarrow\ C \in \mathfrak{C}_A^{\mathrm{id}} \wedge o \in C \wedge \exists o^+ \in C :\ o \lhd_A o^+. \tag{33}$$

The predicate states only that the same declared system identity remains applicable later on the selected realized chain; it does not assert physical non-identity.

The continuing extension of realized change is

$$\begin{aligned}\mathrm{SuccessionExtends}(A)\ :\Longleftrightarrow\ & \forall C \in \mathfrak{C}_A^{\mathrm{id}}\ \forall o \in C : \Big[\mathrm{IdOpen}_A(o; C) \\ & \Longrightarrow \exists o' \in C : \big(o \lhd_A o' \wedge \mathrm{Change}_A(o, o')\big)\Big].\end{aligned} \tag{34}$$

Thus a changing branch cannot mask a permanently constant realized branch. The non-vacuous sustained predicate is

$$\begin{aligned}\text{SustainedChange}(A) \ :\Longleftrightarrow \ &\Big[\exists C_0 \in \mathfrak{C}_A^{\mathrm{id}}\ \exists o_0 \in C_0 : \text{IdOpen}_A(o_0; C_0)\Big] \\ &\wedge \text{SuccessionExtends}(A).\end{aligned} \tag{35}$$

The first conjunct prevents vacuous truth. The second permits finite plateaus, equilibrium, recurrence, periodicity, and equality of selected observables, but excludes permanent physical identity of the complete condition on any realized identity-preserving continuation chain.

The universe-wide commitment is

$$\boxed{\forall A \in \mathbb{S}_{\mathrm{phys}}^{\mathcal{U}} : \ \text{SustainedChange}(A).} \tag{36}$$

Its universality is quantificational, not homogenizing. It compares no two systems in the definition of time and imposes no common mechanism, rate, magnitude, path, or outcome.

5.4 System-specific realization and local evidence

For a selected comparison, system-specific conditioning may be organized analytically as

$$\mathcal{K}_A^{\mathrm{chg}}[\alpha,\beta] := \Big\langle \Theta_A, \mathcal{I}_A^{\mathrm{int}}[\alpha,\beta], \mathcal{E}_A^{\mathrm{ext}}[\alpha,\beta], \mathcal{B}_A^{\mathrm{cond}}[\alpha,\beta] \Big\rangle . \tag{37}$$

This tuple is a bookkeeping decomposition, not an additional physical participant or universal law. The domain supplies the dynamics, and internal constitution is not duplicated as a second independent state input.

For a validated measurement chain,

$$\mathsf{RC}_{M,\mathscr{D}}^{[\alpha,\beta]}(A) \Longrightarrow \text{LocalPhysicalChange}_{\mathscr{D}}^{[\alpha,\beta]}(A). \tag{38}$$

A local result neither proves nor disproves the universal sustained predicate over $\mathbb{S}_{\mathrm{phys}}^{\mathcal{U}}$ by itself:

$$\text{LocalPhysicalChange}_{\mathscr{D}}^{[\alpha,\beta]}(A) \not\models \text{SustainedChange}(A), \tag{39}$$

$$\neg\mathsf{RC}_{M,\mathscr{D}}^{W}(A) \not\models \neg\,\text{SustainedChange}(A), \tag{40}$$

$$\neg\mathsf{RC}_{M,\mathscr{D}}^{W}(A) \not\models \text{SustainedChange}(A). \tag{41}$$

These are limits on inference from a finite representation, not immunity from empirical restriction.

Single bearer and multiple stages. If $o_\alpha, o_\beta \in \mathbb{O}_A$ are derived stages on one identity-preserving history segment, their multiplicity belongs to the occurrences and realized conditions, not to replicated system bearers. The indexing of $\mathbb{O}_A$, $X_A(o_\alpha)$, and $X_A(o_\beta)$ already fixes A as the common bearer. Physical non-identity of the two complete conditions therefore does not multiply the system. Reproduction, fission, fusion, branching, and loss of identity require separately declared successor-system identities; they are not inserted retrospectively into the ended identity of A.

The governing implication is

$$\text{SustainedChange}(A) \implies \Big[\text{PriorLaterSuccession}(A) \wedge \text{EndpointChangeExists}(A) \\ \wedge \text{SuccessionExtends}(A)\Big]. \tag{42}$$

It analytically unpacks the sustained predicate; succession and extension are not additional physical causes.

The extension fixes no cardinality, topology, density, differentiability, adjacency, or real-line parameterization. A finite selection does not exhaust it, and a zero represented difference does not establish absence of a realized history:

$$\delta^{[\alpha,\beta]}_{A,\mathscr{D}} = 0 \not\models \neg\,\text{HistoryRealized}_A[\xi_\alpha, \xi_\beta]. \tag{43}$$

6. Physical Motivation and Evidential Grounds of the Universal Sustained-Change Postulate

Positive evidential basis. The sustained-change postulate is grounded in a convergent physical record: increasingly resolved observations disclose stage-dependent differences, transformations, internal dynamics, and engagement-conditioned histories across microscopic, molecular, macroscopic, relativistic, biological, and astronomical systems. Its empirical strength comes from the diversity, repeatability, and cross-scale convergence of positively resolved physical change, together with explicit tests that support, restrict, or challenge domain specializations.

The universal sustained-change postulate is stronger than the statement that many selected observables vary. Its object is the physically realized system as a whole. Astronomical surveys resolve successive source-dependent records; relativistic clock and particle experiments resolve path- and geometry-conditioned differences; monitored quantum systems disclose transition trajectories; single-molecule experiments resolve dynamics concealed by ensemble averages; and attosecond measurements resolve coupled electronic and nuclear developments on femtosecond and sub-femtosecond scales [23, 24, 26, 29, 33, 34, 35, 36, 37, 38, 40, 41]. These results directly establish particular physical differences and histories in their declared domains. Their convergence supplies positive support for the foundational judgment that admissible identity-extended physical systems do not occupy an absolutely changeless mode of existence.

The cited experiments establish resolved changes and histories in their declared systems, variables, and observation windows. Their cross-domain convergence provides the positive empirical basis for the framework, while the universe-wide statement is presented explicitly as a foundational postulate rather than an enumerative theorem. Scientific accountability is supplied by the exact counterexample class and the domain protocols developed in Section 24.

A system may be stationary relative to a coordinate frame, stable under an engineering criterion, in equilibrium relative to a thermodynamic description, or invariant under a restricted set of observables while remaining physically describable through conditions, relations, constraints, fields, processes, or interactions. ITOF therefore asks whether the complete realized condition of any constituted system can be physically established as absolutely changeless, not merely whether one selected description can remain constant.

6.1 Constitution as a basis of physical susceptibility

A physical system is not treated as a bare name or an analytically structureless point to which change is simply added from outside. It is a physically constituted unity under a declared boundary and identity criterion. Constitution may be elementary, field-theoretic, composite, distributed, or relational; it does not require every system to possess multiple internal components of the same kind. The constitution Θ_A is the single object defined in Equation (15); a domain may project or refine its entries, but it must not redefine Θ_A under a second incompatible tuple. The definition is schematic rather than a universal microscopic ontology.

Constitution supports physical susceptibility to realized difference. Components where applicable may interact, relations may be maintained or transformed, constraints may be satisfied through continuing processes, and boundaries may mediate exchanges or couplings. Accordingly,

$$\mathrm{ConstitutedPhysicalSystem}(A) \Longrightarrow \mathrm{PhysicallySusceptible}(A), \tag{44}$$

where susceptibility means that the physically realized condition is not protected by definition against all internal and external variation. Susceptibility alone neither specifies which change occurs nor deductively establishes sustained realized change. The latter remains the explicit universal postulate; domain dynamics and realized engagements determine the physical content of particular changes.

6.2 Microscopic dynamics without reductive overstatement

For composite systems, apparent macroscopic stability can coexist with resolved dynamics in microscopic or mesoscopic degrees of freedom. Trapped-ion transitions, monitored superconducting artificial-atom trajectories, single-molecule fluctuations, electron-density migration, nuclear wave-packet spreading, relaxation, decay, and field-mediated processes show that a coarse constant observable need not exhaust the realized condition [36, 37, 38, 39, 40, 41]. When a declared microscopic representation resolves a non-zero difference,

$$\mathrm{ResolvedMicrodynamics}^{[\alpha,\beta]}_{A,\mathscr{D}_\mu} \Longrightarrow \mathrm{LocalPhysicalChange}^{[\alpha,\beta]}_{\mathscr{D}_\mu}(A). \tag{45}$$

The implication is evidentially positive and local: it attributes the resolved difference to the constituted system and the domain variables that detect it. It supplies a tested segment of physical development and contributes to the convergent warrant for the sustained-change postulate, but it does not deductively establish uninterrupted change throughout the complete identity history. The converse is not assumed, because a given microscopic model may omit relevant degrees of freedom or fail to resolve an existing difference.

ITOF does not claim that every physical system is molecular or atomic, nor that every higher-level change is reducible to an additive inventory of constituent motions. Elementary, field-theoretic, collective, distributed, and relational systems remain admissible. The relevant principle is scale-sensitive rather than reductive: where a finer physically justified representation reveals continuing development hidden by a coarse one, the finer result constrains the system history without converting that representation into the complete ontology of the system.

6.3 Internal development and external engagement

The sources of realized change should not be collapsed into an exclusively external-cause picture. A system may change through internal development even when the selected external-engagement configuration takes the typed null value. Conversely, external participation may alter, constrain, sustain, or destroy the system. The canonical change-conditioning configuration is $\mathcal{K}_A^{\mathrm{chg}}[\alpha, \beta]$ from Equation (37); no second definition is introduced here. Its external entry satisfies

$$\mathcal{E}_A^{\mathrm{ext}}[\alpha, \beta] \in \mathbb{E}^0_{A,\mathrm{ext}}, \tag{46}$$

where the admissible class includes the typed null value $\varnothing_A^{\mathrm{ext}}$. The general attribution is

$$\mathrm{HistoryRealized}_A[\xi_\alpha, \xi_\beta] \Leftarrow_{\mathscr{D}} \mathcal{K}_A^{\mathrm{chg}}[\alpha, \beta], \tag{47}$$

where the decorated arrow means "is physically accounted for within domain $\mathscr{D}$ by" and is not a universal equation of motion. The concrete law may be classical, relativistic, quantum, statistical, biological, computational, or another domain-appropriate closure.

6.4 Networks of actual engagement without universal all-to-all influence

Advanced observation increasingly resolves systems as embedded in networks of fields, fluxes, exchanges, constraints, and interactions. This supports the physical relevance of continuing internal and external conditioning, but it does not license the claim that every system or factor acts on every other system at every stage. An external participant enters the realization account only through a physically specified path:

$$\mathrm{Engaged}_{\mathscr{D}}(B, A; \Gamma, [\alpha, \beta]) \Longrightarrow B \in \mathrm{Carriers}\Big(\mathcal{E}_A^{\mathrm{ext}}[\alpha, \beta]\Big), \tag{48}$$

where Γ denotes the domain-supported interaction, transfer, propagation, or constraint pathway. Environmental membership without such a path is not counted as realized engagement. The physical picture is therefore one of widespread but typed and pathway-dependent interconnection, not an undifferentiated assertion that everything continuously influences everything else.

6.5 Why size, motion, and apparent stillness do not create exceptions

The universal claim is scale-neutral. It is not restricted to macroscopic moving bodies, nor does it exclude microscopic, composite, extended, diffuse, bound, or approximately isolated systems. If $\mathrm{Scale}(A)$ denotes a chosen scale classification, then

$$\mathrm{Scale}(A) = \sigma \not\models \neg\,\mathrm{SustainedChange}(A) \tag{49}$$

for any scale label σ. Scale affects the appropriate variables, dynamics, resolution, and identity criterion; it does not by itself establish a terminal changeless state.

Likewise, kinematic rest concerns a relation between a system and a reference construction. It does not assert that all internal variables, fields, constraints, exchanges, or relational properties are invariant. Thus

$$\mathrm{Rest}_{\mathcal{R}}(A) \not\models \exists \mathcal{J}\ \mathrm{CompleteConstancy}_A(\mathcal{J}). \tag{50}$$

The same discipline applies to uniform motion. Motion is one form or condition of physical change, not the exhaustive definition of change. ITOF therefore does not derive time from motion and does not suspend time when motion is absent relative to a selected frame.

6.6 Motion and rotation as transparent examples of extended change

Motion and rotation as transparent examples of extended change. For one arbitrary physical system A, physically realized motion or rotation provides a particularly clear example of the continuing extension of change within that system's own physical history. The example does not define time by comparing A with a second system. It begins with the realized conditions of A itself and acquires universal scope only by applying the same construction to arbitrary physical systems.

A merely assigned relative-kinematic classification in a chosen reference description establishes a represented change of spatial relation, but it does not by itself establish an additional internal force or dynamical influence on the system. By contrast, where motion is physically realized in the system and is dynamically effective, it may be part of the realized condition of A and may contribute directly, through the applicable domain dynamics, to further change in that same system. Rotation is likewise a realized physical process rather than a detached geometrical label. Accordingly, for arbitrary $A \in \mathbb{S}^{\mathcal{U}}_{\mathrm{phys}}$ under a declared domain account,

$$\mathrm{RealizedMotion}^{[\alpha,\beta]}_{\mathscr{D}}(A) \Longrightarrow \mathrm{LocalPhysicalChange}^{[\alpha,\beta]}_{\mathscr{D}}(A), \tag{51}$$

$$\mathrm{RealizedRotation}^{[\alpha,\beta]}_{\mathscr{D}}(A) \Longrightarrow \mathrm{LocalPhysicalChange}^{[\alpha,\beta]}_{\mathscr{D}}(A). \tag{52}$$

Each implication establishes a domain-local segment of physically realized change. Under the sustained-change postulate, such segments instantiate the system history in which prior–later succession and its continuation are analytically articulated by Equation (42); no finite motion or rotation record alone proves the universal sustained predicate over $\mathbb{S}^{\mathcal{U}}_{\mathrm{phys}}$. These implications do not introduce motion or rotation as causes acting on succession. Motion and rotation are physically realized forms or conditions of change; the order belongs to their realized stages.

The continuing realization of different positions, orientations, momenta, or dynamical configurations does not multiply the system bearer. For identity-preserving stages $s_\alpha \lhd_A s_\beta \lhd_A s_\gamma$ belonging to $\mathbb{O}_A$, the common index A fixes one bearer while the stages and complete conditions differ. Periodic recurrence of a selected represented variable likewise does not restore an earlier realized stage. For example,

$$\theta_{A,\mathscr{D}}(X_A(s_\gamma)) \equiv_{2\pi} \theta_{A,\mathscr{D}}(X_A(s_\alpha)) \not\models [s_\gamma = s_\alpha\ \vee\ X_A(s_\gamma) \equiv_{\mathrm{phys}} X_A(s_\alpha)]\,. \tag{53}$$

A recurring orientation or represented pattern is therefore realized later in the non-reversible succession; it is not the return of the earlier physical stage.

Motion or rotation may also alter an effective engagement reaching another system and thereby contribute to change realized in that system. Such a case belongs to a relational, causal, or experimental analysis and must be represented through the appropriate engagement pathway. It is not part of the definition of time. Motion and rotation are neither identical with T_{ITOF} nor physical causes acting upon time; they are physically realized processes whose continuing change makes the extension of succession especially explicit.

6.7 Equilibrium, stability, and maintained organization

Equilibrium and stability are domain-relative classifications. A thermodynamic equilibrium state, a dynamically stable configuration, or a functionally maintained regime may suppress or balance selected macroscopic differences without establishing identity of the realized condition across all stages. Write

$$\mathrm{Equilibrium}_{\mathscr{D}}(A) \Longrightarrow \mathrm{Balanced}_{\mathscr{D}}\left(\mathbf{x}_{A,\mathscr{D}}\right), \tag{54}$$

but not

$$\mathrm{Equilibrium}_{\mathscr{D}}(A) \not\models \exists \mathcal{J}\ \ \mathrm{CompleteConstancy}_{A}(\mathcal{J}). \tag{55}$$

The first statement is a permitted domain result; the second is an unjustified promotion from a finite representation to the physically realized condition.

Stability may itself require continuing physical maintenance. A persistent structure can remain within an admissible region while its components exchange energy, preserve constraints, undergo microscopic transitions, or interact with its surroundings. ITOF therefore distinguishes

$$\mathrm{StableForm}(A) \not\models \mathrm{NoHistory}(A). \tag{56}$$

This distinction is especially important because everyday language frequently treats "unchanged" as an unqualified physical statement when it means only "unchanged with respect to the selected criterion."

6.8 Approximate isolation is not absolute cessation

An isolated-system model excludes selected external exchanges under declared assumptions. It does not erase the system's internal constitution, nor does it prove that no physical relation within the system changes. Let

$$\mathcal{E}_{A}^{\mathrm{ext}}[\alpha,\beta] = \varnothing_{A}^{\mathrm{ext}} \tag{57}$$

represent the typed null engagement admitted by domain $\mathscr{D}$. Then

$$\mathcal{E}_{A}^{\mathrm{ext}}[\alpha,\beta] = \varnothing_{A}^{\mathrm{ext}} \not\models \neg\,\mathrm{HistoryRealized}_{A}[\xi_{\alpha},\xi_{\beta}]. \tag{58}$$

The model may still contain internal dynamics, phase development, constraint preservation, stochastic transitions, or other physical structure. If a domain genuinely predicts an invariant represented state, that is a result about that representation under those assumptions, not a proof of complete realized constancy across a nontrivial identity-preserving history segment.

6.9 Stationary quantum representations as a stringent conditional challenge

For a closed quantum model with time-independent Hamiltonian,

$$[H, \rho] = 0 \Longrightarrow \rho(u) = \rho(u_0) \quad \text{for all admitted } u, \tag{59}$$

under the model's declared evolution parameter u. An exact energy eigenstate is a special case. The global phase alone is not counted as an observable physical change, and ITOF does not preserve its postulate by asserting unspecified hidden activity.

To connect the parameterized quantum model to the occurrence ontology, a specialization must declare both a quantum projection and, when needed, a registration of occurrences to the model parameter:

$$\Pi^Q_{A,\mathscr{D}} : \mathbb{X}^{\text{full}}_A \longrightarrow \mathcal{D}(\mathcal{H}_{A,\mathscr{D}}), \qquad \rho_{A,\mathscr{D}}(o) := \Pi^Q_{A,\mathscr{D}}(X_A(o)), \tag{60}$$

$$u_{A,\mathscr{D}} : \mathbb{O}_A \longrightarrow U_{A,\mathscr{D}}, \qquad \rho_{A,\mathscr{D}}(o) = \rho\big(u_{A,\mathscr{D}}(o)\big) \tag{61}$$

whenever the parameterized solution is used. Here $\mathcal{D}(\mathcal{H}_{A,\mathscr{D}})$ is the declared density-operator space. The physically decisive question is whether this same stationary representation is independently complete for the realized condition. Define

$$\text{CompleteRep}_{A,\mathscr{D}}(\rho_{A,\mathscr{D}}) \;:\Longleftrightarrow\; \forall o_1, o_2 \in \mathbb{O}_A : \big[\rho_{A,\mathscr{D}}(o_1) = \rho_{A,\mathscr{D}}(o_2) \Longrightarrow X_A(o_1) \equiv_{\text{phys}} X_A(o_2)\big]. \tag{62}$$

This bridge is not assumed by default. It must be justified by the physical theory, the fixed system specification, and the measurement architecture.

An exact countermodel to the sustained-change postulate can be stated without presupposing stages of change. It exists if

$$\begin{aligned} &\exists A_\star \in \mathbb{S}^{\mathcal{U}}_{\text{phys}}\ \exists C_\star \in \mathfrak{C}^{\text{id}}_{A_\star}\ \exists o_\star \in C_\star : \Big[\text{IdOpen}_{A_\star}(o_\star; C_\star) \\ &\qquad \wedge \forall o' \in C_\star : \Big(o_\star \lhd_{A_\star} o' \Longrightarrow X_{A_\star}(o') \equiv_{\text{phys}} X_{A_\star}(o_\star)\Big)\Big]. \end{aligned} \tag{63}$$

Equation (63) is the logical negation of the branch-complete continuation clause for at least one realized identity-preserving history chain. It is non-vacuous because $\text{IdOpen}_{A_\star}(o_\star; C_\star)$ requires a later occurrence on that chain, and it does not use the derived stage predicate. Any empirical claim that the premises of this countermodel are physically established must be made under an $\text{AdmissibleAnalysis}(A_\star, \mathscr{D}, \mathcal{P})$; methodological admissibility warrants the claim but does not constitute the system or its history.

Accordingly, the stationary quantum case is treated conservatively. If Equation (59), the completeness bridge, continuing identity, and the exact constancy condition are independently established for a realized system, then the universal postulate fails for that system. If completeness is not established, stationarity of ρ remains a stringent constraint on the relevant specialization, not a resolved victory for either side. Open-system couplings, fields, boundaries, or additional degrees of freedom may be relevant only when specified and testable within an appropriate open-system model [42]; they may not be presumed merely to protect the postulate.

6.10 Extension implied by physical change

The distinctive content of the framework is not assembled from an isolated transition plus a second principle that later manufactures extension. Within the sustained-change postulate, SustainedChange(A) analytically entails prior–later succession and the identity-bounded stage extension stated in Equation (42). This does not require one property to change monotonically or one named system identity to persist indefinitely.

If system A transforms so radically that its identity criterion no longer applies, later realization is attributed to one or more successor physical systems under declared boundaries that may encompass resulting products, components, field configurations, or environmental reorganizations. The ending of one identity criterion is not the ending of physical change. Destruction, fusion, decay, and emergence therefore alter the bearer and classification of change without converting products, transfers, or effects into independently quantified systems unless a physical boundary and identity criterion are specified and ontically instantiated.

6.11 Evidential status and rational vulnerability

The universal sustained-change statement is a foundational physical postulate, not a theorem obtained by enumerating systems or generalizing one finite sample as a deductive proof. The cross-domain record described above empirically motivates the postulate, establishes broad compatibility with known physical change, and constrains domain-specific descriptions. It does not measure, count, bound, or exhaust the succession of stages and does not deductively establish

$$\forall A \in \mathbb{S}^{\mathcal{U}}_{\text{phys}} : \text{SustainedChange}(A). \tag{64}$$

Likewise, a constant selected observable, apparent rest, equilibrium classification, or null instrument output concerns a restricted representation and does not by itself establish complete realized constancy across a nontrivial identity-preserving history segment. Domain models remain empirically rejectable within their declared variables, observables, uncertainty, and decision rules; failure of such a model is not automatically failure of the universal postulate.

The postulate remains open to logical and physical criticism, revision, or abandonment if it becomes inconsistent with a better-supported physical theory, if its identity conditions prove incoherent, or if an independently justified account establishes a physically realized system that remains under the same identity while its complete realized condition remains constant across a nontrivial identity-preserving history segment. The manuscript does not claim that an ordinary finite null measurement can establish such exhaustive completeness. Accordingly, direct quantitative falsification belongs primarily to domain specializations, whereas the universal postulate is assessed by coherence, physical compatibility, explanatory necessity, and any independently established counterexample of sufficient scope.

7. Derived Stages, Continuing Succession, and Analytical Access

Occurrence–stage–reference separation. Physical occurrences are primitive with respect to the change definition. A stage is a derived occurrence that participates in realized change. Analytical references locate, compare, represent, or measure occurrences; they create neither the occurrence nor its order.

7.1 Derived stages and admissible references

Equation (25) defines the stage predicate. It does not enumerate all occurrences, impose a stage index, or convert the occurrence domain into a material temporal medium. Analytical work is organized by admissible domains

$$\mathfrak{D}_A := \{\mathscr{D} \mid \mathrm{AdmissibleDomain}_A(\mathscr{D})\}\,, \tag{65}$$

with reference families

$$\Xi_A := \bigsqcup_{\mathscr{D}\in\mathfrak{D}_A} \Xi_{A,\mathscr{D}}. \tag{66}$$

A reference is a locator used by a model, record, intervention, or comparison. It is not an occurrence or a stage.

The locating relation satisfies

$$\mathrm{Locates}_A(\xi, o) \Longrightarrow [\xi \in \Xi_A \wedge \mathrm{OccurrenceOf}_A(o)]. \tag{67}$$

When exact notation $X_A[\xi]$ is used, unique location is required:

$$\mathrm{Locates}_A(\xi, o) \wedge \exists! o' \;\mathrm{Locates}_A(\xi, o') \Longrightarrow X_A[\xi] := X_A(o). \tag{68}$$

Uncertain or distributed localization belongs to the measurement model.

7.2 Reference order from physically warranted occurrence order

The analytical reference order is the relation induced on uniquely located references by the physically warranted occurrence order:

$$\begin{aligned}\prec^{\Xi}_{A} := \Big\{(\xi_\alpha, \xi_\beta) \in \Xi_A \times \Xi_A \;\Big|\; & \exists o_\alpha, o_\beta \in \mathbb{O}_A :\ \mathrm{Locates}_A(\xi_\alpha, o_\alpha) \wedge \mathrm{Locates}_A(\xi_\beta, o_\beta) \\ & \wedge\ \exists! o \in \mathbb{O}_A : \mathrm{Locates}_A(\xi_\alpha, o) \\ & \wedge\ \exists! o \in \mathbb{O}_A : \mathrm{Locates}_A(\xi_\beta, o) \\ & \wedge\ o_\alpha \lhd_A o_\beta \Big\}.\end{aligned} \tag{69}$$

The typed analytical relation $\prec^{\Xi}_{A} \subseteq \Xi_A \times \Xi_A$ records supported order; it does not generate the ontological relation. Totality is not assumed. Causal chains, records, signal exchange, intervention protocols, validated clock procedures, or other domain evidence may support a particular comparison.

For any declared specialization with bearer label K, write

$$\prec^{\Xi}_{K} := \prec^{\Xi}_{A}\Big|_{A=K}. \tag{70}$$

This is only a bearer-specific abbreviation for the analytical relation of Equation (69); it introduces neither an independent local order nor a local time. In particular, $\prec_C^{\Xi}$ and $\prec_S^{\Xi}$ denote the clock- and source-specialized analytical reference orders used below.

For a localized relativistic specialization, let $\Xi_{A,\gamma} \subseteq \Xi_A$ contain only references satisfying the unique-location condition of Equation (68). An order-preserving localization is a declared map

$$\ell_{A,\gamma} : \Xi_{A,\gamma} \longrightarrow \gamma_A \tag{71}$$

satisfying

$$\begin{aligned} &\mathrm{OrderPreservingLocalization}_A(\ell_{A,\gamma}; \gamma_A) \\ &:\Longleftrightarrow \forall \xi_\alpha, \xi_\beta \in \Xi_{A,\gamma}\ \forall o_\alpha, o_\beta \in \mathbb{O}_A : \\ &\quad \Big[\mathrm{Locates}_A(\xi_\alpha, o_\alpha) \wedge \mathrm{Locates}_A(\xi_\beta, o_\beta) \wedge o_\alpha \lhd_A o_\beta \\ &\qquad \Longrightarrow \ell_{A,\gamma}(\xi_\beta) \in I^+(\ell_{A,\gamma}(\xi_\alpha))\Big]. \end{aligned} \tag{72}$$

This is a one-direction preservation condition. Order reflection is an additional assumption and must be stated separately when required.

7.3 Recurrence without reversal

Representational recurrence is typed separately from physical identity:

$$\mathbf{x}_{A,\mathscr{D}}[\xi_\beta] \cong_{\mathscr{D}} \mathbf{x}_{A,\mathscr{D}}[\xi_\alpha] \not\models X_A[\xi_\beta] \equiv_{\mathrm{phys}} X_A[\xi_\alpha]. \tag{73}$$

A later recurrence therefore does not restore the earlier occurrence or reverse its prior–later placement.

8. Physically Realized Conditions, Representations, Differences, and Histories

8.1 Physically realized condition

For a selected physically realized stage s, the notation

$$\mathrm{StageOf}_A(s) \Longrightarrow X_A(s) \in \mathbb{X}_A^{\mathrm{full}} \tag{74}$$

denotes the constituted physical condition of A at that stage. The notation includes the system's structural organization, properties, internal relations, processes, retained consequences, and other physically relevant features. It does not imply that a finite model or test can enumerate them exhaustively.

For a justified reference with unique location, the canonical condition of Equation (68) applies. Explicitly,

$$\mathrm{Locates}_A(\xi, s) \wedge \exists! o' \in \mathbb{O}_A :\ \mathrm{Locates}_A(\xi, o') \Longrightarrow X_A[\xi] := X_A(s). \tag{75}$$

The bracket notation is derived shorthand; it does not make the analytical reference the condition on which physical existence depends.

8.2 Representation and measurement

For domain $\mathscr{D}$, an ideal representation is

$$\mathbf{x}_{A,\mathscr{D}}[\xi] := \Pi_{A,\mathscr{D}}(X_A[\xi]), \qquad \Pi_{A,\mathscr{D}} : \mathbb{X}_A^{\mathrm{full}} \to \mathbb{Y}_{A,\mathscr{D}}. \tag{76}$$

Task-relative sufficiency never establishes identity with the physically realized condition. A test can focus on one branch, component, or sub-system, or combine multiple branches and components to provide a broader representation. The test scope determines the warranted scope of inference; it does not redefine the physical boundary or guarantee exhaustive access to the system.

For every declared measurement and reconstruction task, collect the instrument state, calibration, interpretation rule, uncertainty and nuisance structure, and any required auxiliary physical model into one inference package:

$$\mathcal{Q}_{M,\mathscr{D}}[\xi_{M,\mu}] := \left\langle X_M[\xi_{M,\mu}], \mathcal{C}_M, \mathcal{K}_{\mathscr{D}}^{\mathrm{int}}, \boldsymbol{\eta}_{M,\mathscr{D}} \right\rangle. \tag{77}$$

The package is declared once for the task; calibration parameters, covariance information, propagation models, and nuisance variables are included inside the appropriate entry and are not passed again as duplicate independent arguments. A measured or inferred estimate is then

$$\widehat{\mathbf{x}}_{A,\mathscr{D}}^{(M)}[\xi] := \mathcal{I}_{M,\mathscr{D}}\left(G_M; \mathcal{Q}_{M,\mathscr{D}}[\xi_{M,\mu}]\right). \tag{78}$$

Both the ideal representation and its estimate take values in the declared numerical or structured codomain,

$$\mathbf{x}_{A,\mathscr{D}}[\xi], \widehat{\mathbf{x}}_{A,\mathscr{D}}^{(M)}[\xi] \in \mathbb{Y}_{A,\mathscr{D}}. \tag{79}$$

Provenance belongs to a tagged representation object, not to the raw value alone. Define the disjoint tagged space

$$\mathbb{G}_{A,\mathscr{D}}^{\mathrm{prov}} := \{\mathrm{ideal}\} \bigsqcup \bigsqcup_{M} \{(M, \mathrm{inferred})\}, \qquad \mathbb{Z}_{A,\mathscr{D}} := \bigsqcup_{g \in \mathbb{G}_{A,\mathscr{D}}^{\mathrm{prov}}} (\mathbb{Y}_{A,\mathscr{D}} \times \{g\}), \tag{80}$$

where M ranges over the admitted measurement architectures for the task, with tagged objects

$$\mathbf{z}_{A,\mathscr{D}}^{\mathrm{ideal}}[\xi] := \big(\mathbf{x}_{A,\mathscr{D}}[\xi], \mathrm{ideal}\big), \tag{81}$$

$$\widehat{\mathbf{z}}_{A,\mathscr{D}}^{(M)}[\xi] := \big(\widehat{\mathbf{x}}_{A,\mathscr{D}}^{(M)}[\xi], (M, \mathrm{inferred})\big). \tag{82}$$

The canonical projections satisfy

$$\mathrm{Val}\Big(\mathbf{z}_{A,\mathscr{D}}^{\mathrm{ideal}}[\xi]\Big) = \mathbf{x}_{A,\mathscr{D}}[\xi], \qquad \mathrm{Prov}\Big(\mathbf{z}_{A,\mathscr{D}}^{\mathrm{ideal}}[\xi]\Big) = \mathrm{ideal}, \tag{83}$$

$$\mathrm{Val}\Big(\widehat{\mathbf{z}}_{A,\mathscr{D}}^{(M)}[\xi]\Big) = \widehat{\mathbf{x}}_{A,\mathscr{D}}^{(M)}[\xi], \qquad \mathrm{Prov}\Big(\widehat{\mathbf{z}}_{A,\mathscr{D}}^{(M)}[\xi]\Big) = (M, \mathrm{inferred}). \tag{84}$$

Thus the two numerical values may be equal in $\mathbb{Y}_{A,\mathscr{D}}$ while the tagged representation objects retain different provenance and inferential roles. Each value remains type-distinct from the complete physical condition:

$$\widehat{\mathbf{x}}_{A,\mathscr{D}}^{(M)}[\xi] \not\equiv_{\mathrm{type}} X_A[\xi], \qquad \mathbf{x}_{A,\mathscr{D}}[\xi] \not\equiv_{\mathrm{type}} X_A[\xi]. \tag{85}$$

8.3 Selected-condition difference and physical history

The ideal and measured selected-condition differences are

$$\delta_{A,\mathscr{D}}^{[\alpha,\beta]} := \mathrm{Diff}_{\mathscr{D}}\left(\mathbf{x}_{A,\mathscr{D}}[\xi_\beta], \mathbf{x}_{A,\mathscr{D}}[\xi_\alpha]\right), \tag{86}$$

$$\widehat{\delta}_{A,\mathscr{D}}^{(M)[\alpha,\beta]} := \mathrm{Diff}_{\mathscr{D}}\left(\widehat{\mathbf{x}}_{A,\mathscr{D}}^{(M)}[\xi_\beta], \widehat{\mathbf{x}}_{A,\mathscr{D}}^{(M)}[\xi_\alpha]\right). \tag{87}$$

The general difference operator is typed by

$$\mathrm{Diff}_{\mathscr{D}} : \mathbb{Y}_{A,\mathscr{D}} \times \mathbb{Y}_{A,\mathscr{D}} \longrightarrow \Delta_{A,\mathscr{D}}, \qquad \mathbf{0}_{A,\mathscr{D}} \in \Delta_{A,\mathscr{D}}, \tag{88}$$

where $\Delta_{A,\mathscr{D}}$ is the domain-declared difference space. Euclidean coordinates, norms, covariance matrices, or quadratic statistics are additional structures supplied only when the specialization justifies them.

The selected-condition differences compare domain representations or measured estimates associated with two selected physical-condition occurrences. They do not establish that physical change begins at ξ_α, ends at ξ_β, or is produced by one identifiable stage. The physical history is first a relation among realized stages and conditions; references enter only when that history is registered for analysis:

Physical history and analytical registration.

$$\begin{aligned}&\mathrm{PhysicalHistory}_A(h; s_\alpha, s_\beta)\\ &\qquad \Longrightarrow \Big[h \in \mathbb{H}_A \wedge \mathrm{StageOf}_A(s_\alpha) \wedge \mathrm{StageOf}_A(s_\beta) \wedge s_\alpha \lhd_A s_\beta\Big].\end{aligned} \tag{89}$$

The condition-indexed analytical predicate is then

$$\begin{aligned}&\mathrm{HistoryRealized}_A[\xi_\alpha, \xi_\beta]\\ &\quad \Longleftrightarrow \exists s_\alpha, s_\beta, h \Big[\mathrm{Locates}_A(\xi_\alpha, s_\alpha) \wedge \mathrm{Locates}_A(\xi_\beta, s_\beta) \wedge \mathrm{PhysicalHistory}_A(h; s_\alpha, s_\beta)\Big].\end{aligned} \tag{90}$$

When a domain justifies a particular witness for that registered comparison, it is denoted by $\mathcal{H}_A[\xi_\alpha, \xi_\beta]$. The references analytically delimit the selected comparison; they neither constitute the physical history nor identify its total physical beginning and end. They do not count the realized stages or identify one stage as solely responsible for the observed difference.

$$\delta_{A,\mathscr{D}}^{[\alpha,\beta]} \not\equiv_{\mathrm{type}} \mathcal{H}_A[\xi_\alpha, \xi_\beta], \tag{91}$$

$$\delta_{A,\mathscr{D}}^{[\alpha,\beta]} = 0 \not\models \neg\,\mathrm{HistoryRealized}_A[\xi_\alpha, \xi_\beta], \tag{92}$$

$$\widehat{\delta}_{A,\mathscr{D}}^{(M)[\alpha,\beta]} \neq 0 \not\models \exists! s \left[\mathrm{StageOf}_A(s) \wedge \mathrm{SolelyResponsibleFor}_A\left(s; \widehat{\delta}_{A,\mathscr{D}}^{(M)[\alpha,\beta]}\right)\right]. \tag{93}$$

Condition values alone are not assumed to identify one occurrence, because equivalent represented conditions may recur within different physical developments.

Where the selected condition occurrences satisfy $\xi_\alpha \prec_A^{\Xi} \xi_\gamma \prec_A^{\Xi} \xi_\beta$ and the domain supplies compatible composition,

$$\mathcal{H}_A[\xi_\alpha, \xi_\beta] = \mathcal{H}_A[\xi_\gamma, \xi_\beta] \circ_A \mathcal{H}_A[\xi_\alpha, \xi_\gamma]. \tag{94}$$

This composition is a domain statement about condition-indexed histories, not a count or partition of the physically realized stages. The later condition may retain domain-relevant physical consequences of the realized history without implying that every consequence remains separately identifiable or that one universal computable map exists:

$$\mathrm{Embodies}_A\left(X_A[\xi_\beta] \mid X_A[\xi_\alpha], \mathcal{H}_A[\xi_\alpha, \xi_\beta]\right). \tag{95}$$

A domain may strengthen this predicate only after supplying the required deterministic, stochastic, quantum, geometric, or numerical closure.

9. Physical Engagement, Influencing Systems, and Joint Configuration

> **Engagement rule.** Presence, possible influence, and relevance do not establish realized participation. Attribution requires typed participants, a physically supported path or coupling, and a declared joint configuration.

9.1 From environment to engagement

V23/F3 distinguishes

$$\mathrm{Present}(Y, A), \quad \mathrm{CanInfluence}(Y, A), \quad \mathrm{Relevant}_{\mathscr{D}}(Y, A), \quad \mathrm{Coupled}(Y, A; [\alpha, \beta]). \tag{96}$$

None of the first three alone implies the fourth. Realized coupling requires a typed participant and a supported path:

$$\mathrm{Coupled}(Y, A; [\alpha, \beta]) \Longrightarrow [Y \in \mathbb{F}_{\mathrm{phys}} \cup \mathbb{S}_{\mathrm{phys}} \wedge \mathrm{EffCouplingPath}(Y \to A; [\alpha, \beta])]. \tag{97}$$

For a selected comparison between physically realized conditions, the physically realized external engagement is denoted by

$$\mathcal{E}_A^{\mathrm{ext}}[\alpha, \beta] := \langle \mathcal{F}_{A,\mathrm{eng}}[\alpha, \beta], \mathcal{S}_{\to A,\mathrm{eng}}[\alpha, \beta], \boldsymbol{\kappa}_A[\alpha, \beta] \rangle. \tag{98}$$

Here the first component contains non-system factors, the second influencing systems, and the third the relational configuration. Their typing is

$$\mathcal{F}_{A,\mathrm{eng}}[\alpha, \beta] \subseteq \mathbb{F}_{\mathrm{phys}}, \qquad \mathcal{S}_{\to A,\mathrm{eng}}[\alpha, \beta] \subseteq \mathbb{S}_{\mathrm{phys}}, \qquad \mathcal{F}_{A,\mathrm{eng}}[\alpha, \beta] \cap \mathcal{S}_{\to A,\mathrm{eng}}[\alpha, \beta] = \varnothing. \tag{99}$$

A domain may include direction, pathway, medium, degree, shielding, amplification, thresholds, and relations among participants:

$$\boldsymbol{\kappa}_A[\alpha, \beta] = \langle \mathrm{Direction}, \mathrm{Pathway}, \mathrm{Medium}, \mathrm{Degree}, \mathrm{Thresholds}, \mathrm{ParticipantRelations} \rangle. \tag{100}$$

This is a schema, not a universal finite list. The symbol $\mathcal{E}_A^{\mathrm{ext}}[\alpha, \beta]$ denotes the physically realized engagement itself in typed form; it is not a response variable, an undecomposed environment label, or merely a verbal record. Its domain representation is introduced separately through the projection $\pi^{E}_{A,\mathscr{D}}$.

Let $\mathbb{E}_{A,\mathrm{ext}}$ denote the admissible class of typed physically realized external-engagement configurations. Its null extension is $\mathbb{E}^{0}_{A,\mathrm{ext}} := \mathbb{E}_{A,\mathrm{ext}} \cup \{\varnothing^{\mathrm{ext}}_{A}\}$, where $\varnothing^{\mathrm{ext}}_{A}$ means that no external participant is admitted for the selected realization. It does not deny internal development or assert an empty environment.

9.2 Identity, mediation, and joint interpretation

An influencing system remains a system; a distinct factor remains a factor. If a system generates or mediates a factor, both may be recorded when both are physically required. Direct, mediated, and mutual paths may be represented by

$$Y \to A, \tag{101}$$

$$Y \to B_1 \to \ldots \to B_n \to A, \tag{102}$$

$$A \rightleftarrows B. \tag{103}$$

Reciprocity does not imply identical histories or outcomes.

Joint-conditioning rule. The physically realized engagement is interpreted jointly with the preceding physically realized condition of the target. No admitted contribution is interpreted independently of that preceding condition and the complete realized engagement configuration. This joint conditioning does not by itself imply pairwise interaction, additivity, inseparability, or non-identifiability among all participants. A domain may establish distinguishable, additive, compensating, transforming, overlapping, or practically inseparable effects only through its own physical closure and evidence.

Environment becomes explanatory only after decomposition:

$$\mathrm{Env}_{A,\mathscr{D}} \xrightarrow{\mathsf{decomp}} \mathcal{E}^{\mathrm{ext}}_{A}[\alpha,\beta]. \tag{104}$$

The arrow is methodological: it replaces a coarse contextual label with a typed physical account.

10. Typed Realization, Physical History, and Outcome

Realization schema. The later condition is realized by the constituted system through an admissible physical history under the declared engagement. The schema fixes attribution and type; it is not a universal equation of motion.

10.1 Typed realization schema

The central structural relation is

$$\mathfrak{R}_A \subseteq \mathbb{X}^{\mathrm{full}}_{A} \times \mathbb{E}^{0}_{A,\mathrm{ext}} \times \mathbb{X}^{\mathrm{full}}_{A} \times \mathbb{H}_A. \tag{105}$$

For a selected comparison between two physically realized conditions,

$$\mathfrak{R}_A\left(X_A[\xi_\alpha], \mathcal{E}_A^{\mathrm{ext}}[\alpha,\beta], X_A[\xi_\beta]; \mathcal{H}_A[\xi_\alpha,\xi_\beta]\right). \tag{106}$$

The semicolon marks the particular canonical history witness associated with the selected comparison. No second history relation or extraction operator is introduced. Admissibility requires the witness to satisfy the history architecture of Section 8 and the engagement to have the declared type:

$$\begin{aligned} &\mathfrak{R}_A\left(X_A[\xi_\alpha], \mathcal{E}_A^{\mathrm{ext}}[\alpha,\beta], X_A[\xi_\beta]; \mathcal{H}_A[\xi_\alpha,\xi_\beta]\right) \\ &\quad \Longrightarrow \Big[\exists s_\alpha, s_\beta:\ \mathrm{Locates}_A(\xi_\alpha, s_\alpha) \wedge \mathrm{Locates}_A(\xi_\beta, s_\beta) \\ &\qquad \wedge \mathrm{PhysicalHistory}_A\big(\mathcal{H}_A[\xi_\alpha,\xi_\beta]; s_\alpha, s_\beta\big) \wedge \mathcal{E}_A^{\mathrm{ext}}[\alpha,\beta] \in \mathbb{E}^0_{A,\mathrm{ext}}\Big]. \end{aligned} \tag{107}$$

The selected conditions and references delimit the stated comparison and attribution, not the physical beginning and end of ongoing change. The relation jointly attributes the declared engagement and canonical history witness; it does not define a universal dynamics.

10.2 Domain specialization

The relation permits non-unique later conditions where the domain is stochastic, quantum, chaotic, branching, or incompletely specified:

$$\mathfrak{R}_A(x, e, x_1; h_1) \wedge \mathfrak{R}_A(x, e, x_2; h_2). \tag{108}$$

Any deterministic or probabilistic closure is additional domain structure, not a consequence of $\mathfrak{R}_A$. The canonical signatures, including the required transition descriptor, are stated once in Section 18.

10.3 Constitution, non-duplication, and response

The preceding condition is constitutive, not merely an initial vector. It includes organization, relations, capacities, thresholds, stored consequences, and physically retained history. Therefore

$$X_A[\xi_\alpha] \not\equiv_{\mathrm{type}} \mathbf{x}_{A,\mathscr{D}}[\xi_\alpha]. \tag{109}$$

A represented preceding condition and a represented engagement do not, by the foundational schema alone, determine a unique later representation. Uniqueness requires a declared domain closure together with the domain-relevant constitution, parameters, boundary conditions, and admissible dynamics. This restriction is already expressed by the non-uniqueness relation above and by the deterministic specialization when its additional assumptions are supplied.

Internal processes are not duplicated as external arguments:

$$\mathrm{InternalTo}(Y, A) \Longrightarrow Y \notin \mathcal{F}_{A,\mathrm{eng}}[\alpha,\beta] \cup \mathcal{S}_{\to A,\mathrm{eng}}[\alpha,\beta]. \tag{110}$$

The word *response* remains descriptive language for the system-conditioned manner of change. It introduces no response variable, entity, map, or intermediate stage.

10.4 Outcome and attribution

Evaluation is distinct from change. A domain may define

$$\mathcal{O}_{A,\mathscr{D}}^{\mathrm{eval}[\alpha,\beta]} = \Omega_{A,\mathscr{D}}\left(X_A[\xi_\beta], \mathcal{H}_A[\xi_\alpha, \xi_\beta]; \mathcal{K}_{\mathscr{D}}\right), \tag{111}$$

where $\mathcal{K}_{\mathscr{D}}$ contains the criterion, function, threshold, or reference class. Thus

$$\delta_{A,\mathscr{D}}^{[\alpha,\beta]} \not\equiv_{\mathrm{type}} \mathcal{O}_{A,\mathscr{D}}^{\mathrm{eval}[\alpha,\beta]}. \tag{112}$$

A complete attribution audit identifies the target, preceding condition, engagement, history, later condition, representation, and evaluation criterion:

$$\mathrm{Attribution}_A = \mathrm{Audit}\left[X_A[\xi_\alpha], \mathcal{E}_A^{\mathrm{ext}}[\alpha,\beta], \mathcal{H}_A[\xi_\alpha,\xi_\beta], X_A[\xi_\beta], \Pi_{A,\mathscr{D}}, \mathcal{K}_{\mathscr{D}}\right]. \tag{113}$$

Unknown or omitted components must be stated rather than silently assigned to time or to an unexplained residual.

11. Historical Dependence, Persistence, Stability, and Recurrence

11.1 Later conditions retain consequences of physical history

A later condition is not realized from an abstract copy of the original system. Every later realization proceeds from the physically realized result and retained consequences of the preceding history; whether every consequence remains separately distinguishable is domain-dependent. For ordered references

$$\xi_{A,\alpha} \prec_A^{\Xi} \xi_{A,\beta} \prec_A^{\Xi} \xi_{A,\gamma},$$

the middle condition is both the embodied result of the earlier history and the preceding condition for the later comparison. The ordering of references is analytically justified by physical evidence; it neither counts stages nor turns the selected conditions into boundaries of continuing change.

This dependency is expressed by the same typed embodiment relation used above:

$$\mathrm{Embodies}_A\left(X_A[\xi_{A,\beta}] \,|\, X_A[\xi_{A,\alpha}], \mathcal{H}_A[\xi_{A,\alpha}, \xi_{A,\beta}]\right). \tag{114}$$

The relation states that the later condition physically carries consequences of the realized history; it does not treat the history as a set element contained in that condition.

The result is path dependence. Similar current observables can coexist with distinct capacities and later behavior because retained structural consequences may differ. Hysteresis, fatigue, adaptation, sensitization, aging, learning, deformation, and material memory are familiar domain examples.

11.2 Persistence, transformation, and integration of effects

An effect need not remain independently detectable to remain physically consequential. It may persist in approximately the same form, transform into another property, become distributed across the system, be compensated by another process, or merge into a new organization.

Let e be an effect realized in an earlier history. At a later reference, its status may be represented by

$$\mathrm{Status}_A(e;\xi) \in \left\{ \begin{matrix} \text{Persistent},\ \text{Transformed},\ \text{Integrated}, \\ \text{Compensated},\ \text{Dissipated}_{<\text{detection}} \end{matrix} \right\}. \tag{115}$$

The categories may overlap or be refined by a domain. Their purpose is to prevent the inference

$$\neg\,\mathrm{SeparatelyDetected}(e;\xi) \;\not\models\; \neg\,\mathrm{HistoricalContribution}(e;\xi). \tag{116}$$

Historical dependence is physical, not temporal agency. The system embodies consequences through its material, energetic, structural, informational, or relational organization. Time does not store the history or transmit its effects.

11.3 Apparent stability

A stable observable can coexist with ongoing physical change. Let $q_{A,\mathscr{D}}$ remain within a tolerance band:

$$\left| q_{A,\mathscr{D}}[\xi] - q^*_{A,\mathscr{D}} \right| \le \varepsilon_{\mathscr{D}}. \tag{117}$$

The condition establishes stability under that observable and tolerance. It does not imply identity of physically realized conditions across the band.

Stability may be maintained by active regulation, dynamic equilibrium, competing fluxes, periodic compensation, or structural robustness. A system can therefore be stable precisely because internal change continues in an organized way. In other cases stability may be an artifact of insufficient resolution.

11.4 Failure and resilience

The result of change depends on the constitution and cohesion of the system and on the nature, pathways, relations, and jointly realized effects of the engaged physical factors and influencing systems. Change may support, preserve, adapt, or strengthen the structure; it may also weaken, damage, disable, or destroy it. Failure is therefore an evaluated outcome relative to a required function or integrity condition. Let $\Phi_{A,\mathscr{D}}$ denote a functional criterion. Then

$$\mathrm{Failure}_{A,\mathscr{D}} \Longleftrightarrow \Phi_{A,\mathscr{D}}\left(X_A[\xi_\beta]\right) < \vartheta^{\mathrm{fail}}_{A,\mathscr{D}}. \tag{118}$$

A failed output is still a physical realization of the system. Functional failure need not end the system identity if the constituted structure remains identifiable. Structural disintegration may end that identity when the relations that maintained the system as one system no longer apply. Neither case means that time failed or that physical change ceased.

Resilience concerns the capacity to preserve or recover a function under engagement. It belongs to the physically realized condition and may itself change through history. A system can become more resilient, less resilient, or resilient in one domain and fragile in another.

11.5 Recurrence and cyclic processes

Recurrence should be stated at the level of represented pattern:

$$\mathbf{x}_{A,\mathscr{D}}[\xi_{A,\beta}] \cong_{\mathscr{D}} \mathbf{x}_{A,\mathscr{D}}[\xi_{A,\alpha}], \qquad \xi_{A,\alpha} \prec_A^{\Xi} \xi_{A,\beta}. \tag{119}$$

The later realization remains later. A cycle is a repeating organization of outputs or relations, not a reversal of succession.

Exact equality of one modeled variable does not prove return of the physically realized system condition. Even an ideal mathematical periodicity can coexist with historical distinctions outside the modeled state space. If the domain genuinely defines complete periodic states, that is a domain theorem, not a foundational consequence of the word cycle.

11.6 Observational resolution

Stability, recurrence, and persistence depend partly on resolution. Let $\Pi_{\mathscr{D}_1}$ and $\Pi_{\mathscr{D}_2}$ be representations of different resolution. It is possible that

$$\Pi_{\mathscr{D}_1}(X_A[\xi_\alpha]) = \Pi_{\mathscr{D}_1}(X_A[\xi_\beta]), \qquad \Pi_{\mathscr{D}_2}(X_A[\xi_\alpha]) \neq \Pi_{\mathscr{D}_2}(X_A[\xi_\beta]). \tag{120}$$

The two statements can both be correct. They concern different representations. ITOF therefore requires every stability or recurrence claim to name its domain and tolerance.

12. The Universe-Wide Extension of Change and the ITOF Definition of Time

Temporal definition. Time in ITOF is the universe-wide descriptive expression of the continuing, non-reversing extension of physically realized prior–later succession across the identity-preserving histories of admissible physical systems throughout the universe. It specifies neither the physical content, magnitude, rate, mechanism, nor cause of change.

12.1 One arbitrary system and universality by quantification

For one arbitrary system $A \in \mathbb{S}^{\mathcal{U}}_{\text{phys}}$,

$$\text{SustainedChange}(A) \Longrightarrow [\text{PriorLaterSuccession}(A) \wedge \text{SuccessionExtends}(A)]. \tag{121}$$

Universal scope is obtained by

$$\forall A \in \mathbb{S}^{\mathcal{U}}_{\text{phys}} : \ \text{SustainedChange}(A), \tag{122}$$

not by comparing two systems, merging their histories, or imposing a global numerical index. A second system enters only when the physical question is relational.

12.2 Temporal meaning and formal representation

Definition 12.1 (ITOF time)**.** The semantic temporal meaning T_{ITOF} is the universe-wide descriptive expression of the continuing, non-reversing extension of physically realized prior–later succession across the identity-preserving histories of admissible physical systems throughout the universe. It specifies neither the physical content, magnitude, rate, mechanism, nor cause of change.

Its formal order representation is

$$\boxed{\mathfrak{T}_{\mathrm{ITOF}} := (\mathbb{O}_{\mathrm{phys}}, \prec).} \tag{123}$$

The distinction is canonical:

$$T_{\mathrm{ITOF}} \not\equiv_{\mathrm{type}} \mathfrak{T}_{\mathrm{ITOF}}. \tag{124}$$

T_{ITOF} denotes theoretical temporal meaning; $\mathfrak{T}_{\mathrm{ITOF}}$ represents the occurrence domain and its physical prior–later relation. The distinction is exact: the formal structure represents order without becoming a material container or a producer of the occurrences it orders, and the semantic concept is not an additional physical state.

The word *continuing* means that no permanently constant tail is permitted at any occurrence whose system identity remains open to a later occurrence on the same realized history chain, as specified by Equation (35). It does not assert a real-line continuum, topology, differentiability, dense order, countability, immediate successors, or a fixed stage cardinality.

12.3 Analytical access and numerical plurality

A reference may locate an occurrence,

$$\mathrm{Locates}_A(\xi_{A,\alpha}, o_{A,\alpha}), \tag{125}$$

but neither reference assignment nor label order creates the occurrence relation. The single temporal meaning defined by ITOF is compatible with non-identical clock readings, coordinate assignments, and numerical parameterizations across valid representations. A model parameter may organize a representation,

$$\mathbf{x}(u) = \mathcal{F}(\mathbf{x}_0, u), \tag{126}$$

but its mathematical role does not identify it with T_{ITOF}.

12.4 Temporal non-participation and its argumentative status

Let $\mathbb{D}_{\mathrm{temp}}$ denote the metatheoretical class of well-formed temporal descriptions. The admissible physical argument values of the realization relation are the tagged disjoint union

$$\mathrm{Args}_{\mathrm{phys}}(\mathfrak{R}_A) := (\{\mathrm{in}\} \times \mathbb{X}_A^{\mathrm{full}}) \bigsqcup (\{\mathrm{eng}\} \times \mathbb{E}^0_{A,\mathrm{ext}}) \bigsqcup (\{\mathrm{out}\} \times \mathbb{X}_A^{\mathrm{full}}) \bigsqcup (\{\mathrm{hist}\} \times \mathbb{H}_A). \tag{127}$$

The active type discipline states

$$T_{\text{ITOF}} \in \mathbb{D}_{\text{temp}}, \qquad \mathbb{D}_{\text{temp}} \cap (\mathbb{S}_{\text{phys}} \cup \mathbb{F}_{\text{phys}}) = \varnothing, \qquad \mathbb{D}_{\text{temp}} \cap \text{Args}_{\text{phys}}(\mathfrak{R}_A) = \varnothing. \tag{128}$$

Physical effect is typed on physical participants:

$$\text{Affects}_{\text{phys}} \subseteq (\mathbb{S}_{\text{phys}} \cup \mathbb{F}_{\text{phys}}) \times (\mathbb{S}_{\text{phys}} \cup \mathbb{F}_{\text{phys}}). \tag{129}$$

Hence T_{ITOF} is outside the domain and range of $\text{Affects}_{\text{phys}}$ in the active formalism. This is an ontological postulate and a type-theoretic consequence, not a separately discovered dynamical null result. A rival theory may introduce a temporal physical state, but it must type, couple, measure, and test that additional object independently.

13. Foundational Postulates and Derived Consequences

13.1 Coverage postulate: universe occurrence-domain coverage

Equation (9) is a separate ontological postulate: every occurrence admitted to $\mathbb{O}_{\text{phys}}$ is attributable to at least one admissible identity-extended physical system. It neither defines the occurrence domain nor asserts total comparability, simultaneity, or a countable census of systems.

13.2 Postulate I: constituted systems and attributable occurrences

Every $A \in \mathbb{S}^{\mathcal{U}}_{\text{phys}}$ is a physically constituted system under a declared boundary and identity criterion, and its physical realizations are represented by attributable occurrences $o \in \mathbb{O}_A$. Neither occurrence nor order is created by measurement.

13.3 Postulate II: universal identity-bounded sustained change

The universal commitment is Equation (36). Its exact content is supplied by Equations (33)–(35); it is not defined by variation of every observable or by one finite experiment. It is compatible with temporary stability, equilibrium, recurrence, and stationary represented quantities. It is contradicted by the exact complete-constancy condition in Equation (63) when the stated physical and completeness premises are independently established.

13.4 Analytic consequences: succession, extension, and derived stages

The governing implication is Equation (121); it is not restated here as a second formula. A stage is then derived by Equation (25). These are analytic consequences of the sustained predicate; they add no force, medium, or second cause.

13.5 Postulate III: temporal non-participation

The active ontology assigns T_{ITOF} to a temporal-description type rather than to a physical participant type, as stated in Equation (128). This is a foundational commitment. Its physical adequacy remains open to comparison with any rival that independently defines and detects a temporal physical state.

> **Foundational spine.** Constituted physical systems are the bearers of sustained realized change. On each realized identity-preserving history chain, sustained change analytically entails prior–later succession and its continuing, non-reversing extension. Time is the universe-wide descriptive expression of that extension; it neither supplies the physical content of change nor participates in its production.

13.6 Derived restrictions

A zero represented difference does not by itself establish absence of physical history. Representational recurrence does not establish identity of complete realized conditions. Universal application does not imply a universal rate, mechanism, or numerical clock. Measurement may locate and compare occurrences but does not create them. Formally,

$$\delta_{A,\mathscr{D}}^{[\alpha,\beta]} = 0 \not\models \neg\,\mathrm{HistoryRealized}_A[\xi_\alpha, \xi_\beta], \tag{130}$$

$$\mathbf{x}_{A,\mathscr{D}}[\xi_\alpha] \cong_{\mathscr{D}} \mathbf{x}_{A,\mathscr{D}}[\xi_\gamma] \not\models X_A[\xi_\alpha] \equiv_{\mathrm{phys}} X_A[\xi_\gamma], \tag{131}$$

$$[\forall A \in \mathbb{S}^{\mathcal{U}}_{\mathrm{phys}} : \mathrm{SustainedChange}(A)] \not\models [\exists \lambda_{\mathrm{univ}}\ \forall A \in \mathbb{S}^{\mathcal{U}}_{\mathrm{phys}} : \mathrm{Rate}_A = \lambda_{\mathrm{univ}}]. \tag{132}$$

13.7 Methodological consequence: no unlicensed cross-category transfer

If a quantity $Z_{\mathscr{D}}$ is defined in a domain of clocks, coordinates, signals, geometry, frequency, or measurement, then

$$\Delta Z_{\mathscr{D}} \neq 0 \wedge \neg\,\mathrm{BridgeLawEstablished}_{\mathrm{phys}}\,(Z_{\mathscr{D}}, \mathsf{T}_{\mathrm{phys}}) \not\models \mathsf{PM}_T. \tag{133}$$

This is an inference restriction relative to the declared ontology, not a denial of the measured difference.

14. Order Without Agency: Causation, Realization, and Temporal Description

A recurrent conceptual error is to infer that because change is intelligible only through prior–later distinction, the prior–later order must cause the change. ITOF rejects this inference. The framework separates the physical realization of a transition from the descriptive order of the stages through which the transition is realized.

14.1 Physical production and temporal description

Within a domain $\mathscr{D}$, the later condition is accounted for through the preceding realized condition—which already carries the system's constitution—together with internal processes, admitted engagement, boundary conditions, and applicable dynamics. Schematically,

$$\Big(X_A(s_\alpha), \mathcal{I}_A^{\mathrm{int}}[\alpha,\beta], \mathcal{E}_A^{\mathrm{ext}}[\alpha,\beta], \mathcal{B}_A^{\mathrm{cond}}[\alpha,\beta]\Big) \overset{\mathscr{D}}{\Longrightarrow} X_A(s_\beta). \tag{134}$$

The arrow is domain-dependent. The stage order is

$$s_\alpha \lhd_A s_\beta. \tag{135}$$

Equation (134) concerns physical realization; Equation (135) concerns prior–later position. Order fixes asymmetric placement; the declared systems, factors, engagements, boundary conditions, and domain dynamics account for the later condition. T_{ITOF} is not an additional producer within that physical account.

14.2 Argumentative status and avoidance of causal circularity

ITOF begins from the foundational commitment that physical change is sustained in constituted systems. It does not infer that change from an independently acting time entity. The prior–later succession and continuing extension carried by sustained change are then made explicit, and time is defined as their universe-wide descriptive expression. The dependence is therefore conceptual and descriptive, not causal.

The governing direction is

$$\begin{aligned}&\Big[\forall A \in \mathbb{S}_{\mathrm{phys}}^{\mathcal{U}} : \mathrm{SustainedChange}(A)\Big]\\ &\quad\Longrightarrow \Big[\forall A \in \mathbb{S}_{\mathrm{phys}}^{\mathcal{U}} : \mathrm{PriorLaterSuccession}(A) \wedge \mathrm{SuccessionExtends}(A)\Big]\\ &\quad\xmapsto{\text{descriptive definition}} T_{\mathrm{ITOF}}.\end{aligned} \tag{136}$$

This chain does not claim to derive ordering from premises wholly free of ordering content. Rather, it makes explicit that realized change requires at least a prior and a later stage, while sustained change requires the identity-bounded continuation of that succession. It then separates this analytic temporal content from metric measurement and physical causation. The rejected causal construction is

$$T_{\mathrm{ITOF}} \Longrightarrow \mathrm{SustainedChange}(A) \Longrightarrow T_{\mathrm{ITOF}}, \tag{137}$$

because it would treat the temporal description as a physical input that produces the change later used to define it.

14.3 Causal order and temporal order

Causal relations can justify particular prior–later claims. When a physically realized influence connects a source occurrence to a receiving occurrence, the applicable causal model can support their order. Yet causal and temporal order are not identical categories.

First, a prior stage of one system need not be a cause of every later stage of that system. Second, two stages can be ordered through a record or common comparison without one being the complete cause of the other. Third, causal models specify mediating systems, factors, and laws, whereas temporal order specifies the asymmetric placement of realized stages. A physically established causal connection can therefore supply evidential warrant for assigning the connected occurrences to the physical prior–later relation under the declared causal bridge. The converse is not automatic: prior–later placement does not by itself establish direct causation.

14.4 Direction, irreversibility, and physical arrows

ITOF assigns non-reversal to occurrence order:

$$s_\alpha \lhd_A s_\beta \Longrightarrow \neg(s_\beta \lhd_A s_\alpha). \tag{138}$$

This does not mean that every physical equation must be dynamically irreversible or that every macroscopic variable changes monotonically. A dynamical model may be time-reversal symmetric in its formal parameters; a process may approximately retrace a represented path; a cyclic system may return to a prior represented value. None of these operations makes the later occurrence become the earlier occurrence.

Physical arrows—thermodynamic, radiative, causal, biological, or cosmological—belong to their own domains and require their own physical explanations. They may align with the prior–later extension and provide evidence about particular histories. They do not create time as a physical force. ITOF therefore distinguishes

$$\mathrm{DomainArrow}_{\mathscr{D}} \not\equiv_{\mathrm{type}} T_{\mathrm{ITOF}}, \tag{139}$$

while allowing the domain arrow to reveal asymmetry within realized change.

14.5 No hidden temporal medium

The phrase “change occurs in time” is often read as if systems were located inside a temporal container. ITOF replaces this container picture with a systemwise realization picture. Systems exist physically and undergo change whose stages extend in prior–later succession. The temporal definition describes that extension; it does not add a medium through which systems move.

Accordingly, the physical existence and change of a system do not by themselves warrant positing a temporal substance in which it is immersed. The removal of a temporal medium does not remove order, duration models, coordinates, clocks, or causal structure. It prevents those structures from being reified into an unsupported physical agent.

Order without agency. Physical systems and factors realize change. The sustained-change postulate analytically entails prior–later succession and its identity-bounded extension. Time is the universe-wide descriptive expression of that extension; neither succession nor time physically produces the later condition.

15. Why Ordered Succession Is Necessary for Physical Distinguishability

The ITOF definition of time depends on a prior question: why must physical change be expressed through prior and later stages? The answer is not that a clock first supplies a number or that an observer imposes an order. The two-stage expression explains the minimum meaning of succession: one physically realized stage is prior and another is later. It does not identify adjacent stages, delimit the continuing extension, or isolate a stage responsible for an observed change. Their prior–later relation is a consequence of sustained change, not an external addition to it.

Distinguishability principle. A difference between two admissible conditions does not by itself establish that one was physically realized before the other. A physically justified prior–later relation explains the minimum meaning of succession; it does not bound the continuing, non-reversing extension of stages or identify a stage responsible for the observed difference. Physical history is attributed to the realized change between selected conditions, not to a purportedly isolated pair of stages.

15.1 Difference alone does not constitute realized change

Let $x_1, x_2 \in \mathbb{X}_A^{\text{full}}$ be two admissible realized conditions. The statement

$$x_1 \not\equiv_{\text{phys}} x_2 \tag{140}$$

establishes only physical non-identity. It does not establish that system A physically realized x_1 before x_2, or that both belong to one realized history. They may instead belong to different admissible histories of A, different model solutions, counterfactual alternatives, or mutually exclusive realizations of A.

A physically realized change requires the two selected conditions and their physically justified prior–later relation to be attributed to the same system, while history is stated with respect to the change between those conditions:

$$\begin{aligned} &X_A[\xi_\alpha] = x_1, \qquad X_A[\xi_\beta] = x_2, \qquad \xi_\alpha \prec_A^{\Xi} \xi_\beta, \\ &\text{HistoryRealized}_A[\xi_\alpha, \xi_\beta]. \end{aligned} \tag{141}$$

The reference order is justified through physical evidence of prior and later; it does not turn the selected conditions into the physical beginning and end of change. The history predicate attributes realized development to the condition comparison without identifying a unique responsible stage or the number of stages realized between the conditions.

Thus

$$\begin{aligned} \text{Difference}(x_1, x_2) \not\models \exists \xi_\alpha, \xi_\beta \Big[&X_A[\xi_\alpha] = x_1 \wedge X_A[\xi_\beta] = x_2 \\ &\wedge\ \xi_\alpha \prec_A^{\Xi} \xi_\beta \wedge \text{HistoryRealized}_A[\xi_\alpha, \xi_\beta] \Big]. \end{aligned} \tag{142}$$

whereas the sustained-change postulate analytically entails prior–later succession and its identity-bounded extension. The prior–later distinction explains succession only; it does not delimit the full realized history.

15.2 Why the same conditions do not determine one realized history

The same admissible conditions may occur within physically different histories. For example, two possible histories may be represented as

$$\mathcal{H}_A^{(1)} : x_1 \to x_2 \to x_3, \tag{143}$$

and

$$\mathcal{H}_A^{(2)} : x_1 \to x_3 \to x_2. \tag{144}$$

Although the same condition symbols appear, the realized developments differ:

$$\mathcal{H}_A^{(1)} \neq \mathcal{H}_A^{(2)}. \tag{145}$$

ITOF therefore requires the physically justified prior–later relation to be retained. That relation is not an additional force and does not determine the mechanism of change; it expresses the succession already entailed by the physical realization of change.

15.3 Order is necessary but not sufficient

Prior–later order does not determine the content of change. Given

$$s_\alpha \lhd_A s_\beta, \tag{146}$$

one cannot infer the mechanism, magnitude, rate, energy transfer, causal pathway, or represented difference. The order relation supplies no equation of motion:

$$s_\alpha \lhd_A s_\beta \not\models \mathbf{x}_{A,\mathscr{D}}[\xi_\beta] = \mathcal{F}_{A,\mathscr{D}}\left(\mathbf{x}_{A,\mathscr{D}}[\xi_\alpha], \mathbf{e}_{A,\mathscr{D}}^{[\alpha,\beta]}; \boldsymbol{\theta}_{A,\mathscr{D}}\right). \tag{147}$$

The domain law must be specified independently.

The logical structure is therefore asymmetric:

$$\text{RealizedChange} \Longrightarrow \text{PriorLaterDistinction}, \qquad \text{PriorLaterDistinction} \not\models \text{SpecifiedDynamics}\,. \tag{148}$$

Ordered succession is necessary for the intelligibility of realized change, but it is not a substitute for physical explanation.

15.4 Distinguishability does not require numerical time labels

The distinction between prior and later is more basic than a numerical coordinate. Let

$$\text{StageOf}_A(s) \Longrightarrow \ell_A(s) \in \mathbb{R} \tag{149}$$

be a domain-admissible numerical label assigned to a selected stage when such a labeling is justified. If it preserves order, then

$$s_\alpha \lhd_A s_\beta \Longrightarrow \ell_A(s_\alpha) < \ell_A(s_\beta). \tag{150}$$

But the numerical map is a representation of the order, not its ontological source. The stages do not become ordered because numbers were attached to them. Rather, a valid numerical representation must respect physically justified order.

Consequently,

$$\mathrm{NoAdmissibleGlobalNumericalLabel} \not\models \mathrm{NoPriorLaterOrder}\,. \tag{151}$$

This is essential in domains where only partial order, local coordinates, causal relations, or system-specific parameters are justified.

15.5 Records reveal ordered difference through physical retention

A record at a later stage may retain information about an earlier physical condition. Let R be a recording system and let

$$\mathrm{Retains}_R\,(r_\beta; A, s_\alpha) \tag{152}$$

denote that the record condition r_β physically retains information attributable to system A at stage s_α. If the record itself is realized at $s_{R,\beta}$, the retention relation can support an order inference between the source occurrence and the later record occurrence.

The record does not create the earlier stage. It provides physical evidence of a relation already realized:

$$\mathrm{RecordEvidence}(r_\beta, s_\alpha) \not\models \mathrm{RecordCreates}(s_\alpha). \tag{153}$$

This applies to memory traces, detector outputs, photographs, astronomical signals, geological records, digital logs, and clock readings. Each is a later physical condition whose interpretation depends on a model of retention and transmission.

15.6 Observational indistinguishability is not ontological identity

Let ξ_α and ξ_β locate the selected stages s_α and s_β. The two stages may be indistinguishable under an available measuring procedure:

$$\widehat{\mathbf{x}}^{(M)}_{A,\mathscr{D}}[\xi_\alpha] = \widehat{\mathbf{x}}^{(M)}_{A,\mathscr{D}}[\xi_\beta]. \tag{154}$$

This establishes equality of the measured estimates within the procedure and resolution. It does not establish

$$X_A(s_\alpha) \equiv_{\mathrm{phys}} X_A(s_\beta), \tag{155}$$

nor does it erase the already warranted order relation $s_\alpha \lhd_A s_\beta$. The distinction between epistemic resolution and physical occurrence is therefore indispensable. A measurement can fail to distinguish two selected stages even though they are distinct ordered physical occurrences. That epistemic failure does not erase the physical history associated with the compared conditions.

15.7 The foundational consequence

A description of possible conditions or structural differences does not by itself establish realized becoming from prior to later. Conversely, prior–later order alone does not explain the physical content of the transition. ITOF therefore assigns complementary roles: dynamics and engagement explain physical realization; prior–later order expresses the distinguishability of realized stages; and time gives the resulting stage extension universe-wide descriptive scope.

The necessity of ordered succession is therefore neither a claim that time causes change nor a claim that a numerical clock parameter creates physical distinction. It is the minimal ontological condition under which change is physically distinguishable as an extended realization rather than an unordered collection of alternatives.

16. Boundary Cases and Hard Objections

A foundational theory should be evaluated where its definitions face the strongest apparent counterexamples. The following cases are not treated as rhetorical illustrations. Each identifies what the relevant physical or mathematical description establishes and what it does not establish about complete physical changelessness or temporal agency.

16.1 A body at rest

Let a body have constant spatial coordinates in a chosen frame over an interval:

$$\mathbf{r}_A(t) = \mathbf{r}_0. \tag{156}$$

This establishes kinematic rest relative to that coordinate construction. It does not establish that the body's realized condition, internal relations, fields, boundary exchanges, or constituent processes are identical at all stages. Therefore,

$$\frac{d\mathbf{r}_A}{dt} = 0 \not\models \neg\,\mathrm{SustainedChange}(A). \tag{157}$$

ITOF does not replace the kinematic result; it restricts its ontological scope.

16.2 A system in equilibrium

Equilibrium may entail vanishing macroscopic gradients or stable ensemble averages under a specified thermodynamic or statistical description [43]. It is not equivalent to the absence of microphysical histories or to complete realized constancy across a nontrivial identity-preserving history segment. The proper inference is

$$\mathrm{Equilibrium}_{\mathscr{D}}(A) \Longrightarrow \mathrm{NoResolvedNetChange}_{\mathscr{D}}(A) \tag{158}$$

only when that conclusion is licensed by the domain. The stronger claim

$$\mathrm{Equilibrium}_{\mathscr{D}}(A) \Longrightarrow \neg\,\mathrm{SustainedChange}(A) \tag{159}$$

is not licensed by equilibrium terminology alone.

16.3 A stationary quantum description

A stationary state may yield time-independent expectation values for a specified set of observables under a specified Hamiltonian representation [44]. That result is exact and important within quantum theory. ITOF's question is whether such representational stationarity identifies the physically realized condition of the realized system with one unchanging realized condition across a nontrivial identity-preserving history segment. The formal stationarity of a state representation does not by itself establish this stronger claim.

Let

$$\frac{d}{d\lambda}\langle\widehat{O}\rangle_\psi = 0 \tag{160}$$

for the chosen parameter λ and observable $\widehat{O}$. Then

$$\frac{d}{d\lambda}\langle\widehat{O}\rangle_\psi = 0 \not\models \exists\mathcal{J}\ \text{CompleteConstancy}_A(\mathcal{J}). \tag{161}$$

Any stronger interpretation requires an explicit identification between the formal state, the declared physical ontology, and complete realized constancy across a declared identity-preserving history segment.

16.4 An ideally isolated system

An ideal isolation condition removes the specified external terms while leaving internal evolution governed by the declared model. If

$$\mathcal{E}_A^{\text{ext}}[\alpha,\beta] = \varnothing_A^{\text{ext}}, \tag{162}$$

then the domain may still admit

$$\mathbf{x}_{A,\mathscr{D}}[\xi_\beta] = \mathcal{F}_{A,\mathscr{D}}\left(\mathbf{x}_{A,\mathscr{D}}[\xi_\alpha], \pi^E_{A,\mathscr{D}}\left(\varnothing_A^{\text{ext}}\right); \boldsymbol{\theta}_{A,\mathscr{D}}\right). \tag{163}$$

The internal processes and constraints remain represented within the state, constitution, parameters, and declared domain dynamics; they are not inserted into the external-engagement argument. ITOF therefore distinguishes absence of admitted external engagement from absence of all physical realization.

16.5 Vacuum and low-excitation regions

A vacuum state or a region with no detected particles is not automatically a non-physical nothingness. Its interpretation depends on the relevant physical theory, fields, boundary conditions, geometry, and measurement regime. ITOF does not prescribe a microscopic vacuum ontology. It requires only that absence of a detected object or event not be promoted without argument to absence of all physical structure and all change.

Thus

$$\text{NoDetectedParticle}_{M,\mathscr{D}}(R) \not\models \text{NoPhysicalHistory}(R). \tag{164}$$

A genuine counterexample would need a positive physical characterization of complete realized constancy across a nontrivial identity-preserving history segment, not merely an observational null.

16.6 Exact recurrence and cyclic systems

Suppose ξ_n and ξ_{n+N} locate the selected occurrences s_n and s_{n+N}, and a cyclic model yields

$$\mathbf{x}_{A,\mathscr{D}}[\xi_{n+N}] = \mathbf{x}_{A,\mathscr{D}}[\xi_n]. \tag{165}$$

The equality belongs to the represented state. The occurrences remain ordered:

$$s_n \lhd_A s_{n+N}. \tag{166}$$

The later cycle includes the intervening history and is not the numerical or ontological erasure of that history. Cyclicity therefore supports repeated character, not reversal of occurrence.

16.7 A stopped or failed clock

If a clock output becomes constant,

$$t_C[\xi_\beta] - t_C[\xi_\alpha] = 0, \tag{167}$$

the result concerns the clock's output mapping. The clock may have failed, saturated, lost power, become decoupled from its counting process, or remained unable to resolve a change. It does not follow that the physical system, its surroundings, or the extension of change has stopped:

$$\Delta t_C = 0 \not\models \neg\,\text{SustainedChange}(C). \tag{168}$$

The case makes the distinction between a numerical standard and time especially clear.

16.8 System destruction and loss of identity

A system may cease to satisfy its identity criterion. This does not create a completely changeless physical stage. Let

$$\text{IdentityApplies}_A[s_\alpha, s_\beta] \wedge \neg\,\text{IdentityApplies}_A[s_\beta, s_\gamma]. \tag{169}$$

The later physical realization may belong to successor physical systems $B_1, \ldots, B_n$, including systems whose declared boundaries encompass resulting components, products, field configurations, or environmental reorganizations. ITOF does not require $\text{StageOf}_A(s_\gamma)$ once the identity criterion of A no longer applies. It requires that the end of one system identity not be treated, without further physical argument, as the disappearance of every physically realized successor system or as an absolutely changeless nothing.

16.9 A hypothetical final equilibrium or heat-death condition

A cosmological model may approach a state described as maximal entropy, thermal equilibrium, or absence of usable free-energy gradients. Such a model concerns the asymptotic behavior of specified macroscopic variables under specified cosmological assumptions. The phrase "heat death" acquires terminal significance only through a physically specified condition satisfying the counterexample requirements below."

The ITOF challenge is precise: does the model imply a physically realized terminal cosmic condition

$$\exists \mathcal{C}_* \left[\text{TerminalCosmicCondition}(\mathcal{C}_*) \wedge \forall A \in \mathbb{S}^{\mathcal{U}}_{\text{phys}} \neg \text{PhysicalContinuationAfter}(A, \mathcal{C}_*)\right] \quad (170)$$

and does it provide a physically coherent condition in which no field, relation, fluctuation, decay, interaction, boundary condition, or successor system can realize any difference? The symbol $\mathcal{C}_*$ occurs only inside this rival cosmological hypothesis; it is not a field or carrier of stages in ITOF. Unless those requirements are met, the model describes extreme physical conditions, not the demonstrated termination of change.

ITOF treats cosmology as a substantive test domain. A rigorously developed cosmological theory that genuinely entails and evidentially supports a terminal realized condition directly challenges the universal postulate. The framework specifies the physical and evidential content required for such a counterexample.

16.10 Permanent observational non-resolution

Suppose every available instrument returns no resolved difference for a target system over an observation window. This result strengthens the empirical case for stability within the accessible representation. Identity of the complete realized condition requires the additional completeness and scope conditions stated by the framework. The directly permitted conclusion is

$$\forall M \in \mathcal{M}_{\text{available}} : \neg \mathsf{RC}^{W}_{M,\mathscr{D}}(A), \quad (171)$$

not

$$\exists \mathcal{J} \ \text{CompleteConstancy}_A(\mathcal{J}). \quad (172)$$

This restriction is not unique to ITOF; it is a general consequence of the difference between evidence and exhaustive ontology. The theory remains responsible for developing domain models that predict where change should become detectable.

Boundary-case verdict. Rest, equilibrium, stationarity, isolation, recurrence, clock stoppage, system destruction, and observational null results can all be physically meaningful. None, without additional argument, establishes complete realized constancy across a nontrivial identity-preserving history segment or a physically acting time.

17. Measurement as Physical Access: Observation, Resolution, and Limits

Measurement is a physical interaction followed by registration and inferential reconstruction under calibration, representation, and uncertainty. A numerical result is an output of that chain, not immediate access to the complete realized condition. The vocabulary of uncertainty, calibration, and metrological comparability is used in the disciplined operational sense represented by the JCGM guides [8, 9].

Physical realization precedes analytical access. Measurement is itself a physical interaction and may alter the target or the measuring system. Its registered output and inferred estimate remain distinct from the target's complete realized condition; they do not by themselves exhaust the target history, and analytical labels do not create the prior–later order they are used to represent.

17.1 Measurement as a realized physical chain

Let $M \in \mathbb{S}_{\text{phys}}$ be a measuring system and A the target. The measurement interaction is first a physical realization in M:

$$\mathfrak{R}_M \left(X_M[\xi_{M,\mu}], \mathcal{E}^{\text{meas}}_{M \leftarrow A}[\mu, \nu], X_M[\xi_{M,\nu}]; \mathcal{H}_M[\xi_{M,\mu}, \xi_{M,\nu}] \right). \tag{173}$$

The later condition of M supports a registered output

$$G_M[\xi_{M,\nu}] := \text{Reg}_M \left(X_M[\xi_{M,\nu}] \right). \tag{174}$$

The output may be a detector excitation, voltage, count, image, trace, memory state, printed symbol, digital record, or another physically retained configuration.

A domain estimate is then inferred:

$$\widehat{\mathbf{x}}^{(M)}_{A,\mathscr{D}}[\xi_{A,\alpha}] = \mathcal{I}_{M,\mathscr{D}} \left(G_M[\xi_{M,\nu}]; \mathcal{Q}_{M,\mathscr{D}}[\xi_{M,\nu}] \right). \tag{175}$$

The complete chain is

$$X_A[\xi_{A,\alpha}] \xrightarrow{\text{physical coupling}} X_M[\xi_{M,\nu}] \xrightarrow{\text{registration}} G_M \xrightarrow{\text{inference}} \widehat{\mathbf{x}}^{(M)}_{A,\mathscr{D}}. \tag{176}$$

No arrow in this chain is an identity.

17.2 Ideal representation and measured estimate

The ideal domain representation

$$\mathbf{x}_{A,\mathscr{D}}[\xi] = \Pi_{A,\mathscr{D}}(X_A[\xi])$$

and the measured estimate $\widehat{\mathbf{x}}^{(M)}_{A,\mathscr{D}}[\xi]$ play different roles. The former belongs to the model's declared representational space; the latter is reconstructed from a physical output under calibration and inference. Their relation requires both a physical output channel and an inferential model. At the output level,

$$G_M \sim P_M^{\text{phys}}\left(dG \,\middle|\, X_A, X_M, \mathcal{E}_{M\leftarrow A}^{\text{meas}}, \boldsymbol{\eta}_M^{\text{phys}}\right), \tag{177}$$

while the estimate is obtained from G_M through $\mathcal{I}_{M,\mathscr{D}}(G_M; \mathcal{Q}_{M,\mathscr{D}})$, or through an explicitly declared posterior distribution on the represented state. The physical channel, the registered output, and the inferential distribution are distinct typed objects. The nuisance structures $\boldsymbol{\eta}_M^{\text{phys}}$ and $\boldsymbol{\eta}_{M,\mathscr{D}}$ collect only the parameters assigned to their respective physical and inferential levels. The familiar additive model

$$\widehat{q} = q + \epsilon \tag{178}$$

is one possible specialization, not the universal form of measurement. Here ϵ is defined only after the property, instrument, calibration, and statistical model have been specified.

17.3 Accuracy without completeness

Accuracy concerns a declared property and reference procedure. Completeness concerns the physical condition. Therefore

$$\text{Accurate}_{\mathscr{D}}\left(\widehat{\mathbf{x}}_{A,\mathscr{D}}^{(M)}[\xi]\right) \not\models \widehat{\mathbf{x}}_{A,\mathscr{D}}^{(M)}[\xi] \equiv_{\text{type}} X_A[\xi]. \tag{179}$$

A measurement can be highly accurate and still represent only a small subset of the target's physically relevant constitution and history. Conversely, incompleteness does not imply inaccuracy. These are different evaluative dimensions.

Equal readings also do not establish equal realized conditions:

$$\widehat{\mathbf{x}}_{A,\mathscr{D}}^{(M)}[\xi_{A,\alpha}] = \widehat{\mathbf{x}}_{B,\mathscr{D}}^{(M)}[\xi_{B,\beta}] \not\models \mathbf{x}_{A,\mathscr{D}}[\xi_{A,\alpha}] \cong_{\mathscr{D}} \mathbf{x}_{B,\mathscr{D}}[\xi_{B,\beta}]. \tag{180}$$

The equality may reflect projection, thresholding, finite resolution, non-identifiability, compensating differences, or genuine similarity in the represented property. Even represented equivalence in a shared domain would not by itself establish identity of the two physically realized systems.

17.4 The measurement license

Definition 17.1 (Measurement license)**.** The inferential license of a measurement result m is

$$\text{Lic}(m) := \left\langle A, \mathscr{D}, q_{A,\mathscr{D}}, M, \mathcal{C}_M, \mathcal{K}_{\mathscr{D}}^{\text{int}}, \Sigma_M, \Pi_{A,\mathscr{D}} \right\rangle. \tag{181}$$

The entries identify the target, domain, property, instrument, calibration, interpretation rule, uncertainty structure, and representation map.

Let Scope(Lic(m)) be the set of propositions licensed by the measurement tuple. A supported claim must satisfy:

$$\text{Claim}(m) \in \text{Scope}\left(\text{Lic}(m)\right). \tag{182}$$

A claim that exceeds the license requires an additional model or physical bridge, not merely stronger rhetoric.

17.5 Visibility and detection thresholds

Visibility is a relation among target, signal, detector, background, threshold, and processing rule. An external participant may be physically engaged yet fail to produce a separately detectable signature:

$$\mathrm{Coupled}(Y, A; [\alpha, \beta]) \not\models \mathrm{SeparatelyDetected}_M(Y). \tag{183}$$

The converse also requires care: an apparent signal can be produced by artifacts, cross-sensitivity, reconstruction bias, or an incorrect background model. Detection requires a declared decision rule and error structure.

17.6 Measurement disturbance

A measurement may alter the target, the measuring system, or both. Any physically significant measuring-system back-action must therefore be included among the influencing systems in the realized engagement:

$$\mathrm{PhysicallyRelevantBackAction}\,(M \to A; [\alpha, \beta]) \Longrightarrow M \in \mathcal{S}_{\to A,\mathrm{eng}}[\alpha, \beta]. \tag{184}$$

The framework does not assume that every measurement is strongly disturbing; it requires the disturbance question to be stated rather than hidden.

17.7 Robustness, calibration, and model dependence

A robust result should survive justified variation in calibration, preprocessing, parameterization, sampling, and reconstruction:

$$\mathrm{Robust}(m) \Longrightarrow \mathrm{StableConclusion}\left(\mathcal{C}_M, \mathcal{K}^{\mathrm{int}}_{\mathscr{D}}, \boldsymbol{\lambda}_M, \Sigma_M\right) \tag{185}$$

within the declared admissible range. Robustness increases confidence in the represented claim; it still does not convert the measured estimate into the realized condition or the measurement record into the full physical history.

17.8 Resolution, thresholds, and observational indistinguishability

A measuring system distinguishes possible target conditions only through differences that its physical output and inference rule can preserve. Let d_M be a declared statistical distinguishability functional on the conditional output distributions, and let $\rho_{M,\mathscr{D}}$ be the effective resolution threshold for the selected domain. Define

$$X_A[\xi_1] \approx^{\mathrm{obs}}_{M,\mathscr{D},\rho} X_A[\xi_2] \quad \Longleftrightarrow \quad d_M(P_M(\,\cdot \mid X_A[\xi_1]), P_M(\,\cdot \mid X_A[\xi_2])) \le \rho_{M,\mathscr{D}}. \tag{186}$$

The relation means observational indistinguishability under the declared instrument model, resolution, noise structure, and decision rule. It is not assumed to be transitive and is therefore not called a mathematical equivalence relation unless the declared decision rule genuinely partitions the admissible condition space. The instrument can consequently leave physically different realized conditions observationally unresolved.

This relation explains why a zero or unchanged output is weaker than physical identity. If

$$G_M[\xi_{M,1}] = G_M[\xi_{M,2}], \tag{187}$$

the licensed conclusion is that the registered outputs agree under the operating conditions. The result may support equality of a declared property after calibration, but it does not by itself establish equality of the physically realized target conditions or absence of the intervening history.

Detection thresholds introduce a further distinction. Let $S_M(Y \mid \mathcal{E}_A^{\mathrm{ext}}[\alpha, \beta])$ be the detector signal contrast assigned to participant Y within the declared full engagement configuration, and let θ_M be a declared threshold. Then

$$S_M(Y \mid \mathcal{E}_A^{\mathrm{ext}}[\alpha, \beta]) < \theta_M \Longrightarrow \mathrm{NotSeparatelyDetected}_M(Y), \tag{188}$$

while

$$\mathrm{NotSeparatelyDetected}_M(Y) \not\models \mathrm{NotPhysicallyRealized}(Y). \tag{189}$$

The second relation is a logical restriction, not evidence that an undetected contribution exists. Existence still requires physical support. The equation blocks only the invalid inference from non-detection to necessary non-existence.

For a declared change comparison whose specialization equips $\Delta_{A,\mathscr{D}}$ with a norm, let $\varepsilon_{M,\mathscr{D}}$ denote the effective resolution threshold and let W_{obs} denote the observation window. An operationally unresolved result may be written

$$\left\| \widehat{\delta}_{A,\mathscr{D}}^{(M)[\alpha,\beta]} \right\| \le \varepsilon_{M,\mathscr{D}} \Longrightarrow \neg \mathsf{RC}_{M,\mathscr{D}}^{W_{\mathrm{obs}}}(A). \tag{190}$$

Let $\mathrm{Dur}(W_{\mathrm{obs}})$ denote the duration assigned to the observation window by the declared clock or coordinate procedure. If $\tau_{A,M,\mathscr{D}}^{\mathrm{dist}}$ is the minimum observation scale required by the declared model for the change to become distinguishable, then

$$\mathrm{Dur}(W_{\mathrm{obs}}) < \tau_{A,M,\mathscr{D}}^{\mathrm{dist}} \Longrightarrow \neg \mathsf{RC}_{M,\mathscr{D}}^{W_{\mathrm{obs}}}(A). \tag{191}$$

Let $\xi_{A,\alpha}$ and $\xi_{A,\beta}$ identify the two physically realized conditions selected for the comparison. Neither an unresolved result nor the finite observation window implies an empty physical history:

$$\neg \mathsf{RC}_{M,\mathscr{D}}^{W_{\mathrm{obs}}}(A) \not\models \neg\, \mathrm{HistoryRealized}_A[\xi_{A,\alpha}, \xi_{A,\beta}]. \tag{192}$$

Observation-window limitation. The limits of W_{obs} are limits of access and recording, not the physical beginning and end of change. A laboratory may determine when a selected record first crosses a declared detection threshold, but that operationally identified occurrence is not thereby the first physically realized stage of every process contributing to the record. Sub-resolution, cumulative, compensated, or unrepresented developments may precede detectability. The experiment therefore neither enumerates the realized extension nor reconstructs the complete physical condition or history, and it does not identify a unique stage as the complete origin of an observed difference.

17.9 Calibration transport and instrument comparability

Calibration connects a registered output to a declared reference procedure. Let

$$\mathcal{C}_M = \left\langle \mathcal{R}_M^{\mathrm{ref}}, \mathcal{N}_M, \boldsymbol{\lambda}_M, \Sigma_M, \mathcal{V}_M \right\rangle, \tag{193}$$

where $\mathcal{R}_M^{\mathrm{ref}}$ is the reference relation, $\mathcal{N}_M$ the numerical assignment, $\boldsymbol{\lambda}_M$ calibration parameters, Σ_M the uncertainty structure, and $\mathcal{V}_M$ the validity domain. A result obtained outside $\mathcal{V}_M$ cannot inherit the calibration merely because the instrument continues to display a number.

Two instruments M_1 and M_2 are comparable only through a transfer procedure $\mathcal{T}_{12}$:

$$\widehat{\mathbf{x}}^{(M_2)} \approx \mathcal{T}_{12}\left(\widehat{\mathbf{x}}^{(M_1)}; \mathcal{C}_{M_1}, \mathcal{C}_{M_2}\right). \tag{194}$$

The transfer can involve shared standards, intercomparison, traceability chains, environmental corrections, and statistical adjustment. Agreement after transfer supports operational compatibility. Disagreement can arise from target variation, instrument history, calibration drift, model inadequacy, or unrepresented coupling. The discrepancy has no unique attribution before these alternatives are investigated.

Calibration is itself historically dependent. If an instrument undergoes a history $\mathcal{H}_M$ outside the validated range, the effective calibration may change:

$$\mathcal{C}_M^{(\beta)} = \mathrm{CalUpdate}_M\left(\mathcal{C}_M^{(\alpha)}, \mathcal{H}_M[\xi_{M,\alpha}, \xi_{M,\beta}]\right). \tag{195}$$

This is especially important for clocks, detectors, sensors, and biological assays whose physical output depends on aging, radiation, temperature, pressure, contamination, mechanical stress, or prior use.

17.10 Inverse reconstruction and identifiability

Measurement usually poses an inverse problem. Let the forward model be

$$G_M \sim P_M(\,\cdot \mid \mathbf{x}_{A,\mathscr{D}}, \boldsymbol{\eta}_M)\,, \tag{196}$$

where $\boldsymbol{\eta}_M$ denotes declared nuisance parameters.

Conditional identifiability given $\boldsymbol{\eta}$ holds on an admissible domain when

$$\mathbf{x}_1 \neq \mathbf{x}_2 \Longrightarrow P_M(\,\cdot \mid \mathbf{x}_1, \boldsymbol{\eta}) \neq P_M(\,\cdot \mid \mathbf{x}_2, \boldsymbol{\eta}) \quad \text{for the fixed declared } \boldsymbol{\eta}. \tag{197}$$

This criterion does not establish identifiability when nuisance parameters are unknown.

Global nuisance-robust identifiability requires

$$P_M(\,\cdot \mid \mathbf{x}_1, \boldsymbol{\eta}_1) = P_M(\,\cdot \mid \mathbf{x}_2, \boldsymbol{\eta}_2) \Longrightarrow \mathbf{x}_1 = \mathbf{x}_2 \tag{198}$$

for all admissible $(\mathbf{x}_i, \boldsymbol{\eta}_i)$; nuisance values need not themselves be uniquely identified. If nuisance variables are marginalized or profiled, the measure, prior, profiling rule, and resulting criterion must be stated explicitly. Local identifiability requires the analogous property in a neighborhood or a justified rank condition.

Non-identifiability must not be hidden by a single numerical estimate. The result should then be represented by a set, distribution, confidence region, or posterior family:

$$\mathfrak{X}^{(M)}_{A,\mathscr{D}}(G_M) := \left\{\mathbf{x} \mid \mathrm{Compatible}_{M,\mathscr{D}}(\mathbf{x}, G_M)\right\}. \tag{199}$$

A point estimate is justified only when its selection rule, nuisance treatment, and uncertainty are declared.

17.11 Records, retention, and later interpretation

A measurement output must remain physically retained if it is to support later comparison. Let R_M be the retained record. Then

$$G_M[\xi_{M,\nu}] \xrightarrow{\text{retention}} R_M[\xi_{M,\rho}], \qquad \xi_{M,\nu} \prec_M \xi_{M,\rho}. \tag{200}$$

Retention is itself a physical process and can introduce corruption, loss, compression, or transformation. A later analyst accesses R_M, not the vanished earlier detector condition directly. Therefore reproducibility depends on preservation, metadata, calibration history, processing records, and the stability of the interpretive chain.

The distinction matters when historical data are reanalyzed under a new model. The retained record may support a new inference, but it does not retroactively change the physical interaction that produced it:

$$\mathcal{I}^{\mathrm{new}}(R_M) \neq \mathcal{I}^{\mathrm{old}}(R_M) \not\models \mathrm{Changed}(\mathcal{H}^{\mathrm{past}}_M). \tag{201}$$

The change belongs to inference and representation unless new evidence establishes a change in the record itself.

18. From Foundational Structure to Quantitative Domain Models

ITOF supplies a typed foundational architecture. Numerical prediction requires a domain to specify represented variables, engagement variables, laws, parameters, boundary conditions, observables, and uncertainty. The specialization must operate on declared representational spaces rather than pretending to compute the unknowable realized condition in full.

18.1 Projected quantitative states

Let

$$\mathbf{x}_{A,\mathscr{D}}[\xi] = \Pi_{A,\mathscr{D}}(X_A[\xi]) \in \mathbb{Y}_{A,\mathscr{D}}. \tag{202}$$

Let the domain engagement projection be

$$\pi^E_{A,\mathscr{D}} : \mathbb{E}^0_{A,\mathrm{ext}} \longrightarrow \mathbb{E}_{A,\mathscr{D}}, \qquad \mathbf{e}^{[\alpha,\beta]}_{A,\mathscr{D}} := \pi^E_{A,\mathscr{D}}\left(\mathcal{E}^{\mathrm{ext}}_A[\alpha,\beta]\right). \tag{203}$$

A quantitative theory specifies a law on these declared represented objects. It does not thereby identify them with the physically realized condition, the typed physical engagement, or the realized physical history. The projection is an analytical representation step, not a physical transformation of the engagement.

18.2 Continuous and discrete representations

A domain may parameterize represented development by u, where u can be a coordinate, clock-derived parameter, proper-time functional, event count, computational index, path parameter, or other declared variable. Continuous and discrete forms include

$$\frac{d\mathbf{x}}{du} = \mathbf{f}_{A,\mathscr{D}}(\mathbf{x}, \mathbf{e}, u; \boldsymbol{\theta}), \tag{204}$$

$$\mathbf{x}_{k+1} = \mathbf{F}_{A,\mathscr{D}}(\mathbf{x}_k, \mathbf{e}_k; \boldsymbol{\theta}). \tag{205}$$

The parameter u and the index k organize the representation. Neither defines the physical meaning of time or the realized extension of change.

18.3 Deterministic domain closure

Let $\mathbb{P}_{A,\mathscr{D}}$ be the declared parameter space and $\boldsymbol{\theta}_{A,\mathscr{D}} \in \mathbb{P}_{A,\mathscr{D}}$. Let $\mathbb{K}_{A,\mathscr{D}}$ be the transition-descriptor space and $\kappa^{[\alpha,\beta]}_{A,\mathscr{D}} \in \mathbb{K}_{A,\mathscr{D}}$ declare the interval, path, duration, control schedule, boundary segment, or other domain structure needed to distinguish the selected transition. A deterministic specialization has the signature

$$\mathcal{F}_{A,\mathscr{D}} : \mathbb{Y}_{A,\mathscr{D}} \times \mathbb{E}_{A,\mathscr{D}} \times \mathbb{K}_{A,\mathscr{D}} \times \mathbb{P}_{A,\mathscr{D}} \longrightarrow \mathbb{Y}_{A,\mathscr{D}}. \tag{206}$$

Under the domain assumptions,

$$\mathbf{x}_{A,\mathscr{D}}[\xi_{A,\beta}] = \mathcal{F}_{A,\mathscr{D}}\left(\mathbf{x}_{A,\mathscr{D}}[\xi_{A,\alpha}], \mathbf{e}^{[\alpha,\beta]}_{A,\mathscr{D}}, \kappa^{[\alpha,\beta]}_{A,\mathscr{D}}; \boldsymbol{\theta}_{A,\mathscr{D}}\right). \tag{207}$$

The function is a domain closure, not a replacement for the foundational realization relation $\mathfrak{R}_A$.

18.4 Probabilistic domain closure

Where uniqueness is not justified, use a stochastic kernel:

$$K_{A,\mathscr{D}}\left(d\mathbf{x}_\beta \,\middle|\, \mathbf{x}_\alpha, \mathbf{e}_{\alpha\beta}, \kappa^{[\alpha,\beta]}_{A,\mathscr{D}}; \boldsymbol{\theta}_{A,\mathscr{D}}\right). \tag{208}$$

The kernel can represent stochastic dynamics, incomplete modeled information, coarse graining, or quantum-statistical structure. The interpretation must be supplied by the domain theory rather than inferred from the notation alone.

18.5 Rates and intervals

A rate is defined relative to a declared parameter and property:

$$\mathbf{v}^{(u)}_{A,\mathscr{D}} := \frac{d\mathbf{x}_{A,\mathscr{D}}}{du} \tag{209}$$

when the derivative exists. A change in rate is a change in this defined relation. It does not, by itself, license PM_T. The parameter may be indispensable to prediction while remaining representational or operational.

18.6 Class-level models

A class-level model should state the criteria under which an arbitrary system is admitted to the class. Membership licenses the declared class law within its validity domain; it does not determine the member's complete constitution, realized condition, or full physical history. Class laws abstract from system-specific constitution, and their success must not be interpreted as proof that all omitted structure is physically absent.

18.7 Dimensional and operational closure

Every specialization must declare units, dimensions, reference procedures, parameter ranges, and boundary conditions. An admissible model package may be written

$$\mathcal{M}_{A,\mathscr{D}} = \left\langle \mathbb{Y}_{A,\mathscr{D}}, \mathbb{E}_{A,\mathscr{D}}, \mathbb{K}_{A,\mathscr{D}}, \mathbb{P}_{A,\mathscr{D}}, \mathcal{L}^{\text{law}}_{A,\mathscr{D}}, \boldsymbol{\theta}_{A,\mathscr{D}}, \mathcal{G}^{\text{obs}}_{A,\mathscr{D}}, \Sigma^{\text{unc}}_{A,\mathscr{D}}, \mathcal{C}^{\text{test}}_{A,\mathscr{D}} \right\rangle. \tag{210}$$

Here $\mathbb{K}_{A,\mathscr{D}}$ is the transition-descriptor space introduced above, $\Sigma^{\text{unc}}_{A,\mathscr{D}}$ denotes the declared uncertainty structure and $\mathcal{C}^{\text{test}}_{A,\mathscr{D}}$ the test conditions and acceptance rules. ITOF constrains the type and interpretation of these components. It does not predetermine their numerical content.

19. Clocks and Numerical Timekeeping: Duration, Proper Time, and Physical Output

A clock is a physical measurement system configured to use a selected reproducible physical process as a numerical standard [27, 28]. A clock measures through its own physical change: it registers, counts, or maps distinguishable cycles, transitions, or other changes of the selected process into symbolic numerical output under a declared scale, calibration, and interpretation rule. It does not measure T_{ITOF} as a physical state, field, or agent. Its metrological force lies in the reproducibility, comparability, and transferability of that output, not in access to an independently existing temporal substance.

The distinction is categorical:

Clock-output distinction.

$$C \in \mathbb{S}_{\text{phys}}, \qquad G_C \not\equiv_{\text{type}} T_{\text{ITOF}}, \qquad t_C \not\equiv_{\text{type}} T_{\text{ITOF}}, \qquad D_C \not\equiv_{\text{type}} T_{\text{ITOF}}. \tag{211}$$

Here C is a physical system, whereas G_C, t_C, and D_C are a physical record and numerical quantities constructed from its operation. None is identical with the universe-wide descriptive meaning of time.

19.1 The clock as a physical system

Let $C \in \mathbb{S}_{\text{phys}}$ be a clock. Its operation belongs to the same physical realization architecture as any other physical system:

$$\mathfrak{R}_C\left(X_C[\xi_{C,\mu}], \mathcal{E}_C^{\text{ext}}[\mu,\nu], X_C[\xi_{C,\nu}]; \mathcal{H}_C[\xi_{C,\mu}, \xi_{C,\nu}]\right). \tag{212}$$

Its output depends on its constitution, selected physical process, control architecture, calibration, readout mechanism, physical history, and actual engagements. The clock is therefore neither external to physical change nor ontologically privileged over other systems.

A later clock condition can support a registered physical record

$$G_C[\xi_{C,\nu}] := \text{ClockReg}_C\left(X_C[\xi_{C,\nu}]; \mathcal{A}_C^{\text{reg}}\right), \tag{213}$$

where $\mathcal{A}_C^{\text{reg}}$ is the physical registration architecture, including the selected process, counter or discriminator, control, and readout components.

19.2 Numerical reading as symbolic output

A numerical clock reading is assigned through a calibration and interpretation map:

$$t_C[\xi_{C,\nu}] = \mathcal{N}_C\left(G_C[\xi_{C,\nu}]; \mathcal{C}_C, \mathcal{K}_C^{\text{int}}\right), \tag{214}$$

where $\mathcal{C}_C$ contains the declared scale and calibration, and $\mathcal{K}_C^{\text{int}}$ contains the counting and interpretation conventions. The construction is therefore

$$\mathcal{H}_C[\xi_{C,\mu}, \xi_{C,\nu}] \longrightarrow X_C[\xi_{C,\nu}] \longrightarrow G_C[\xi_{C,\nu}] \longrightarrow t_C[\xi_{C,\nu}]. \tag{215}$$

The reading is a symbolic numerical output grounded in a physical process. It is not the realized clock history, the physically realized condition of the clock, or the universe-wide descriptive meaning expressed by T_{ITOF}.

This applies equally to mechanical, astronomical, electronic, and atomic clocks. The selected process may be rotational, oscillatory, transitional, resonant, or otherwise reproducible. Greater regularity and precision improve the numerical standard; they do not change the ontological type of the instrument or its output.

19.3 Duration as a constructed numerical difference

For two justified references in the clock history,

$$D_C^{[\mu,\nu]} := t_C[\xi_{C,\nu}] - t_C[\xi_{C,\mu}]. \tag{216}$$

The quantity $D_C^{[\mu,\nu]}$ is a numerical difference defined by the clock scale and comparison procedure. It is operationally indispensable, but it is not a portion removed from a temporal substance and is not identical with T_{ITOF}.

A clock supplies selected numerical references against which changes in other systems may be compared. The resulting interval is constructed from clock output; it is not a measurement of the universe-wide temporal meaning defined by ITOF.

19.4 Coordinate time, proper time, and clock realization

A coordinate t belongs to a chart, parameterization, or operational coordinate construction. Proper time along a timelike path γ in a metric g is a path-dependent geometric functional, for example

$$\tau[\gamma, g] = \frac{1}{c}\int_\gamma \sqrt{-g_{\mu\nu}\, dx^\mu dx^\nu}, \tag{217}$$

for metric signature $(-,+,+,+)$, with coordinates x^μ taken to have dimensions of length and $x^0 = ct$.

A suitable clock can realize a reading that agrees with this functional to declared precision. This is a major empirical relation among a physical clock, its path, and metric geometry. The agreement does not identify the clock output, proper-time functional, or coordinate parameter with the ITOF definition of time:

$$t_C \not\equiv_{\mathrm{type}} T_{\mathrm{ITOF}}, \qquad D_C^{[\mu,\nu]} \not\equiv_{\mathrm{type}} T_{\mathrm{ITOF}}, \qquad \tau[\gamma, g] \not\equiv_{\mathrm{type}} T_{\mathrm{ITOF}}. \tag{218}$$

although a clock-defined duration $D_C^{[\mu,\nu]}$ may agree numerically, within stated uncertainty, with the proper-time functional assigned to the corresponding worldline segment under an ideal-clock model.

A real clock is represented more generally by a declared conditional realization model,

$$D_C^{[\mu,\nu]} \sim P_C\Big(\cdot \,\Big|\, \tau[\gamma_{\mu\nu}, g], \Theta_C, \mathcal{E}_C^{\mathrm{ext}}, \mathcal{A}_C^{\mathrm{reg}}, \mathcal{C}_C, \mathcal{K}_C^{\mathrm{int}}\Big). \tag{219}$$

The distribution may collapse to a deterministic map when justified. An additive form $D_C = M_C(\cdots) + \epsilon_C$ is one possible specialization after the residual structure has been physically and statistically defined; it is not the universal decomposition.

When the non-ideal terms are negligible within uncertainty, the result establishes successful clock realization of the proper-time model. It does not identify the clock-defined duration or the proper-time functional with T_{ITOF}.

19.5 Observed difference, relativistic prediction, and residual

For two clocks C_1 and C_2 compared by a declared procedure, define the observed duration difference

$$\Delta D_{12}^{\mathrm{obs}} := D_{C_1}^{[\mu_1,\nu_1]} - D_{C_2}^{[\mu_2,\nu_2]}. \tag{220}$$

where the reference pairs $[\mu_1, \nu_1]$ and $[\mu_2, \nu_2]$ are matched by the declared comparison protocol. For the corresponding worldline segments γ_1 and γ_2 in metric g, define the relativistic prediction

$$\Delta D_{12}^{\mathrm{rel}} := \tau[\gamma_1, g] - \tau[\gamma_2, g]. \tag{221}$$

The comparison residual is

$$r_{12}^{C} := \Delta D_{12}^{\mathrm{obs}} - \Delta D_{12}^{\mathrm{rel}}. \tag{222}$$

Agreement within the declared uncertainty supports the relativistic clock-comparison model. A significant residual directs inquiry toward instrument behavior, calibration, signal transfer, environmental decomposition, path or metric modeling, omitted physical interactions, or a more adequate theory. Neither agreement nor residual, by itself, licenses PM_T.

The distinction prevents three different phenomena from being collapsed:

(i) a lawfully predicted difference between ideal clock realizations on different paths or under different metric conditions;

(ii) an instrumental deviation from the applicable ideal or reference relation;

(iii) functional failure of the clock or its output-producing process.

Only the second is an instrumental error relative to the adopted model, and only the third is a failure of clock function. The first can be a fully successful physical and geometric prediction.

19.6 Worked attribution chain: an optical-clock comparison

A comparison of two optical clocks at different gravitational potentials provides a compact domain specialization of the ITOF discipline [34, 35]. The target objects are the two constituted clock systems, their transitions, support and control systems, comparison link, worldline segments, and the applicable metric model. In the cited optical-clock experiments, the primary reported observable is a fractional frequency ratio, difference, or spatial frequency gradient. A cumulative duration difference $\Delta D_{12}^{\mathrm{obs}}$ is obtained only after integration over a declared comparison interval and under a specified synchronization and transfer protocol. The analysis then proceeds without adding a new temporal variable:

1. The optical outputs define the declared frequency observable; where the protocol integrates that observable over a comparison window, it yields the duration difference $\Delta D_{12}^{\mathrm{obs}}$ in Equation (220).
2. The worldlines and metric geometry define the corresponding relativistic frequency or integrated proper-time prediction, specialized to $\Delta D_{12}^{\mathrm{rel}}$ when the duration formulation is used.

3. Their comparison defines the residual r_{12}^{C} in Equation (222), interpreted under the declared calibration and uncertainty model.

4. Agreement supports the clock, link, path, and relativistic realization model in the tested domain. A significant residual directs inquiry toward those physical and modeling components or toward a better domain theory.

5. A temporal-physical attribution is admissible only through the independently specified bridge criteria of Section 22.3; the observed result itself remains a clock-, path-, link-, and metric-based result.

Licensed conclusion of the worked comparison. The experiment can establish a reproducible difference between physical clock outputs and test its agreement with a proper-time prediction. It does not count stages of change, reconstruct the complete histories of the clocks, or measure T_{ITOF} as a physical state. The ITOF contribution is the explicit preservation of each result in the category that defines and detects it.

19.7 Tolerance, drift, and functional failure

A clock error relative to a declared reference may be written

$$\varepsilon_C^{[\mu,\nu]} = D_C^{[\mu,\nu]} - D_{\mathrm{ref}}^{[\mu,\nu]}. \tag{223}$$

The error belongs to the instrument, its reference relation, and the comparison procedure. Material drift can arise from the clock's design, temperature, pressure, radiation exposure, electromagnetic conditions, aging, control behavior, energy supply, or other physically specified engagements. Such effects must be attributed to the relevant physical systems and physical factors rather than to an unanalyzed "environment."

A diving watch exposed beyond its rated pressure illustrates the distinction. Pressure can deform the case, compromise seals, alter the mechanism, corrupt the readout, or destroy the device. The resulting drift or failure belongs to the watch and its pressure engagement; it is not a failure, slowing, or deformation of time.

A failed clock supplies a direct category test. Suppose the output becomes constant:

$$\xi_{C,\mu} \prec_C^{\Xi} \xi_{C,\nu} \wedge G_C[\xi_{C,\mu}] = G_C[\xi_{C,\nu}]. \tag{224}$$

The clock can nevertheless continue to undergo physical change. A frozen, drifting, absent, or incoherent output diagnoses failure or degradation of the selected process, control architecture, readout, or numerical function. Clock failure is failure of a physical system or declared function; it is neither cessation of change nor failure of time.

Formally,

$$\mathrm{Failure}(C) \Longrightarrow \mathrm{FailureOfClockFunction}(C) \ \vee\ \mathrm{Unreliable}(t_C) \ \vee\ \mathrm{Undefined}(t_C). \tag{225}$$

The predicate Failure is well-typed for a physical system or a declared function, not for T_{ITOF}:

$$T_{\mathrm{ITOF}} \notin \mathrm{Dom}\,(\mathrm{Failure})\,. \tag{226}$$

19.8 Synchronization and clock ensembles

Synchronization is a procedure for relating outputs of distinct physical systems under declared assumptions. Let $\mathcal{S}_{12}$ be a synchronization protocol for clocks C_1 and C_2:

$$\mathcal{S}_{12} : (G_{C_1}, G_{C_2}, \mathcal{P}_{12}) \longmapsto \mathrm{SyncRel}_{12}, \tag{227}$$

where $\mathcal{P}_{12}$ contains signal assumptions, path corrections, coordinate conventions, calibration, and uncertainty. An equality

$$t_{C_1}[\xi_1] = t_{C_2}[\xi_2] \tag{228}$$

means that the readings satisfy the protocol. It does not establish equality of the physically realized clock conditions or a shared physical state of time.

Practical reference scales may be constructed from clock ensembles. For clocks $\{C_i\}_{i=1}^{N}$ with weights w_i, a scale may be written schematically as

$$t_{\mathrm{ens}} = \mathcal{A}_{\mathrm{ens}}\left(\{t_{C_i}\}_{i=1}^{N}; \{w_i\}, \mathcal{Q}_{\mathrm{steer}}, \mathcal{C}_{\mathrm{ens}}\right). \tag{229}$$

The stability of an ensemble is an achievement of instrumentation, statistical construction, correction, and institutional maintenance. It does not make the ensemble a detector of T_{ITOF} as a physical state or substance.

20. Distance, Light Propagation, and Successive Records of Change

Distant observation joins but does not collapse distinct physical domains: source realization, radiation as a physical factor, propagation, detector registration, inferred source condition, and temporal description. A received record is not the source occurrence; it is a propagated physical record whose interaction with the detector produces a later detector condition.

20.1 Distance as spatial separation

Distance is a domain-defined measure of spatial separation between locations, systems, events, or geometric structures. In Euclidean settings it may be represented by a norm; in curved geometry by a metric or path functional. The quantity belongs to the spatial or geometric domain that defines it:

$$L_{AB} = \mathrm{Dist}_{\mathscr{G}}(A, B). \tag{230}$$

A light-year is the distance light propagates in vacuum during one Julian year under the standard unit convention. The word *year* in the unit does not convert distance into time or imply that light carries time.

20.2 Light as a physical factor and an ongoing optical stream

A star, galaxy, planet, or detector can be treated as a physical system under a defensible structural boundary. In the declared source–propagation–detector attribution account $\mathscr{A}_{\text{light}}$, the received radiation along path γ is assigned the role of a physical factor rather than that of a separately constituted system within the same account:

$$R_\gamma \in \mathbb{F}_{\text{phys}}^{(\mathscr{A}_{\text{light}})}, \qquad R_\gamma \notin \mathbb{S}_{\text{phys}}^{(\mathscr{A}_{\text{light}})}. \tag{231}$$

The radiation carries the physically encoded optical record. The source remains a system and the radiation retains its factor role in this account; another analysis may adopt a different explicit boundary and role assignment, provided that no physical contribution is duplicated.

For a source that remains emissive along an available observational path, the emitted light is not modeled as one isolated record that ceases and is later replaced by an unrelated light record when the source changes. At the observational level it forms an ongoing and successive optical stream whose successive portions reflect successive realized conditions of the source. The word *ongoing* denotes sustained record succession at the observational level; it does not impose a classical substance ontology or deny the quantum description of radiation.

20.3 Source conditions and emitted records

Let $\xi_{S,\alpha}$ and $\xi_{S,\beta}$ identify two selected source-condition occurrences for which the source order is physically justified:

$$\xi_{S,\alpha} \prec_S^{\Xi} \xi_{S,\beta}. \tag{232}$$

This analytical order registers the prior–later relation relevant to the compared records. It neither identifies a unique stage responsible for the observed source difference nor implies that the selected occurrences are adjacent or that intervening stages can be counted.

Write $\prec_\gamma^{\text{em}}$ for the emission order of portions of the ongoing optical stream and $\prec_M^{\text{det}}$ for the order of the corresponding registered detector records. The source-dependent portions of the emitted stream are represented by

$$R_{\gamma,\alpha} := \mathcal{E}_{\gamma,S}(X_S[\xi_{S,\alpha}])\,, \qquad R_{\gamma,\beta} := \mathcal{E}_{\gamma,S}(X_S[\xi_{S,\beta}])\,. \tag{233}$$

The map states dependence on selected source-condition occurrences under an emission model. It does not assert that every physical difference is optically encoded or that one identifiable stage produced the detected change. The emitted record is not the physically realized source condition and is not time:

$$R_{\gamma,\alpha} \not\equiv_{\text{type}} X_S[\xi_{S,\alpha}], \qquad R_{\gamma,\alpha} \not\equiv_{\text{type}} T_{\text{ITOF}}. \tag{234}$$

When the declared emission model preserves the justified source order,

$$\xi_{S,\alpha} \prec_S^{\Xi} \xi_{S,\beta} \Longrightarrow R_{\gamma,\alpha} \prec_\gamma^{\text{em}} R_{\gamma,\beta}. \tag{235}$$

20.4 Propagation, detection, and inference

For each emitted record, let Γ_α denote its realized propagation path and $\mathcal{P}_{\Gamma_\alpha}$ the corresponding record-specific propagation map. The notation $\mathcal{P}_\gamma$ denotes the declared propagation model within which such record-specific maps are specified. The physical and inferential chain is

$$R^{\mathrm{em}}_{\gamma,\alpha} \xrightarrow{\mathcal{P}_{\Gamma_\alpha}} R^{\mathrm{arr}}_{\gamma,\alpha} \xrightarrow{\mathcal{J}_M} X_M[\xi_{M,\alpha}] \xrightarrow{\mathrm{Reg}_M} G_{M,\alpha} \xrightarrow{\mathcal{I}_{M,\mathscr{D}}} \widehat{\mathbf{x}}^{(M)}_{S,\mathscr{D}}[\alpha]. \tag{236}$$

Here $\mathcal{P}_{\Gamma_\alpha}$ maps the emitted radiation record into the arrived radiation record, while $\mathcal{J}_M$ denotes the detector interaction that changes the detector condition. Equivalently,

$$R^{\mathrm{arr}}_{\gamma,\alpha} = \mathcal{P}_{\Gamma_\alpha}\left(R^{\mathrm{em}}_{\gamma,\alpha}\right), \qquad G_{M,\alpha} = \mathrm{Reg}_M\left[\mathcal{J}_M\left(R^{\mathrm{arr}}_{\gamma,\alpha}, X_M\right)\right]. \tag{237}$$

No arrow is an identity. The emitted and arrived records are distinct physical conditions of the radiation under the propagation model; radiation is not the source, detector output is not the radiation, and the inferred representation is not the physically realized source condition. In particular,

$$G_{M,\alpha} \not\equiv_{\mathrm{type}} R_{\gamma,\alpha}, \qquad R_{\gamma,\alpha} \not\equiv_{\mathrm{type}} T_{\mathrm{ITOF}}. \tag{238}$$

20.5 Propagation duration and differential arrival intervals

In an effective path model, the propagation duration of record α may be written

$$D_{\mathrm{prop},\alpha} = \int_{\Gamma_\alpha} \frac{d\ell}{v_{\mathrm{eff},\alpha}(\ell)}. \tag{239}$$

This formula is not asserted as a universal relativistic description. In relativistic geometry, null curves, coordinate choices, metric structure, and observer procedures supply the appropriate closure.

Within a declared propagation model, let $u_{S,\alpha}$ and $u_{M,\alpha}$ label the emission and detection events of record α in one operational comparison convention, so that

$$u_{M,\alpha} = u_{S,\alpha} + D_{\mathrm{prop},\alpha}. \tag{240}$$

Define

$$D^{\alpha\beta}_S := u_{S,\beta} - u_{S,\alpha}, \qquad D^{\alpha\beta}_M := u_{M,\beta} - u_{M,\alpha}. \tag{241}$$

It then follows identically that

$$D^{\alpha\beta}_M = D^{\alpha\beta}_S + \Delta D^{\alpha\beta}_{\mathrm{prop}}, \tag{242}$$

where

$$\Delta D^{\alpha\beta}_{\mathrm{prop}} := D_{\mathrm{prop},\beta} - D_{\mathrm{prop},\alpha}. \tag{243}$$

If source and detector intervals are initially reported in different local clock standards or coordinate conventions, the propagation model must first map them into the declared comparison convention used in Equations (240)–(242). For this differential comparison, any propagation contribution common to the two records cancels algebraically. The arrival-spacing relation therefore depends on the emission spacing and on the differential propagation term $\Delta D^{\alpha\beta}_{\mathrm{prop}}$, not on the common propagation baseline considered separately. Accordingly,

$$\Delta D^{\alpha\beta}_{\mathrm{prop}} \approx 0 \Longrightarrow D^{\alpha\beta}_{M} \approx D^{\alpha\beta}_{S}. \tag{244}$$

Successive-record relation.

$$D^{\alpha\beta}_{M} = D^{\alpha\beta}_{S} + \Delta D^{\alpha\beta}_{\mathrm{prop}}, \qquad \Delta D^{\alpha\beta}_{\mathrm{prop}} \approx 0 \Longrightarrow D^{\alpha\beta}_{M} \approx D^{\alpha\beta}_{S}.$$

For records compared under the same declared propagation model, common propagation contributions cancel in the differential relation, leaving the source-emission interval together with the residual propagation difference between the selected records.

20.6 Astronomical evidence from short recorded changes

Astronomical observation has established detectable variability in stars and galactic sources over short recorded intervals—days, months, or years—after observationally stable intervals. The TESS and ZTF references document the observing platforms and cadence capabilities, while the cited variability analyses provide examples of source change reconstructed from successive received records [23, 24, 25, 26]. Within the present formulation, these observations support modelling the received records, over the observed intervals, as an ongoing succession of source-dependent records rather than as one isolated record followed by an unrelated replacement. They do not establish that every unobserved interval is free of interruption. When differential propagation is negligible within the declared accuracy, short separations registered at the observatory correspond closely to the separations between the compared source-dependent emission records under the stated propagation model.

The resulting order chain is

$$\xi_{S,\alpha} \prec^{\Xi}_{S} \xi_{S,\beta} \Longrightarrow R_{\gamma,\alpha} \prec^{\mathrm{em}}_{\gamma} R_{\gamma,\beta} \Longrightarrow G_{M,\alpha} \prec^{\mathrm{det}}_{M} G_{M,\beta}, \tag{245}$$

provided the relevant propagation and detection relations preserve the order of the compared records.

20.7 Distant observation and source reconstruction

A detector receives a present physical signal whose structure depends on source realization and the intervening propagation history. What propagates is radiation carrying physical records, not time. The reconstructed source representation is

$$\widehat{\mathbf{x}}^{(M)}_{S,\mathscr{D}} = \mathcal{I}_{M,\mathscr{D}}\left(G_M; \mathcal{Q}^{(\gamma)}_{M,\mathscr{D}}\right), \tag{246}$$

where $\mathcal{Q}^{(\gamma)}_{M,\mathscr{D}}$ is the declared inference package augmented by the emission and propagation model $\mathcal{P}_{\gamma}$. Reliability depends on the adequacy of the emission, propagation, detector, calibration, and reconstruction components contained in that package.

20.8 Factorization of source, propagation, and detection models

A distant-observation model should factor its physical components and transformations:

$$\widehat{\mathbf{z}} = \mathcal{G}_M^{\mathrm{det}} \circ \mathcal{P}_\gamma^{\mathrm{prop}} \circ \mathcal{E}_S^{\mathrm{emit}} \left(\mathbf{x}_{S,\mathscr{D}}\right). \tag{247}$$

A discrepancy may arise from the source model, propagation geometry, intervening medium, detector output, calibration, or statistical assumptions. A temporal label cannot substitute for this decomposition.

20.9 Redshift and frequency attribution

Let ν_{emit} and ν_{obs} be frequencies defined by source and observer procedures. The redshift parameter

$$z := \frac{\nu_{\mathrm{emit}} - \nu_{\mathrm{obs}}}{\nu_{\mathrm{obs}}} \tag{248}$$

is a relation among emission, propagation, and detection quantities. Its explanation can involve relative motion, gravitational geometry, cosmological modeling, medium effects, or combinations of these. The measured frequency relation does not, by itself, establish a change in a separately specified temporal physical state:

$$\nu_{\mathrm{emit}} \neq \nu_{\mathrm{obs}} \not\models \mathsf{PM}_T. \tag{249}$$

Radiation may change, or may be differently related to source and detector standards, under a declared propagation model. Any further temporal-physical attribution requires an independently defined state, bridge law, and testable evidence.

20.10 Information loss and reconstruction limits

Propagation can erase distinctions that existed at the source. If

$$R_{\mathrm{emit}}^{(1)} \neq R_{\mathrm{emit}}^{(2)}, \qquad \mathcal{P}_\gamma^{\mathrm{prop}}\left(R_{\mathrm{emit}}^{(1)}\right) = \mathcal{P}_\gamma^{\mathrm{prop}}\left(R_{\mathrm{emit}}^{(2)}\right), \tag{250}$$

then inverse source reconstruction is non-identifiable from that received record alone. Absorption, scattering, finite bandwidth, lensing degeneracy, detector saturation, and noise can contribute to such non-injectivity.

20.11 Multiple paths and differential propagation

When records propagate along different admissible paths, path delay, attenuation, phase change, lensing, or medium variation can make $\Delta D_{\mathrm{prop}}^{\alpha\beta}$ non-negligible. The ordering of reception events is then an order in the detector history; inferring the source interval and order requires the propagation model. Thus the approximation in Equation (244) is a controlled condition, not an unconditional identity.

20.12 Successive records and justified source order

The physical succession chain supports an epistemic reconstruction only when emission, propagation, and detection are sufficiently controlled. Under a declared propagation model $\mathcal{P}_\gamma$, the relevant records and link evidence may warrant assigning $\xi_{S,\alpha} \prec_S^\Xi \xi_{S,\beta}$; the evidence licenses the assignment but does not create the source order. The inference concerns source change reconstructed through physical records. It does not require time to be emitted, propagated, or absorbed.

21. Relativity as a Domain Application of the ITOF Attribution Architecture

ITOF-centered scope. Relativity is a major domain application of ITOF and not the source of its definition. ITOF begins from its own ontology of systems, occurrences, realized change, prior–later order, and temporal meaning. It then assigns each relativistic quantity to the mathematical, geometric, operational, or physical category that defines it.

Standard relativity does not require time to be treated as an independent force or material substance. ITOF therefore does not compete with relativistic equations; it disciplines the ontological attribution of the quantities those equations relate. This section takes the validated formalism and evidence as domain input while preserving an independently defined temporal meaning. The governing question is

Which defined object differs, transforms, accumulates, curves, or requires correction, and what physical or geometric structure warrants that attribution?

21.1 The ITOF attribution baseline

A coordinate belongs to a chart or reference construction; proper time is a metric functional along a timelike worldline; a clock reading is an output of a physical device; a frequency ratio belongs to emitters, receivers, signals, paths, and geometry; curvature belongs to the spacetime metric and connection. ITOF preserves each of these assignments. Its independent temporal meaning is neither a replacement variable for them nor a quantity calculated by comparing two clocks:

$$T_{\text{ITOF}} \not\equiv_{\text{type}} t_{\mathcal{R}}, \qquad T_{\text{ITOF}} \not\equiv_{\text{type}} \tau[\gamma, g], \qquad T_{\text{ITOF}} \not\equiv_{\text{type}} D_C, \qquad T_{\text{ITOF}} \not\equiv_{\text{type}} g_{\mu\nu}. \tag{251}$$

These are type distinctions established by the ITOF architecture. Their scientific function is to prevent category drift when a successful quantity is interpreted; they are not presented as new empirical discoveries about relativity.

21.2 Coordinates, worldlines, and proper time

For standard inertial coordinates,

$$t' = \gamma_v \left(t - \frac{vx}{c^2} \right), \qquad x' = \gamma_v (x - vt), \qquad \gamma_v = \frac{1}{\sqrt{1 - v^2/c^2}}. \tag{252}$$

The Lorentz transformation relates coordinate assignments. It acts on the coordinate representation, not on T_{ITOF}, which is not a coordinate variable [1, 3].

For an arbitrary timelike worldline described in an inertial Minkowski chart,

$$\Delta\tau = \int_{t_1}^{t_2} \sqrt{1 - \frac{v^2(t)}{c^2}}\, dt. \tag{253}$$

Constant v is the inertial special case; variable $v(t)$ describes a more general timelike path in the same chart. In a general metric with signature $(- + ++)$,

$$\tau[\gamma, g] = \frac{1}{c} \int_\gamma \sqrt{-g_{\mu\nu}\, dx^\mu dx^\nu}. \tag{254}$$

Different worldlines may yield different proper-time values, and properly operating clocks can realize the corresponding comparison under stated conditions [18, 19]. A difference between worldlines does not by itself guarantee a proper-time difference, and a clock comparison requires the realization and comparison protocol developed in Section 19. ITOF's contribution is to keep the worldline functional, clock output, and temporal meaning distinct while accepting the physical comparison.

21.3 Clock outputs, frequency relations, and operational systems

The observed clock difference, relativistic prediction, and residual are defined in Equations (220)–(222). Agreement within uncertainty supports the combined clock, worldline, metric, signal-transfer, and comparison model in the tested domain. It is a positive physical result about those systems and relations.

For an emitter at x_{em} and a receiver at x_{rec} that satisfy the assumptions of a static spacetime and stationary observation, the gravitational frequency relation may be written

$$\frac{\nu_{\mathrm{rec}}}{\nu_{\mathrm{em}}} = \sqrt{\frac{-g_{00}(x_{\mathrm{em}})}{-g_{00}(x_{\mathrm{rec}})}}. \tag{255}$$

The emitter and receiver roles are explicit. A measured frequency difference is attributed through the source–signal–path–detector chain and is gravitationally assigned only after kinematic, medium, link, and instrumental contributions are controlled or modeled. Satellite navigation provides an important operational example: relativistic clock, orbit, signal, coordinate, and synchronization corrections are indispensable to the navigation solution [7]. These results strengthen the physical scope of ITOF's attribution program because they require a complete and testable realization chain rather than a verbal assignment.

21.4 Causal order, simultaneity, and extended systems

Relativity of simultaneity constrains cross-system coordinate assignments; it does not require ITOF to introduce a hidden universal synchronization surface. The temporal definition is constructed for one arbitrary system and universalized by quantification. Cross-system comparisons therefore use three explicitly distinct relations. A frame-indexed coordinate order and a protocol-indexed operational order may be defined by

$$o_A \prec_{\mathcal{R}} o_B :\Longleftrightarrow t_{\mathcal{R}}(o_A) < t_{\mathcal{R}}(o_B), \tag{256}$$

$$o_A \prec_{\mathcal{P}} o_B :\Longleftrightarrow \mathrm{ProtocolOrders}_{\mathcal{P}}(o_A, o_B). \tag{257}$$

These indexed relations remain within their declared frame or protocol. Promotion to the framework relation $\prec$ requires independent physical warrant:

$$\mathrm{SupportedPhysicalBridge}_{\mathcal{B}}(o_A, o_B) \Longrightarrow o_A \prec o_B, \tag{258}$$

where $\mathcal{B}$ may be a causal, signal, or physically retained record bridge. Coordinate order alone, especially for spacelike-separated occurrences, is not promoted to $\prec$; convention-dependent operational order likewise remains $\prec_{\mathcal{P}}$ unless additional physical evidence warrants the stronger relation.

For a localized system represented by a future-directed timelike worldline γ_A, let references $\xi_p = (\mathscr{D}, p)$ and $\xi_q = (\mathscr{D}, q)$ locate occurrences $o_p, o_q \in \mathbb{O}_A$ at $p, q \in \gamma_A$. Then an order-preserving localization licenses

$$\begin{aligned}
&\mathrm{FutureDirectedTimelike}(\gamma_A) \wedge p, q \in \gamma_A \wedge \mathrm{Locates}_A(\xi_p, o_p) \wedge \mathrm{Locates}_A(\xi_q, o_q) \\
&\wedge \mathrm{OrderPreservingLocalization}_A(\ell_{A,\gamma}; \gamma_A) \wedge o_p \lhd_A o_q \\
&\wedge \ell_{A,\gamma}(\xi_p) = p \wedge \ell_{A,\gamma}(\xi_q) = q \Longrightarrow q \in I^+(p).
\end{aligned} \tag{259}$$

The occurrence relation and the spacetime causal relation retain their types; Equation (259) is a consistency and order-preservation condition for a declared localization model, not a derivation of occurrence order from spacetime order [20, 21, 22]. For extended systems, a specialization must additionally declare the hypersurface, foliation, or covariant local-field construction used to represent the system and must establish covariance or state any residual representation dependence. Promoting $q \in I^+(p)$ to $o_p \lhd_A o_q$ requires the independent bridge of Equation (258) or an explicitly declared order-reflection condition. No total order of spacelike-separated events or preferred inertial frame follows from ITOF.

21.5 General relativity, geometry, and the scope of the temporal definition

Einstein's field equations,

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}, \tag{260}$$

relate spacetime geometry to stress–energy. ITOF accepts the mathematical and empirical role of the metric, curvature, geodesic structure, and gravitational dynamics [2, 4, 5, 6]. It leaves open disputes over whether the metric is best interpreted as a field, relation, geometry, or other physical structure. Its claim is narrower and exact: the framework's temporal meaning is independently defined and is not identical with the metric or any one of its components.

This separation is compatible with Lorentz covariance, relativistic causal structure, and the absence of a preferred inertial frame. Any model that introduces an additional temporal physical degree of freedom is evaluated by the same requirements of type, coupling, prediction, and detection stated in Section 22.3. The criterion is evidential and type-based rather than terminological.

21.6 Relativity within the ITOF empirical program

ITOF position. Relativity supplies validated domain relations among coordinates, worldlines, clocks, signals, frequencies, causal structure, and spacetime geometry. ITOF preserves those relations and contributes an independent temporal definition plus a disciplined attribution architecture. Standard relativistic theory need not be portrayed as claiming that time is a force or substance. The only additional issue is whether a distinct temporal physical state is independently defined, coupled, predicted, and detected; absent that further construction, the established relativistic quantities remain in the categories that define them.

Relativity is therefore a demanding compatibility and application domain for ITOF, but it does not determine the framework's identity. ITOF stands on its occurrence ontology, sustained-change postulate, temporal definition, empirical specialization program, and general non-transfer rule.

22. The ITOF Attribution Rule and the Non-Transfer Principle

A difference must first be attributed within the domain that defines it; cross-category transfer requires an independently specified physical relation.

22.1 Attribution within the defining domain

Let $Z_{\mathscr{D}}$ be a quantity defined within a physical, geometric, operational, or mathematical domain $\mathscr{D}$. A difference

$$\Delta Z_{\mathscr{D}} = Z_{\mathscr{D}}^{(\beta)} - Z_{\mathscr{D}}^{(\alpha)} \tag{261}$$

first establishes variation of $Z_{\mathscr{D}}$ under the assumptions and procedures that define it. The explanatory burden begins in that domain.

A clock-reading difference belongs first to the clocks and their physical histories. A proper-time difference belongs to paths and metric geometry. A coordinate change belongs to representation. A frequency shift belongs to sources, observers, signals, and propagation relations. A metric or curvature variation belongs to the geometric and physical model. None of these attributions prevents deeper physical explanation; each prevents a premature transfer to another category.

22.2 The non-transfer principle

Principle 22.1 (Non-transfer)**.** For a quantity Z and a proposed target state Y of a distinct type, a physical attribution to Y is not licensed by variation in Z unless an independently specified physical bridge connects the types:

$$\Delta Z \neq 0, \qquad \neg\,\text{BridgeLawEstablished}_{\text{phys}}(Z, Y) \not\models \text{PhysicalVariation}(Y). \tag{262}$$

Here $\not\models$ denotes absence of a licensed inference, not denial of the measured or calculated difference. The expression $\neg\,\text{BridgeLawEstablished}_{\text{phys}}(Z, Y)$ means that no adequate bridge law has been specified and supported for the inference; it does not claim proof that no such law could ever exist. A merely terminological, coordinate, representational, or definitional identification is insufficient for a claim of physical variation; the bridge must specify a physical state or relation and testable evidential consequences.

The principle does not deny the measured or calculated difference. It denies only that the difference, by itself, proves physical alteration or causal agency in another category. In the temporal application the target conclusion is PM_T, not a well-typed physical variation of T_{ITOF} inside ITOF. The principle is therefore conservative: it preserves established quantities while preventing ontological conclusions from being smuggled into technical terminology.

Scope of non-transfer. The denial of independent temporal agency or temporal substance does not, by itself, reject geometric, causal, relational, or structural descriptions used in physical theories.

$$\text{no independent temporal agency} \not\models \text{no geometric, causal, relational, or structural temporal description.}$$

The principle restricts only unsupported transfer from established structures or measured quantities to an independently acting physical time entity.

22.3 Admissible cross-category transfer

Non-transfer is not a permanent prohibition against cross-category explanation. It fixes the minimum burden under which such an explanation becomes physically admissible and empirically testable. Suppose a model proposes that variation in Y causes variation in Z. At minimum it should provide

1. definitions of the physical or mathematical types of Y and Z;
2. an interaction, constraint, or governing relation connecting them;
3. a mechanism or coupling parameter where the theory requires one;
4. differential predictions that distinguish the claim from alternatives;
5. an empirical procedure capable of testing those predictions.

Without these elements,

$$\text{Correlation}(Y, Z) \not\models \text{PhysicalAction}(Y \to Z). \tag{263}$$

Mathematical dependence may be representational, definitional, or evidential rather than causal.

22.4 Application discipline across clocks, geometry, signals, and residuals

The complete clock-comparison chain is developed in Section 19. Its observed difference, relativistic prediction, and residual retain their clock-, path-, metric-, signal-, and calibration-based meanings. The same discipline applies to proper time, coordinates, curvature, and frequency: each result remains significant in its defining domain, while any additional attribution to a distinct temporal physical state must satisfy Section 22.3.

A measured property difference is likewise first attributed to the measured system, property, instrument, engagement, and interpretation rule. It does not identify the complete system-wide difference, reconstruct the realized history, or determine its own cause. When a residual remains, calibration, uncertainty, parameterization, omitted interactions, boundaries, and competing model classes must be examined before any new ontology is proposed.

Technical expressions such as "time dilation," "time-dependent field," or "time evolution" may remain useful when their formal meanings are explicit. ITOF does not police vocabulary in isolation; it prevents compressed terminology from functioning as evidence for a physical ontology that has not been independently defined and tested.

The principle is open to discovery rather than prohibitive. Any proposed physical degree of freedom associated with temporal phenomena is assessed by the same requirements of type, coupling, differential prediction, and reproducible detection that apply to every proposed physical entity. The non-transfer principle preserves measured differences while restricting only unsupported promotion into physical modification or agency of time.

23. Documented Physical Instantiations and Experimental Constraints

Empirical instantiation. The experiments in this section do more than illustrate the language of the framework. Each resolves a physically attributable difference or history in a declared system, identifies the variables and engagement pathways through which the difference is reconstructed, and constrains any ITOF specialization applied to that domain. Their cross-domain convergence strengthens the physical motivation for sustained system change, while their direct evidential force remains attached to the systems and quantities actually tested.

A documented experiment enters ITOF through an explicit chain:

$$\begin{aligned}&\Big\langle X_A[\xi_\alpha], X_A[\xi_\beta], \mathcal{E}_A^{\text{ext}}[\alpha,\beta], \mathscr{D}, M, \mathcal{Q}_{M,\mathscr{D}}\Big\rangle\\ &\qquad \longrightarrow (G_{M,\alpha}, G_{M,\beta})\\ &\qquad \longrightarrow \Big(\widehat{\mathbf{x}}^{(M)}_{A,\mathscr{D}}[\xi_\alpha], \widehat{\mathbf{x}}^{(M)}_{A,\mathscr{D}}[\xi_\beta]\Big)\\ &\qquad \longrightarrow \widehat{\delta}^{(M)[\alpha,\beta]}_{A,\mathscr{D}}.\end{aligned} \tag{264}$$

A non-zero, reproducible difference under a validated measurement and inference chain is positive evidence of change in the represented physical variables and an experimentally resolved segment of physical history. When the declared analysis protocol $\mathcal{P}$ attributes a specific chain C, it records the corresponding evidential warrant as $\text{HistoryLicensed}_{A,\mathscr{D},\mathcal{P}}(C)$. Reconstruction of the complete realized condition is a stronger task governed by the declared completeness bridge.

Documented system or test	Directly established result	ITOF physical use and test obligation
Time-domain astronomical surveys and source monitoring [23, 24, 25, 26]	Successive photometric and spectroscopic detector records and received-signal differences over declared observation windows	Directly instantiates detector-record and received-signal histories; source-history reconstruction remains conditional on explicit emission, propagation, cadence, calibration, and inverse models.
Single-system quantum jumps in trapped ions and monitored superconducting artificial atoms [36, 37]	Resolved transitions and continuously monitored precursor or trajectory structure under a declared quantum measurement model	Tests whether a coarse apparently stable record omits finer development and requires the specialization to distinguish physical state, monitoring channel, conditional trajectory, and detector output.
Single-molecule enzymatic dynamics [38]	Fluctuating catalytic dynamics concealed by ensemble averaging	Demonstrates that a stable ensemble statistic need not exhaust the history of an individual constituted system; constrains state identification, sampling, and hidden-state models.
Attosecond molecular charge and electron–nuclear dynamics [39, 40, 41]	Electron-density migration, sub-10-fs charge transfer, nuclear wave-packet development, and a measured femtosecond population-transfer delay	Resolves physically ordered internal developments at scales far below ordinary observation and directly tests constitution dependence, intermediate-state structure, and coupled electronic–nuclear models.
Pound–Rebka and gravitational redshift tests [29, 31, 32]	Frequency relations under specified source, detector, path, gravitational, and reduction conditions	Constrains the complete emission–propagation–detection model and tests gravitational attribution after kinematic, link, and instrumental effects are controlled.
Transported, optical, and millimetre-scale clock comparisons [33, 34, 35]	Reproducible path- and geometry-dependent differences between physical clock outputs	Tests clock realization, calibration, link transfer, proper-time prediction, and residual structure. It supports path- and geometry-dependent differences in accumulated cycle counts and clock outputs only under a validated comparison protocol.

Documented system or test	Directly established result	ITOF physical use and test obligation
CERN muon storage ring [30]	Worldline-conditioned decay statistics consistent with special relativity for unstable particles in circular motion	Requires ITOF to preserve relativistic process laws beyond manufactured clocks without interpreting coordinate motion itself as a separate force or treating time as a physical agent.

Across these cases, the directly licensed conclusions concern the physical systems, paths, transitions, frequencies, records, and observables actually tested. Their stronger collective significance is convergence: highly different instruments and theories repeatedly resolve domain-local physical development rather than complete realized constancy. That convergence supports the foundational postulate without converting any one local result into a proof of sustained universal change. Motion and rotation remain transparent physical examples in Section 6; they are not counted as a separately documented experiment without a specified protocol. The next section separates empirical anchoring and specialization tests from the genuinely differential comparison required for model discrimination.

24. Empirical Anchoring, Counterexample Classes, and Model Discrimination

Layered evaluation and positive testability. The ontology and type discipline are judged by coherence and category consistency; declared domain specializations are judged by reproducible quantitative tests; and the universal sustained-change postulate is assessed through cross-domain compatibility, explicit counterexample conditions, and comparison with better-supported alternatives. Tests I–IV anchor and constrain specializations without becoming unique confirmations when competitors predict the same result. Test V becomes discriminating only when independently specified models make statistically distinguishable predictions under a declared decision design.

24.1 Three connected levels of evaluation

ITOF distinguishes foundational coherence, the universal sustained-change commitment, and domain specialization. Evidence moves among these levels through explicit bridge arguments. A local success supports the tested specialization, while repeated independent successes provide inductive support for the empirical program. The quantified commitment over $\mathbb{S}^{\mathcal{U}}_{\text{phys}}$ retains its status as a foundational postulate assessed additionally through coherence, cross-domain compatibility, and the explicit counterexample class. Every empirical protocol below is evaluated under a fixed AdmissibleAnalysis$(A, \mathscr{D}, \mathcal{P})$; this methodological condition governs the warrant for the result and remains distinct from the ontological membership of A in $\mathbb{S}^{\mathcal{U}}_{\text{phys}}$.

24.2 General intervention formulation

An intervention is a protocol-defined physical operation, not automatically Pearl's causal do-operator. Write

$$\text{Intervene}_{\mathcal{P}}(V \mapsto v) \tag{265}$$

for a protocol $\mathcal{P}$ that declares the target variable V, set value v, assignment mechanism, controlled covariates, boundary conditions, spillover assumptions, measurement channel, and identity-preservation conditions. If a structural causal model and its identification assumptions are supplied, the same operation may be represented by $\text{do}(V = v)$. Otherwise the protocol notation is retained and no unearned causal identification is inferred.

For outcome $\mathbf{y}$, let $\mathcal{L}_{\mathcal{P},v}(\mathbf{y})$ denote its law under the declared intervention. A general comparison is defined by a preregistered two-law functional

$$\mathcal{C}_\Psi : \mathfrak{L}_{\mathbf{y}} \times \mathfrak{L}_{\mathbf{y}} \longrightarrow \mathbb{C}_\Psi, \qquad \Delta^{\Psi}_{\mathcal{P}}\mathbf{y} := \mathcal{C}_\Psi(\mathcal{L}_{\mathcal{P},v_1}(\mathbf{y}), \mathcal{L}_{\mathcal{P},v_0}(\mathbf{y}))\,. \tag{266}$$

The comparison may be a difference of means, quantiles, variances, covariances, transition probabilities, or spectral/path summaries when the codomain supports subtraction; it may instead be a distributional distance, divergence, test functional, or another genuinely binary comparison. Mean difference is one specialization, not the universal intervention form. Physical interpretation remains limited by the protocol and identification assumptions actually established.

24.3 Test I: resolved domain-local physical change

Choose A, $\mathscr{D}$, two ordered registered occurrences, a projection, measurement model, and uncertainty model. Define

$$\widehat{\delta}^{(M)[\alpha,\beta]}_{A,\mathscr{D}} := \text{Diff}_{\mathscr{D}}\left(\widehat{\mathbf{x}}^{(M)}_{A,\mathscr{D}}[\xi_\beta], \widehat{\mathbf{x}}^{(M)}_{A,\mathscr{D}}[\xi_\alpha]\right). \tag{267}$$

For vector tests, declare

$$\text{Diff}_{\mathscr{D}} : \mathbb{Y}_{A,\mathscr{D}} \times \mathbb{Y}_{A,\mathscr{D}} \longrightarrow \Delta^{(p)}_{A,\mathscr{D}} \subseteq \mathbb{R}^p. \tag{268}$$

For the mean-shift specialization the null is $H_0 : \mathbb{E}[\widehat{\delta}] = \mathbf{0}$. Whenever a Moore–Penrose inverse is used, decompose

$$\widehat{\delta} = P_{\text{Range}(\Sigma_\delta)}\widehat{\delta} + P_{\ker(\Sigma_\delta)}\widehat{\delta}.$$

The quadratic form evaluates only the range component; a nonzero null-space component must be handled separately as a deterministic constraint violation, covariance-model failure, or separately specified test. Subject to that convention, a quadratic diagnostic is

$$Q_{\text{chg}} := \widehat{\delta}^T \Sigma^+_\delta \widehat{\delta}. \tag{269}$$

The rejection threshold must be obtained from the declared sampling distribution, sample size, covariance rank, nuisance-parameter treatment, and estimation procedure. Only under justified Gaussian/asymptotic conditions may Q_{chg} be assigned a chi-square reference law. A positive result supports $\text{LocalPhysicalChange}^{[\alpha,\beta]}_{\mathscr{D}}(A)$, not $\text{SustainedChange}(A)$ by itself.

24.4 Test II: identity-preserving constitution intervention

Let ϑ_A be a physically defined constitutive parameter with $v_0, v_1 \in \mathcal{V}_A^{\mathrm{id}}$, a region in which the declared identity of A remains applicable. With external protocol held fixed,

$$\mathcal{L}^{(i)}_{\vartheta,\mathcal{P}}(\mathbf{y}) := \mathcal{L}[\mathbf{y} \mid \mathrm{Intervene}_{\mathcal{P}}(\vartheta_A \mapsto v_i), \mathrm{Intervene}_{\mathcal{P}}(u_E \mapsto u_0)]\,, \qquad i \in \{0,1\}, \tag{270}$$

$$\Delta^{\Psi}_{\vartheta,\mathcal{P}}\mathbf{y} := \mathcal{C}_{\Psi}\Big(\mathcal{L}^{(1)}_{\vartheta,\mathcal{P}}(\mathbf{y}), \mathcal{L}^{(0)}_{\vartheta,\mathcal{P}}(\mathbf{y})\Big)\,. \tag{271}$$

The protocol must verify identity preservation and control or model any effect of the constitutive intervention on the external pathway. A reproducible contrast supports constitution-dependent realization in the tested domain.

24.5 Test III: controlled engagement-path intervention

Let u_Γ be a controllable variable for a declared physical pathway Γ, with

$$\mathcal{E}^{\mathrm{ext}}_A[\alpha, \beta; u_\Gamma] \in \mathbb{E}^0_{A,\mathrm{ext}}. \tag{272}$$

The pathway contrast is

$$\mathcal{L}^{(i)}_{\Gamma,\mathcal{P}}(\mathbf{y}) := \mathcal{L}[\mathbf{y} \mid \mathrm{Intervene}_{\mathcal{P}}(u_\Gamma \mapsto u_i)]\,, \qquad i \in \{0,1\}, \tag{273}$$

$$\Delta^{\Psi}_{\Gamma,\mathcal{P}}\mathbf{y} := \mathcal{C}_{\Psi}\Big(\mathcal{L}^{(1)}_{\Gamma,\mathcal{P}}(\mathbf{y}), \mathcal{L}^{(0)}_{\Gamma,\mathcal{P}}(\mathbf{y})\Big)\,. \tag{274}$$

The path, spillovers, compensating variables, boundary effects, and identification assumptions must be declared. Motion and rotation may enter either as dynamically effective parts of the target condition or as controls of an external pathway; mere coordinate classification is not an intervention.

24.6 Test IV: process-level stationarity challenge

Prepare the strongest physically realizable stationarity candidate and preregister a family of process descriptors $\widehat{\mathcal{Z}}_{k,\mathscr{D}}$, metrics d_k, and activity functionals $\mathcal{A}_k$. For an admissible analysis $(A, \mathscr{D}, \mathcal{P})$, choose a licensed realized history chain C and a nontrivial order-convex occurrence segment $\mathcal{J}$ satisfying

$$\begin{aligned}\mathrm{HistorySegment}_A(\mathcal{J}; C) :\Longleftrightarrow\ & C \in \mathfrak{C}^{\mathrm{id}}_A \wedge \mathcal{J} \subseteq C \\ & \wedge\ \exists o_-, o_+ \in \mathcal{J}:\ o_- \lhd_A o_+ \\ & \wedge\ \forall o_1, o, o_2 \in C: \\ & \quad \left[\begin{matrix} o_1 \in \mathcal{J} \wedge o_2 \in \mathcal{J} \wedge o_1 \lhd_A o \\ \wedge\ o \lhd_A o_2 \end{matrix} \Longrightarrow o \in \mathcal{J}\right].\end{aligned} \tag{275}$$

Define its uniquely locating reference family by

$$\Xi_A(\mathcal{J}) := \{\xi \in \Xi_A \mid \exists o \in \mathcal{J}:\ \mathrm{Locates}_A(\xi, o) \wedge \exists! o' \in \mathbb{O}_A:\ \mathrm{Locates}_A(\xi, o')\}\,. \tag{276}$$

The test is evaluable only when

$$\begin{gathered}\text{AdmissibleAnalysis}(A, \mathscr{D}, \mathcal{P}) \wedge \text{HistoryLicensed}_{A,\mathscr{D},\mathcal{P}}(C) \wedge \text{HistorySegment}_A(\mathcal{J}; C),\\ \exists \xi_-, \xi_+ \in \Xi_A(\mathcal{J}):\ \xi_- \prec_A^{\Xi} \xi_+,\end{gathered} \tag{277}$$

and the declared descriptors are defined on that reference family. Then define

$$\begin{aligned}\mathcal{N}_N^{\text{proc}}(A; \mathcal{J}) := \bigwedge_{k=1}^{N} \Bigg[&\sup_{\xi,\xi' \in \Xi_A(\mathcal{J})} d_k\Big(\widehat{\mathcal{Z}}_{k,\mathscr{D}}[\xi], \widehat{\mathcal{Z}}_{k,\mathscr{D}}[\xi']\Big) \le u_k^{\text{shape}} \\ &\wedge \mathcal{A}_k\Big(\widehat{\mathcal{Z}}_{k,\mathscr{D}}; \mathcal{J}\Big) \le u_k^{\text{act}}\Bigg].\end{aligned} \tag{278}$$

The descriptors may include moments, distributions, correlation functions, transition kernels, spectral content, trajectories, or a density operator. This criterion is stronger than endpoint equality: a periodic, fluctuating, stochastic, or transition-active process is not completely constant merely because one mean recurs. Persistent null results increasingly constrain the specialization but become an exact contradiction only when an independently justified completeness bridge, such as Equation (62) or a domain analogue, and the branch-constancy condition of Equation (63) are both established.

24.7 Test V: conditional temporal-physical model discrimination

Compare a system model M_{sys} with a rival model M_T that adds an independently defined temporal physical state T_{phys}, coupling g_T, and detection channel. Let

$$\Delta\widehat{\mathbf{y}}_T := \widehat{\mathbf{y}}_T - \widehat{\mathbf{y}}_{\text{sys}}. \tag{279}$$

Decompose $\Delta\widehat{\mathbf{y}}_T$ into the range and null-space components of Σ_Δ. The quadratic expression below is used only for the range component; any nonzero null-space component requires a separate deterministic or model-consistency assessment. The quadratic separation

$$\Lambda_T := (\Delta\widehat{\mathbf{y}}_T)^T \Sigma_\Delta^+ (\Delta\widehat{\mathbf{y}}_T) \tag{280}$$

is a design and power-planning quantity, not a universal decision rule. A valid test must additionally specify the sampling distributions, sample size, nuisance parameters, parameter-estimation procedure, covariance rank, decision function $\delta_{\mathcal{P}}$, and thresholds satisfying, for the preregistered design,

$$\Pr_{M_{\text{sys}}}(\delta_{\mathcal{P}} = 1) \le \alpha, \qquad \Pr_{M_T}(\delta_{\mathcal{P}} = 1) \ge 1 - \beta. \tag{281}$$

Equivalent likelihood-ratio, information-criterion, predictive, or Bayes-factor designs are admissible when fully specified and used under their stated assumptions [11, 10]. The rival state, coupling, and detector must be defined independently of the residual they are introduced to explain, and differential success must survive independent or reserved-data validation. For every concrete rival with numerical predictions, this architecture specifies the corresponding discrimination test and decision design.

24.8 Residuals, quadratic diagnostics, and degrees of freedom

For model m, define $\mathbf{r}^{(m)} := \mathbf{y} - \widehat{\mathbf{y}}^{(m)}$. When Σ is singular, the residual is first decomposed into $\mathrm{Range}(\Sigma)$ and $\ker(\Sigma)$; the quadratic form applies only to the range component, while a nonzero null-space component is assessed separately. Then

$$Q_m := (\mathbf{r}^{(m)})^T \Sigma^+ \mathbf{r}^{(m)}. \tag{282}$$

Q_m is a quadratic residual diagnostic. It may be denoted χ^2_m only when the residual law, covariance treatment, and regularity assumptions justify a chi-square reference distribution. The effective degrees of freedom must account for the supported covariance rank and parameters estimated from the same data; a schematic form is $\nu_{\mathrm{eff}} = \mathrm{rank}(\Sigma) - q_{\mathrm{eff}}$, subject to the model's actual estimation geometry. Blockwise sums require a block-diagonal covariance or a justified approximation.

A residual must be diagnosed within the declared model architecture; it is not a license for ontological invention. It may reflect calibration, omitted engagement, boundary error, non-identifiability, stochastic fluctuation, model inadequacy, or new physics.

24.9 Structural admissibility, adverse outcomes, and null inference

Before fitting, a specialization must declare the system and identity criterion, occurrence-order evidence, projection and difference space, dynamics, controls, measurement channel, calibration, uncertainty, nuisance structure, decision criterion, and the result that would support, restrict, or reject the model. Testability begins with a predeclared adverse outcome: an account that can absorb every result by redefining engagement or system identity after observation is not predictively closed.

Scientifically adverse outcomes include a failed preregistered local prediction, exclusion of a required pathway, independent establishment of Equation (63), reproducible differential success of a rival temporal-physical model, or inconsistency of the type architecture with a better-supported theory.

A finite null result remains limited to the declared architecture:

$$\begin{aligned}
&\mathrm{Null}_{M,\mathscr{D},W}(A) \not\models X_A[\xi_\alpha] \equiv_{\mathrm{phys}} X_A[\xi_\beta],\\
&\mathrm{Null}_{M,\mathscr{D},W}(A) \not\models \neg\,\mathrm{SustainedChange}(A),\\
&\mathrm{Null}_{M,\mathscr{D},W}(A) \not\models \neg\,\mathrm{SuccessionExtends}(A).
\end{aligned} \tag{283}$$

This limitation does not protect a failed specialization: a preregistered prediction that fails under an adequate design is rejected or restricted.

25. Scope, Physical Reach, and the ITOF Empirical Program

ITOF V23/F3 integrates a temporal definition, a typed ontology of physical attribution, a separation of stage from reference, and a concrete protocol for empirical specialization. Its physical reach is architectural rather than dynamical: established specialist theories supply the domain laws, while ITOF governs how systems, internal structure, external engagements, measurement chains, and ordered histories are typed, connected, and attributed without transferring measured variation to an undefined temporal agent.

The sustained-change postulate is supported by convergent observations of physical development across astronomical, relativistic, quantum, molecular, biological, and macroscopic domains. The framework makes that support operational through four empirical anchoring and specialization tests: domain-local resolved change, identity-preserving constitution intervention, controlled engagement-pathway intervention, and process-level stationary preparation. A fifth test compares the system-based attribution with any rival temporal-physical model that supplies an independent state, coupling, detector channel, and resolvable differential prediction. Finite experiments test the systemwise predictions through which the universal commitment acquires scientific content. Repeated success across independent systems and scales increases its warrant; reproducible failure restricts or rejects the affected specialization; an independently established complete-constancy counterexample over a nontrivial identity-preserving history segment challenges the postulate itself.

ITOF accommodates domain closures that are classical, relativistic, quantum, stochastic, statistical, biological, computational, or hybrid. This disciplined plurality preserves specialist dynamics while requiring every specialization to declare its state, engagement pathway, dynamics, measurement package, uncertainty, differential prediction, and adverse outcome in advance.

The extension statement is neutral among real-line, discrete, countable, non-countable, dense, and non-dense representations unless a domain specialization supplies additional structure. The empirical program is already organized by Tests I–IV for sharply specified domains and by Test V for any explicit rival temporal-physical model with a genuinely differential prediction. Each implementation declares its mathematical order representation, system identity, measurement architecture, and decision rule, thereby connecting relativistic causal structure, quantum descriptions, statistical mechanics, cosmology, and scale-dependent system identity to the current framework.

The framework is strengthened when its distinctions change experimental design or diagnosis: when a coarse null motivates finer state resolution, when constitution and engagement are independently intervened upon, when a clock residual is traced through its physical chain, or when a proposed temporal agency is required to produce a new measurable state and differential prediction. These procedures connect the foundational ontology directly to a physically accountable empirical program.

26. Conclusion: The Foundational Identity of ITOF

ITOF V23/F3 begins with a universal, identity-bounded physical commitment: every admissible identity-extended physical system undergoes sustained realized change while its declared identity remains applicable. The occurrence ontology permits change to be defined without presupposing stages; stages are derived from realized ordered non-identity, and sustained change analytically entails prior–later succession and its continuing identity-bounded extension. Universality is obtained by applying that construction to one arbitrary system and quantifying over $\mathbb{S}^{\mathcal{U}}_{\text{phys}}$, not by comparing two systems or imposing one global numerical clock.

The framework keeps the physical bearer, complete realized condition, representation, measurement, selected-condition difference, and physical history as distinct typed objects. Internal constitution and actual external engagement jointly condition realized outcomes without being counted twice. The realization relation is an attribution schema rather than a substitute for domain dynamics; classical, relativistic, quantum, stochastic, statistical, biological, computational, or hybrid theories supply the applicable laws and closure.

The empirical architecture gives this foundation explicit scientific accountability. Domain-local measurements, identity-preserving constitutive interventions, controlled engagement-path interventions, and process-level stationarity challenges support, restrict, or reject specified specializations. The universal postulate receives inductive support across systems and remains directly exposed to the exact complete-constancy countermodel and to incompatibility with better-supported physical theory. A rival temporal-physical model becomes discriminating when it defines an independent state, coupling, detection channel, and statistically resolvable prediction.

Foundational Statement 26.1. Time in ITOF is the universe-wide descriptive expression of the continuing, non-reversing extension of physically realized prior–later succession across the identity-preserving histories of admissible physical systems throughout the universe. It specifies neither the physical content, magnitude, rate, mechanism, nor cause of change.

The invariant named by the framework is the non-reversal of the physical prior–later relation. Order preservation under admissible re-expression is a derivative fidelity requirement: it represents the invariant relation without creating or constituting it. T_{ITOF} remains distinct from its formal representation $\mathfrak{T}_{\mathrm{ITOF}}$, from clock outputs, coordinate assignments, proper-time functionals, signals, and metric quantities. Relativity is respected as a validated domain theory and used as a stringent application of the ITOF attribution architecture. The framework's case rests on its own ontology, definitions, formal discipline, empirical protocols, and comparison with explicit alternatives—not on promoting representation, measurement, or inherited terminology into an untyped physical cause.

Foundational identity of ITOF. Physical systems are the bearers of change; physically realized prior–later succession is the ordered form analytically entailed by sustained realized change; and time is the universe-wide descriptive expression of its continuing, non-reversing extension. The framework separates bearer from description, occurrence from derived stage, stage from reference, realized condition from representation, history from selected-condition difference, environment from actual engagement, system identity from influencing role, and tested variation from unsupported cross-category transfer. It neither replaces domain dynamics nor converts temporal description into a physical agent.

A. Canonical Type System and Symbol Discipline

A.1 Primary categories

Symbol	Canonical meaning
$A \in \mathbb{S}_{\mathrm{phys}}$	Constituted physical system under a declared boundary and identity criterion.
$\mathbb{S}^{\mathcal{U}}_{\mathrm{phys}} \subseteq \mathbb{S}_{\mathrm{phys}}$	Admissible identity-extended physical systems to which the universal sustained-change postulate applies.
$\mathbb{S}^{\mathrm{phys}}_{\mathrm{spec}}$	Domain of physical system specifications carrying a declared boundary and identity criterion.
$\mathbb{S}^{\mathrm{an}}_{\mathrm{spec}}$	Domain of analysis specifications combining a fixed physical system specification with a declared domain and protocol.
$\mathrm{Spec} : \mathbb{S}_{\mathrm{phys}} \to \mathbb{S}^{\mathrm{phys}}_{\mathrm{spec}}$	Physical specification map assigning a fixed boundary and identity criterion to each system token.
OnticallyInstantiates	Ontic relation stating that a constituted system instantiates the specified boundary and identity-bearing physical organization; it is not an evidential verdict.
$\mathrm{AnalysisSpec}(A, \mathscr{D}, \mathcal{P})$	Analysis specification combining the fixed physical system specification with a declared domain and protocol.
OutcomeIndependent	Boolean predicate on $\mathbb{S}^{\mathrm{an}}_{\mathrm{spec}}$ requiring the analysis specification to be fixed independently of the observed outcome.
$\mathrm{AdmissibleAnalysis}(A, \mathscr{D}, \mathcal{P})$	Methodologically admissible analysis using a physically admissible system and an outcome-independent analysis specification.
$\mathrm{AdmissibleSystem}(A)$	Ontic instantiation by A of its fixed physical system specification; methodological admissibility is assessed separately.
$\mathbb{O}_{\mathrm{phys}}$	Primitive universe-domain of physical occurrences; covered, but not defined, by the system occurrence domains.
$\mathbb{O}_A$	Occurrences attributable to A while its identity criterion applies.
$\mathrm{OccurrenceOf}_A(o)$	Attribution predicate assigning occurrence o to A.
$X_A(o) \in \mathbb{X}^{\mathrm{full}}_A$	Ontological complete physically realized condition of A at occurrence o.
$\mathbb{M}^{\mathrm{full}}_A$	Formal full-state model space obtained by quotienting gauge-, coordinate-, and representation-redundant raw descriptions.

Symbol	Canonical meaning
Den_A	Semantic denotation map from a formal full-state model representative to the ontological complete-condition domain; it does not ontologically generate the condition.
$\mathbf{m}_A : \mathbb{O}_A \rightharpoonup \mathbb{M}_A^{\mathrm{full}}$	Partial full-state model-representation map, defined only where a declared complete formal representative is supplied.
$\prec$	Universe-domain physical prior–later relation; evidential warrants justify assigning particular occurrence pairs to it but do not constitute the relation.
$\prec_{\mathcal{R}}, \prec_{\mathcal{P}}$	Frame-indexed coordinate order and protocol-indexed operational order; neither is automatically promoted to $\prec$.
$\lhd_A$	Restriction of $\prec$ to $\mathbb{O}_A$; not an independent local time.
$\mathrm{IdentityExtended}(A)$	Existence of a nontrivial ordered pair of occurrences attributable to the same admissible system identity.
$\mathrm{OrderFaithful}(\Phi)$	Bijection-pair predicate preserving and reflecting order and preserving occurrence-to-system attribution.
$\mathrm{Change}_A(o_\alpha, o_\beta)$	Endpoint-resolved ordered physical non-identity of complete conditions; it does not exclude intervening process change when selected endpoints recur.
$\mathrm{PriorLaterSuccession}(A)$	Expository alias for $\mathrm{IdentityExtended}(A)$; it introduces no second independent predicate.
$\mathrm{EndpointChangeExists}(A)$	Existence of at least one ordered pair whose complete realized endpoint conditions are physically non-identical.
$\mathrm{StageOf}_A(o)$	Derived predicate: occurrence o participates in at least one realized change.
$\mathrm{Chain}_A(C)$	Nonempty subset of $\mathbb{O}_A$ whose members are pairwise comparable under $\lhd_A$.
$\mathrm{MaximalChain}_A(C)$	Chain maximality under inclusion within $\mathbb{O}_A$; mathematical maximality alone does not establish one physical history.
$\mathrm{RealizedHistoryChain}_A(C)$	Ontological predicate that C is one physically realized identity-preserving history chain.
$\mathrm{HistoryLicensed}_{A,\mathscr{D},\mathcal{P}}(C)$	Protocol-indexed epistemic license, supplied by a declared analysis, for attributing C as a physically realized history chain.
$\mathfrak{C}_A^{\mathrm{id}}$	Maximal realized identity-preserving chains defined by Equations (28)–(32).
$\mathrm{IdOpen}_A(o; C)$	Occurrence o has a later occurrence on realized identity-preserving history chain C; does not itself assert change.

Symbol	Canonical meaning
$\mathrm{SustainedChange}(A)$	Non-vacuous branch-complete identity-bounded continuation of later physical non-identity.
Ξ_A	Analytical reference family.
$\mathrm{Locates}_A(\xi, o)$	Relation locating an occurrence by an analytical reference.
$\prec_A^{\Xi} \subseteq \Xi_A \times \Xi_A$	Analytical reference order induced by uniquely located occurrence pairs in the physical order; not an independent local time.
$\mathrm{HistorySegment}_A(\mathcal{J}; C)$	Nontrivial order-convex occurrence segment of one realized identity-preserving history chain.
$\mathrm{OrderPreservingLocalization}_A$	Predicate asserting one-direction preservation of occurrence order by a declared localization map onto a worldline.
$\mathbf{x}_{A,\mathscr{D}}[\xi]$	Ideal domain-representation value of a uniquely located complete condition.
$\widehat{\mathbf{x}}^{(M)}_{A,\mathscr{D}}[\xi]$	Measured or inferred value produced by measurement architecture M.
$\mathbf{z}^{\mathrm{ideal}}_{A,\mathscr{D}}, \widehat{\mathbf{z}}^{(M)}_{A,\mathscr{D}}$	Tagged representation objects carrying a value and a provenance label.
$\mathrm{Val}(z), \mathrm{Prov}(z)$	Value and provenance projections on the tagged representation space $\mathbb{Z}_{A,\mathscr{D}}$.
$\mathcal{H}_A[\xi_\alpha, \xi_\beta]$	Domain-justified physical history associated with selected occurrences; not a difference vector.
$\mathrm{PhysicalHistory}_A$	Typed physical-history relation among a history witness and two derived stages.
$\rho_{A,\mathscr{D}}(o)$	Quantum representation obtained from the complete condition by the declared projection $\Pi^Q_{A,\mathscr{D}}$.
$\mathcal{Q}^{\mathrm{occ}}_{A,\mathscr{D}}$	Space of occurrence-indexed quantum-representation maps used as arguments of the completeness predicate.
$\mathrm{CompleteRep}_{A,\mathscr{D}}(\rho_{A,\mathscr{D}})$	Explicit completeness bridge from the declared occurrence-indexed quantum representation to complete physical-condition identity.
$\mathrm{Intervene}_{\mathcal{P}}(V \mapsto v)$	Protocol-defined intervention; equivalent to $\mathrm{do}(V = v)$ only under an identified structural causal model.
$\mathcal{C}_\Psi$	Preregistered binary comparison functional on two intervention outcome laws.
$\mathrm{Dur}(W_{\mathrm{obs}})$	Duration assigned to an observation window by the declared clock or coordinate procedure.
$\mathfrak{R}_A$	Typed realization/attribution schema; not a universal equation of motion.

Symbol	**Canonical meaning**
$\mathrm{Args}_{\mathrm{phys}}(\mathfrak{R}_A)$	Tagged disjoint union of the admissible physical argument values of the realization relation.
$\kappa^{[\alpha,\beta]}_{A,\mathscr{D}}$	Declared transition descriptor carrying interval, path, duration, control, or boundary-segment information required by a domain closure.
T_{ITOF}	Semantic temporal meaning: the universe-wide descriptive expression of the continuing, non-reversing extension of physically realized prior–later succession across the identity-preserving histories of admissible physical systems throughout the universe; it specifies neither the physical content, magnitude, rate, mechanism, nor cause of change.
$\mathfrak{T}_{\mathrm{ITOF}} = (\mathbb{O}_{\mathrm{phys}}, \prec)$	Formal order representation of the occurrence domain.
$\tau[\gamma, g]$	Proper-time functional along timelike path γ under metric g.
$\equiv_{\mathrm{phys}}, \not\equiv_{\mathrm{phys}}$	Physical identity/non-identity of complete realized conditions.
$\cong_{\mathscr{D}}, \ncong_{\mathscr{D}}$	Equivalence/non-equivalence in a declared representation domain.
$\equiv_{\mathrm{type}}, \not\equiv_{\mathrm{type}}$	Identity/non-identity of ontological or formal type.
$\not\models$	Semantic non-entailment relative to declared premises; not proof-theoretic non-derivability.

A.2 Canonical signatures

$$\mathrm{Spec} : \mathbb{S}_{\mathrm{phys}} \to \mathbb{S}^{\mathrm{phys}}_{\mathrm{spec}}, \tag{284}$$

$$\mathrm{Spec}(A) = (\partial A, \mathcal{I}_A), \tag{285}$$

$$\mathrm{AnalysisSpec}(A, \mathscr{D}, \mathcal{P}) = (\mathrm{Spec}(A), \mathscr{D}, \mathcal{P}) \in \mathbb{S}^{\mathrm{an}}_{\mathrm{spec}}, \tag{286}$$

$$\mathrm{OnticallyInstantiates} : \mathbb{S}_{\mathrm{phys}} \times \mathbb{S}^{\mathrm{phys}}_{\mathrm{spec}} \to \{\mathrm{true}, \mathrm{false}\}, \tag{287}$$

$$\mathrm{OccurrenceOf} \subseteq \mathbb{S}_{\mathrm{phys}} \times \mathbb{O}_{\mathrm{phys}}, \tag{288}$$

$$\mathrm{AdmissibleSystem} : \mathbb{S}_{\mathrm{phys}} \to \{\mathrm{true}, \mathrm{false}\}, \tag{289}$$

$$\mathrm{OutcomeIndependent} : \mathbb{S}^{\mathrm{an}}_{\mathrm{spec}} \to \{\mathrm{true}, \mathrm{false}\}, \tag{290}$$

$$\mathrm{AdmissibleAnalysis}(A, \mathscr{D}, \mathcal{P}) \in \{\mathrm{true}, \mathrm{false}\}, \tag{291}$$

$$\mathbb{O}_A := \{o \in \mathbb{O}_{\mathrm{phys}} : \mathrm{OccurrenceOf}_A(o)\}, \tag{292}$$

$$\mathbb{S}^{\mathcal{U}}_{\mathrm{phys}} := \{A \in \mathbb{S}_{\mathrm{phys}} : \mathrm{AdmissibleSystem}(A) \wedge \mathrm{IdentityExtended}(A)\}, \tag{293}$$

$$\lhd_A := \prec \cap (\mathbb{O}_A \times \mathbb{O}_A), \tag{294}$$

$$\mathrm{IdentityExtended} : \mathbb{S}_{\mathrm{phys}} \to \{\mathrm{true}, \mathrm{false}\}, \tag{295}$$

$$\mathrm{PriorLaterSuccession} : \mathbb{S}_{\mathrm{phys}} \to \{\mathrm{true}, \mathrm{false}\}, \tag{296}$$

$$\mathrm{PriorLaterSuccession}(A) \iff \mathrm{IdentityExtended}(A) \quad (A \in \mathbb{S}_{\mathrm{phys}}), \tag{297}$$

$$\mathrm{Change}_A : \mathbb{O}_A \times \mathbb{O}_A \to \{\mathrm{true}, \mathrm{false}\}, \tag{298}$$

$$\mathrm{StageOf}_A : \mathbb{O}_A \to \{\mathrm{true}, \mathrm{false}\}, \tag{299}$$

$$\mathrm{EndpointChangeExists} : \mathbb{S}_{\mathrm{phys}} \to \{\mathrm{true}, \mathrm{false}\}, \tag{300}$$

$$\mathrm{SuccessionExtends} : \mathbb{S}_{\mathrm{phys}} \to \{\mathrm{true}, \mathrm{false}\}, \tag{301}$$

$$\mathrm{SustainedChange} : \mathbb{S}_{\mathrm{phys}} \to \{\mathrm{true}, \mathrm{false}\}, \tag{302}$$

$$X_A : \mathbb{O}_A \to \mathbb{X}^{\mathrm{full}}_A, \tag{303}$$

$$\mathbb{M}^{\mathrm{full}}_A := \widetilde{\mathbb{X}}^{\mathrm{full}}_A / \sim^{\mathrm{phys}}_A, \tag{304}$$

$$\mathrm{Den}_A : \mathbb{M}^{\mathrm{full}}_A \to \mathbb{X}^{\mathrm{full}}_A, \tag{305}$$

$$\mathbf{m}_A : \mathbb{O}_A \rightharpoonup \mathbb{M}^{\mathrm{full}}_A, \tag{306}$$

$$\Pi_{A,\mathscr{D}} : \mathbb{X}^{\mathrm{full}}_A \to \mathbb{Y}_{A,\mathscr{D}}, \tag{307}$$

$$\mathrm{Diff}_{\mathscr{D}} : \mathbb{Y}_{A,\mathscr{D}} \times \mathbb{Y}_{A,\mathscr{D}} \to \Delta_{A,\mathscr{D}}, \tag{308}$$

$$\mathrm{Locates}_A \subseteq \Xi_A \times \mathbb{O}_A, \tag{309}$$

$$\prec^{\Xi}_A \subseteq \Xi_A \times \Xi_A. \tag{310}$$

$$\mathrm{Chain}_A : 2^{\mathbb{O}_A} \to \{\mathrm{true}, \mathrm{false}\}, \tag{311}$$
$$\mathrm{MaximalChain}_A : 2^{\mathbb{O}_A} \to \{\mathrm{true}, \mathrm{false}\}, \tag{312}$$
$$\mathrm{RealizedHistoryChain}_A : 2^{\mathbb{O}_A} \to \{\mathrm{true}, \mathrm{false}\}, \tag{313}$$
$$\mathrm{HistoryLicensed}_{A,\mathscr{D},\mathcal{P}} : 2^{\mathbb{O}_A} \to \{\mathrm{true}, \mathrm{false}\}, \tag{314}$$
$$\mathrm{HistorySegment}_A : 2^{\mathbb{O}_A} \times 2^{\mathbb{O}_A} \to \{\mathrm{true}, \mathrm{false}\}, \tag{315}$$
$$\mathfrak{C}_A^{\mathrm{id}} \subseteq 2^{\mathbb{O}_A}, \tag{316}$$
$$\mathrm{IdOpen}_A \subseteq \mathbb{O}_A \times \mathfrak{C}_A^{\mathrm{id}}, \tag{317}$$
$$\mathrm{OrderPreservingLocalization}_A \subseteq \mathrm{Map}(\Xi_{A,\gamma}, \gamma_A) \times \{\gamma_A\}, \tag{318}$$
$$\mathrm{Val} : \mathbb{Z}_{A,\mathscr{D}} \to \mathbb{Y}_{A,\mathscr{D}}, \tag{319}$$
$$\mathrm{Prov} : \mathbb{Z}_{A,\mathscr{D}} \to \mathbb{G}_{A,\mathscr{D}}^{\mathrm{prov}}, \tag{320}$$
$$\Pi_{A,\mathscr{D}}^{Q} : \mathbb{X}_A^{\mathrm{full}} \to \mathcal{D}(\mathcal{H}_{A,\mathscr{D}}), \tag{321}$$
$$\mathcal{Q}_{A,\mathscr{D}}^{\mathrm{occ}} := \mathrm{Map}\left(\mathbb{O}_A, \mathcal{D}(\mathcal{H}_{A,\mathscr{D}})\right), \tag{322}$$
$$\mathrm{CompleteRep}_{A,\mathscr{D}} : \mathcal{Q}_{A,\mathscr{D}}^{\mathrm{occ}} \to \{\mathrm{true}, \mathrm{false}\}, \tag{323}$$
$$\mathrm{Intervene}_{\mathcal{P}} : (V, v) \mapsto \mathcal{L}_{\mathcal{P},v}, \tag{324}$$
$$\mathcal{C}_\Psi : \mathfrak{L}_{\mathbf{y}} \times \mathfrak{L}_{\mathbf{y}} \to \mathbb{C}_\Psi, \tag{325}$$
$$\mathfrak{R}_A \subseteq \mathbb{X}_A^{\mathrm{full}} \times \mathbb{E}_{A,\mathrm{ext}}^{0} \times \mathbb{X}_A^{\mathrm{full}} \times \mathbb{H}_A. \tag{326}$$

The chain family is fixed by Equations (28)–(32); mathematical maximality is not sufficient without the ontological realized-history condition of Equation (30); empirical attribution additionally requires the separate evidential predicate typed in Equation (31).

The predicates $\mathrm{CompleteRep}_{A,\mathscr{D}}$ and $\mathrm{PhysicalHistory}_A$ are relations, not universal functions. Stronger functional, probabilistic, quantum, or causal specializations must declare their additional assumptions, state spaces, nuisance treatment, and data model.

A.3 Use restrictions

No occurrence is called a stage before Equation (25) is satisfied. No finite representation is identified with the complete condition without an explicit completeness bridge. T_{ITOF} and $\mathfrak{T}_{\mathrm{ITOF}}$ remain different types. The realization schema fixes attribution types and does not calculate a later condition without a domain law.

B. Hierarchy and Reading of the Governing Relations

The governing order is:

H1. primitive occurrence domain, physical-system domain, and fixed system specification;

H2. system-restricted occurrence ontology and physical prior–later order;

H3. ontic system admissibility, nontrivial identity extension, construction of $\mathbb{S}_{\mathrm{phys}}^{\mathcal{U}}$, and the universe occurrence-domain coverage postulate;

H4. realized change, Equation (24);

H5. derived stages, Equation (25);

H6. realized-history chains and identity-bounded sustained change, Equations (28)–(35);

H7. temporal meaning and formal representation, Definition 12.1 and Equation (123);

H8. typed realization and domain dynamics;

H9. measurement, intervention, statistical decision, and model comparison;

H10. relativistic and other domain applications.

A lower level may represent or test a higher-level claim but may not redefine it merely because the same word "time" is used.

C. Formal Consistency Consequences of the Reconstructed Architecture

From the active definitions:

$$\mathrm{Change}_A(o_\alpha, o_\beta) \Longrightarrow o_\alpha \lhd_A o_\beta, \tag{327}$$

$$\mathrm{Change}_A(o_\alpha, o_\beta) \Longrightarrow X_A(o_\alpha) \not\equiv_{\mathrm{phys}} X_A(o_\beta), \tag{328}$$

$$\mathrm{StageOf}_A(o) \Longrightarrow o \in \mathbb{O}_A, \tag{329}$$

$$\mathrm{SustainedChange}(A) \Longrightarrow \big[\mathrm{PriorLaterSuccession}(A) \wedge \mathrm{EndpointChangeExists}(A) \wedge \mathrm{SuccessionExtends}(A)\big], \tag{330}$$

$$\mathcal{T}_{\mathrm{ITOF}} \not\equiv_{\mathrm{type}} \mathfrak{T}_{\mathrm{ITOF}}, \qquad \mathcal{T}_{\mathrm{ITOF}} \notin \mathrm{Args}_{\mathrm{phys}}(\mathfrak{R}_A). \tag{331}$$

These are analytic consequences of the framework; they do not replace domain dynamics or empirical tests.

D. Domain-Specialization and Empirical Evaluation Protocol

A specialization should:

1. declare and fix the physical system specification $\mathrm{Spec}(A)$, the analysis specification $\mathrm{AnalysisSpec}(A, \mathscr{D}, \mathcal{P})$, the occurrence domain, and the evidence warranting any assigned order relation;
2. define complete-condition projections, observables, and the difference space;
3. specify internal constitution and external engagement without duplication;
4. state the domain dynamics, control variables, parameters, initial/boundary data, and path or interval information;
5. define measurement, calibration, uncertainty, missing-data, and nuisance structures;

6. preregister the intervention or comparison protocol and its identification assumptions;
7. specify the sampling distribution or simulation procedure, error rates, power, and decision rule;
8. declare what outcome supports, restricts, rejects, or leaves the specialization unresolved.

E. Controlled Historical Inheritance from V14 to V23/F3

This appendix records the conceptual lineage of the present reconstruction. It is not an alternative formal system. Historical equations are included only through their function in the development; superseded notation has no active authority over the current definitions.

The public developmental record and prior public versions are indexed through the Research21 platform and preserved in continuing Zenodo and Open Science Framework archives [45, 46, 47]. These sources document provenance, public availability, and version history; they are not used as independent evidence for the present foundational or empirical claims.

E.1 V14: structure-dependent measurable realization

V14 established the decisive separation between invariant ordered succession and measurable physical change. Its central advance was to locate measurable difference in the structure of the affected system and the physical influences realized in it. Residuals were thereby reinterpreted as possible differences of physical realization rather than automatic evidence of temporal deformation.

What is retained is the system-conditioned site of measurable realization. What is replaced is any formulation that could leave prior–later succession and physical state insufficiently distinguished or treat separately named factors as a complete account of engagement.

E.2 V15: temporal non-agency and physical attribution

V15 fixed the ontological exclusion of time from the arguments responsible for physical change and refined the attribution of change to physical factors and the constituted system. It made the theory explicitly about attribution rather than merely about rate comparison.

V23 retains temporal non-agency and physical closure. It uses response only as descriptive language for system-conditioned change and removes response as a formal variable, layer, or realization site.

E.3 V16: predictive closure and residual discipline

V16 required comparison between calculated and observed residuals under an uncertainty criterion. It converted residual explanation from retrospective language into a program of quantitative closure.

V23 preserves the requirement that a specialization define predictions, uncertainties, and rejection rules. It strengthens the restriction that residuals are diagnostics rather than causes or direct proofs of new ontology.

E.4 V17: domain specialization and context

V17 introduced explicit domain and contextual dependence. This prevented one abstract equation from being applied indiscriminately across physical, biological, or technical systems.

V23 retains domain specialization but removes environment as an independent determinant category. Environmental descriptions must be decomposed into systems, physical factors, and physically realized engagement under the selected boundary.

E.5 V18: difference, outcome, and evaluation

V18 distinguished physical change from the evaluation of its result. Success, failure, damage, usefulness, stability, and function require a criterion and reference system.

V23 retains this distinction through the evaluated-outcome map $\mathcal{O}^{\mathrm{eval}}_{A,\mathscr{D}}$. It places the difference, the physical history, and the evaluated outcome in separate categories.

E.6 V19: relativity as an attribution application

V19 made clocks, proper time, coordinates, simultaneity, spacetime geometry, and relativistic practice a major application of ITOF's attribution discipline. Its lasting contribution was to ask which defined physical, operational, or geometric quantity differs in a successful relativistic comparison.

V23 retains that direct question while correcting the historical notation and aggregated architecture. It does not portray standard relativity as requiring time to be a force or substance. Relativity is treated respectfully as a validated domain theory, while ITOF grounds its own independent temporal definition and applies the same bridge requirements to any additional temporal-physical ontology.

E.7 V20: the non-transfer principle

V20 generalized the relativistic argument: properties of an instrument, coordinate, output, mathematical object, or geometric quantity may not be transferred to time without an explicit physical bridge.

V23 makes this principle a general rule of typed inference. The rule now applies throughout measurement, engagement, representation, and model comparison, not only in temporal vocabulary.

E.8 V21/F1: systematic reattribution

V21/F1 developed a method for decomposing phenomena linguistically attributed to time into their physical systems, determinants, records, and measurement relations. It transformed temporal non-agency into a general reattribution procedure.

V23 retains the procedural discipline but replaces the broad determinant list with a more exact architecture of realized condition, external engagement, realized history, representation, and outcome.

E.9 V22/F2: systemic change-realization

V22/F2 stated the general law of change-realization in the affected system. It distinguished factors, influencing systems, engagement, structure, capacity, a separate response category, change content, and outcome. It also expanded the analysis of environment, clocks, light, distance, records, spacetime, and higher-dimensional representation.

V23 preserves the affected system as the bearer of change and retains the practical analyses. It revises three parts of the V22 foundation. First, it makes prior–later succession and identity-bounded stage extension analytic consequences of the sustained-change postulate. Second, it removes response from the formal architecture and retains the term only as descriptive language. Third, it distinguishes the selected-condition difference from the physical history associated with the realized change and later condition.

E.10 V23/F3: continuing succession of change stages and typed realization

V23/F3 combines system-specific physical change, selected analytical references and justified prior–later order, realized conditions and realized physical history, physically realized external engagement and system-conditioned realization, and a disciplined separation of representation, measurement, and physical attribution. The development is cumulative in purpose but selective in formula. A historical insight is retained only after it is rewritten consistently with the current types.

E.11 Authority rule

The authority order is: current canonical definitions first, current explanatory prose second, and historical formulations third. This rule is necessary because earlier versions remain part of the intellectual history and may still contain useful explanations, while their symbols and ontological assumptions are not all compatible with V23/F3.

Formal Constraint E.1. Controlled Inheritance.

V23/F3 preserves the central direction of ITOF: admissible identity-extended physical systems undergo sustained realized change; within the sustained-change postulate, this realization analytically entails the minimum prior–later distinction and the identity-bounded continuation of the succession of its derived stages wherever the identity-open occurrence condition of Equation (33) is satisfied. The extension predicate is a constitutive clause of the sustained-change predicate and is not a second free-standing postulate. The temporal definition then obtains universe-wide scope by quantification over the admissible identity-extended domain $\mathbb{S}^{\mathcal{U}}_{\text{phys}}$: time is the universe-wide descriptive expression of the continuing, non-reversing extension of physically realized prior–later succession across the identity-preserving histories of admissible physical systems throughout the universe, and specifies neither the physical content, magnitude, rate, mechanism, nor cause of change. Post-identity physical realization is attributed to successor physical systems under their own identities rather than inserted into the history of the ended system. Invariant temporal ordering means the non-reversal of the physically realized prior–later relation. Admissible analytical re-expression must preserve that relation, but representational preservation neither creates nor constitutes the invariance. T_{ITOF} is typed as a temporal description rather than a physical participant; the term denotes neither a universal scalar interval, preferred frame, nor total cross-system order. The current definition and its equations govern the manuscript; no alternative wording or representation may override this relation.

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