MONOGRAPH

BASIC KLT-RBD PROJECT

VOLUME II

STRICT NONASSOCIATIVE PACKET REPER GEOMETRY NAPG 3.0

Controlled English Derivative - Frozen Authorial Release

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CHECKPOINT. T2-EN-FREEZE-v1.0 is the immutable authorial English release of Volume II. It is issued exclusively from the accepted freeze candidate T2-EN-FC-v0.9 after final render, integrity, bilingual-audit, no-scientific-change, accessibility, and visual-QA gates.

FROZEN STATUS LOCK. truth_layer_promotion=0. Authority(T2-RU v1.0) > Authority(T2-EN). Chapters 1-24, canonical Appendices T2-A-T2-E, derivative Appendices T2-F-T2-G, 339 typed formal objects, 500 evidence obligations, 404 formula identifiers, negative results, OPEN, COND, MODEL, PHY-HYP, ABSTAIN, and the absence of independent EXT-RUN / EMP-OBS are unchanged from the accepted v0.9 candidate. Every later change requires a documented change-set and a new version. An external signed bilingual audit remains OPEN NON-VETO.

Frozen Release Passport

Field	Fixed value
Author	Ivan Borisovich Kurpishev
Project	KURPISHEV LOGIC 2 · Basic KLT-RBD Project
Volume	II · Strict Nonassociative Packet Reper Geometry NAPG 3.0
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Upstream English authority	T1-EN-FREEZE-v1.0
Translated scope	Chapters 1-24; Appendices T2-A-T2-E; derivative Appendices T2-F-T2-G; formulas T2-F001-T2-F404; Figures 3-63
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Mathematical status	DEF-A / THM / COND / MODEL / OPEN / FROZEN-AUTHORIAL-RELEASE; Russian source statuses preserved
Physical status	No empirical validation; EXT-RUN and EMP-OBS absent
Next checkpoint	No in-place successor; changes only through a documented change-set and a new version

AUTHORIAL ATTRIBUTION. Ivan Borisovich Kurpishev is the author of the KLT-RBD and NAPG project architecture, the authorial Desargues-Kurpishev construction, the model-form mathematical PN.2 principle, KLT algorithms, and the Reper database architecture. Classical category theory, projective geometry, cohomology, deformation theory, Hodge analysis, and related prior art remain attributed to their established authors.

Frozen Release Contract for v1.0

- The canonical formula index is synchronized as T2-F001-T2-F404 with a crosswalk to the Russian source identifiers.
- Reper, NAPG, KLT-RBD, RBD, RPD, PN.2, D/Dom, R⋆R, PredRep, EXT-RUN, and ABSTAIN remain controlled project terms.
- The symbols ⊙, ⋆_Hdg, R⋆R, Ass_⊙, δ_min, external δ, and δ_Hdg are not conflated.
- An undefined operation is not translated as a zero value. A missing arrow remains a domain failure.
- The word “duality” is qualified by its precise categorical content: representable anti-equivalence, conditional Spec_R/Gamma_R reconstruction, or another explicitly stated bridge.
- No numerical certificate is translated as an independent empirical observation.

Status in Russian source	English derivative rule
DEF-A / definition	Definition; no theorem language added.
THM / proposition / lemma	Preserved only under the source hypotheses and domain.
COND	Conditional statement; all bridge hypotheses retained.
MODEL / NUM	Model or computational result; not promoted to general theorem or experiment.
OPEN / blocker	Remains open and blocks downstream promotion.
PHY-HYP / EMP-PLAN	Physical hypothesis or empirical plan; EMP-OBS remains absent.

Static Contents and Navigation of the Frozen v1.0 Release

Chapter 1. Interface with Volume I: Subject and Method Boundaries

ONTOLOGY	The section fixes an autonomous mathematical object within the architecture of Volume II.
EPISTEMOLOGY	Its content is regarded as known only after the carrier, maps, and conditions of applicability have been specified.
PHENOMENOLOGY	Its phenomenological meaning appears through computable invariants and distinguishable regimes.
LIMITATION	No conclusion is transported beyond the declared domain without a separate bridge.
AUTHORIAL NOVELTY	Novelty is determined not by an isolated term but by its role in the packet-Reper KLT-RBD system.

1.1. Canonical Import from Volume I

Volume I v197 RU establishes the language of packet Reper logic, Reper(R,I,U;D), the projective-harmonic coordinate, PN.2 in its proved model form, and the evidential discipline of KLT-RBD. Volume II does not rewrite those foundations; it builds geometric, deformation-theoretic, analytic, and predictive layers over them.

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1.2. Subject of Volume II

The subject is not a universal theory of the future but a strict architecture of admissible structural continuations. It asks which configurations are defined, which invariants are preserved, where an obstruction occurs, which transitions are excluded within the model, and under which conditions a transition candidate may be admitted.

ONTOLOGY	The end-to-end operator exists as a composition of partial certified modules.
EPISTEMOLOGY	Its correctness is established through local soundness, interface contracts, and transport of budgets.
PHENOMENOLOGY	It appears as a set of admissible continuations carrying proof certificates.
LIMITATION	Heterogeneous errors may not be silently scalarised, and status may not be promoted according to the strongest module.
AUTHORIAL NOVELTY	The authorial contribution is a unified blocker-safe KLT-RBD predictive operator and a falsifiability matrix.

1.3. Partial Predictive Operator

The KLT-RBD predictive operator is partial: it is defined only on a certified domain. Its value is a set of admissible candidates accompanied by an evidential passport. Missing foundation is not hidden by a numerical score; it yields ABSTAIN.

ONTOLOGY	The historical layer exists as a network of sources and priorities, not as an anonymous background.
EPISTEMOLOGY	Knowledge of authorship requires separation of classical constructions from the new composition.

ONTOLOGY	The historical layer exists as a network of sources and priorities, not as an anonymous background.
PHENOMENOLOGY	It appears as a precise bibliography and a dependency map of ideas.
LIMITATION	Use of prior art does not diminish the novelty of a synthesis, but it forbids reattribution of classical results.
AUTHORIAL NOVELTY	Novelty is fixed in the architecture of connection, new objects, and evidential gates.

1.4. Authorial and Classical Layers

The authorial novelty of Volume II lies in the typed connection of Reper, D/Dom, NAPG, R⋆R, the λ-selector, obstruction carriers, transition horizons, and the algorithmic contract. Categories, cohomology, Hodge theory, deformation theory, moduli, stochastic analysis, and large deviations are used as classical apparatus and are not reattributed.

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1.5. Boundary of Physical Interpretation

Mathematical impossibility within a model is not physical impossibility in general. A transition candidate is not an event. A probabilistic bound is not a causal conclusion. Export to physics, chemistry, biology, economics, or another field requires a separate adapter, data, calibration, and independent validation.

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Chapter 2. Frozen Notation Registry

Layer	Controlled meaning
ONTOLOGY	Notation is part of the mathematical object: it fixes the type, degree, and role of a symbol. Changing a sign without a collision ledger can silently replace one theory by another.
EPISTEMOLOGY	Reading a formula begins by answering four questions: where its arguments live, where the value lands, on what domain the operation is defined, and which choices affect the result.
PHENOMENOLOGY	A notational collision appears as the inability to read a diagram or composition unambiguously. Therefore the star of the associator layer and ⋆_Hdg are never treated as one operator.
BOUNDARY	The registry does not prove existence. It prohibits use of a symbol before definition and prohibits transfer of properties among internal δ_min, external δ, and δ_Hdg.

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2.1. Formal Notation Architecture

2.1.1. Basic Sorts and Types

Fix a commutative ground field $\mathbb{K}$. Unless stated otherwise, the algebraic core is constructed in the category of $\mathbb{K}$-vector spaces. Analytic norms, topologies, completeness, and continuity are not included automatically; they form an additional data layer. The set of degrees is denoted by Γ. In the basic case $\Gamma=\mathbb{Z}$, but the proofs for the category NAPG_q use only a degree function and a compatible rule for deriving the degree of a product.

$$\mathscr{A}^\bullet = \oplus_{p\in\Gamma} \mathscr{A}^p, \qquad |x|=p \text{ for } x\in\mathscr{A}^p. \tag{T2-F001}$$

The structural data $\mathfrak{G}$ include admissible generators, syntactic operations, domain restrictions, the degree law χ, and, where required, Reper, D/Dom, and provenance labels. Thus the domain of an operation is part of the object rather than an editorial footnote.

Symbol	Fixed meaning	Type	Safeguard
$\mathbb{K}$	commutative ground field	data object	Not replaced by $\mathbb{R}$ without an explicit restriction.
Γ	set/semigroup of degrees	grading index	$\Gamma=\mathbb{Z}$ in the basic model.
$\mathscr{A}^\bullet$	Γ-graded $\mathbb{K}$-space	carrier	A direct sum, not an unlabelled set.

Symbol	Fixed meaning	Type	Safeguard
$\odot$	bilinear operation on declared $\mathrm{Dom}_\odot$	operation	Generally nonassociative; not the Hodge star.
$\mathrm{Ass}_\odot$	$(x\odot y)\odot z - x\odot(y\odot z)$	trilinear defect	Defined only when both bracketings exist.
$R\star R$	authorial object of the associator-packet layer	object/notation	The star is not used for Hodge.
$\star_{\mathrm{Hdg}}$	Hodge operator	analytic-geometric operator	Requires a metric, orientation, and regularity.
$\mathscr{R}$	admissible Reper class	subspace/class	Closure conditions are stated explicitly.
F^2_N	formal language of degree ≤ 2	syntax vector space	Pre-evaluation; not automatically a subset of X^2.
X^2_N	tested quadratic layer	subspace of $\mathscr{A}^\bullet$ or T_N	Quadratic, not the associator channel.
Ψ^2_N	$F^2_N \to X^2_N$	linear evaluation map	Codomain is fixed in advance.
$O_B(N)$	$X^2_N/\mathrm{Im}\,\Psi^2_N$	obstruction quotient	Depends on the selected language F^2_N.
Π_N	$X^2_N \to O_B(N)$	canonical projection	Not the external E-bridge.
$C_{\min}^\bullet$	minimal internal complex	cochain complex	Concentrated in degrees 2 and 3.
$\delta_{\min}$	$\delta_{\min}^2=\Psi^2$, $\delta_{\min}^3=0$	internal differential	Not conflated with external δ.
$\Theta_{\min}$	$\mathrm{id}_{X^2_N}: X^2_N \to C_{\min}^3(N)$	canonical internal bridge	An identity, not a physical hypothesis.
λ	$\mathrm{cr}(U,I;R,\underline{D})$	projective coordinate	Defined away from poles and degeneracies.
δ_{truth}	$\lvert\lambda+1\rvert$	diagnostic defect	Only after choosing an absolute value/norm.
D/Dom	sufficient foundation and admissible domain	validation barrier	$\lambda\approx-1$ does not replace D/Dom.

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2.1.2. Degree Law and Admissible Compositions

For homogeneous elements introduce a partial degree law $\chi:\mathrm{Dom}(\chi)\subseteq\Gamma\times\Gamma\to\Gamma$. If $(p,q)\in\mathrm{Dom}(\chi)$, an admissible product $\mathscr{A}^p\otimes\mathscr{A}^q$ lands in $\mathscr{A}^{\chi(p,q)}$. The standard case $\chi(p,q)=p+q+s$ includes an operation of fixed degree s. Partiality of χ records impossible compositions without assigning them the artificial value zero.

$\odot_{p,q}: \mathrm{Dom}_{p,q} \subseteq \mathscr{A}^p \otimes \mathscr{A}^q \to \mathscr{A}^{\chi(p,q)}$.	**T2-F002**

MEANING OF THE DIFFICULT TRANSITION. If a product is forbidden by the domain, it is not zero. Zero is a value of a defined operation; undefinedness means that no arrow exists. Conflating the two destroys the distinction between structural prohibition and actual cancellation. In the predictive method, a candidate outside Dom receives no “bad score”; it is excluded as untyped.

Lemma 2.1. Type of the associator [THM] Let $x\in\mathscr{A}^p$, $y\in\mathscr{A}^q$, $z\in\mathscr{A}^r$, and suppose both bracketings are defined. If $\chi(\chi(p,q),r)=\chi(p,\chi(q,r))=s$, then $\mathrm{Ass}_\odot(x,y,z)\in\mathscr{A}^s$. If the branch degrees differ, their difference is not a homogeneous associator and must either be placed in a direct sum or the test must be rejected.

Proof. Each branch belongs to the component obtained by successive application of χ. A difference of two vectors lies in one homogeneous component only when the degrees agree. If they differ, it lies in their direct sum but has no single degree s. □

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2.1.3. NOTATION LEDGER Extension Protocol

1. Every new notation receives a unique NTL-xxx identifier, Dom, Cod, degree, source, status, and collision list.
2. A symbol already occupied in P0 is not redefined; only an indexed form with an explicit map to the canon is permitted.
3. A temporary notation is marked TMP and does not enter the theorem package until the mark is removed.
4. Every transition from algebraic to topological, analytic, or physical meaning is represented by a separate bridge symbol.
5. In predictive formulas the word “truth” is not used as a numerical variable; λ and δ_{truth} are diagnostic coordinates, not substitutes for proof.

Counterexample 2.1. Collision of δ [COUNTEREXAMPLE] Let $\delta_{min}^2=\Psi^2$ in the internal two-stage complex, while δ_{Hdg} denotes the codifferential on forms. From $\delta_{min}^3\delta_{min}^2=0$ one cannot infer $\delta_{Hdg}^2=0$, nor conversely: the domains, degrees, and definitions differ. The same unindexed letter creates a false bridge.

Counterexample 2.2. Inhomogeneous associator [COUNTEREXAMPLE] If $\chi(\chi(p,q),r)\neq\chi(p,\chi(q,r))$, the two branches lie in different components. The statement $\mathrm{Ass}_\odot\in\mathscr{A}^s$ with a single s is untyped even when both branches are computable.

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Chapter 3. The Category NAPG_q: Objects, Morphisms, and Domains

Layer	Controlled meaning
ONTOLOGY	The minimal object is a typed quadratic frame sufficient to construct a formal language, evaluation, and an obstruction quotient.
EPISTEMOLOGY	Objects are known through morphisms: if an obstruction class changes under an admissible relabelling or isomorphism, it is not a structural invariant of the chosen category.
PHENOMENOLOGY	Commutative diagrams reveal correct transport. Failure of two routes to agree is a specific typing or naturality error, not a metaphysical incompleteness.
BOUNDARY	NAPG_q is an internal algebraic category. It does not automatically contain manifolds, Hodge operators, connections, dynamics, or measurement procedures.

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3.1. Categorical Core

3.1.1. Object of the Category

> **Definition 3.1. Typed Quadratic NAPG Frame [DEF-A]** An object of NAPG_q is a tuple $N=(\mathbb{K},\mathscr{A}^\bullet,\odot,\mathfrak{G},\mathscr{R};F^2\_N,X^2\_N,\Psi^2\_N)$, where $\mathbb{K}$ is a commutative field; $\mathscr{A}^\bullet$ is graded; $\odot$ is bilinear on domains encoded by $\mathfrak{G}$; $\mathscr{R}\subseteq\mathscr{A}^\bullet$ is an admissible class; F^2_N is a vector space of admissible formal expressions of degree at most two; X^2_N is the tested quadratic layer; and $\Psi^2\_N:F^2\_N\to X^2\_N$ is a linear evaluation map. The inclusion $\mathrm{Im}\ \Psi^2\_N\subseteq X^2\_N$ is built into the codomain.

$$X^2\_N = \mathrm{Span}\_\mathbb{K}\{\ R\odot R,\ R\odot S+S\odot R :\ R,S,R+S\in\mathscr{R} \text{ and all products are defined }\}. \qquad \text{T2-F003}$$

$$O\_B(N)=X^2\_N/\mathrm{Im}\ \Psi^2\_N,\quad \Pi\_N:X^2\_N\to O\_B(N). \qquad \text{T2-F004}$$

The formal language F^2_N must be separated from the evaluated layer X^2_N. A strict implementation may use the free $\mathbb{K}$-space on typed syntax trees of height at most two and quotient by linear syntactic relations. Ψ^2_N evaluates a tree in $\mathscr{A}^\bullet$. Distinct languages may share the same algebra and have different O_B; hence O_B measures completeness of the selected language relative to X^2_N, not “absolute nonassociativity”.

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3.1.2. Morphism and Four Compatibility Conditions

Definition 3.2. Morphism of Quadratic Frames [DEF-A] A morphism $f:N\to N'$ is a family $f=(\Phi^\bullet,\varphi\_G,\varphi\_F,\varphi\_X,\varphi\_O)$. Here $\Phi^\bullet:\mathscr{A}^\bullet\to\mathscr{A}^\bullet$ is graded linear; φ_G transports generators, domains, and labels; $\varphi\_F:F^2\_N\to F^2\_N'$ transports the formal language; $\varphi\_X:X^2\_N\to X^2\_N'$ transports evaluated elements; and $\varphi\_O:O\_B(N)\to O\_B(N')$ is induced. The family is a morphism only when M1-M4 hold.

Code	Compatibility	Formula / requirement	Purpose
M1	Algebra and Dom	$\Phi(x\odot y)=\Phi(x)\odot'\Phi(y)$ for every admissible pair; $\Phi(\mathscr{R})\subseteq\mathscr{R}'$.	Preserves the operation and does not silently enlarge the domain.
M2	Syntax	φ_F is compatible with φ_G and substitution of Φ into expression leaves.	Prevents the formal language from changing meaning.
M3	Evaluation	$\varphi\_X\circ\Psi^2\_N=\Psi^2\_N'\circ\varphi\_F$.	Commutativity of the evaluation square.
M4	Quotient	$\varphi\_O\circ\Pi\_N=\Pi\_N'\circ\varphi\_X$.	Naturality of the obstruction class.

$$\varphi\_X\ \Psi^2\_N = \Psi^2\_N'\ \varphi\_F, \qquad \varphi\_O\ \Pi\_N = \Pi\_N'\ \varphi\_X. \tag{T2-F005}$$

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3.1.3. Well-Defined Quotient Transport

Lemma 3.1. Descent to the Quotient [THM] If M3 holds, then $\varphi\_X(\mathrm{Im}\ \Psi^2\_N)\subseteq\mathrm{Im}\ \Psi^2\_N'$. Therefore $\varphi\_O([x])=[\varphi\_X(x)]$ defines the unique linear map satisfying M4.

Proof. For $y=\Psi^2\_N(a)$, $\varphi\_X(y)=\varphi\_X\Psi^2\_N(a)=\Psi^2\_N'\varphi\_F(a)$, hence $\varphi\_X(y)$ lies in $\mathrm{Im}\ \Psi^2\_N'$. Representatives x and $x+y$ of one class are therefore sent to elements differing by an element of $\mathrm{Im}\ \Psi^2\_N'$. Well-definedness and uniqueness follow from the universal property of the quotient. □

Theorem 3.1. Existence of the Category NAPG_q [THM] Typed quadratic frames with morphisms M1-M4 form a category. Identity morphisms have identity components; composition is componentwise and again satisfies M1-M4.

Proof. Identity maps preserve all data and make the diagrams commute. If $f:N\to N'$ and $g:N'\to N''$, product preservation follows for $\Phi_g\Phi_f$. Condition M3 follows from $\varphi_X^g\varphi_X^f\Psi_N=\varphi_X^g\Psi_{N'}\varphi_F^f=\Psi_{N''}\varphi_F^g\varphi_F^f$, and M4 is analogous. Associativity and unit laws are inherited from vector spaces. □

Proposition 3.2. Isomorphism Criterion [THM] A morphism f is an isomorphism in NAPG_q if $\Phi\bullet$, φ_G, φ_F, and φ_X are invertible and the inverse maps satisfy M1-M3. Then φ_O is automatically invertible and is induced by φ_X^{-1}.

Proof. The inverse components define f^{-1}; the quotient map is well-defined by Lemma 3.1. The compositions are identities on representatives, so $\varphi_O^{-1}([x'])=[\varphi_X^{-1}(x')]$. □

ONTOLOGY	Nonassociativity is treated as intrinsic structure, not as a computational error.
EPISTEMOLOGY	It is known through the associator, nuclei, ideals, invariants, and explicit countermodels.
PHENOMENOLOGY	It appears as dependence of the result on the bracketing architecture of a packet.
LIMITATION	A nonzero associator is not by itself physical curvature or a physical event.
AUTHORIAL NOVELTY	The authorial node is R⋆R and its role in packet Reper-harmonic geometry.

3.1.4. Functors of the Internal Core

Theorem 3.3. Quadratic Obstruction Functor [THM] The assignments $N\mapsto O_B(N)$ and $f\mapsto\varphi_O$ define a functor $O_B:NAPG_q\to Vect_{\mathbb{K}}$.

Proof. The identity morphism induces the identity on classes. For $g\circ f$, the map $[x]\mapsto[\varphi_X^f(x)]\mapsto[\varphi_X^g\varphi_X^f(x)]$ is precisely the quotient map of the composition. □

Theorem 3.4. Minimal Complex as a Functor [THM] Put $C_{min}^2(N)=F^2_N$, $C_{min}^3(N)=X^2_N$, all other degrees zero, $\delta_{min}^2=\Psi^2_N$, and $\delta_{min}^3=0$. Then $C_{min}\bullet:NAPG_q\to CoCh_{\mathbb{K}}$ is a functor, and $\kappa_N:O_B(N)\to H^3(C_{min}\bullet(N))$, $\kappa_N([x])=[x]$, is a natural isomorphism.

$$H^3(C_{min}\bullet(N))=\mathrm{Ker}\,\delta_{min}^3/\mathrm{Im}\,\delta_{min}^2=X^2_N/\mathrm{Im}\,\Psi^2_N=O_B(N). \qquad \text{T2-F006}$$

Proof. Nilpotency follows from $\delta_{min}^3=0$. M3 is exactly the cochain-map condition in degree 2. The canonical identification of quotient spaces is representative-independent, and naturality holds because both routes send $[x]$ to $[\varphi_X(x)]$. □

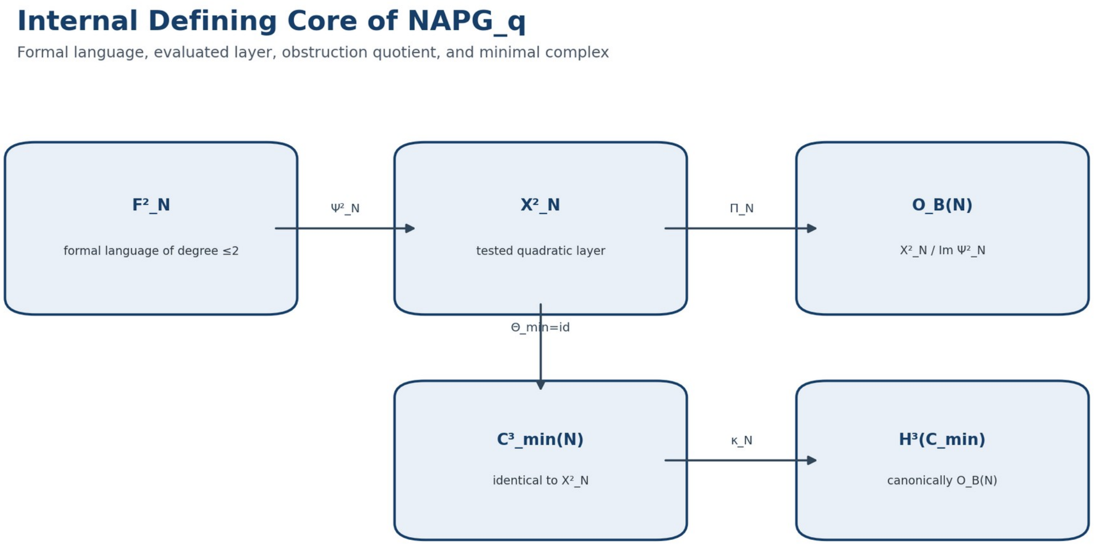

Figure 3. Internal defining core of NAPG_q and the minimal complex. English reconstruction of the authorial diagram in the frozen Russian Volume II.

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3.1.5. Countermodels to Weakened Morphisms

Counterexample 3.1. Failure of M1 [COUNTEREXAMPLE] Let $\mathscr{A}=\mathbb{K}e$ with $e\odot e=e$, $\mathscr{A}'=\mathbb{K}e'$ with $e'\odot' e'=0$, and $\Phi(e)=e'$. Linearity holds, but $\Phi(e\odot e)=e'\neq 0=\Phi(e)\odot'\Phi(e)$. The map does not transport the algebra and is not a NAPG_q morphism.

Counterexample 3.2. Failure of M3 [COUNTEREXAMPLE] Let $F^2=X^2=\mathbb{K}$ with $\Psi=\mathrm{id}$, while $\Psi'=0$ in the target. Take $\varphi_F=\mathrm{id}$ and $\varphi_X=\mathrm{id}$. Then $\varphi_X\Psi=\mathrm{id}$ but $\Psi'\varphi_F=0$. A formally realisable element ceases to be formally realisable; quotient transport is not canonical.

Counterexample 3.3. Arbitrary Map of Classes [COUNTEREXAMPLE] Even when O_B(N) and O_B(N′) are isomorphic as vector spaces, an arbitrarily chosen isomorphism is not a morphism component until M4 holds. Otherwise the class is no longer the transported result of the original quadratic element.

Counterexample 3.4. Forgotten Dom [COUNTEREXAMPLE] A map Φ may preserve the product formula on the common part of two domains while sending an admissible pair to a forbidden one. Then the right-hand side of M1 is undefined. Preservation of Dom is part of the morphism, not a later check.

Counterexample 3.5. O_B Does Not Detect the Associator [COUNTEREXAMPLE] In a nonassociative algebra Ψ^2 can be surjective, giving $O\_B=0$. Conversely, a poor F^2 can give $O\_B\neq 0$ in an associative algebra. Thus O_B is not an associator functor without a separate map β_Ass.

Counterexample 3.6. Nonnatural Basis Choice [COUNTEREXAMPLE] If φ_X changes sign while a manually assigned “external” identification of classes does not, the M4 square fails. Isomorphism invariance requires a natural map, not merely one with the same name.

ONTOLOGY	A Reper exists as the quadruple R,I,U;D, not as a triad without foundation.
EPISTEMOLOGY	The harmonic coordinate is informative only together with an evidence package and a domain.
PHENOMENOLOGY	Phenomenologically, λ records the alignment of fact, idea, possibilities, and foundation.
LIMITATION	The equality λ=-1 does not replace proof, measurement, or causal identification.
AUTHORIAL NOVELTY	The authorial contribution is the strict KLT-RBD λ-gate with D/Dom and an abstention rule.

Chapter 4. Graded Packet Algebra and the Strict Selector

Layer	Controlled meaning
ONTOLOGY	The predictive Reper method acquires mathematical meaning only as a composition of invariants and barriers: projective harmony evaluates a configuration of points, D/Dom validates admissibility, and the NAPG obstruction checks internal expressibility in the selected language.
EPISTEMOLOGY	No numerical proximity produces knowledge by itself. Knowledge requires invariance, stability under admissible transport, control of poles, and an explicit abstention rule.
PHENOMENOLOGY	In data the method appears as a candidate set that narrows as measurement improves and whose structural verdict is unchanged by a projective coordinate change or a NAPG basis change.
BOUNDARY	This chapter constructs a selector of structural admissibility, not a theorem asserting the occurrence of physical events. Statistical calibration, causality, and independent validation are later layers.

ONTOLOGY	Nonassociativity is treated as intrinsic structure, not as a computational error.
EPISTEMOLOGY	It is known through the associator, nuclei, ideals, invariants, and explicit countermodels.
PHENOMENOLOGY	It appears as dependence of the result on the bracketing architecture of a packet.
LIMITATION	A nonzero associator is not by itself physical curvature or a physical event.
AUTHORIAL NOVELTY	The authorial node is R⋆R and its role in packet Reper-harmonic geometry.

4.1. Algebraic Core

4.1.1. Graded Operation and Associator

Definition 4.1. Graded Packet Algebra [DEF-A] A graded packet algebra is a tuple $(\mathbb{K},\mathscr{A}^\bullet,\odot,\mathfrak{G})$, where $\mathscr{A}^\bullet=\bigoplus_{p\in\Gamma}\mathscr{A}^p$ and, for every admissible pair of degrees (p,q), a bilinear map $\odot_{p,q}:\mathrm{Dom}_{p,q}\to\mathscr{A}^{\chi(p,q)}$ is specified. The operation may be partial and need not be associative, commutative, alternative, or unital.

$\mathrm{Ass}_\odot(x,y,z)=(x\odot y)\odot z-x\odot(y\odot z).$	**T2-F007**

Lemma 4.1. Trilinearity on a Common Domain [THM] If both bracketings are defined on a linear subspace $T_{\mathrm{Ass}}\subseteq\mathscr{A}^{\bullet\otimes 3}$ and $\odot$ is bilinear, then $\mathrm{Ass}_\odot:T_{\mathrm{Ass}}\to\mathscr{A}^\bullet$ is linear in formal triples and trilinear in the arguments on rectangular domain components.

Proof. Each branch is a composition of bilinear maps and is therefore trilinear on the common domain. Their difference is trilinear. □

ONTOLOGY	The differential layer exists as an operator with a domain, degree, and rule of action.
EPISTEMOLOGY	Its correctness is tested by Leibniz rules, locality, gluing, and the square of the operator.

ONTOLOGY	The differential layer exists as an operator with a domain, degree, and rule of action.
PHENOMENOLOGY	It appears through flows of forms, compatibility defects, and differential curvature.
LIMITATION	A Leibniz rule does not imply $d^2=0$.
AUTHORIAL NOVELTY	The authorial contribution is a typed differential firewall inside NAPG and KLT-RBD.

4.1.2. Formal Quadratic Language

Let $Syn_2(N)$ be the set of typed syntax trees whose leaves are elements of $\mathscr{R}$ and admissible generators of $\mathfrak{G}$, and whose internal vertices are linear operations and one application of $\odot$. Define F^2_N as the free $\mathbb{K}$-space on $Syn_2(N)$, quotiented by linear syntactic relations. This makes "formal expressions of degree at most two" mathematically reproducible.

$F^2\_N := \mathbb{K}[Syn_2(N)] / J\_syn, \quad \Psi^2\_N([t]) := eval\_N(t).$	**T2-F008**

Theorem 4.2. Quadratic Completeness Criterion [THM] For a quadratic frame N the following are equivalent: (i) every element of X^2_N is evaluated from an admissible expression in F^2_N; (ii) Ψ^2_N is surjective; (iii) $O\_B(N)=0$.

Proof. Condition (i) is the definition of surjectivity. The quotient $X^2\_N/\mathrm{Im}\ \Psi^2\_N$ vanishes exactly when $\mathrm{Im}\ \Psi^2\_N=X^2\_N$. □

ONTOLOGY	A model is a concrete carrier of a definition; a counterexample is a boundary of an admissible claim.
EPISTEMOLOGY	Knowledge is produced by explicit computation rather than analogy.
PHENOMENOLOGY	It appears through the operation of formulas on a basis or parameterised family.
LIMITATION	One example does not prove universality, while one valid counterexample refutes an overstrong statement.
AUTHORIAL NOVELTY	The authorial contribution is the systematic inclusion of countermodels in KLT-RBD predictive audit.

4.1.3. Explicit Nontrivial Models

Example 4.1. Two-Dimensional Nonassociative Model [MODEL] Let $\mathscr{A}=\mathrm{Span}\_\mathbb{K}\{e_1,e_2\}$, with $e_1\odot e_1=e_2$, $e_2\odot e_1=e_1$, and all remaining products zero. Then $Ass\_\odot(e_1,e_1,e_1)=e_1\neq0$. If $\mathscr{R}=\mathscr{A}$ and the quadratic language is complete, Ψ^2 is surjective, so $O\_B=0$ although the associator is nonzero.

Proof. $(e_1\odot e_1)\odot e_1=e_2\odot e_1=e_1$, whereas $e_1\odot(e_1\odot e_1)=e_1\odot e_2=0$. The complete language contains every basis quadratic expression, hence its image is X^2. □

Example 4.2. Associative Model with a Language Obstruction [MODEL] Assume $\mathrm{char}(\mathbb{K})\neq2$ and take $\mathscr{A}=\mathbb{K}[t]/(t^2)$ with ordinary associative multiplication, $\mathscr{R}=\mathscr{A}$, $X^2=\mathrm{Span}\{1,t\}$, and F^2 chosen so that $\mathrm{Im}\ \Psi^2=\mathrm{Span}\{1\}$. Then $O\_B\cong\mathrm{Span}\{[t]\}\neq0$ while $Ass\_\odot=0$.

Proof. Associativity is inherited from the quotient ring. The quotient of the two-dimensional X^2 by the one-dimensional image has dimension one. □

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EPISTEMOLOGY	The harmonic coordinate is informative only together with an evidence package and a domain.

ONTOLOGY	A Reper exists as the quadruple R,I,U;D, not as a triad without foundation.
PHENOMENOLOGY	Phenomenologically, λ records the alignment of fact, idea, possibilities, and foundation.
LIMITATION	The equality λ=-1 does not replace proof, measurement, or causal identification.
AUTHORIAL NOVELTY	The authorial contribution is the strict KLT-RBD λ-gate with D/Dom and an abstention rule.

4.1.4. Anchored Sufficient Foundation and Strict Reper

To remove the ambiguity between D as the fourth projective point and D as sufficient foundation, introduce an anchored sufficient foundation. This does not change the canonical notation (R,I,U;D), but it exposes the internal type of D.

> **Definition 4.2. Anchored Sufficient Foundation [DEF-A]** Let L be a two-dimensional $\mathbb{K}$-space, $\mathbb{P}(L)$ its projective line, and $\mathfrak{D}\_\Omega$ a class of evidence objects for domain Ω. An anchored foundation is a pair D=(d,E_D), where d∈$\mathbb{P}(L)$ is the projective anchor and E_D∈$\mathfrak{D}\_\Omega$ is the evidence object. Write $\underline{D}$=d and Valid_Ω(D)∈{0,1}. A typed Reper is ρ=(R,I,U;D), with R,I,U,$\underline{D}$∈$\mathbb{P}(L)$.

The projective coordinate uses $\underline{D}$; evidential authorisation uses Valid_Ω(D). Thus one letter preserves the authorial semantics of sufficient foundation while the mathematical notation no longer conflates a point with a document.

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4.1.5. Projective-Harmonic Coordinate

For nonzero representatives r,i,u,d∈L write [x,y]=det(x,y) relative to any oriented basis. The determinant ratio is independent of the scale of representatives and of the common determinant factor introduced by a basis change.

$\lambda(\rho)=\mathrm{cr}(U,I;R,\underline{D})=([u,r][i,d])/([u,d][i,r]).$	**T2-F009**

The domain consists of quadruples with [u,d]≠0 and [i,r]≠0. This holds for pairwise distinct points. In an affine chart the formula becomes $((u-r)(i-d))/((u-d)(i-r))$. The harmonic condition $\lambda=-1$ is used below under char($\mathbb{K}$)≠2; characteristic 2 requires a separate formulation.

> **Theorem 4.3. Projective Invariance of λ [THM]** For every g∈PGL(L) and every ρ in the domain, λ(gρ)=λ(ρ). In particular, $\lambda=-1$ is a projective invariant.

Proof. Choose a linear representative G∈GL(L) of g. Then det(Gx,Gy)=det(G)det(x,y). The numerator and denominator each acquire two identical factors det(G), which cancel. The scales of individual representatives cancel pairwise as well. □

> **Counterexample 4.1. Cross-Ratio Pole [COUNTEREXAMPLE]** If U=$\underline{D}$ or I=R, the denominator is zero. The numerical λ is undefined; assigning it a large value or zero is an editorial substitution for Dom.

Counterexample 4.2. Harmony without Foundation [COUNTEREXAMPLE] Four points may satisfy $\lambda=-1$ while $Valid\_\Omega(D)=0$. The projective configuration is harmonic, but the structural selector must abstain because the D/Dom barrier has not been passed.

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4.1.6. Strict Structural Selector of the Predictive Method

Definition 4.3. Structural Selector [DEF-A] Let $N\in NAPG\_q$, let $\rho=(R,I,U;D)$ be a typed Reper, and let $x\in X^2\_N$ be the candidate quadratic test. Define $Sel\_N(\rho,x)=1$ exactly when: (S1) $\rho\in Dom\ \lambda$; (S2) $Valid\_\Omega(D)=1$; (S3) $\lambda(\rho)=-1$; and (S4) $\Pi\_N(x)=0$. Otherwise $Sel\_N=0$, while failure of S1 or missing D receives a separate ABSTAIN status rather than a negative verdict.

$$Sel\_N(\rho,x)=1 \Leftrightarrow Dom\_\lambda(\rho) \wedge Valid\_\Omega(D) \wedge \lambda(\rho)=-1 \wedge \Pi\_N(x)=0. \quad \text{T2-F010}$$

The condition $\Pi\_N(x)=0$ means $x\in Im\ \Psi^2\_N$: the selected quadratic test is reproducible in the formal language of the frame. It does not mean $Ass\_\odot=0$ and does not prove physical realisability of the candidate.

Theorem 4.4. Double Invariance of the Selector [THM] Let $g\in PGL(L)$, let $f:N\to N'$ be an isomorphism in NAPG_q, and suppose evidence transport $D\mapsto gD$ preserves Valid_Ω. Then for every admissible (ρ,x), $Sel\_N(\rho,x)=Sel\_N'(g\rho,\varphi\_X(x))$.

Proof. S1 and S3 are preserved by projective invariance of λ. S2 is preserved by the evidence-transport hypothesis. For S4, M4 gives $\Pi\_N'(\varphi\_Xx)=\varphi\_O(\Pi\_Nx)$. Because φ_O is an isomorphism, $\Pi\_Nx=0$ exactly when $\Pi\_N'\varphi\_Xx=0$. □

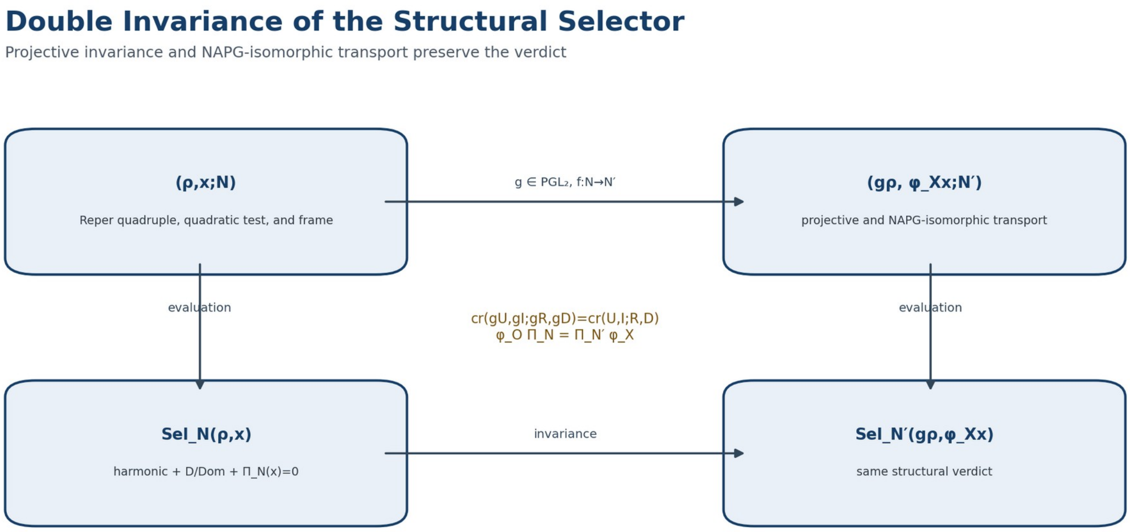

Figure 4. Double invariance of the structural selector. English reconstruction of the authorial diagram in the frozen Russian Volume II.

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4.1.7. Approximate Harmony and Local Stability

For $\mathbb{K}=\mathbb{R}$ or $\mathbb{C}$ with a fixed absolute value define $\delta\_truth(\rho)=|\lambda(\rho)+1|$. This defect is meaningful only inside Dom λ. For $\tau\geq 0$ define the τ-harmonic sector $H\_\tau=\{\rho:\delta\_truth(\rho)\leq\tau\}$.

$$\delta\_truth(\rho)=|\lambda(\rho)+1|,\qquad H\_\tau=\{\rho\in \mathrm{Dom}\,\lambda : \delta\_truth(\rho)\leq\tau\}. \tag{T2-F011}$$

Theorem 4.5. Local Lipschitz Stability [THM] Let $\Omega\subset\mathbb{R}^4$ be a compact convex set of affine coordinates (u,i,r,d) such that $|u-d|\geq m>0$ and $|i-r|\geq m>0$. Then there is a finite L_Ω with $|\delta\_truth(q)-\delta\_truth(q')|\leq L\_\Omega\|q-q'\|$ for all $q,q'\in\Omega$ whose connecting segment stays inside the domain.

Proof. The rational function λ is smooth where its denominator is nonzero. Its gradient is bounded on compact Ω: $L\_\Omega:=\sup\_\{q\in\Omega\}\|\nabla\lambda(q)\|<\infty$. The mean-value theorem gives $|\lambda(q)-\lambda(q')|\leq L\_\Omega\|q-q'\|$, and $||a+1|-|b+1||\leq|a-b|$ completes the proof. □

STABILITY LIMITATION. L_Ω may grow sharply near the poles u=d or i=r. Therefore small numerical noise does not imply a small λ error without an explicit estimate of distance to the degenerate set. The KLT software layer requires a separate pole margin, not δ_truth alone.

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4.1.8. Interval Reper and the Abstention Rule

Definition 4.4. Interval Image of λ [DEF-A] Let $B\subset \mathrm{Dom}\ \lambda$ be the set of all quadruples compatible with input uncertainty. Define $\Lambda(B)=\{\lambda(q):q\in B\}$. A candidate is τ-certified if $\sup_{z\in\Lambda(B)}|z+1|\le\tau$ and $\inf_{q\in B}|u-d||i-r|>0$. If B intersects a pole, the status is ABSTAIN_POLE.

Lemma 4.2. Monotonicity under Refinement [THM] If $B'\subseteq B$, then $\Lambda(B')\subseteq\Lambda(B)$. Hence $\sup_{\Lambda(B')}|z+1|$ does not exceed the corresponding bound for B.

Proof. The image of a subset is contained in the image of the containing set. Supremum is monotone under inclusion. □

ONTOLOGY	The section fixes an autonomous mathematical object within the architecture of Volume II.
EPISTEMOLOGY	Its content is regarded as known only after the carrier, maps, and conditions of applicability have been specified.
PHENOMENOLOGY	Its phenomenological meaning appears through computable invariants and distinguishable regimes.
LIMITATION	No conclusion is transported beyond the declared domain without a separate bridge.
AUTHORIAL NOVELTY	Novelty is determined not by an isolated term but by its role in the packet-Reper KLT-RBD system.

4.1.9. Set of Structurally Admissible Candidates

Let Cand(y) be the set of state or event candidates generated by observation y. Associate to every c a Reper ρ_c, a quadratic test $x_c\in X^2_N$, and an evidence foundation D_c. Define exact and robust sets of structural admissibility.

$$C_0(y;N)=\{c\in \mathrm{Cand}(y):\ \mathrm{Sel}_N(\rho_c,x_c)=1\}. \tag{T2-F012}$$

$$C_{\tau,\eta}(y;N)=\{c:\ \mathrm{Valid}(D_c),\ \delta_{truth}(\rho_c)\le\tau,\ \mathrm{dist}(x_c,\mathrm{Im}\ \Psi^2_N)\le\eta\}. \tag{T2-F013}$$

The formula containing dist requires a norm on X^2_N and therefore has MODEL status until an analytic layer has been selected. C_0 is purely algebraic. If C_0 is empty, the method need not choose the “least bad” outcome; ABSTAIN correctly reports insufficiency of the current language, domain, or foundation.

Corollary 4.1. Coordinate Independence of the Exact Candidate Set [THM] Under the hypotheses of Theorem 4.4, an isomorphism of candidates $c\mapsto c'$ induces a bijection $C_0(y;N)\cong C_0(gy;N')$.

Proof. Membership of each candidate is preserved by Theorem 4.4, and invertibility of g and f gives the inverse correspondence. □

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4.1.10. Negative Results and Forbidden Shortcuts

Counterexample 4.3. $\lambda\approx-1$ Does Not Give Truth Status [COUNTEREXAMPLE] Let δ_truth be small while D is invalid or the candidate is outside the subject-domain. Numerical proximity remains, but Sel=ABSTAIN. Any automatic rule “small δ_truth ⇒ true” violates S2.

Counterexample 4.4. O_B=0 Does Not Give Physics [COUNTEREXAMPLE] The minimal complex and O_B are defined for a finite-dimensional formal algebra without topology, time, or observables. A zero class reports only quadratic expressibility in the selected language.

Counterexample 4.5. The Associator Does Not Automatically Live in X^2 [COUNTEREXAMPLE] Ass_⊙ depends on three arguments and two bracketings, while X^2 is built from quadratic expressions. Without β_Ass:T_Ass→X^2 the formula Π(Ass_⊙)=0 is untyped.

Counterexample 4.6. Instability at a Pole [COUNTEREXAMPLE] A sequence of quadruples may converge to U=D̲ while λ becomes unbounded. Thus there is no global Lipschitz constant over the whole affine domain.

Counterexample 4.7. Narrowing Candidates Is Not Causal Prediction [COUNTEREXAMPLE] Even if C_0(y;N) contains one element, this proves uniqueness only inside the selected formal language and domain, not causal occurrence of the event in the external world.

4.2. Bibliographic Synchronisation

This checkpoint uses classical sources as prior art and does not attribute categories, cross-ratio, quotient spaces, or general deformation theory to the project. The authorial contribution is their typed assembly into NAPG_q, anchored sufficient foundation, the structural selector, and the D/Dom evidential discipline.

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[S2] Mac Lane, S. Categories for the Working Mathematician. 2nd ed. Springer. DOI 10.1007/978-1-4757-4721-8.

[S3] Gerstenhaber, M. On the Deformation of Rings and Algebras. Annals of Mathematics 79 (1964), 59-103. DOI 10.2307/1970484.

[S4] Veblen, O.; Young, J. W. Projective Geometry. Vol. I. Ginn, 1910.

[S5] Kurpishev, I. B. Basic KLT-RBD Project. Volume I. Edition v197 RU. §§26.5, 52.9-52.18. 2026.

[S6] Kurpishev, I. B. Reper-Projective Architecture of Formula Chains: PILOT-01. 2026.

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Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants

EPISTEMOLOGICAL BLOCK. Observation of a single diagonal of a multilinear object inevitably loses information. For the associator this is decisive: an alternative algebra may have $\mathrm{Ass}(x,x,x)=0$ for every x and still be essentially nonassociative. Knowledge must retain the channel type, argument order, and admissible domain in addition to the value.

ONTOLOGY	Nonassociativity is treated as intrinsic structure, not as a computational error.
EPISTEMOLOGY	It is known through the associator, nuclei, ideals, invariants, and explicit countermodels.
PHENOMENOLOGY	It appears as dependence of the result on the bracketing architecture of a packet.
LIMITATION	A nonzero associator is not by itself physical curvature or a physical event.
AUTHORIAL NOVELTY	The authorial node is R⋆R and its role in packet Reper-harmonic geometry.

5.1. Associator and Invariant Core

5.1.1. Typed Domain of the Associator

Definition 5.1. Domain of the Associator [DEF-A] Let $(\mathscr{A},\odot)$ be a packet algebra with a possibly partial operation. Dom_Ass consists of triples (a,b,c) for which $a\odot b$, $b\odot c$, $(a\odot b)\odot c$, and $a\odot(b\odot c)$ are all defined. On Dom_Ass set $\mathrm{Ass}_\odot(a,b,c)=(a\odot b)\odot c-a\odot(b\odot c)$.

$$\mathrm{Dom\_Ass} = \{(a,b,c)\colon (a,b),(b,c),(a\odot b,c),(a,b\odot c) \in \mathrm{Dom}\_\odot\}.$$

Lemma 5.2. Trilinearity on the Full Domain [THM] If $\odot$ is an everywhere-defined $\mathbb{K}$-bilinear operation, then $\mathrm{Ass}_\odot\colon\mathscr{A}\otimes\mathscr{A}\otimes\mathscr{A}\to\mathscr{A}$ is $\mathbb{K}$-linear.

Proof. Each term is a composition of bilinear maps and is therefore trilinear; their difference is trilinear. □

For a partial operation, trilinearity is asserted only on compatible linear slices of Dom_Ass. Extending it beyond the domain by formal analogy is prohibited.

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PHENOMENOLOGY	It appears as dependence of the result on the bracketing architecture of a packet.
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AUTHORIAL NOVELTY	The authorial node is R⋆R and its role in packet Reper-harmonic geometry.

5.1.2. Left, Middle, and Right Nuclei

Definition 5.3. Three Nuclei and the Nucleus [DEF-A] For an everywhere-defined algebra $\mathscr{A}$ define $N_l=\{a:\mathrm{Ass}(a,x,y)=0 \text{ for all } x,y\}$, $N_m=\{a:\mathrm{Ass}(x,a,y)=0 \text{ for all } x,y\}$, and $N_r=\{a:\mathrm{Ass}(x,y,a)=0 \text{ for all } x,y\}$. The full nucleus is $N(\mathscr{A})=N_l\cap N_m\cap N_r$.

$$N\_l = \ker L\_Ass, \quad N\_m = \ker M\_Ass, \quad N\_r = \ker R\_Ass,$$

$$L\_Ass(a)(x,y)=Ass(a,x,y), \quad M\_Ass(a)(x,y)=Ass(x,a,y), \quad R\_Ass(a)(x,y)=Ass(x,y,a).$$

Proposition 5.4. Linearity of the Nuclei [THM] If 𝒜 is a bilinear algebra, then N_l, N_m, N_r, and N(𝒜) are linear subspaces.

Proof. L_Ass, M_Ass, and R_Ass are linear in the distinguished argument. Their kernels are subspaces, and an intersection of subspaces is a subspace. □

Definition 5.5. Commutant and Center [DEF-A] The commutant C_comm(𝒜) consists of z satisfying z⊙x=x⊙z for every x. The center is Z(𝒜)=N(𝒜)∩C_comm(𝒜).

PHENOMENOLOGICAL BLOCK. A central element does more than “not disturb” multiplication. It is insensitive both to permutation and to a change of bracketing. The center therefore defines a stable layer relative to which different packet-assembly routes agree.

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5.1.3. Associator Ideal and Universal Associative Reflection

Definition 5.6. Associator Ideal [DEF-A] J_Ass(𝒜) is the least two-sided ideal of 𝒜 containing all values Ass_⊙(a,b,c). The internal KLT-RBD notation Rad_Ass(𝒜):=J_Ass(𝒜) is permitted, but it is not identified with the Jacobson radical or another classical radical.

Theorem 5.7. Universal Associative Reflection [THM] For every everywhere-defined bilinear algebra 𝒜, the quotient 𝒜_as:=𝒜/J_Ass(𝒜) is associative. Moreover, every homomorphism f:𝒜→B into an associative algebra B factors uniquely through q:𝒜→𝒜_as.

Proof. Every associator has zero image in the quotient, so the quotient multiplication is associative. If B is associative, then f(Ass(a,b,c))=Ass(fa,fb,fc)=0; hence J_Ass⊆ker f. The universal property of the quotient gives a unique f̄ with f=f̄∘q. □

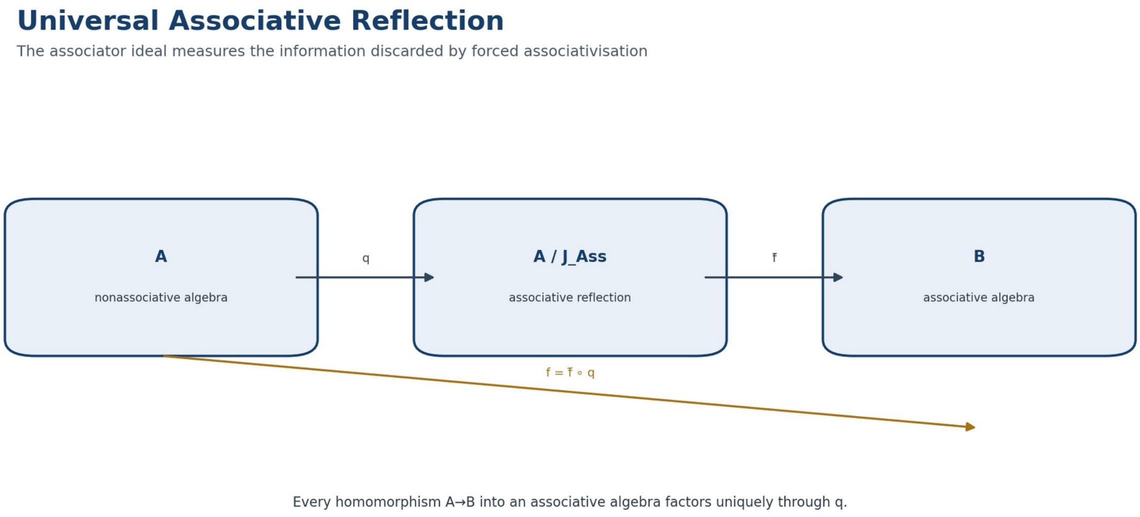

Figure 5. Universal associative reflection. English reconstruction of the authorial diagram in the frozen Russian Volume II.

The reflection gives a strict measure of information loss under forced associativisation. If $J_{Ass}=0$, the algebra is already associative; if $J_{Ass}=\mathscr{A}$, the associative reflection is zero.

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PHENOMENOLOGY	Its phenomenological meaning appears through computable invariants and distinguishable regimes.
LIMITATION	No conclusion is transported beyond the declared domain without a separate bridge.
AUTHORIAL NOVELTY	Novelty is determined not by an isolated term but by its role in the packet-Reper KLT-RBD system.

5.1.4. No Universal Diagonal-Quadratic Encoding

Theorem 5.8. Degree No-Go [THM] There is no nonzero homogeneous quadratic map $Q:\mathscr{A}\to W$ that, functorially for every bilinear algebra and every x, coincides with the diagonal associator $Ass(x,x,x)$.

Proof. For a scalar t, $Q(tx)=t^2Q(x)$, while $Ass(tx,tx,tx)=t^3Ass(x,x,x)$. Over a field with more than two elements, equality for every t is possible only when $Ass(x,x,x)=0$. Thus a general cubic diagonal channel is not quadratic. □

Theorem 5.9. Even the Cubic Diagonal Is Insufficient [THM] In general the map $q_{Ass}(x)=Ass(x,x,x)$ does not determine the full trilinear associator.

Proof. In an alternative algebra the associator is alternating, so $Ass(x,x,x)=0$ for every x. The real octonions are nonassociative and have nonzero values on triples of distinct units. Hence $q_{Ass}\equiv 0$ does not imply $Ass\equiv 0$. □

LIMITATION. The symbol $R\star R$ cannot mean one number or one diagonal quadratic form capable of recovering arbitrary nonassociativity. A complete certificate needs several polarised channels and a separate alternating component.

ONTOLOGY	Nonassociativity is treated as intrinsic structure, not as a computational error.
EPISTEMOLOGY	It is known through the associator, nuclei, ideals, invariants, and explicit countermodels.
PHENOMENOLOGY	It appears as dependence of the result on the bracketing architecture of a packet.
LIMITATION	A nonzero associator is not by itself physical curvature or a physical event.
AUTHORIAL NOVELTY	The authorial node is R⋆R and its role in packet Reper-harmonic geometry.

5.1.5. Quadratic-Alternating R⋆R Certificate

Definition 5.10. Three Quadratic Pencils [DEF-A] For the trilinear tensor $T=\mathrm{Ass}\_\odot$ define $Q_{12}(c;x)=T(x,x,c)$, $Q_{13}(b;x)=T(x,b,x)$, and $Q_{23}(a;x)=T(a,x,x)$. If char $\mathbb{K}\neq 2$, their polarisations recover the symmetrisations of T in the corresponding pairs of slots.

$$S_{12}T(x,y,c) = \tfrac{1}{2}[Q_{12}(c;x+y)-Q_{12}(c;x)-Q_{12}(c;y)] = \tfrac{1}{2}[T(x,y,c)+T(y,x,c)],$$

$$S_{13}T(x,b,y) = \tfrac{1}{2}[T(x,b,y)+T(y,b,x)],$$

$$S_{23}T(a,x,y) = \tfrac{1}{2}[T(a,x,y)+T(a,y,x)].$$

Definition 5.11. Alternating Component [DEF-A] If char $\mathbb{K}\neq 2,3$, set $\mathrm{Alt}(T)=(1/6)\Sigma\_\{\sigma\in S_3\}\ \mathrm{sgn}(\sigma)\cdot T\circ\sigma$.

Theorem 5.12. Completeness of the Quadratic-Alternating Certificate [THM] If char $\mathbb{K}\neq 2,3$, the map $T\mapsto(S_{12}T,S_{13}T,S_{23}T,\mathrm{Alt}(T))$ is injective. Therefore the three polarised quadratic pencils together with Alt(T) determine T uniquely.

Proof. Assume all four components vanish. The equations $S\_ijT=0$ say that T changes sign under each transposition of the corresponding slots, so T is alternating. For an alternating T, Alt(T)=T; the hypothesis Alt(T)=0 therefore gives T=0. □

Definition 5.13. Strict Realisation of R⋆R [DEF-A] For an admissible Reper layer $\mathscr{R}\subseteq\mathscr{A}$ define R⋆R as the certificate $(\mathrm{Dom\_Ass}|\mathscr{R}^3, Q_{12}, Q_{13}, Q_{23}, \mathrm{Alt}(\mathrm{Ass}), \mathrm{J\_Ass}, \mathrm{Prof\_Ass})$. This is neither a new multiplication nor a Hodge operator; the star is reserved for the associator-packet layer.

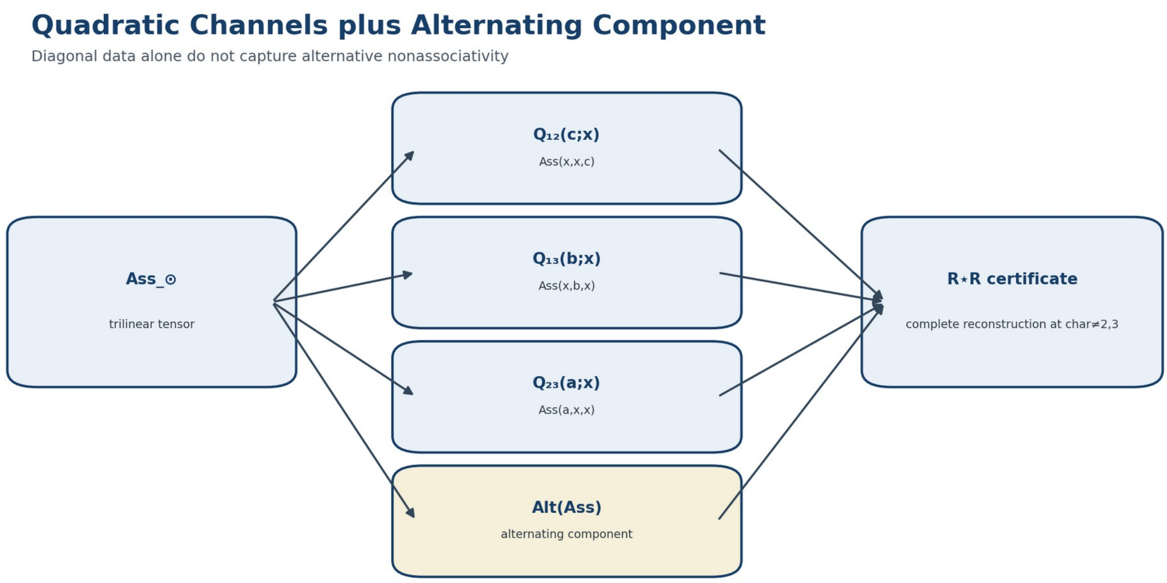

Figure 6. Full R⋆R certificate: quadratic channels and the alternating component. English reconstruction of the authorial diagram in the frozen Russian Volume II.

ONTOLOGY	A model is a concrete carrier of a definition; a counterexample is a boundary of an admissible claim.
EPISTEMOLOGY	Knowledge is produced by explicit computation rather than analogy.
PHENOMENOLOGY	It appears through the operation of formulas on a basis or parameterised family.
LIMITATION	One example does not prove universality, while one valid counterexample refutes an overstrong statement.
AUTHORIAL NOVELTY	The authorial contribution is the systematic inclusion of countermodels in KLT-RBD predictive audit.

5.1.6. Explicit Models and Counterexamples

Model $\mathscr{A}_2$. Let $\mathscr{A}_2=\mathrm{span}\{u,v\}$ and define $u\odot u=u$, $u\odot v=v$, $v\odot u=0$, $v\odot v=u$.

⊙	u	v
u	u	v
v	0	u

$$\mathrm{Ass}(v,u,v)=-u,\quad \mathrm{Ass}(v,v,u)=u,\quad \mathrm{Ass}(v,v,v)=v.$$

Proposition 5.14. Profile of Model $\mathscr{A}_2$ [THM] For $\mathscr{A}_2$, $N\_l=\mathbb{K}u$, $N\_m=0$, $N\_r=0$, $N=0$, $Z=0$, and $J\_\mathrm{Ass}=\mathscr{A}_2$.

Proof. Direct computation on basis triples gives the displayed associators. The nucleus conditions reduce to a linear system: the left nucleus is generated by u, while the middle and right nuclei are trivial. The values $\mathrm{Ass}(v,v,u)=u$ and $\mathrm{Ass}(v,v,v)=v$ span the algebra, so $J\_\mathrm{Ass}=\mathscr{A}_2$. □

Model M_2. For the matrix algebra $M_2(\mathbb{K})$, the associator is identically zero, all three nuclei are $M_2(\mathbb{K})$, $J\_\mathrm{Ass}=0$, and the center consists of scalar matrices.

Model $\mathbb{O}$. In the real octonions choose the oriented cycles (123), (145), (176), (246), (257), (347), (365). Then

$$\mathrm{Ass}(e_1,e_2,e_4) = (e_1e_2)e_4 - e_1(e_2e_4) = e_7 - (-e_7) = 2e_7 \neq 0,$$

while alternativity gives Ass(x,x,y)=Ass(y,x,x)=0 and in particular Ass(x,x,x)=0. This is a certificate against diagonal recovery.

Model	rank Ass	N_l/N_m/N_r	Z	J_Ass	Role
$M_2(\mathbb{K})$	0	whole algebra	$\mathbb{K}\cdot I$	0	associative zero control
$\mathscr{A}_2$	>0	1 / 0 / 0	0	$\mathscr{A}_2$	explicit complete collapse of the associative reflection
$\mathbb{O}$	>0	$\mathbb{K}$ / $\mathbb{K}$ / $\mathbb{K}$	$\mathbb{K}$	not fixed here	counterexample to diagonal encoding

ONTOLOGY	Nonassociativity is treated as intrinsic structure, not as a computational error.
EPISTEMOLOGY	It is known through the associator, nuclei, ideals, invariants, and explicit countermodels.
PHENOMENOLOGY	It appears as dependence of the result on the bracketing architecture of a packet.
LIMITATION	A nonzero associator is not by itself physical curvature or a physical event.
AUTHORIAL NOVELTY	The authorial node is R⋆R and its role in packet Reper-harmonic geometry.

5.1.7. Associator Invariant Profile

Definition 5.15. Basic Profile [DEF-A] For a finite-dimensional algebra define Prof_Ass($\mathscr{A}$)=(n,r_Ass,n_l,n_m,n_r,n_N,n_Z), where n=dim$\mathscr{A}$, r_Ass=rank(Ass:$\mathscr{A}$^{⊗3}→$\mathscr{A}$), and the remaining coordinates are the dimensions of the three nuclei, their intersection, and the center. An extended profile additionally records dim J_Ass and the ranks of selected quadratic channels.

Theorem 5.16. Isomorphism Invariance of the Profile [THM] If $\Phi:\mathscr{A}\to\mathscr{B}$ is an algebra isomorphism, then Prof_Ass($\mathscr{A}$)=Prof_Ass($\mathscr{B}$).

Proof. The identity Φ(Ass_$\mathscr{A}$(a,b,c))=Ass_$\mathscr{B}$(Φa,Φb,Φc) gives conjugate structural maps. Ranks are preserved, and Φ bijectively transports N_l,N_m,N_r,N, and Z. □

Definition 5.17. Profile Pseudodistance [DEF-A] For weights w_j≥0 set d_prof($\mathscr{A}$,$\mathscr{B}$)=Σ_j w_j|p_j($\mathscr{A}$)−p_j($\mathscr{B}$)|. This is a coarse isomorphism-invariant diagnostic, not a complete classifier: d_prof=0 need not imply isomorphism.

ONTOLOGY	The section fixes an autonomous mathematical object within the architecture of Volume II.
EPISTEMOLOGY	Its content is regarded as known only after the carrier, maps, and conditions of applicability have been specified.
PHENOMENOLOGY	Its phenomenological meaning appears through computable invariants and distinguishable regimes.
LIMITATION	No conclusion is transported beyond the declared domain without a separate bridge.
AUTHORIAL NOVELTY	Novelty is determined not by an isolated term but by its role in the packet-Reper KLT-RBD system.

5.1.8. Determinantal Horizon of Structural Transitions

ONTOLOGICAL BLOCK. A structural change need not be visible in individual coefficients. It becomes mathematically detectable when a tensor rank or the dimension of a nucleus or center changes. Such changes are not arbitrary: they are localised by zeros of determinants.

Definition 5.18. Polynomial Family of Algebras [DEF-A] Let V be n-dimensional, T an irreducible algebraic parameter variety, and $\mu_t \in \mathrm{Hom}(V\otimes V,V)$ have structure constants polynomial in t. Let A_t, L_t, M_t, R_t, and C_t be the matrices of the associator, the three nucleus maps, and the commutator channel.

Definition 5.19. Determinantal Horizon [DEF-A] Δ_{NAPG} is the union of determinantal loci where the rank of at least one of A_t,L_t,M_t,R_t, the block nucleus matrix $N_t=(L_t,M_t,R_t)$, or the block center matrix $Z_t=(L_t,M_t,R_t,C_t)$ is below its generic rank on a nonempty open subset of T.

Theorem 5.20. Localisation of Structural Transitions [THM] On the nonempty Zariski-open set $T°=T\setminus\Delta_{NAPG}$, the basic profile $\mathrm{Prof\_Ass}(\mathscr{A}_t)$ is constant. In particular, along a continuous path γ contained in one connected component of T°, the profile does not change. Any change of profile requires crossing Δ_{NAPG}.

Proof. The matrix entries are polynomial in t. The condition rank≤r is defined by vanishing of all minors of order r+1. Each matrix reaches its generic rank on a nonempty Zariski-open set. After removing the union of the corresponding determinantal loci, all ranks are constant. The dimensions of the nuclei and center are n minus the ranks of the relevant linear or block maps; hence all profile coordinates are constant. □

Corollary 5.21. Negative Prediction Theorem [THM] If $\gamma([t_0,t_1])\cap\Delta_{NAPG}=\varnothing$, then a change of the basic associator profile is excluded throughout the interval within the model.

Proof. This is immediate from Theorem 5.20. The claim is exact inside the specified family μ_t and does not automatically transfer to physical systems. □

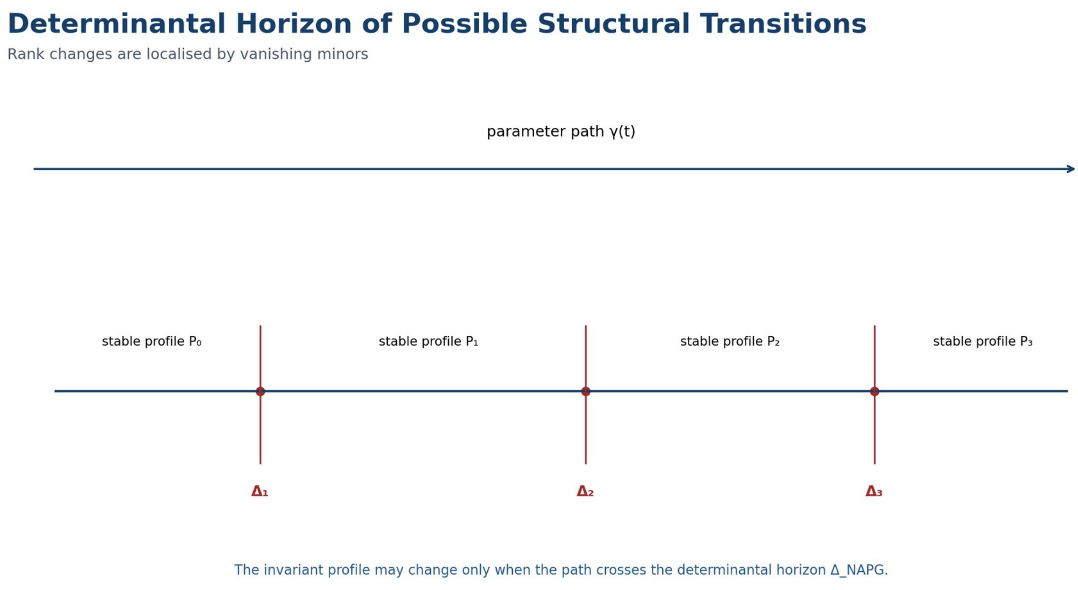

Figure 7. Determinantal horizon of possible structural transitions. English reconstruction of the authorial diagram in the frozen Russian Volume II.

ONTOLOGY	A Reper exists as the quadruple R,I,U;D, not as a triad without foundation.
EPISTEMOLOGY	The harmonic coordinate is informative only together with an evidence package and a domain.
PHENOMENOLOGY	Phenomenologically, λ records the alignment of fact, idea, possibilities, and foundation.
LIMITATION	The equality λ=-1 does not replace proof, measurement, or causal identification.
AUTHORIAL NOVELTY	The authorial contribution is the strict KLT-RBD λ-gate with D/Dom and an abstention rule.

5.1.9. Projective-Harmonic Localisation of Candidates

Definition 5.22. Predictive Horizon along a Path [DEF-A] For an observed parameter t_0 and a path $\gamma:[t_0,t_1]\to T$, set Hor_Ass(γ)=γ^{-1}(Δ_NAPG). This is the set of parameter times at which a structural transition is not excluded by the determinantal theorem.

Definition 5.23. Harmonic Transition Candidate [DEF-A] Compactify the parameter line to $P^1(\mathbb{K})$, and let ρ=(r,i,u;d) be a Reper with u∈Δ_NAPG. The candidate is harmonic if λ(u,i;r,d)=−1, Valid(D)=1, ρ∈Dom_λ, and the minor certificate is reproducible.

$$\mathrm{Cand\_H} = \{\rho : u\in\Delta\_\mathrm{NAPG},\ \lambda(\rho)=-1,\ \mathrm{Valid}(D)=1,\ \mathrm{Cert\_det}(u)=\mathrm{PASS}\}.$$

Level	Condition	Permitted conclusion
Algebraic locus	u∈Δ_NAPG	a structural transition is not excluded
Harmonic candidate	u∈Δ_NAPG and λ=−1 with D/Dom	coordinate-invariant candidate for testing
Certified transition	one-sided profiles differ and computations are reproducible	the profile changes in the specified model
Physical event	independent data and operationalisation	only after a separate external protocol

Theorem 5.24. Projective Invariance of a Harmonic Candidate [THM] Under a projective change of coordinate on the parameter line, λ=−1 is preserved and the determinantal locus is transported by the family isomorphism. Thus Cand_H is invariant under a compatible projective reparameterisation and transport of D.

Proof. Cross-ratio is projectively invariant. Under isomorphic transport, the structural matrices are conjugated by invertible matrices, so their ranks and determinantal loci are preserved. Valid(D) is transported under the separate evidence-equivalence hypothesis. □

LIMITATION. Harmony λ=−1 does not create a transition. It marks a projectively invariant relation among four already defined points. A positive conclusion requires the simultaneous determinantal, domain, evidence, and reproducible-computation conditions.

ONTOLOGY	A computational object exists only together with inputs, an algorithm, and a reproducible certificate.
EPISTEMOLOGY	Knowledge is supported by repeatability, exact tests, and control of numerical conditioning.
PHENOMENOLOGY	It appears as agreement between expected and computed invariants.

ONTOLOGY	A computational object exists only together with inputs, an algorithm, and a reproducible certificate.
LIMITATION	A successful run proves neither a universal theorem nor an empirical claim.
AUTHORIAL NOVELTY	The authorial contribution is a proof-carrying computational circuit within KLT-RBD.

5.1.10. Computational Certificate

For a basis $e_1,\dots,e_n$ and structure constants $\mu(e_i,e_j)=\Sigma_k c^k_{ij} e_k$, the certificate performs the following sequence:

Step	Operation	Check
C1	construct the matrix $Ass:V^{\otimes 3}\to V$	exact coefficients or controlled arithmetic
C2	construct $L_{Ass},M_{Ass},R_{Ass},C_{comm}$	agreement with the chosen basis order
C3	compute ranks and kernels	exact values and kernel bases
C4	construct J_{Ass} by $I_{k+1}=I_k+VI_k+I_kV$	stabilisation within at most n strict increases
C5	check Q_{12},Q_{13},Q_{23} and Alt(Ass)	reconstruction of Ass when char≠2,3
C6	for μ_t compute maximal minors	obtain Δ_{NAPG} and control polynomials
C7	check λ, D/Dom, and source hashes	do not merge algebraic and physical statuses

> **Proposition 5.25. Finiteness of the Construction of J_{Ass} [THM]** In an n-dimensional algebra, the increasing chain $I_0\subseteq I_1\subseteq\dots$ with $I_0=\mathrm{span}\,\mathrm{Im}\,Ass$ and $I_{k+1}=I_k+\mathscr{A}I_k+I_k\mathscr{A}$ stabilises after at most n strict increases; its limit is J_{Ass}.

Proof. Every strict inclusion increases the dimension by at least one, while the dimension is bounded by n. A stable subspace contains Im Ass and is closed under multiplication on the left and right, so it is the required least two-sided ideal. □

5.2. Bibliographic Synchronisation

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[4] Salzmann, H. et al. The Role of Nonassociative Algebra in Projective Geometry. Graduate Studies in Mathematics 159, AMS, 2014.

[5] Kaygorodov, I. Non-associative Algebraic Structures: Classification and Structure. arXiv:2306.00425, revised 2023.

[6] Kurpishev, I. B. Volume I v197 RU and T2-RP-v0.2: canonical internal sources of this edition.

Classical definitions of the associator, nuclei, center, alternativity, and octonions are prior art. The authorial contribution of this layer is the strict R⋆R certificate, its connection to D/Dom and the λ-selector, the KLT-RBD associator profile, and the determinantal horizon for predictive exclusion.

Chapter 6. Packet-Reper Algebraic-Geometric Duality

ONTOLOGY	The historical layer exists as a network of sources and priorities rather than an anonymous background.
EPISTEMOLOGY	Knowledge of authorship requires separation of classical constructions from the new composition.
PHENOMENOLOGY	It appears as a precise bibliography and a dependency map of ideas.
LIMITATION	Use of prior art does not reduce the novelty of synthesis but prohibits reattribution of classical results.
AUTHORIAL NOVELTY	Novelty is fixed in the architecture of connection, new objects, and evidential gates.

6.1. Duality Core

6.1.1. Boundary between Prior Art and the Authorial Construction

Classical mathematics contains several inequivalent paradigms of duality: anti-equivalence between commutative rings and affine schemes; recovery of a compact space from a commutative C*-algebra; correspondence between vector bundles and finitely generated projective modules; and reconstruction of an object from its Hom functor. This chapter neither renames those results nor claims them as authorial.

The authorial construction of Volume II is their disciplined transport into NAPG: a representable functor of packet-Reper points, a reconstruction defect, a projective Reper atlas, coordination of algebraic and geometric determinantal horizons, and a blocker-safe rule for predictive transport.

Classical line	Imported principle	What is not transported automatically
Affine schemes	Contravariance of Spec and recovery from global sections on the affine layer.	A noncommutative or nonassociative algebra has no canonical scheme spectrum without an additional construction.
Gelfand-Naimark	Recovery of a space from a function algebra.	The C*-topology, positivity, and involution are absent from the general NAPG core.
Serre-Swan	Relation between local bundle geometry and projective modules.	An arbitrary NAPG module is not automatically a vector bundle.
Yoneda	Full faithfulness of the representable Hom functor.	A representable functor is not automatically an ordinary topological space.

ONTOLOGY	Algebraic and geometric carriers are distinct representations of structure.
EPISTEMOLOGY	Their correspondence is established only through functors, unit/counit maps, and reconstruction defects.
PHENOMENOLOGY	Duality appears as mutual recovery of invariants.
LIMITATION	A static anti-equivalence creates neither dynamics nor causality.
AUTHORIAL NOVELTY	The authorial contribution is Reper duality with explicit control of losses in D, Dom, and predictive status.

6.1.2. Two Different Dualities

Definition 6.1. Representable Duality [DEF-A] Let $\mathscr{C}$=NAPG_q^fin be a small category of finite-dimensional NAPG_q objects with the four compatibility conditions of Chapter 3. For A∈Ob($\mathscr{C}$), define the covariant functor of points h_A:$\mathscr{C}$→Set by h_A(T)=Hom_$\mathscr{C}$(A,T). A morphism f:A→B induces h_f:h_B→h_A by precomposition h_f(T)(g)=g∘f. Thus A↦h_A is contravariant from algebras to geometric functors.

$$\mathrm{h\_A} : \mathscr{C} \to \mathrm{Set}, \qquad \mathrm{h\_A(T)=Hom\_}\mathscr{C}\mathrm{(A,T)}.$$

Definition 6.2. Spatial Duality [DEF-A] Spatial duality requires another category Geo_R whose objects possess a carrier, local charts, a structure sheaf, packet-Reper data, and gluing rules. It is given by contravariant functors Spec_R and Gamma_R and does not follow merely from the existence of h_A.

$$\mathrm{Spec\_R} : \mathrm{Alg\_R} \to \mathrm{Geo\_R\hat{\ }op}, \qquad \mathrm{Gamma\_R} : \mathrm{Geo\_R\hat{\ }op} \to \mathrm{Alg\_R}.$$

Restriction on the word “duality”	Meaning
Prohibition 1	Full faithfulness of a functorial description does not imply an ordinary set of points with a topology.
Prohibition 2	Coincidence of character sets does not imply isomorphism of algebras.
Prohibition 3	Existence of an adjoint pair does not imply that unit and counit are isomorphisms.
Prohibition 4	Anti-equivalence of static categories does not define a law of evolution for a parameter.

ONTOLOGY	Algebraic and geometric carriers are distinct representations of structure.
EPISTEMOLOGY	Their correspondence is established only through functors, unit/counit maps, and reconstruction defects.
PHENOMENOLOGY	Duality appears as mutual recovery of invariants.
LIMITATION	A static anti-equivalence creates neither dynamics nor causality.
AUTHORIAL NOVELTY	The authorial contribution is Reper duality with explicit control of losses in D, Dom, and predictive status.

6.2. Yoneda-Safe Representable Duality

ONTOLOGY	The section fixes an autonomous mathematical object within the architecture of Volume II.
EPISTEMOLOGY	Its content is regarded as known only after the carrier, maps, and conditions of applicability have been specified.
PHENOMENOLOGY	Its phenomenological meaning appears through computable invariants and distinguishable regimes.
LIMITATION	No conclusion is transported beyond the declared domain without a separate bridge.
AUTHORIAL NOVELTY	Novelty is determined not by an isolated term but by its role in the packet-Reper KLT-RBD system.

6.2.1. Full-Faithfulness Theorem

Theorem 6.3. Yoneda-Safe Anti-Equivalence [THM] The functor $Spec\_Y:\mathscr{C}^{op}\to Set^{\mathscr{C}}$ defined by $Spec\_Y(A)=h\_A$ is full and faithful. Its essential image Aff_NAPG^{rep} is the category of representable NAPG geometries, and Spec_Y defines an anti-equivalence $\mathscr{C}^{op}\simeq Aff\_NAPG^{rep}$.

$$\mathscr{C}^{op} \simeq Aff\_NAPG^{rep}.$$

Proof. For $A,B\in\mathscr{C}$, Yoneda gives a natural bijection $Nat(h\_B,h\_A)\cong Hom\_\mathscr{C}(A,B)$, compatible with identities and composition. Hence Spec_Y is full and faithful; restriction to its essential image is an equivalence. □

This result is unconditional within the selected small category. It requires no prime spectrum, maximal ideals, norm, topology, or associativity. Its cleanliness is precisely why no stronger claim may be silently attached to it.

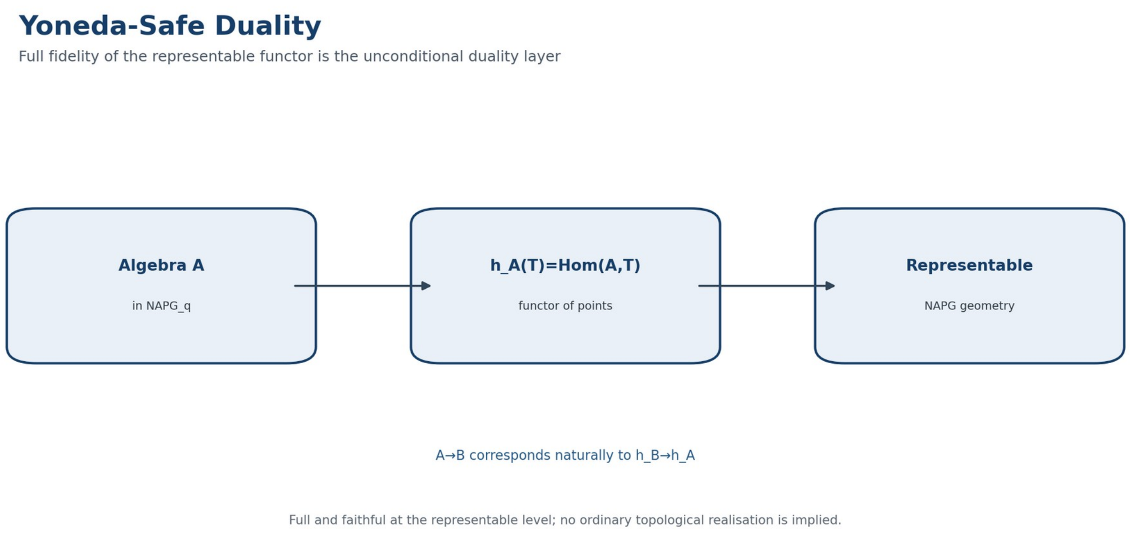

Figure 8. Yoneda-safe representable duality for NAPG_q. English reconstruction of the authorial diagram in the frozen Russian Volume II.

ONTOLOGY	The section fixes an autonomous mathematical object within the architecture of Volume II.
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6.2.2. Reper Configuration Functor

Definition 6.4. Rep_A(T) [DEF-A] For a test object T set $Rep\_A(T)=\{(r,i,u,d)\in h\_A(T)^4:Adm\_T(r,i,u,d)=1,\ Valid\_T(D)=1\}$. The four entries are morphisms $A\to T$; Adm_T checks domain admissibility, distinctness, and absence of poles, while Valid_T(D) checks the evidence package. Rep_A is a subfunctor of h_A^4 when admissibility and sufficient foundation are preserved by all test morphisms.

$$\mathrm{Rep\_A}(T) = \{ (r,i,u,d) \in \mathrm{h\_A}(T)^4 : \mathrm{Adm\_T}(r,i,u,d)=1,\ \mathrm{Valid\_T}(D)=1 \}.$$

Proposition 6.5. Functoriality of Reper Configurations [THM] If s:T→T′ preserves Adm and Valid(D), then (r,i,u,d)↦(s∘r,s∘i,s∘u,s∘d) defines Rep_A(T)→Rep_A(T′). Identities and composition hold componentwise, so Rep_A:𝒞→Set is a functor.

Corollary 6.6. Isomorphism Invariance [THM] An isomorphism A≅B induces a natural isomorphism Rep_B≅Rep_A. Therefore representable Reper geometry is independent of the chosen isomorphic algebraic presentation.

ONTOLOGY	Algebraic and geometric carriers are distinct representations of structure.
EPISTEMOLOGY	Their correspondence is established only through functors, unit/counit maps, and reconstruction defects.
PHENOMENOLOGY	Duality appears as mutual recovery of invariants.
LIMITATION	A static anti-equivalence creates neither dynamics nor causality.
AUTHORIAL NOVELTY	The authorial contribution is Reper duality with explicit control of losses in D, Dom, and predictive status.

6.3. Conditional Pair Spec_R / Gamma_R

ONTOLOGY	The section fixes an autonomous mathematical object within the architecture of Volume II.
EPISTEMOLOGY	Its content is regarded as known only after the carrier, maps, and conditions of applicability have been specified.
PHENOMENOLOGY	Its phenomenological meaning appears through computable invariants and distinguishable regimes.
LIMITATION	No conclusion is transported beyond the declared domain without a separate bridge.
AUTHORIAL NOVELTY	Novelty is determined not by an isolated term but by its role in the packet-Reper KLT-RBD system.

6.3.1. Adjunction and Reconstruction Maps

Hypothesis 6.7. Spatial Realisation [COND] Assume a category Geo_R and functors Spec_R,Gamma_R with a natural bijection Hom_Geo_R(X,Spec_R A)≅Hom_Alg_R(A,Gamma_R X). This is an adjunction Spec_R⊣Gamma_R between Alg_R and Geo_R^op. It has a unit η_A:A→Gamma_R Spec_R(A) and a geometrically written counit ε̄_X:X→Spec_R Gamma_R(X).

$$\mathrm{Hom\_Geo\_R}(X,\ \mathrm{Spec\_R}\ A) \cong \mathrm{Hom\_Alg\_R}(A,\ \mathrm{Gamma\_R}\ X).$$

$$\eta\_A : A \to \mathrm{Gamma\_R\ Spec\_R}(A), \qquad \bar{\varepsilon}\_X : X \to \mathrm{Spec\_R\ Gamma\_R}(X).$$

Existence of these maps is not asserted for all NAPG objects without a specification of spectrum, sheaf, and admissible localisations. The checkpoint records an exact proof obligation rather than making it disappear rhetorically.

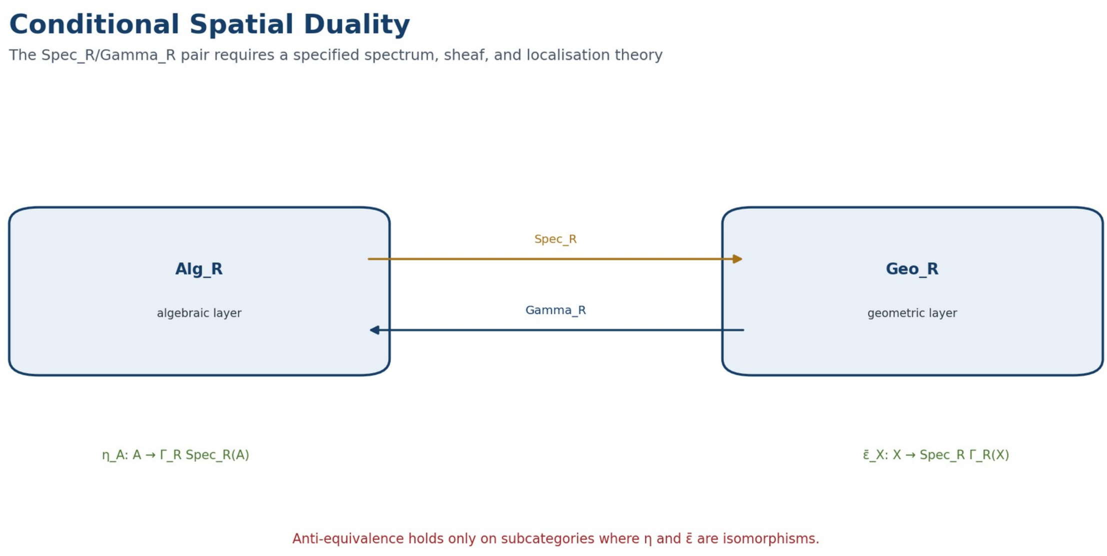

Figure 9. Conditional Spec_R/Gamma_R pair and reconstruction maps. English reconstruction of the authorial diagram in the frozen Russian Volume II.

ONTOLOGY	Algebraic and geometric carriers are distinct representations of structure.
EPISTEMOLOGY	Their correspondence is established only through functors, unit/counit maps, and reconstruction defects.
PHENOMENOLOGY	Duality appears as mutual recovery of invariants.
LIMITATION	A static anti-equivalence creates neither dynamics nor causality.
AUTHORIAL NOVELTY	The authorial contribution is Reper duality with explicit control of losses in D, Dom, and predictive status.

6.3.2. Reconstruction Defects

Definition 6.8. Algebraic Defect [DEF-A] For finite-dimensional A define K_rec(A)=ker(η_A), Q_rec(A)=coker(η_A), and def_alg(A)=dim K_rec(A)+dim Q_rec(A). In a nonadditive category use the Boolean defect def_alg(A)=0 when η_A is an isomorphism and 1 otherwise.

$$K\_rec(A)=\ker(\eta\_A), \quad Q\_rec(A)=\mathrm{coker}(\eta\_A), \quad def\_alg(A)=\dim K\_rec(A)+\dim Q\_rec(A).$$

Definition 6.9. Geometric Defect [DEF-A] Set def_geo(X)=0 if ε̃_X is an isomorphism in Geo_R and def_geo(X)=1 otherwise. A finite-dimensional coordinate model may refine this by ranks of maps on local coordinates and structure sheaves. Set def_rec(A,X)=def_alg(A)+def_geo(X).

$$def\_rec(A,X)=def\_alg(A)+def\_geo(X).$$

Zero reconstruction defect is necessary for transport of a strict predictive status. A nonzero defect does not refute either object; it forbids identification of its algebraic and geometric versions.

ONTOLOGY	Algebraic and geometric carriers are distinct representations of structure.
EPISTEMOLOGY	Their correspondence is established only through functors, unit/counit maps, and reconstruction defects.
PHENOMENOLOGY	Duality appears as mutual recovery of invariants.
LIMITATION	A static anti-equivalence creates neither dynamics nor causality.
AUTHORIAL NOVELTY	The authorial contribution is Reper duality with explicit control of losses in D, Dom, and predictive status.

6.3.3. Reconstruction Anti-Equivalence Theorem

Theorem 6.10. Restricted Reconstruction Theorem [THM under Hypothesis 6.7] Assume Hypothesis 6.7. Let Alg_rec be the full subcategory of A for which η_A is an isomorphism, and Geo_rec the full subcategory of X for which ε̄_X is an isomorphism. Then Spec_R and Gamma_R restrict to an anti-equivalence Alg_rec^op≃Geo_rec.

$$\mathrm{Alg\_rec}^{\mathrm{op}} \simeq \mathrm{Geo\_rec}.$$

Proof. On these subcategories the unit and counit are natural isomorphisms. The triangular identities of the adjunction show that the restricted functors are quasi-inverse. □

Corollary 6.11. Preservation of Isomorphism Invariants [THM under Hypothesis 6.7] Under Hypothesis 6.7, every invariant defined functorially on Alg_rec transports to Geo_rec and back. Numerical features chosen after inspection of the result receive no such right.

ONTOLOGY	Algebraic and geometric carriers are distinct representations of structure.
EPISTEMOLOGY	Their correspondence is established only through functors, unit/counit maps, and reconstruction defects.
PHENOMENOLOGY	Duality appears as mutual recovery of invariants.
LIMITATION	A static anti-equivalence creates neither dynamics nor causality.
AUTHORIAL NOVELTY	The authorial contribution is Reper duality with explicit control of losses in D, Dom, and predictive status.

6.4. Countertheorems to False Duality

ONTOLOGY	The section fixes an autonomous mathematical object within the architecture of Volume II.
EPISTEMOLOGY	Its content is regarded as known only after the carrier, maps, and conditions of applicability have been specified.
PHENOMENOLOGY	Its phenomenological meaning appears through computable invariants and distinguishable regimes.
LIMITATION	No conclusion is transported beyond the declared domain without a separate bridge.
AUTHORIAL NOVELTY	Novelty is determined not by an isolated term but by its role in the packet-Reper KLT-RBD system.

6.4.1. A Character Set Does Not Reconstruct an Algebra

Theorem 6.12. Character-Spectrum No-Go [THM] Let K be a field and V_m an m-dimensional K-space. On A_m=K⊕V_m define the commutative associative multiplication (a,u)(b,v)=(ab,av+bu), with $V\_m^2=0$. Every unital K-algebra character χ:A_m→K equals χ(a,u)=a. Hence the K-valued character sets of all A_m are singletons, although A_m≄A_n when m≠n.

$$(a,u)(b,v)=(ab,\ av+bu),\qquad V\_m^2=0.$$

Proof. Write $\chi(a,u)=a+\ell(u)$. Multiplicativity gives $\ell(u)\ell(v)=0$ for every u,v. Over a field this implies $\ell=0$. Different dimensions prohibit $A\_m\cong A\_n$ when $m\neq n$. □

A point-set spectrum without a structure sheaf or full functor of points therefore loses nilpotent directions. This countertheorem already holds in the associative case; nonassociativity cannot be blamed for every oversimplification.

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6.4.2. A Nonprojective Chart Change Destroys λ

Counterexample 6.13. Nonprojective Chart Failure [THM / COUNTEREXAMPLE] On the affine line take $(r,i,u,d)=(0,1,2,3)$. Then $\lambda(u,i;r,d)=((u-r)(i-d))/((u-d)(i-r))=4$. After the nonlinear coordinate change $x\mapsto x^2$ the quadruple is $(0,1,4,9)$ and $\lambda'=32/5\neq 4$. Hence a global Reper λ-coordinate exists only for $PGL_2(K)$ chart transitions or another separately proved cross-ratio-preserving class.

ONTOLOGY	Algebraic and geometric carriers are distinct representations of structure.
EPISTEMOLOGY	Their correspondence is established only through functors, unit/counit maps, and reconstruction defects.
PHENOMENOLOGY	Duality appears as mutual recovery of invariants.
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6.4.3. Static Duality Does Not Create Dynamics

Proposition 6.14. No-Dynamics Principle [THM] An anti-equivalence transports objects, morphisms, and functorial invariants. It does not select a time parameter, flow generator, probability law, or causal direction. Therefore $Alg\_rec^{op}\simeq Geo\_rec$ does not imply event prediction without additional dynamic structure.

Proof. The same static category admits different families of endofunctors and different parameterisations of paths of objects. The equivalence chooses none of them. □

ONTOLOGY	A global object exists only after effective gluing of local data.
EPISTEMOLOGY	Globality requires cocycle, descent, and compatibility on triple overlaps.
PHENOMENOLOGY	Local solutions appear as compatible or conflicting charts.
LIMITATION	Pairwise agreement does not guarantee a global section.
AUTHORIAL NOVELTY	The authorial contribution is a globalisation-safe KLT-RBD gate and an explicit blocker register.

6.5. Projective-Reper Atlases and the Global Harmonic Coordinate

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6.5.1. Definition of an Atlas

Definition 6.15. Projective Reper Atlas [DEF-A] Let $X\in Geo\_R$. A projective Reper atlas consists of a cover $\{U\_\alpha\}$ and charts $\kappa\_\alpha:U\_\alpha\to P^1(K)$ such that, on every nonempty overlap $U\_\alpha\cap U\_\beta$, the transition $\kappa\_\beta\circ\kappa\_\alpha\text{^}\{-1\}$ is the restriction of an element of $PGL_2(K)$. An admissible Reper quadruple must lie in one common chart or possess a compatible continuation through a chain of overlaps.

Theorem 6.16. Globalisation of λ [THM] On a projective Reper atlas, $\lambda(u,i;r,d)$ is chart-independent and therefore defines a global function on the space of admissible Reper quadruples.

Proof. On overlaps the charts differ by a projective transformation, and cross-ratio is $PGL_2(K)$-invariant. Transitivity of transitions ensures compatibility on triple overlaps. □

Corollary 6.17. Global Harmonic Locus [THM] $Harm(X)=\{\rho\in Rep(X):\lambda(\rho)=-1\}$ is a well-defined subset of the configuration space. If char K=2, harmonic marking requires another normalisation and is not included in this package.

$$Harm(X)=\{\rho\in Rep(X):\ \lambda(\rho)=-1\}.$$

ONTOLOGY	Only a typed structure with declared domain and codomain counts as an object.
EPISTEMOLOGY	Knowledge is obtained by checking morphisms, commutative diagrams, and admissible domains.
PHENOMENOLOGY	The structure appears as the ability to transport data correctly without loss of type.
LIMITATION	Similarity of notation neither licenses composition nor proves existence.
AUTHORIAL NOVELTY	The authorial contribution is the packet-Reper typing of NAPG and the inclusion of D/Dom in the object itself.

6.5.2. Naturality with Respect to Morphisms

Definition 6.18. Projective-Reper Morphism [DEF-A] A morphism $F:X\to Y$ is projective-Reper if it is locally represented by elements of $PGL_2(K)$, transports Adm, Valid(D), and obstruction labels, and is compatible with the structure sheaves.

Theorem 6.19. Invariance of the Harmonic Locus [THM] $F(Harm(X))\subseteq Harm(Y)$. If F is an isomorphism of projective-Reper objects, then $F(Harm(X))=Harm(Y)$.

Proof. This follows from local PGL_2-invariance and preservation of D/Dom. □

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AUTHORIAL NOVELTY	Novelty is determined not by an isolated term but by its role in the packet-Reper KLT-RBD system.

6.6. Double Determinantal Horizon

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6.6.1. Algebraic and Geometric Channels

Let $t \mapsto A_t$ be the algebraic family of Chapter 5 and let $X_t=\mathrm{Spec}_R(A_t)$ be its geometric realisation on the reconstructible layer. The algebraic horizon Δ_{alg} is defined by rank drops of the associator, nucleus, center, and J_Ass maps. The geometric horizon Δ_{geo} is defined by rank drops of the corresponding tangent, sheaf, or incidence maps.

Hypothesis 6.20. Conjugacy Bridge [COND] For every structural map $M_{alg}(t)$ there is a geometric map $M_{geo}(t)$ and invertible matrices $U(t),V(t)$ such that $M_{geo}(t)=U(t)M_{alg}(t)V(t)^{-1}$.

$$M_{geo}(t)=U(t)\, M_{alg}(t)\, V(t)^{-1}.$$

Theorem 6.21. Coincidence of Rank Horizons [THM under Hypothesis 6.20] Under Hypothesis 6.20, $\Delta_{alg}=\Delta_{geo}$.

Proof. Left and right multiplication by invertible matrices preserves rank. The parameter sets where corresponding maps lose generic rank therefore coincide. Taking the union over the finite family of structural maps gives equality of horizons. □

Corollary 6.22. Double Negative-Prediction Theorem [THM under Hypotheses 6.7 and 6.20] Under Hypotheses 6.7 and 6.20, if a path $\gamma([t_0,t_1])$ avoids the common horizon and reconstruction defect is zero, both the algebraic profile $\mathrm{Prof}_{Ass}(A_t)$ and its geometric dual profile are constant on the interval.

This excludes a structural transition within the specified model. It does not assert that a physical system is unchanged unless the system is proved to realise the model and parameter path.

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6.6.2. Horizon Mismatch as a Blocker

Definition 6.23. Dual Mismatch Set [DEF-A] Define Mis_dual=Δ_alg△Δ_geo, the symmetric difference. A nonempty mismatch means that reconstruction is not exact, the selected structural maps are not functorial correspondences, or the computational certificate is defective. A transition candidate is then not published.

$$\mathrm{Mis\_dual} = \Delta\_\mathrm{alg} \,\triangle\, \Delta\_\mathrm{geo}.$$

Situation	Conclusion	Status
t outside both horizons	Structural profile is constant in both layers.	NO-CHANGE
t in both horizons	A transition candidate is permitted; λ, D/Dom, and obstruction gates remain required.	CANDIDATE
t in only one horizon	Reconstruction conflict.	ABSTAIN
η or ε̄ is not an isomorphism	Algebraic-geometric transport is prohibited.	ABSTAIN

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6.7. Double KLT-RBD Predictive Gate

ONTOLOGY	The section fixes an autonomous mathematical object within the architecture of Volume II.
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AUTHORIAL NOVELTY	Novelty is determined not by an isolated term but by its role in the packet-Reper KLT-RBD system.

6.7.1. Blocker System

Definition 6.24. Block_dual [DEF-A] Set $Block\_dual=B\_rec∪B\_var∪B\_chart∪B\_D∪B\_Dom∪B\_ob∪B\_ind$.

$$Block\_dual = B\_rec \cup B\_var \cup B\_chart \cup B\_D \cup B\_Dom \cup B\_ob \cup B\_ind.$$

- B_rec: unit or counit is not an isomorphism;
- B_var: algebraic and geometric horizons do not coincide;
- B_chart: transitions of the Reper atlas are not proved projective;
- B_D and B_Dom: sufficient foundation or admissible domain is missing;
- B_ob: an internal or declared external obstruction is nonzero;
- B_ind: an independent computational or empirical certificate is absent when required.

Definition 6.25. Dual Harmonic Candidate [DEF-A] $Cand\_dual(t)=1$ iff $t∈Δ\_alg∩Δ\_geo$, $λ\_t=−1$, $Valid(D\_t)=1$, $Π\_t=0$, and $Block\_dual=∅$. In a numerically relaxed mode $λ=−1$ is replaced by $δ\_truth≤τ$, but the status remains CANDIDATE. The threshold $τ$ is fixed before result disclosure and belongs to D.

$$Cand\_dual(t)=1 \Leftrightarrow t\in\Delta\_alg\cap\Delta\_geo \wedge \lambda\_t=-1 \wedge Valid(D\_t)=1 \wedge \Pi\_t=0 \wedge Block\_dual=\varnothing.$$

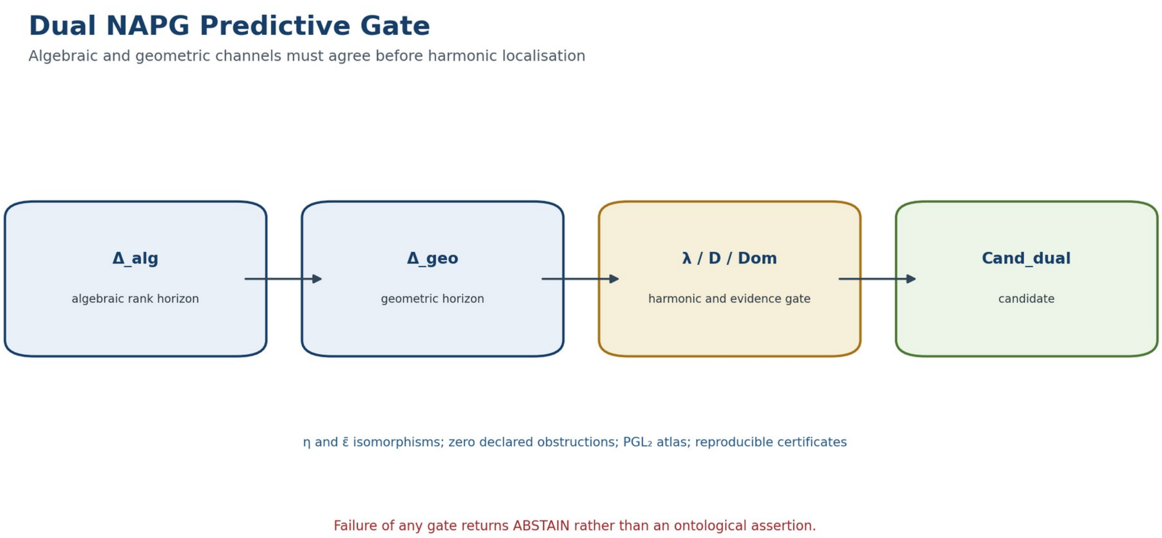

Figure 10. Double NAPG/KLT-RBD predictive gate. English reconstruction of the authorial diagram in the frozen Russian Volume II.

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6.7.2. Main Conditional Theorem of Candidate Transport

Theorem 6.26. Functorial Predictive Transport [COND] Assume H1-H8 below. Then Cand_dual is invariant under isomorphisms of the family A_t, projective-Reper isomorphisms of X_t, and projective coordinate changes on the parameter line. If a path does not cross the common horizon, the algorithm must return NO-STRUCTURAL-CHANGE-IN-MODEL. If Block_dual is nonempty, it must return ABSTAIN.

- H1. $t \mapsto A\_t$ is a finite-dimensional algebraic or analytic family with computable Δ_alg.
- H2. An adjoint pair Spec_R⊣Gamma_R exists.
- H3. $\eta\_\{A\_t\}$ and $\bar{\varepsilon}\_\{X\_t\}$ are isomorphisms in the studied neighbourhood.
- H4. Structural maps satisfy the Conjugacy Bridge 6.20.
- H5. X_t carries a projective Reper atlas.
- H6. D/Dom are valid and fixed before testing.
- H7. Internal obstructions and all declared external obstructions vanish.
- H8. Computational certificates for the algebraic and geometric channels are reproducible.

Proof. Isomorphism invariance of the algebraic horizon was proved in Chapter 5. Theorem 6.21 transports it to the geometric layer. Theorems 6.16 and 6.19 provide invariance of λ. H6-H8 preserve the evidence gates. Hence the Boolean selector Cand_dual is representation-independent. The negative branch follows from constant ranks outside the horizon; the ABSTAIN branch is the definition of the blocker-safe protocol. □

Phenomenological element	Meaning
Observable	The geometric channel shows how structural possibility appears in configuration space.
Foundation	The algebraic channel fixes which operation, associator, and ideal actually change rank.
Coordination	Projective-harmonic λ localises a symmetric Reper candidate, but only inside the common determinantal horizon.
Abstention	When the channels disagree, the system does not guess a hidden meaning; it returns ABSTAIN and a register of missing bridges.

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6.8. Geometric Meaning of R⋆R

ONTOLOGY	Nonassociativity is treated as intrinsic structure, not as a computational error.
EPISTEMOLOGY	It is known through the associator, nuclei, ideals, invariants, and explicit countermodels.
PHENOMENOLOGY	It appears as dependence of the result on the bracketing architecture of a packet.
LIMITATION	A nonzero associator is not by itself physical curvature or a physical event.
AUTHORIAL NOVELTY	The authorial node is R⋆R and its role in packet Reper-harmonic geometry.

6.8.1. Representable Image of the Associator

For $T\in\mathscr{C}$, every T-point $x:A\to T$ transports the associator by

$$x(Ass\_A(a,b,c)) = Ass\_T(xa,xb,xc).$$

Consequently the R⋆R certificate of Chapter 5 defines a natural family of functions on the functor of points. Its zero locus on a test object T is

$$Z\_Ass(T)=\{x\in h\_A(T): x(J\_Ass(A))=0\}.$$

Proposition 6.27. Representability of the Associative Reflection [THM] For test objects and morphisms for which A/J_Ass exists in $\mathscr{C}$, Z_Ass(T)≅Hom_$\mathscr{C}$(A/J_Ass(A),T).

Proof. A morphism $x:A\to T$ kills J_Ass exactly when it factors uniquely through the universal associative reflection A→A/J_Ass. □

Thus the associative geometric layer is a representable subfunctor of the full NAPG geometry. “Geometry sees the associator” now means a factorisation locus rather than a metaphor.

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6.8.2. Geometry of Nuclei and the Center

For every test T, define subfunctors N_l,N_m,N_r,N,Z by vanishing of the corresponding natural associator and commutator functions. Under finite representability they are systems of polynomial equations in structural coordinates.

Proposition 6.28. Functoriality of Nucleus Loci [THM] NAPG isomorphisms transport the loci N_l,N_m,N_r,N,Z into one another. Their dimension profiles are invariants on the reconstructible geometric layer.

Proof. The loci are defined by natural identities Ass=0 and [a,b]=0, preserved by morphisms. □

ONTOLOGY	A computational object exists only together with inputs, an algorithm, and a reproducible certificate.
EPISTEMOLOGY	Knowledge is supported by repeatability, exact tests, and control of numerical conditioning.
PHENOMENOLOGY	It appears as agreement between expected and computed invariants.
LIMITATION	A successful run proves neither a universal theorem nor an empirical claim.
AUTHORIAL NOVELTY	The authorial contribution is a proof-carrying computational circuit within KLT-RBD.

6.9. Computational Certificate

ONTOLOGY	Only a typed structure with declared domain and codomain counts as an object.
EPISTEMOLOGY	Knowledge is obtained by checking morphisms, commutative diagrams, and admissible domains.
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6.9.1. Required Data Objects

ID	Object	Certificate fields
DUAL-OBJ	Algebra / geometry	object_id, version, basis/atlas, source hash, status
DUAL-FUN	Spec / Gamma	domain, codomain, object map, morphism map, identity/composition tests
DUAL-UNIT	η / $\bar{\varepsilon}$	matrix or symbolic map, rank, inverse witness, defect
DUAL-REP	Reper atlas	charts, PGL_2 transition matrices, overlap tests, pole set
DUAL-HOR	Horizons	minor polynomials, generic rank, Δ_alg, Δ_geo, symmetric difference
DUAL-GATE	Predictive gate	λ, δ_truth, D/Dom, Π, blockers, output

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AUTHORIAL NOVELTY	The authorial contribution is a proof-carrying computational circuit within KLT-RBD.

6.9.2. Automatic Tests

- TEST-YONEDA-01: verify the bijection Hom(A,B)↔Nat(h_B,h_A) on a finite test subcorpus;
- TEST-FUN-02: preserve identities and composition for Spec_R/Gamma_R;
- TEST-ADJ-03: verify the natural Hom bijection and triangular identities;
- TEST-REC-04: exact invertibility tests for η and $\bar{\varepsilon}$;
- TEST-PGL-05: verify that every chart transition is represented by an invertible 2×2 matrix up to scalar;
- TEST-CR-06: equality of cross-ratio in all overlapping charts;
- TEST-NONPGL-07: mandatory negative test on a nonlinear chart;
- TEST-HOR-08: equality of Δ_alg and Δ_geo;
- TEST-GATE-09: ABSTAIN for every nonzero blocker;
- TEST-HASH-10: control hashes of code, data, matrices, and report.

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6.9.3. Blocker-Safe Algorithm

```
INPUT: family A_t, realisation X_t, Reper ρ_t, evidence D_t
1. compute Δ_alg; 2. compute Δ_geo; 3. test η and ε̄;
4. verify the PGL₂ atlas and λ; 5. evaluate Π and D/Dom;
6. if Block_dual ≠ ∅: return ABSTAIN;
7. if path ∩ Δ_alg = ∅: return NO-STRUCTURAL-CHANGE-IN-MODEL;
8. if t ∈ Δ_alg=Δ_geo and λ=-1: return CANDIDATE;
9. otherwise: return UNRESOLVED-HORIZON.
```

Chapter 7. Atlases, Bundles, and Globalisation Obstructions

ONTOLOGY	A global object exists only after effective gluing of local data.
EPISTEMOLOGY	Globality requires cocycle, descent, and compatibility on triple overlaps.
PHENOMENOLOGY	Local solutions appear as compatible or conflicting charts.
LIMITATION	Pairwise agreement does not guarantee a global section.
AUTHORIAL NOVELTY	The authorial contribution is a globalisation-safe KLT-RBD gate and an explicit blocker register.

This chapter separates local NAPG descriptions from genuinely global objects. A cover of charts, even one whose pairwise overlaps look consistent, does not define a bundle until the transition arrows satisfy an associative cocycle and the declared algebraic, Reper, Hodge, and Evidence-D data descend effectively. The predictive consequence is strict: a family of local candidates is not a global scenario unless it is the restriction of an admissible global section.

7.1. NAPG Atlases and the Transition Groupoid

ONTOLOGY	Only a typed structure with declared domain and codomain counts as an object.
EPISTEMOLOGY	Knowledge is obtained by checking morphisms, commutative diagrams, and admissible domains.
PHENOMENOLOGY	The structure appears as the ability to transport data correctly without loss of type.
LIMITATION	Similarity of notation neither licenses composition nor proves existence.
AUTHORIAL NOVELTY	The authorial contribution is the packet-Reper typing of NAPG and the inclusion of D/Dom in the object itself.

Definition 7.1. Local NAPG Model [DEF-A] A local model is an object F of NAPG_q equipped with the chosen topology or smooth structure on its carriers. The group Aut_NAPG(F) of admissible continuous or smooth automorphisms is regarded as a topological group only when that topology has been supplied; otherwise only the categorical formulation is licensed.

Definition 7.2. NAPG Atlas [DEF-A] An atlas of type F on X consists of an open cover {U_i}, local objects E_i=U_i x F, and overlap isomorphisms phi_ij:E_i|U_ij -> E_j|U_ij. Every phi_ij preserves grading, the operation odot, structural data G, admissible domains, the R-star-R layer, and each evidential field declared global.

phi_ii = id, phi_ji = phi_ij^{-1}, phi_jk o phi_ij = phi_ik on U_ijk.	**T2-F014**

Definition 7.3. Structural Groupoid [DEF-A] Objects are local NAPG models over charts and arrows are admissible overlap isomorphisms. Composition is ordinary composition of maps and remains associative even when the fibre operation odot is nonassociative.

Theorem 7.4. Associative Transition Groupoid Is Necessary [THM] Ordinary gluing of local NAPG objects requires transition data to form a category or groupoid with associative composition. The fibre operation odot cannot itself serve as the transition law unless additional 2-morphisms and explicit coherence data are supplied.

Proof. The quotient of the disjoint union of local trivialisations requires a transitive equivalence relation. On a fourfold overlap the two composites (phi_34 o phi_23) o phi_12 and phi_34 o (phi_23 o phi_12) must agree. Ordinary maps satisfy this identity. A transition law with a nonzero associator makes the equivalence class depend on bracketing and leaves the quotient undefined. A bicategorical repair is a separate OPEN layer. □

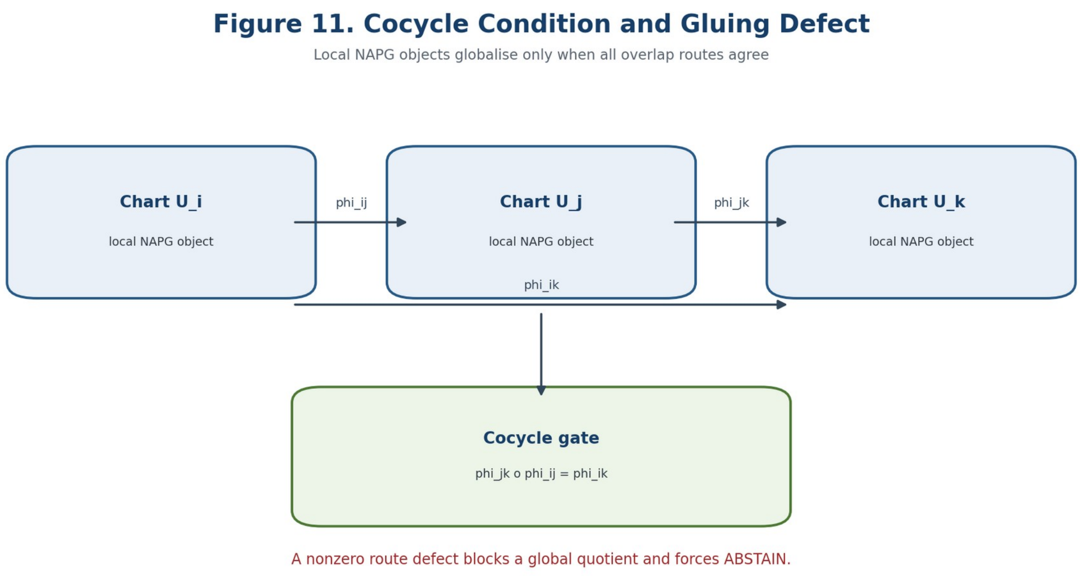


Figure 11. Cocycle condition and gluing defect of local NAPG objects. English reconstruction of the authorial scheme in the frozen Russian Volume II.

7.1.2. Projective-Reper Atlas

Definition 7.5. Projective-Reper Chart [DEF-A] A chart over U_i consists of kappa_i:U_i->P^1(K), a local Evidence-D package E_D,i, and a class of admissible Reper quadruples. On overlaps one requires kappa_j o kappa_i^{-1} in PGL_2(K) together with compatible transport of E_D,i.

Theorem 7.6. Globality of lambda [THM] If every transition belongs to PGL_2(K), the cross-ratio lambda(u,i;r,d) and the harmonic locus lambda=-1 are chart-independent. If a transition fails to preserve cross-ratio, lambda remains only a local coordinate.

Proof. Cross-ratio is invariant under PGL_2. Equality on every overlap therefore glues the local values to a global function on the admissible quadruple space. No converse is claimed for a finite sample of values, since a nonprojective map may accidentally preserve selected quadruples without preserving cross-ratio globally. □

7.2. Descent Data and the Gluing Theorem

ONTOLOGY	A global object exists only after effective gluing of local data.
EPISTEMOLOGY	Globality requires cocycle, descent, and compatibility on triple overlaps.
PHENOMENOLOGY	Local solutions appear as compatible or conflicting charts.
LIMITATION	Pairwise agreement does not guarantee a global section.
AUTHORIAL NOVELTY	The authorial contribution is a globalisation-safe KLT-RBD gate and an explicit blocker register.

Definition 7.7. Descent Datum [CL / DEF-A] For a fibred category p:S->C and a cover U_i->U, a descent datum consists of objects X_i over U_i and isomorphisms phi_ij:pr_0^*X_i->pr_1^*X_j over U_i x_U U_j satisfying the triangle identity on the triple fibre product. In NAPG, the X_i are local packet-Reper structures.

pr_12^* phi_jk o pr_01^* phi_ij = pr_02^* phi_ik on U_i x_U U_j x_U U_k.	**T2-F015**

Definition 7.8. Effective Descent [CL / COND] A descent datum is effective if it is induced by a global object X over U. The cocycle condition is necessary but, in a general fibred category, not sufficient; sufficiency is a stack or effective-descent property of the selected class of objects.

Theorem 7.9. Gluing of an NAPG Bundle [THM] Let X be paracompact Hausdorff, F a topological NAPG object, and G=Aut_NAPG(F) a topological group. Continuous maps g_ij:U_ij->G satisfying g_ii=e, g_ji=g_ij^{-1}, and g_ij g_jk=g_ik define a locally trivial NAPG bundle E=(disjoint union U_i x F)/~. Its isomorphism class depends only on the gauge class of the cocycle.

Proof. Set (x,v,i)~(x,g_ji(x)v,j). Reflexivity and symmetry follow from the first two identities; transitivity follows from the cocycle. The local inclusions give trivialisations. Since every g_ij is an NAPG automorphism, the grading, operation, structural data, and declared invariants descend. Gauge-related cocycles produce an explicit bundle isomorphism. □

Counterexample 7.10. Pairwise Compatibility Is Not Enough [THM / COUNTEREXAMPLE] Choose three charts with nonempty triple overlap and transitions satisfying g_23 g_12 != g_13. Every pair may be glued in isolation, but the transition from chart 1 to chart 3 depends on the route. No unique global quotient exists.

For KLT-RBD this means that pairwise consistency of sources or models does not establish consistency of the full formula cycle. Triple and higher-route audits are mandatory whenever alternative derivation paths exist.

7.3. Algebra, Reper, and Hodge Bundles

ONTOLOGY	A global object exists only after effective gluing of local data.
EPISTEMOLOGY	Globality requires cocycle, descent, and compatibility on triple overlaps.
PHENOMENOLOGY	Local solutions appear as compatible or conflicting charts.
LIMITATION	Pairwise agreement does not guarantee a global section.
AUTHORIAL NOVELTY	The authorial contribution is a globalisation-safe KLT-RBD gate and an explicit blocker register.

Definition 7.11. Bundle of NAPG Algebras [DEF-A] An NAPG algebra bundle is a locally trivial vector or module bundle E->X with local operations odot_i such that every transition satisfies g_ij(a odot_j b)=g_ij(a) odot_i g_ij(b) and preserves Dom_odot.

Theorem 7.12. Descent of the Operation [THM] Under Definition 7.11 the local operations glue to a unique fibrewise operation odot:Dom_odot subset E x_X E -> E. The associator, left/middle/right nuclei, and J_Ass form global subbundles wherever their ranks are locally constant.

Definition 7.13. Operation Descent Defect [DEF-A] For transitions that are merely linear isomorphisms, define q_ij(a,b)=g_ij(a odot_j b)-g_ij(a) odot_i g_ij(b). A nonzero q_ij blocks a global operation even when the transition cocycle is perfect.

q_ij(a,b)=g_ij(a odot_j b)-g_ij(a) odot_i g_ij(b).	**T2-F016**

Definition 7.14. Reper Bundle [DEF-A] The fibre of Rep(E)->X consists of admissible quadruples (R,I,U;d) together with an Evidence-D package. Transitions act on the geometric anchor d and on the provenance object E_D; transport of E_D must be traceable and reversible.

Theorem 7.15. Double Descent of Reper [COND] A global Reper exists only when both geometric descent of the quadruple and evidential descent of Evidence-D are effective. Failure in either channel yields ABSTAIN even when every local chart satisfies lambda=-1.

Definition 7.16. Hodge-Compatible Atlas [DEF-A] For fixed-rank oriented metric fibres, an atlas is Hodge-compatible when transitions are orientation-preserving isometries and preserve the declared class of differential forms.

Theorem 7.17. Descent of the Hodge Star [THM] In a Hodge-compatible atlas the local Hodge stars glue to a global fibrewise operator. An orientation-reversing transition introduces a sign; O(n)-compatibility alone is insufficient without an orientation local system.

7.4. Cohomologicalical Globalisation Obstructions

ONTOLOGY	An obstruction is a class of failure of a lift inside a declared structure.
EPISTEMOLOGY	It is established by complexes, quotient spaces, and independence from representatives.
PHENOMENOLOGY	It appears as a residual component that cannot be removed by an admissible correction.
LIMITATION	A zero primary class does not exclude higher obstructions and proves no physical realisation.
AUTHORIAL NOVELTY	The authorial contribution is the internal carrier, its external bridge, and its use in the Reper predictive gate.

For a central extension 1->Z->G_tilde->G->1, local lifts of a G-valued transition cocycle need not satisfy the cocycle identity. Their triple-overlap defect z_ijk is central and defines the obstruction to lifting the structure group.

Theorem 7.19. Central Obstruction Class [THM / COND] The family z_ijk is a Cech 2-cocycle with coefficients in the sheaf Z. Its class [z] in Cech H^2(X,Z) is independent of the chosen local lifts. Under the standard effectiveness hypotheses, the principal G-bundle admits a G_tilde lift iff [z]=0.

[z] in Cech H^2(X,Z), G-tilde lift exists iff [z]=0.	**T2-F017**

Figure 12. Central Extension and Cech H2 Obstruction

A principal G-bundle lifts to G~ only after the central cocycle vanishes

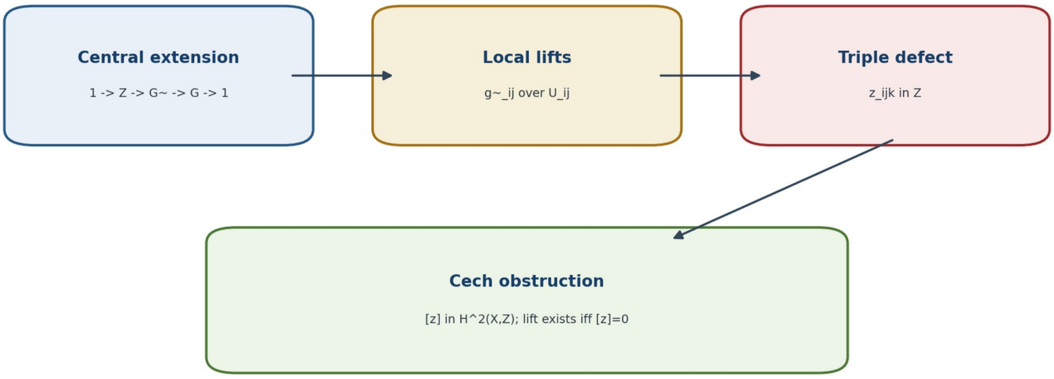


Figure 12. Central extension and Cech H2 obstruction to lifting the structure group.

Definition 7.20. Globalisation Defect Vector [DEF-A] For an atlas A set Def_glue(A)=(c,q,a,p,h,d,s), where c is the transition cocycle defect, q the operation descent defect, a the coherence defect of the associator layer, p nonprojectivity of Reper charts, h Hodge incompatibility, d the Evidence-D/Dom defect, and s the obstruction to the required global section.

Def_glue(A)=(c,q,a,p,h,d,s).	**T2-F018**

Theorem 7.21. Cellular Obstruction Tower [CL / COND] For a fibration p:E->X over a CW complex with connected simple fibre F, extension of a partial section from the k-skeleton to the (k+1)-skeleton is governed by o_{k+1} in H^{k+1}(X;pi_k(F)_rho). Vanishing of the successive classes, with the standard completeness assumptions, yields a global section.

Consequently, locally admissible scenarios do not guarantee a single global scenario. The coefficient module and monodromy action must be built for the actual model.

7.5. Globalisation Horizons and Negative Prediction

Definition 7.22. Parametric NAPG Bundle [DEF-A] A family over an interval I is an NAPG object E->X x I whose restriction E_t->X is the state at parameter t. The transition maps g_ij(x,t) remain continuous and lie in Aut_NAPG(F) on the admissible domain.

Theorem 7.23. Homotopy Constancy [THM] If E->X x I is a numerable NAPG bundle with fixed structural groupoid and effective descent over all of X x I, then E_t0 and E_t1 are isomorphic for all t0,t1 in I. The discrete bundle isomorphism class cannot change inside one admissible continuous family.

Corollary 7.24. Negative Global Prediction [THM] A topological change of the NAPG bundle is impossible while the family remains defined and effective, the structural groupoid remains fixed, and no globalisation horizon is crossed. An observed change of discrete class forces failure of at least one hypothesis.

Definition 7.25. Globalisation Horizon [DEF-A] Define Delta_glue as the union of the cocycle, effectiveness, operation, associator, chart, Hodge, Dom, D, and section-failure loci. Each component is the parameter set where the corresponding gluing or section condition loses its certificate.

Delta_glue = Delta_coc union Delta_eff union Delta_op union Delta_ass union Delta_chart union Delta_Hdg union Delta_Dom union Delta_D union Delta_sec.	T2-F019

Theorem 7.26. Localisation of a Possible Global Transition [COND] Under the hypotheses of Theorem 7.23, a discrete algebraic-geometric bundle profile can change only on Delta_total. Outside Delta_total it is locally constant. Membership in the horizon is necessary, not sufficient, for a transition.

7.6. Predictive Reper Bundle

Definition 7.27. Predictive Reper Bundle [DEF-A] Let X encode domains, sources, or space-time windows, and let F_x be the admissible future Reper states at x. A predictive Reper bundle p:P->X carries these fibres, chart transitions, and an admissible subspace fixed by D/Dom, obstructions, and subject-matter limits.

Definition 7.28. Globally Admissible Scenario [DEF-A] A scenario is a section s:X->P. It is globally admissible only when local representations agree under transitions, Evidence-D has effective descent, and every mandatory blocker is empty.

Definition 7.29. Global Structural Candidate [DEF-A] A section has status GLOBAL-CANDIDATE when Block_glue is empty, the internal obstruction vanishes, all declared external obstruction classes vanish, lambda satisfies a predeclared exact or interval criterion, and independent computational checks pass.

Theorem 7.30. No Local-to-Global Substitution [THM] Local candidates s_i with lambda_i=-1 and Pi_i=0 do not form a global candidate when transition compatibility fails or the global-section obstruction is nonzero. An algorithm returning EVENT in that situation violates the v0.5 specification.

Main Conditional Theorem 7.31. Globalisation-Safe Predictive Transport [COND] Assume effective NAPG descent, descent of operation and associator, a projective-Reper atlas, Hodge compatibility when used, proved Evidence-D transport, vanishing of internal and declared external obstructions, existence of a global admissible section, and reproducible local and global certificates. Then GLOBAL-CANDIDATE is invariant under refinement of the cover, gauge-equivalence of cocycles, NAPG isomorphisms, and projective changes of Reper charts.

The theorem concerns invariance of a structural candidate inside the formal model. It proves no physical, chemical, biological, or economic event without a domain adapter, data, and independent validation.

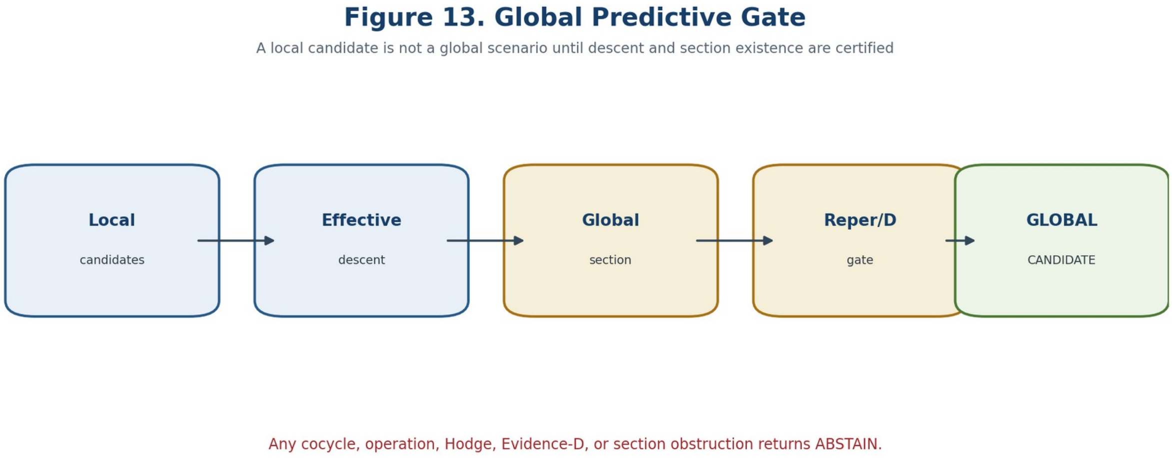


Figure 13. Global predictive gate: a local candidate is admitted only after effective descent and existence of a global section.

7.7. Models, Certificate, and Blocker-Safe Algorithm

> **Example 7.32. Moebius No-Go [CL / EXAMPLE]** The Moebius strip and the cylinder are locally products of an interval and a line. Their distinction is entirely in the overlap transition: -1 versus +1. The global object cannot be reconstructed from the local fibre alone.

> **Example 7.33. Associator Rank Horizon [COND]** For local algebras A_t with associator matrix M_Ass(t), constant rank and effective operation descent give nucleus subbundles of constant rank. A rank change can occur only on the determinantal locus or when operation descent fails.

Certificate object	Required fields
Atlas	cover, overlap list, transition maps, chart versions
Cocycle	double/triple-overlap residuals, gauge class
Operation descent	q_ij, Dom_odot transport, associator compatibility
Reper descent	PGL_2 matrices, lambda parity, Evidence-D provenance
Hodge descent	metric/orientation transport or orientation local system
Section witness	local sections, compatibility, obstruction classes
Verdict	blocker set, GLOBAL-CANDIDATE / ABSTAIN, hashes

- TEST-ATLAS-01: verify that the charts cover X and no unlabelled region remains;
- TEST-INV-02: verify phi_ji o phi_ij=id on every double overlap;
- TEST-COC-03: verify phi_jk o phi_ij=phi_ik on every triple overlap;
- TEST-OP-05: verify q_ij=0 and preservation of Dom_odot;
- TEST-PGL-07: verify PGL_2 Reper transitions and equality of lambda;
- TEST-D-08: verify reversible Evidence-D transport and provenance hashes;
- TEST-SEC-11: verify that local sections form a global witness;
- TEST-GATE-12: force ABSTAIN for every nonzero blocker.

```
INPUT: atlas, local NAPG objects, transitions, local candidates, Evidence-D
CHECK cover, inverse identities, triple cocycle, and refinement invariance
CHECK operation/associator descent, PGL2 Reper charts, Hodge transport
COMPUTE internal and external obstruction classes and section witness
IF any blocker is nonzero or uncertified: RETURN ABSTAIN
IF a certified path avoids Delta_glue: RETURN NO-GLOBAL-STRUCTURAL-CHANGE-IN-MODEL
IF horizon crossed and global section exists: RETURN GLOBAL-CANDIDATE
ELSE: RETURN ABSTAIN
```

Chapter 8. Tangent and Cotangent Objects of NAPG

ONTOLOGY	A tangent direction records only the first order of a possible change.
EPISTEMOLOGY	It is known after genuine deformations are separated from gauge directions and higher obstructions are tested.
PHENOMENOLOGY	It appears as local sensitivity of structure to parameter variation.
LIMITATION	A tangent candidate is neither an integrable trajectory nor an event.
AUTHORIAL NOVELTY	The authorial node joins the deformation complex to R-star-R, lambda, and a blocker-safe lift gate.

The chapter distinguishes four notions often compressed into the word tangent: dual-number lifts, first-contact classes of curves, the cotangent module, and the linearisation of the space of algebraic operations. Their agreement requires explicit smoothness, representability, field, and finite-generation hypotheses. In singular sectors, the Zariski tangent space may contain directions that are not velocities of any admissible arc.

8.1. Four Tangent Constructions

Definition 8.1. Dual-Number Tangent [CL / DEF-A] For a functor of points X and x in $X(K)$, define T_xX as the fibre of $X(K[\epsilon]/\epsilon^2)\to X(K)$ over x. A vector-space structure is asserted only after the deformation-functor hypotheses have been checked.

Lemma 8.2. Derivation Representation [THM] For an affine local object A and K-rational point $x:A\to K$, a map $a\mapsto x(a)+\epsilon D(a)$ is a homomorphism iff D is a K-derivation relative to x. Hence T_xX is naturally identified with $\mathrm{Der}_K(A,K_x)$.

Proof. Comparison of the epsilon coefficients in $f(ab)=f(a)f(b)$ gives $D(ab)=x(a)D(b)+D(a)x(b)$. Conversely this identity makes the lift multiplicative because $\epsilon^2=0$. □

Definition 8.3. Curve Tangent [CL / COND / OPEN] In a smooth sector, admissible curves through x are equivalent when their coordinate derivatives at zero agree. For a singular, algebraic, or partially defined NAPG object this construction depends on the chosen class of arcs and is not universal without a comparison theorem.

Definition 8.4. Kahler Cotangent Module [CL / COND] For a commutative coordinate algebra A over K, $\Omega_{A/K}$ with the universal derivation represents K-derivations. In NAPG it is applied to a commutative coordinate envelope; genuinely noncommutative or nonassociative differential modules require separate definitions.

Definition 8.5. Cotangent at a Rational Point [CL] For maximal ideal m_x and residue field K, $T_x^*X=m_x/m_x^2$ and $T_xX=\mathrm{Hom}_K(m_x/m_x^2,K)$. At a nonrational point the base is the residue field $\kappa(x)$.

$$T_x^*X=m_x/m_x^2,\quad T_xX=\mathrm{Hom}_K(m_x/m_x^2,K). \qquad \text{T2-F020}$$

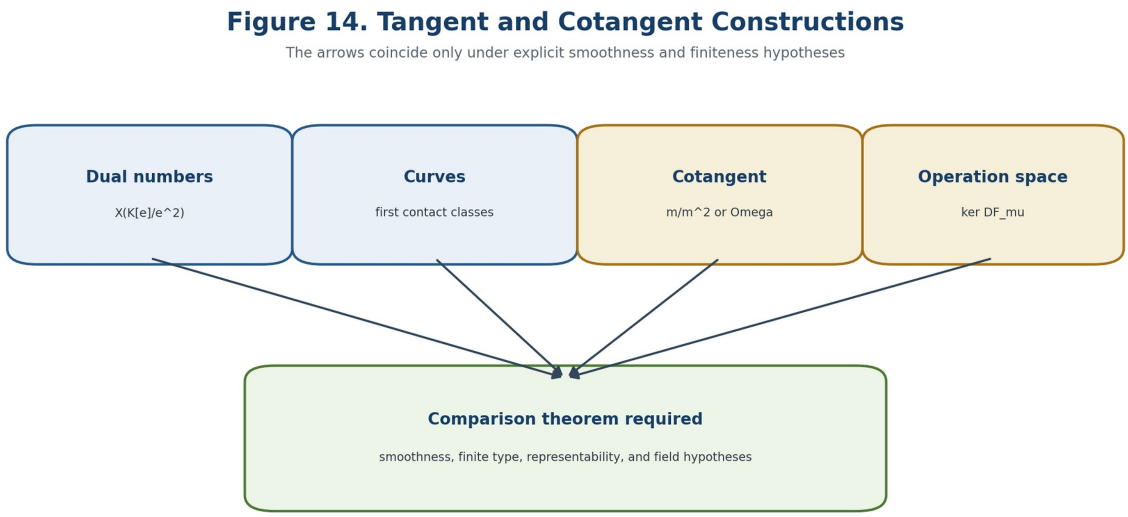


Figure 14. Comparison of tangent and cotangent constructions; coincidence requires explicit hypotheses.

8.2. Tangent Cone and Singular Sector

Definition 8.6. Algebraic Tangent Cone [CL] For the local ring (O_X,x,m_x), set gr_m O_X,x = direct sum m_x^n/m_x^{n+1}. The tangent cone C_xX=Spec(gr_m O_X,x) retains the initial homogeneous parts of the local equations.

Proposition 8.7. Cone-to-Tangent Inclusion [CL / THM] The reduced support of C_xX embeds in the Zariski tangent space. At a smooth point the cone is a vector space and equals the tangent space; at a singular point its linear span may be strictly larger than the cone.

Example 8.8. Node No-Go [THM / EXAMPLE] For X={xy=0} at the origin, the Jacobian vanishes, so the Zariski tangent space is all of A^2. The tangent cone is the union of the coordinate axes. A vector such as (1,1) passes the linear test but is not the leading velocity of an admissible analytic arc on X.

Example 8.9. Hidden Infinitesimal Thickness [CL / EXAMPLE] Spec K[epsilon]/epsilon^2 has one topological point but a one-dimensional tangent space. A point set or incidence graph therefore cannot reconstruct all NAPG deformations.

8.3. Linearisation of the Space of NAPG Operations

Definition 8.10. Ambient Operation Space [DEF-A] For finite-dimensional graded A, let C^2_adm(A,A) be the admissible bilinear variations respecting grading, Dom_odot, and frozen structural data. The NAPG structures are the zeros F(mu)=0 inside an admissible sector U_adm.

M_NAPG={mu in U_adm subset C^2_adm(A,A): F(mu)=0}.	**T2-F021**

Definition 8.11. Linearised Structure Space [DEF-A] At mu in M_NAPG define Z^2_NAPG(mu)=ker D F_mu. These are formal first-order variations preserving the chosen equations to order t.

Theorem 8.12. Differential of the Associator [THM] For bilinear operations mu and nu, the derivative of Ass at mu in direction nu is DAss_mu(nu)(a,b,c)=nu(mu(a,b),c)+mu(nu(a,b),c)-nu(a,mu(b,c))-mu(a,nu(b,c)). Moreover Ass_{mu+t nu}=Ass_mu+t DAss_mu(nu)+t^2 Ass_nu.

Ass_{mu+t nu}=Ass_mu+t DAss_mu(nu) +t^2 Ass_nu.	T2-F022

Definition 8.14. Gauge Differential [DEF-A] For structural endomorphisms xi, d^1_mu(xi)(a,b)=xi(mu(a,b))-mu(xi a,b)-mu(a,xi b). Its kernel is the structural derivation space and its image is tangent to the admissible change-of-basis orbit.

d^1_mu(xi)(a,b)=xi(mu(a,b))-mu(xi a,b)-mu(a,xi b).	T2-F023

Definition 8.16. Reduced Tangent Space [DEF-A] When im d^1_mu is contained in Z^2_NAPG(mu), set H^2_red(mu)=Z^2_NAPG(mu)/im d^1_mu. It classifies first-order deformations modulo infinitesimal gauge but does not assert integrability.

H^2_red(mu)=Z^2_NAPG(mu)/im d^1_mu.	T2-F024

Figure 15. Two-Term NAPG Tangent Complex

Stabilisers, formal deformations, and the second-order obstruction

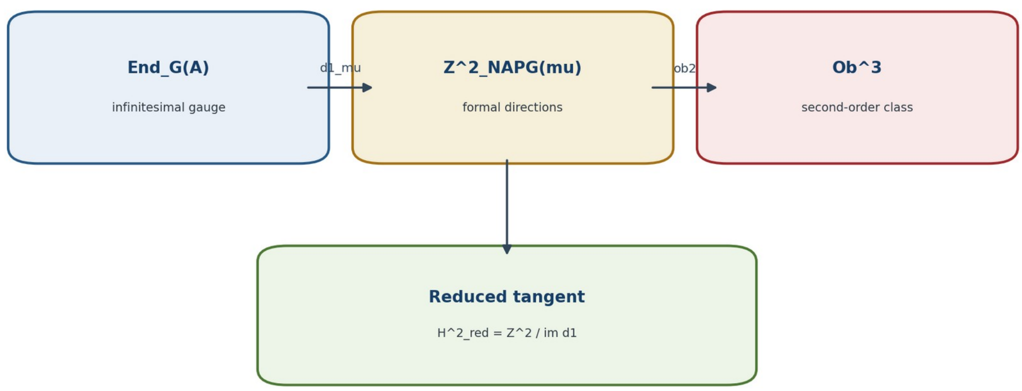


Figure 15. Two-term NAPG tangent complex: stabilisers, first-order deformations, and second-order obstruction.

8.4. Tangent Complex and Cotangent Duality

Definition 8.17. Tangent Complex [DEF-A] For the quotient presentation, use T_mu^bullet=[End_G(A) --d^1_mu--> Z^2_NAPG(mu)] in degrees -1 and 0. Its H^{-1} is the derivation/stabiliser space and H^0 is H^2_red(mu).

Theorem 8.18. No Canonical Self-Duality [CL / THM] A general finite-dimensional vector space V has no natural isomorphism V congruent V^* without an additional nondegenerate bilinear form. Only the evaluation map V->V^{**} is canonical, and it is an isomorphism in the finite-dimensional or finite-projective regime.

Corollary 8.19. NAPG Duality Boundary [THM / COND] The cotangent complex cannot automatically be identified with the tangent complex. Dualisation requires finite projectivity; identification requires a chosen pairing or metric compatible with gauge and descent.

HODGE BOUNDARY. The Hodge star acts on exterior degrees after a metric and orientation are chosen. It does not itself produce a canonical self-duality of the deformation tangent module.

8.5. Second-Order Obstruction and Integrable Arcs

Let mu_t=mu+t nu+t^2 w+O(t^3) be a proposed deformation. The order-t equation places nu in Z^2_NAPG(mu); the order-t^2 equation has the form D F_mu(w)+Q_mu(nu,nu)=0. The class of Q_mu(nu,nu) in the appropriate obstruction quotient is independent of the chosen correction and is the primary second-order obstruction.

Definition 8.20. Second-Order Obstruction Class [DEF-A] For a formal tangent direction nu, define ob_2(nu) as the class of the quadratic coefficient Q_mu(nu,nu) modulo im D F_mu.

ob_2(nu)=[Q_mu(nu,nu)] in C^3_red/im D F_mu.	**T2-F025**

Theorem 8.21. Second-Order Lift Criterion [THM] A correction w solving the second-order equation exists iff ob_2(nu)=0. When solutions exist, the set of corrections is an affine space over ker D F_mu.

Theorem 8.22. Tangent Is Not an Arc [THM] Membership of nu in H^2_red(mu) is necessary for a first-order deformation class but does not by itself imply the existence of an analytic or formal arc. Higher obstruction classes and convergence may still fail.

8.6. Differential of lambda and Projective Invariance

On an affine chart, lambda=((u-r)(i-d))/((u-d)(i-r)). Differentiation is permitted only off the pole divisor and only after the four Reper components have typed tangent directions.

d log lambda = (du-dr)/(u-r)+(di-dd)/(i-d)-(du-dd)/(u-d)-(di-dr)/(i-r).	**T2-F026**

Theorem 8.29. Infinitesimal PGL2 Invariance [THM] If r,i,u,d move under one common infinitesimal sl_2 field on P^1, then d lambda=0 away from poles. A nonzero derivative detects relative motion among the four Reper components, not a common projective coordinate change.

Theorem 8.31. First-Order Blindness at Exact Harmony [THM] For q=|lambda+1|^2, Dq(v)=2 Re(conj(lambda+1) Dlambda(v)). At lambda=-1, Dq vanishes in every direction. The second differential, containing 2|Dlambda(v)|^2, is the first nondegenerate test when Dlambda(v) is nonzero.

lambda=-1 implies D|lambda+1|^2=0; D^2 q(v,v) contains 2|Dlambda(v)|^2.	**T2-F027**

8.7. Linearised Horizon and Local Predictive Cone

Definition 8.32. Structural Constraint Map [DEF-A] Let G=(F_NAPG,Pi,h,B_D,B_Dom,B_glue), with h=lambda+1. At a point x with G(x)=0, the linearly admissible directions form ker D G_x.

Definition 8.33. Integrable Predictive Direction [DEF-A] A direction v receives status INT-DIR only if it lies in the tangent cone of G^{-1}(0), has a second-order witness, is realised by an admissible arc, transports Evidence-D and Dom, satisfies the required jet-order harmonic criterion, and has an empty blocker set.

Block_tan=B_rank union B_cone union B_ob2 union B_arc union B_dual union B_lambda union B_D union B_Dom union B_glue.	**T2-F028**

Theorem 8.34. Tangent-Safe Predictive Transport [COND] Under an NAPG isomorphism preserving the constraint map, gauge action, projective-Reper atlas, Evidence-D, and descent, an integrable predictive direction is transported to an integrable direction and its INT-DIR status is invariant.

Theorem 8.35. No Event from Tangent Data Alone [THM] A nonzero H^2_red, a large Zariski tangent space, or a direction decreasing a local diagnostic does not imply a future event. Without cone, obstruction, and arc witnesses the only allowed statuses are FORMAL-DIRECTION or ABSTAIN.

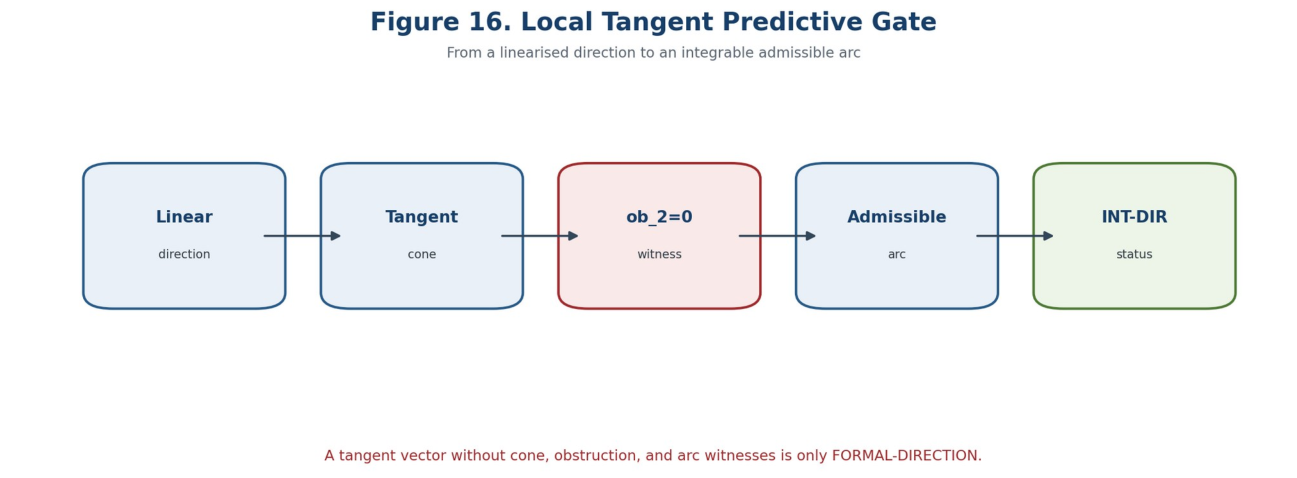


Figure 16. Local predictive gate from a linear direction to an integrable admissible arc.

8.8. Tangent/Cotangent Computational Certificate

Object	Certificate
Ambient operation space	basis, grading, Dom, structural equations F
Linearisation	exact Jacobian D F_mu, rank, kernel basis
Gauge action	d^1_mu matrix, derivation kernel, orbit rank
Singular geometry	initial ideal, tangent cone, arc witnesses
Second order	quadratic coefficient, obstruction quotient, correction witness
Reper tangent	PGL2 chart, pole audit, d lambda, Hessian at harmony
Verdict	FORMAL-DIRECTION / INT-DIR / ABSTAIN and blocker list

- TEST-TAN-01: verify the types and sizes of C^2_adm, F, and D F;
- TEST-DER-02: compare ker d^1 with direct derivation equations;
- TEST-CONE-06: compute the initial ideal and tangent cone in exact arithmetic;
- TEST-NODE-07: reject direction (1,1) for xy=0 at the cone/arc gate;
- TEST-ASS-08: verify Ass_{mu+t nu}=Ass_mu+t DAss_mu(nu)+t^2 Ass_nu;
- TEST-OB2-09: solve the second-order equation or return an obstruction class;
- TEST-LAM-10: confirm invariance of d lambda under a common PGL2 motion;
- TEST-GATE-13: absence of an arc witness forces FORMAL-DIRECTION or ABSTAIN.

Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature

ONTOLOGY	A connection compares fibres; curvature measures the defect of this comparison.
EPISTEMOLOGY	Knowledge is obtained from parallel transport, small loops, and typed action on the associator.
PHENOMENOLOGY	The phenomenon is path memory and variation of structural tensors.
LIMITATION	Holonomy is not the associator and is not automatically causality.
AUTHORIAL NOVELTY	The authorial node is associator curvature as a typed bridge between NAPG and transport.

This theorem/conditional package separates the classical geometry of connections and holonomy from the authorial NAPG bridge. Parallel transport is composition of linear maps and is associative even when the fibre multiplication is not. Curvature, holonomy, multiplication compatibility, and the associator are therefore distinct objects. They may interact only through explicitly typed tensors and transport defects.

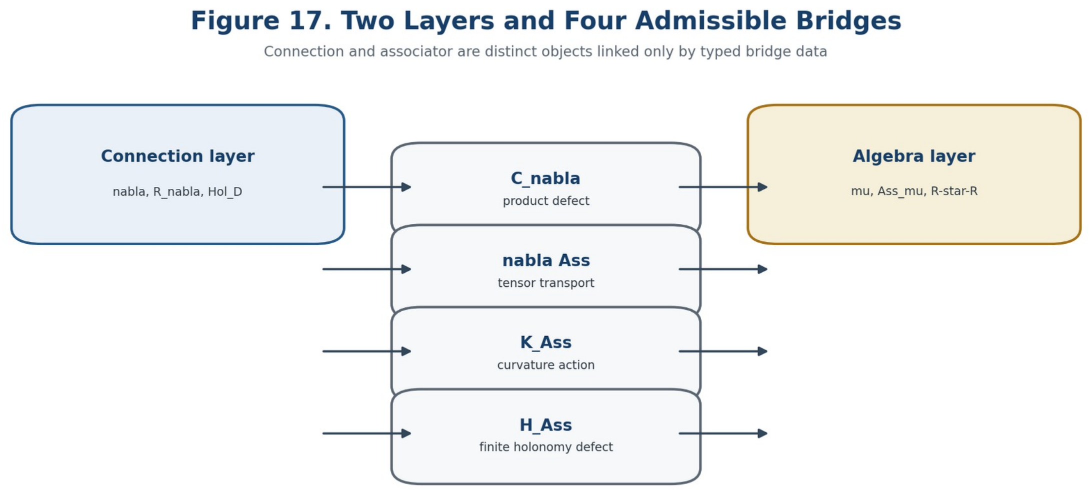


Figure 17. Two layers and four admissible bridges: C_nabla, nabla Ass, K_Ass, and H_Ass.

9.1. Typed NAPG Connection and D-Admissible Paths

Definition 9.1. Algebraic NAPG Bundle [DEF-A] Let X be a smooth sector, A->X a finite-dimensional vector bundle, and mu a smooth section of Hom(A tensor A,A). Each fibre carries the algebra (A_x,odot_x). Grading, structural data, and D/Dom restrictions are included as subbundles or admissible subsets.

mu_x:A_x tensor A_x -> A_x, a odot_x b := mu_x(a,b).	**T2-F029**

Definition 9.2. D-Admissible Path Category [DEF-A] P_D(X) has points of X as objects and piecewise C^1 paths as arrows, restricted by Dom and equipped with Evidence-D. It must be closed under constant paths, admissible reparameterisation, and composition; inverse paths are additionally required when a holonomy group is claimed.

Definition 9.3. NAPG Connection [DEF-A] A connection is a K-linear operator nabla:Gamma(A)->Omega^1(X;A) satisfying nabla(f s)=d f tensor s+f nabla s. It is structurally admissible only when it preserves the declared grading, structural subbundles, and Dom restrictions.

nabla(fs)=df tensor s+f nabla s.	**T2-F030**

Definition 9.4. Parallel Transport [CL / DEF-A] For a D-admissible path gamma, P_gamma:A_gamma(0)->A_gamma(1) is defined by the ODE nabla_{dot gamma}s=0.

Theorem 9.5. Associativity of Transport Composition [THM] For composable admissible paths, P_{gamma_2*gamma_1}=P_{gamma_2} o P_{gamma_1}; all bracketings of three transports agree. The associator of ordinary transport composition is identically zero.

(P_gamma3 o P_gamma2) o P_gamma1 = P_gamma3 o (P_gamma2 o P_gamma1).	**T2-F031**

Corollary 9.6. First No-Go [THM] Hol_D cannot be identified literally with Ass_odot: holonomy consists of linear automorphisms A_x->A_x, while Ass_odot is a ternary map A_x^3->A_x.

9.2. Curvature, Small Loops, and D-Holonomy

Definition 9.7. Curvature [CL] R_nabla(X,Y)=[nabla_X,nabla_Y]-nabla_[X,Y], an End(A)-valued 2-form.

R_nabla in Omega^2(X;End(A)), R_nabla(X,Y)=[nabla_X,nabla_Y]-nabla_[X,Y].	**T2-F032**

Definition 9.8. Small-Loop Certificate [DEF-A] For an oriented small rectangle contained in the D-admissible sector, fix the sign convention R_nabla(X,Y)=-lim_{epsilon->0} epsilon^{-2} (P_square_epsilon-Id), when the limit exists in the chosen trivialisation.

Theorem 9.9. Small Loops Localise Curvature [CL / THM] For a C^2 connection, P_square_epsilon=Id-epsilon^2 R_nabla(X,Y)+O(epsilon^3) in the selected convention. Curvature is the first nontrivial coefficient of small-loop holonomy, not an associator of transport composition.

Definition 9.10. D-Holonomy [DEF-A] Hol_D(x)={P_gamma: gamma is a D-admissible loop at x}. If inverse paths are admissible, this is a subgroup of GL(A_x). The component generated by contractible admissible loops is Hol_D^0(x).

Proposition 9.11. Base-Point Change [THM] For an admissible path eta:x->y, Hol_D(y)=P_eta Hol_D(x) P_eta^{-1}, provided conjugation preserves the admissible loop class. Matrix representatives are gauge-dependent; dimension, conjugacy class, and invariant polynomials are legitimate RBD candidates.

Theorem 9.12. Ambrose-Singer: Classical Layer [CL] For an ordinary smooth connection, the restricted holonomy algebra is generated by parallel translates of curvature. This theorem is imported only for the full smooth path category or after accessibility of the required small loops has been proved for the D-subcategory.

Hypothesis 9.13. D-Ambrose-Singer Bridge [COND / OPEN] If D-admissible paths form a regular controlled system, contain the required local rectangles, and are stable under curvature transport, then Lie(Hol_D^0(x)) is generated by D-accessible translates of R_nabla. Without these hypotheses no automatic import is made.

9.3. Compatibility with Packet Multiplication

Definition 9.14. Product Defect [DEF-A] For a vector field X and local sections a,b, define C_nabla(X;a,b)=nabla_X(a odot b)-(nabla_X a) odot b-a odot(nabla_X b).

C_nabla(X;a,b)=nabla_X(a odot b)-(nabla_X a) odot b-a odot(nabla_X b).	**T2-F033**

Definition 9.15. Product-Compatible Connection [DEF-A] The connection is compatible with odot when C_nabla=0; equivalently, mu is a parallel tensor.

Theorem 9.16. Transport Preserves the Product [THM] On a connected D-sector, C_nabla=0 iff every admissible parallel transport is a homomorphism of the fibre algebras.

Corollary 9.17. Holonomy Preserves Structure [THM] If C_nabla=0, then Hol_D(x) is contained in Aut(A_x,odot_x). It preserves the associator, nuclei, centre, J_Ass, and the full R-star-R certificate whenever those constructions are functorial.

Definition 9.18. Finite Multiplication Holonomy Defect [DEF-A] For gamma:x->y, H_mu(gamma;a,b)=P_gamma(a odot_x b)-P_gamma(a) odot_y P_gamma(b).

Definition 9.19. Finite Associator Holonomy Defect [DEF-A] H_Ass(gamma;a,b,c)=P_gamma Ass_x(a,b,c)-Ass_y(P_gamma a,P_gamma b,P_gamma c).

9.4. Covariant Derivative and Associator Curvature

Theorem 9.20. Derivative of the Associator through C_nabla [THM] The induced connection on Hom(A^3,A) differentiates Ass by the sum of four product-defect terms obtained by expanding nabla((a odot b) odot c-a odot(b odot c)).

In particular, C_nabla=0 implies nabla Ass=0 and hence H_Ass(gamma)=0 on every admissible path. The converses fail: an associative algebra has Ass=0 for every connection, including connections with nonzero C_nabla.

Definition 9.22. Associator Curvature K_Ass [DEF-A] K_Ass is the curvature of the induced connection acting on the associator field, not ordinary curvature and not the associator itself. In tensor notation, K_Ass=(R_nabla.Hom)Ass.

K_Ass(X,Y) = (R_nabla^{Hom(A^3,A)} (X,Y)) Ass.	**T2-F034**

Theorem 9.23. Necessary Condition for Parallelism [THM] If nabla Ass=0, then K_Ass=0. Thus nonzero K_Ass is a local obstruction to parallelity of the associator.

Definition 9.25. Full Associator-Holonomy Bridge Package [DEF-A] B_Ass=(C_nabla, nabla Ass, K_Ass, H_Ass), together with domains, gauges, norms, and provenance. No component may be replaced by another solely by analogy.

Theorem 9.26. Holonomy Principle for the Associator [CL / THM] On a connected sector, parallel tensors of type (3,1) correspond to tensors at one point fixed by full holonomy. A global parallel associator arises from Ass_x exactly when Ass_x is Hol_D(x)-invariant, provided D-paths connect the sector and path-independence is secured by that invariance.

9.5. Separating Models and Universal No-Go

Example 9.28. Flat Nonassociative Model [THM / EXAMPLE] On a trivial bundle over R^2 with constant nonassociative algebra A_2 and nabla=d, one has R_nabla=0, trivial restricted holonomy, C_nabla=0, but Ass is nonzero. Nonassociativity does not generate curvature automatically.

Example 9.29. Curved Associative Model [THM / EXAMPLE] For A=X x M_2(R) and nabla=d+[B,·] with B=x dy H, curvature dx wedge dy ad_H may be nonzero while Ass=0 because matrix multiplication is associative. Curvature does not generate nonassociativity automatically.

Example 9.30. Flat but Incompatible Connection [THM / EXAMPLE] For nabla=d+omega Id with d omega=0, curvature vanishes but C_nabla(X;a,b)=-omega(X)(a odot b). Flatness does not imply preservation of the packet product.

Example 9.31. Curved Compatible Octonion Model [MODEL / THM] For A=R^2 x O, a nonzero derivation D of the octonions, and nabla=d+x dy D, one has C_nabla=0, R_nabla=dx wedge dy D nonzero, holonomy in G_2, and a nonzero parallel associator.

Theorem 9.32. Universal-Equality No-Go [THM] Across all algebra bundles, no universal identity determines curvature or holonomy solely from the associator, and no universal identity recovers the associator solely from curvature or holonomy.

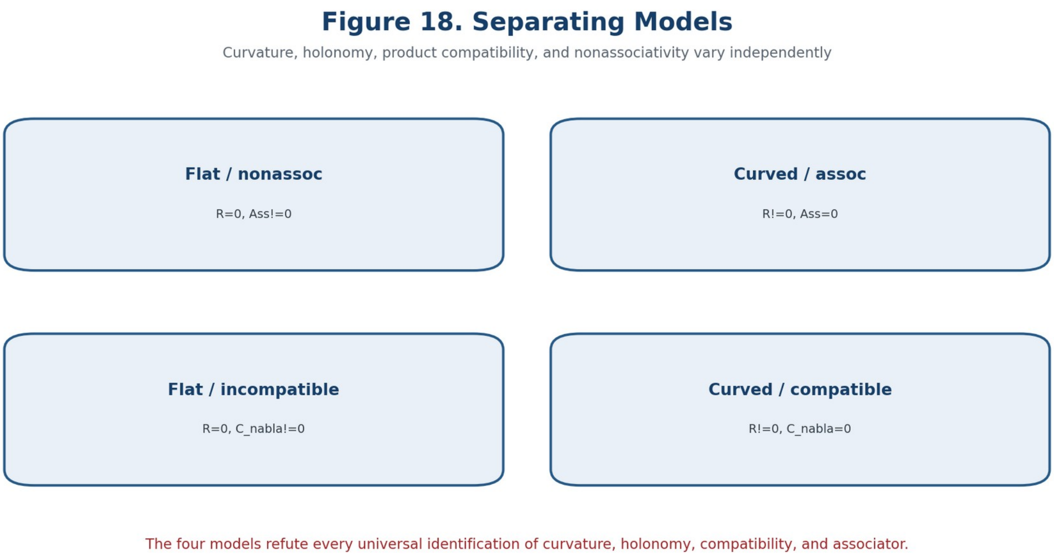


Figure 18. Four models separating curvature, holonomy, compatibility, and associator.

9.6. Akivis/Sabinin Bridge

Definition 9.33. Akivis Algebra [CL] A vector space with an antisymmetric binary operation and a ternary operation is an Akivis algebra when the Jacobiator of the binary operation equals the alternating sum of the ternary operation.

Definition 9.34. Bridge Datum beta [DEF-A] A bridge from a fibre NAPG algebra to a local Akivis structure is a family of linear maps or a functor between the relevant ternary carriers together with commutative diagrams matching bracket, ternary operation, transport, and domains.

BRIDGE STATUS. The Akivis/Sabinin layer is conditional. It is not a licence to identify an arbitrary NAPG associator with geodesic-loop torsion or curvature without the full bridge obligations.

9.7. Holonomy Signature and Horizon

Definition 9.36. D-Holonomy Signature [DEF-A] For parameter t, the signature stores the certified rank of a finite holonomy generator matrix, representation type on A_t, stabiliser dimension of Ass_t, zero/nonzero states of C_nabla, nabla Ass and K_Ass, projective-Reper data, and D/Dom validity.

Definition 9.37. Finite Holonomy Certificate [DEF-A] Choose finitely many D-admissible paths and covariant derivatives of curvature up to order N. After transport to a base point, their coordinates form G_N(t); rank G_N(t) is a reproducible finite approximation to the generated holonomy space.

Theorem 9.38. Local Constancy of Certified Rank [THM] For analytic G_N(t), if a maximal r x r minor remains nonzero on an interval, rank G_N(t)=r there. A rank change can occur only where the selected minors vanish or the family exits its domain.

Definition 9.40. Connection-Holonomy Horizon [DEF-A] Delta_conn includes changes of the D-path category, loss of transport existence, vanishing of certified maximal minors, stabiliser jumps of Ass, poles of lambda, failure of C_nabla=0, and loss of Evidence-D globalisation.

Theorem 9.41. Negative Holonomy Prediction [COND] For an analytic family with a complete stabilised certificate, unchanged D/Dom and gauge category, and a parameter path avoiding Delta_conn, the holonomy-algebra rank, representation type on Ass, and compatibility status remain constant. The corresponding structural transition is excluded inside the model.

9.8. Projective Reper Transport

Theorem 9.42. Common Projective Transport Invariance [THM] If all four Reper points are transported by the same PGL_2 transformation g_t, then lambda(g_t r,g_t i,g_t u,g_t d)=lambda(r,i,u,d).

Corollary 9.43. Relative Transport Is Necessary [THM] Away from poles, d lambda/dt != 0 implies that the four velocities cannot all be generated by one infinitesimal sl_2 field. Nonzero d lambda detects relative, not common projective, dynamics.

Definition 9.44. Relative Reper Connection [DEF-A] Allow four projective connections nabla^r,nabla^i,nabla^u,nabla^d. Their differences from a common projective part form nabla^rel, which is the component entering the derivative of lambda.

9.9. Main Conditional Predictive Theorem

Theorem 9.46. Holonomy-Associator-Safe Predictive Theorem [COND] For a C^2 family (A_t,odot_t,nabla_t,rho_t,D_t), assume fixed types, a stable D-path groupoid, solvable transport ODEs, versioned D/Dom, a complete finite holonomy certificate, a computed B_Ass package, closed Akivis/Sabinin obligations when used, PGL_2 Reper charts, separation of common and relative transport, valid globalisation/tangent certificates, and a path avoiding Delta_conn. Then the certified holonomy rank, its action type on A, the stabiliser dimension of Ass, the zero/nonzero states of C_nabla, nabla Ass and K_Ass, and lambda under common transport are constant on each component of the complement.

Corollary 9.47. Necessary Condition for a Structural Event [COND] A transition candidate can arise only at Delta_conn, through relative Reper dynamics, a nonzero bridge defect, or a change of D/Dom. None is sufficient by itself.

Corollary 9.48. Blocker-Safe Verdict [THM / PROTOCOL] Incomplete or conflicting certificates yield ABSTAIN. A complete path avoiding the horizon yields NO-STRUCTURAL-TRANSITION-IN-MODEL. A verified crossing yields only CANDIDATE-TRANSITION.

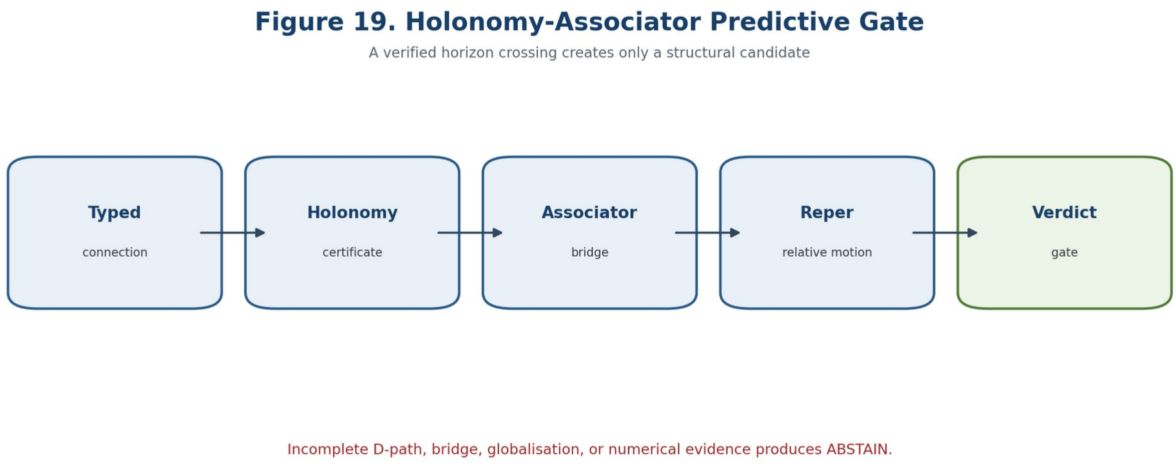


Figure 19. Blocker-safe gate for holonomy-associator prediction.

9.10. HOL-ASS Computational Certificate

- TEST-CONN-01: verify the scalar Leibniz rule for the connection;
- TEST-PATH-02: verify closure of P_D under composition and inverse where a group is claimed;
- TEST-PT-03: verify transport composition to solver tolerance;
- TEST-CURV-04: compare coordinate and operator curvature formulas;
- TEST-LOOP-05: verify the epsilon^{-2}(P_square-Id) limit with the declared sign;
- TEST-HOL-06: certify rank of G_N by exact or interval arithmetic;
- TEST-PROD-07: verify equivalence between C_nabla=0 and product-preserving transport;
- TEST-KASS-09: verify K_Ass against the induced curvature formula;
- TEST-NOGO-10: run the four separating models;
- TEST-GATE-13: force ABSTAIN whenever a bridge remains open.

Chapter 10. NAPG Differential Forms and Typed Differentials

ONTOLOGY	A differential layer exists as an operator with domain, degree, and an action rule.
EPISTEMOLOGY	Its correctness is tested by Leibniz, locality, gluing, and the square of the operator.
PHENOMENOLOGY	It appears as transport of forms, compatibility defects, and differential curvature.
LIMITATION	The Leibniz rule does not imply d squared equals zero.
AUTHORIAL NOVELTY	The authorial contribution is a typed differential firewall inside NAPG and KLT-RBD.

The internal differential candidate d_N, the external operator delta_E, the Hodge codifferential delta_Hdg, and the Hodge star are distinct typed objects. A notation collision is a proof blocker. The chapter proves that the graded Leibniz identity does not imply nilpotency, and that a total complex exists only after the internal square, external square, and mixed commutator have all been certified.

Figure 20. Three Differential Layers

Internal, external, and Hodge operators remain distinct until a bridge certificate is supplied

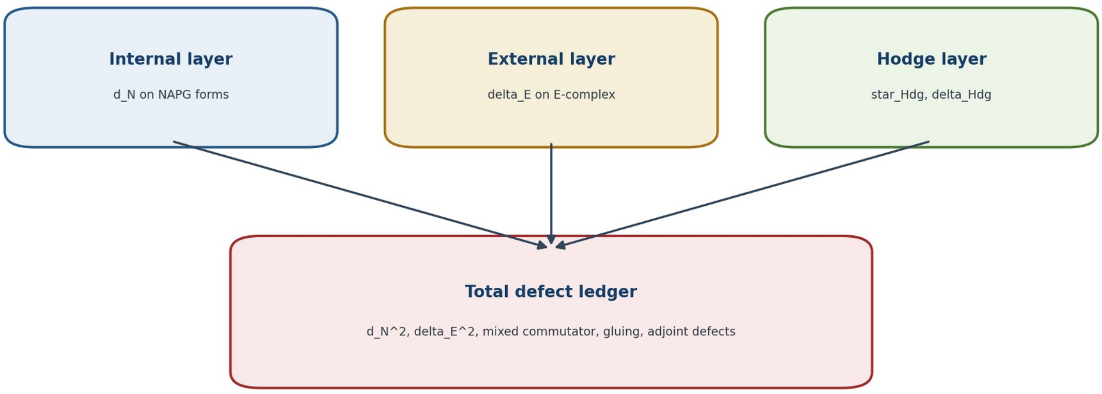


Figure 20. Three differential layers and decomposition of the total defect.

10.1. Frozen Notation and Operator Types

Definition 10.1. Internal Packet Forms [DEF-A] For an admissible smooth or stratified sector X, Omega_N^p(U) is the module of NAPG p-forms over U. The assignment U |-> Omega_N^p(U) is a sheaf or presheaf according to the verified descent axioms.

Omega_N^bullet = direct_sum_{p>=0} Omega_N^p, |alpha|=p for alpha in Omega_N^p.	**T2-F035**

Definition 10.2. Internal Differential Candidate [DEF-A] d_N^p is a partial linear map Dom(d_N^p) subset Omega_N^p -> Omega_N^{p+1}. It is called a candidate until locality, restriction compatibility, the graded Leibniz identity, and nilpotency have been checked.

Definition 10.3. External E-Operator [DEF-A / COND] delta_E:E^q->E^{q+1} belongs to the external layer. The relation delta_E^2=0 must be proved in the selected E-complex and is not imported from the internal layer.

Definition 10.4. Hodge Operators [CL / DEF-A] On an oriented metric n-sector, star_Hdg is the Hodge star, delta_Hdg the codifferential, and Delta_Hdg the Hodge Laplacian. The star in R-star-R is not the Hodge star.

NOTATION FIREWALL. Any formula interchanging d_N, external delta_E, delta_Hdg, or the star in R-star-R without an explicit typed map receives blocker NOTATION-COLLISION.

10.2. Graded Leibniz Calculus

Definition 10.6. Leibniz Defect [DEF-A] For a degree-compatible bilinear product odot and homogeneous alpha,beta, set L_d(alpha,beta)=d_N(alpha odot beta)-d_N alpha odot beta-(-1)^{|alpha|} alpha odot d_N beta.

L_d(alpha,beta)=d_N(alpha odot beta)-d_N alpha odot beta-(-1)^{|alpha|} alpha odot d_N beta.	**T2-F036**

Definition 10.7. Graded Derivation [CL / DEF-A] d_N is a degree +1 graded derivation exactly when L_d=0 on the declared domain.

Lemma 10.8. Value on the Unit [THM] In a unital sector of characteristic not equal to 2, the graded Leibniz identity implies d_N(1)=0.

Theorem 10.9. Closure of Derivations [THM] For homogeneous graded derivations D,E on a possibly nonassociative graded algebra, [D,E]=D o E-(-1)^{|D||E|}E o D is again a derivation of degree |D|+|E|. The proof uses only the Leibniz identities, not associativity of odot.

[D,E]=D o E-(-1)^{|D||E|}E o D.	**T2-F037**

Corollary 10.10. Square of an Odd Derivation [THM] When char K != 2 and |d_N|=1, [d_N,d_N]=2d_N^2. Hence d_N^2 is a degree +2 derivation but need not vanish.

Theorem 10.11. Associator Leibniz Identity [THM] For a degree +1 derivation, d_N Ass(alpha,beta,gamma)=Ass(d_N alpha,beta,gamma)+(-1)^{|alpha|}Ass(alpha,d_N beta,gamma)+(-1)^{|alpha|+|beta|}Ass(alpha,beta,d_N gamma).

d_N Ass(alpha,beta,gamma)=Ass(d_N alpha,beta,gamma)+(-1)^{|alpha|} Ass(alpha,d_N beta,gamma)+(-1)^{|alpha|+|beta|}Ass(alpha,beta,d_N gamma).	**T2-F038**

10.3. Nilpotency Is Not Automatic

Definition 10.13. Differential Curvature [DEF-A] For a degree +1 derivation set Omega_d=d_N^2:Omega_N^p->Omega_N^{p+2}. This internal term is not identified with R_nabla, although in a covariant model it may act through curvature.

Omega_d := d_N^2.	**T2-F039**

Lemma 10.14. Operator Bianchi Identity [THM] [d_N,Omega_d]=0, since both terms are d_N^3.

Definition 10.15. Precomplex and Complex [DEF-A] A typed sequence Omega_N^p->Omega_N^{p+1} is a precomplex. It is a cochain complex only when d_N^{p+1}d_N^p=0 in every degree. Cohomology is defined only in the second case.

Example 10.16. Leibniz without Nilpotency [THM / EXAMPLE] In the free graded nonassociative algebra on generators a,b,c of degrees 0,1,2, define d(a)=b,d(b)=c,d(c)=0 and extend by the graded Leibniz rule. Then L_d=0 but d^2(a)=c!=0.

Example 10.17. Covariant Exterior Derivative [CL / THM] For a connection nabla, d_nabla^2 acts by curvature; it need not vanish.

Example 10.18. Superconnection Curvature [CL / THM] For an odd superconnection A=d+omega, A^2=d omega+omega^2, which is generally nonzero.

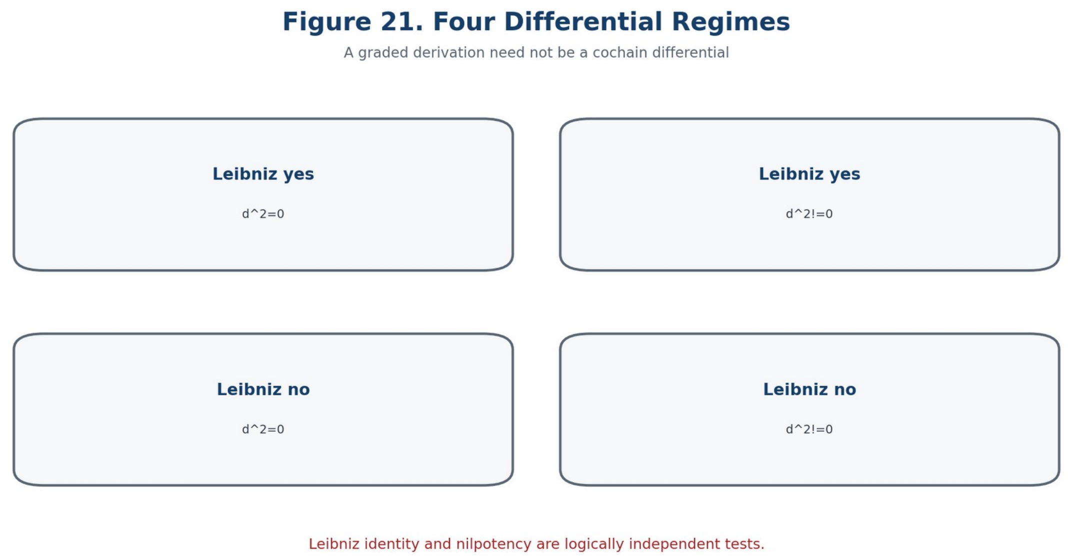


Figure 21. Four regimes showing logical independence of the Leibniz identity and nilpotency.

10.4. Locality, Restrictions, and Gluing

Definition 10.20. Sheaf-Local Operator [DEF-A] A family d_U is local when for every V subset U, restriction commutes with d: $res_{U,V}\, d_U=d_V\, res_{U,V}$ on the common domain.

Lemma 10.21. Support Nonincrease [THM] For a sheaf-local operator, supp(d alpha) is contained in supp(alpha). This does not by itself classify d as a finite-order differential operator.

Theorem 10.22. Gluing of Local Differentials [THM] Local degree +1 operators d_i glue through bundle transitions g_{ij} when $d_i\, g_{ij}=g_{ij}\, d_j$ on every overlap and their domains are transported compatibly.

Definition 10.23. Differential Gluing Defect [DEF-A] $K_{ij}=d_i\, g_{ij}-g_{ij}\, d_j$. A nonzero K_{ij} blocks a global d_N even if every d_i is nilpotent.

$$K_{ij}=d_i\, g_{ij}-g_{ij}\, d_j. \qquad \text{T2-F040}$$

Counterexample 10.24. Local Nilpotency Does Not Repair Gluing [THM / EXAMPLE] With $g_{12}=Id$, $d_1=d$ and $d_2=d+A$ fail to glue whenever A is nonzero, regardless of nilpotency of the separate operators.

10.5. Internal and External Layers

Definition 10.25. Bigraded Bridge Object [DEF-A / COND] Let B^{p,q}=Omega_N^p tensor E^q. The internal d_N has bidegree (1,0), the external delta_E has bidegree (0,1), and the total operator is D_tot=d_N tensor 1+(-1)^p 1 tensor delta_E on bidegree (p,q), subject to the declared domain.

Theorem 10.26. Square Decomposition [THM] D_tot^2 decomposes into the internal square, the external square, and the graded mixed commutator. A total cohomology exists only when all three components vanish and gluing is certified.

D_tot^2 = d_N^2 tensor 1 + 1 tensor delta_E^2 + Mix(d_N,delta_E).	**T2-F041**

Corollary 10.27. Cohomology Firewall [THM / PROTOCOL] If any component of D_tot^2 is nonzero or uncomputed, H^*(Tot B,D_tot) is not declared. KLT-RBD stores the defect triple rather than a fictitious cohomology label.

Definition 10.28. Differential Bridge Certificate [DEF-A] A map Pi_E:O_B->H^3(E^bullet) requires typed source and target, a proof that representatives descend, compatibility with differentials, naturality under morphisms, and a reproducible computational witness.

Chapter 11. Hodge Operators, Codifferential, and Laplacian

ONTOLOGY	A harmonic object is defined by a concrete Hilbert or Fredholm realisation.
EPISTEMOLOGY	Knowledge requires closed operators, adjoint domains, boundary conditions, and spectral control.
PHENOMENOLOGY	It appears through canonical harmonic representatives and stability of a Green operator.
LIMITATION	Formal symmetry is not self-adjointness, and Hodge decomposition is not automatic.
AUTHORIAL NOVELTY	The authorial node inserts the Hodge-Fredholm profile into the predictive Reper horizon.

The Hodge layer is meaningful only on an oriented metric sector with a declared measure and operator domains. The chapter preserves the source numbering, where the imported differential package continues labels 10.30 onward. These numbers are not renumbered in translation.

11.1. Hodge Sector and Operator Definitions

Definition 10.30. Hodge Sector [CL / COND] Let U be an oriented n-dimensional smooth sector with a nondegenerate metric g and admissible measure. The Hodge star star_Hdg:Omega^p(U)->Omega^{n-p}(U) is defined by the metric, orientation, and volume form.

Definition 10.31. Codifferential [CL / COND] In the selected Riemannian sign convention, delta_Hdg=(-1)^{n(p+1)+1} star_Hdg d_N star_Hdg on p-forms, with the common operator domain explicitly stated.

delta_Hdg = (-1)^{n(p+1)+1} star_Hdg d_N star_Hdg.	**T2-F042**

Definition 10.32. Hodge Laplacian [CL / COND] Delta_Hdg=d_N delta_Hdg+delta_Hdg d_N on the intersection of the corresponding domains.

Delta_Hdg=d_N delta_Hdg+delta_Hdg d_N.	**T2-F043**

Theorem 10.33. Nilpotency Transfer [THM] If d_N^2=0 and star_Hdg is a valid isomorphism on the sector, then delta_Hdg^2=0. When d_N^2 is nonzero, nilpotency of delta_Hdg does not follow.

11.1.2. Hodge Compatibility Defects

Definition 10.35. Hodge Transport Defect [DEF-A] For a chart transition g_ij, set H_ij=g_ij star_j-star_i g_ij. A nonzero defect blocks a global Hodge star in the declared trivialisation.

Definition 10.36. Formal-Adjoint Defect [DEF-A] When an inner product is defined, A_adj(alpha,beta)=<d_N alpha,beta>-<alpha,delta_Hdg beta>, including boundary terms and operator-domain conditions.

Vanishing of the displayed formal expression is weaker than self-adjointness of a closed unbounded operator. Boundary conditions, closures, and deficiency data remain separate analytical obligations.

11.2. Differential Reper and lambda Harmony

Definition 10.37. Differential Reper [DEF-A] A differential object is packaged as Rep_diff=(R_op,I_inv,U_def;D_cert), where R_op is the realised operator system, I_inv the selected invariant signature, U_def the admissible deformation universe, and D_cert the full operator-domain and evidence certificate.

Definition 10.38. Differential Defect Vector [DEF-A] Def_diff=(L_d,Omega_d,K_glue,H_transport,A_adj,M_mix,B_D,B_Dom), collecting Leibniz, square, gluing, Hodge, adjoint, mixed, and evidential defects.

Def_diff=(L_d,Omega_d,K_glue,H_transport,A_adj,M_mix,B_D,B_Dom).	**T2-F044**

Definition 10.40. Relaxed Differential Candidate [DEF-A] For predeclared thresholds tau and eta, a candidate requires delta_truth<=tau and norm Def_diff<=eta together with valid D/Dom. Thresholds are fixed before disclosure and do not convert an approximate numerical state into an exact theorem.

11.3. Differential Transition Horizon

Definition 10.41. Finite Differential Signature [DEF-A] For a finite-dimensional truncation, store ranks of d_t^p, dimensions of kernels and cohomology when defined, ranks of Hodge/Laplacian matrices, zero/nonzero states of all defects, lambda data, and conditioning bounds.

Definition 10.42. Differential Horizon [DEF-A] Delta_diff is the union of zeros of certified maximal minors, changes of operator domains, poles of lambda, insufficient precision loci, and conflicts in gluing, Hodge transport, or the E-bridge.

Theorem 10.43. Rank Constancy [THM] For an analytic finite-dimensional family, all certified matrix ranks are constant on each connected component of the complement of Delta_diff. If d_t^2=0 and adjacent ranks remain constant, the corresponding cohomology dimensions remain constant.

Theorem 10.44. Differential Negative Prediction [COND] With a complete certificate and a parameter path avoiding the strengthened safe horizon, the certified differential-complex type, cohomology dimensions, and zero/nonzero status of differential defects cannot change inside the model.

Corollary 10.45. Horizon Crossing Is Only a Candidate [COND] Crossing Delta_diff creates a candidate transition. It does not establish an integrable deformation, a global event, or a physical realisation.

11.4. Separating Models

Model	Leibniz	d squared	Hodge/global status	Lesson
de Rham forms	yes	zero	classical Hodge sector	baseline complex
free graded NAPG	yes	nonzero	no cohomology	Leibniz is insufficient
covariant forms	yes	curvature action	bundle-dependent	connection curvature survives
locally nilpotent but nongluing	local yes	local zero	K_ij nonzero	global differential absent

11.5. Main Conditional Theorem

Theorem 10.47. Differential-Calculus-Safe Predictive Theorem [COND] For a family (Omega_t^bullet,odot_t,d_t,delta_E,t,star_t,rho_t,D_t), assume fixed typed domains, certified Leibniz and square tests, effective gluing, a valid Hodge sector when used, a closed external complex and mixed bridge, a projective-Reper atlas, valid D/Dom, finite-rank analytic certificates, and a path avoiding the full differential horizon. Then the certified differential signature is constant on each connected component.

Corollary 10.48. Three-Valued Verdict [THM / PROTOCOL] A complete noncrossing certificate yields NO-DIFFERENTIAL-TRANSITION-IN-MODEL; a verified crossing yields CANDIDATE-TRANSITION; any open blocker yields ABSTAIN.

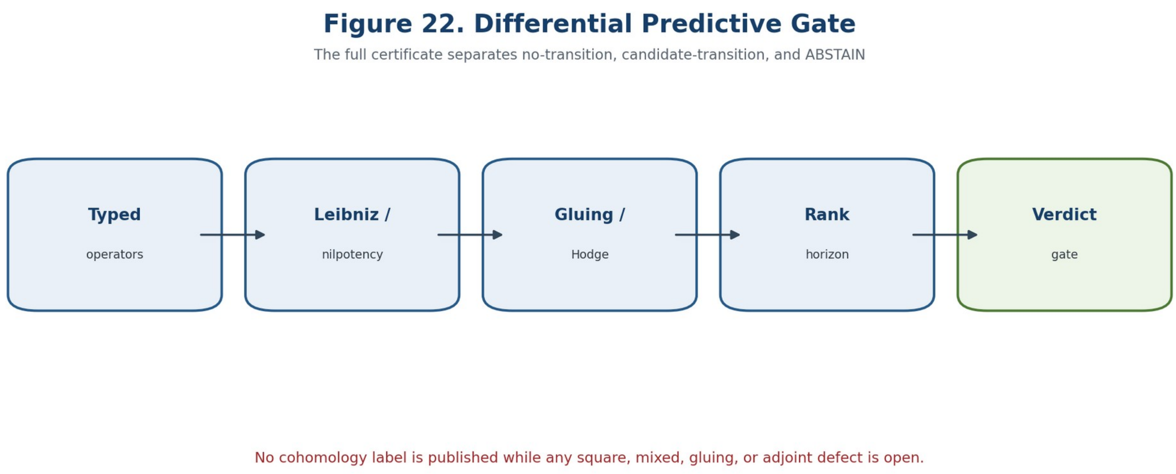


Figure 22. Blocker-safe gate for differential prediction.

11.6. DIFF-NAPG Computational Certificate

- TEST-TYPE-01: verify degree, domain, codomain, and restriction maps;
- TEST-LEIB-02: compute the full Leibniz defect on a basis;
- TEST-SQ-03: compute d_N^2 exactly or with certified intervals;
- TEST-ASS-04: verify the associator Leibniz identity;
- TEST-GLUE-05: compute K_ij on every overlap;
- TEST-HDG-06: verify metric/orientation transport and star_Hdg parity;

- TEST-ADJ-07: verify formal adjoint identity with boundary terms;
- TEST-TOT-08: verify internal, external, and mixed square components;
- TEST-RANK-09: certify maximal minors and conditioning;
- TEST-GATE-10: force ABSTAIN whenever any operator domain or bridge is open.

Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min

ONTOLOGY	An obstruction is a class of failure of a lift inside a declared structure.
EPISTEMOLOGY	It is established by complexes, quotient spaces, and independence from representatives.
PHENOMENOLOGY	It appears as a residual component that cannot be removed by an admissible correction.
LIMITATION	A zero primary class does not exclude higher obstructions and proves no physical realisation.
AUTHORIAL NOVELTY	The authorial contribution is the internal carrier, its external bridge, and its use in the Reper predictive gate.

The chapter gives the internal quadratic obstruction carrier a canonical two-term cochain complex. The construction is intentionally minimal: it controls only the declared quadratic evaluation problem. It does not absorb higher obstructions, global descent, the external E-complex, or a physical interpretation.

12.1. Quadratic Frame and Minimal Complex

Definition 12.1. NAPG Quadratic Frame [DEF-A] An object N consists of K, a graded carrier A^bullet, the admissible operation odot, structural data G, a class of Reper generators R, a formal quadratic space F_N^2, an evaluated space X_N^2, and a linear evaluation map Psi_N^2:F_N^2->X_N^2. All degrees, domains, codomains, and bases belong to the object passport.

Definition 12.2. Internal Minimal Complex [THM / IMPORT] Set C_min^2(N)=F_N^2, C_min^3(N)=X_N^2, all other relevant components zero, and delta_min^2=Psi_N^2.

0 -> F_N^2 --Psi_N^2--> X_N^2 -> 0.	**T2-F045**

Lemma 12.1. Nilpotency [THM] C_min^bullet is a cochain complex: the only possible composition after Psi_N^2 lands in C_min^4=0, and all other successive compositions include a zero arrow.

Definition 12.3. Canonical Map Theta_min [THM / IMPORT] Theta_min is the degree-three structure map that identifies an evaluated quadratic term with its position in C_min^3; it is not the quotient obstruction map.

Definition 12.4. Internal Obstruction Class [DEF-A] For q in X_N^2, let pi_N:X_N^2->X_N^2/im Psi_N^2. The obstruction is o_N(q)=[q]=pi_N(q) in H^3(C_min).

Figure 23. Minimal Complex and Exact Sequence

The internal obstruction carrier is the cokernel of the quadratic evaluation map

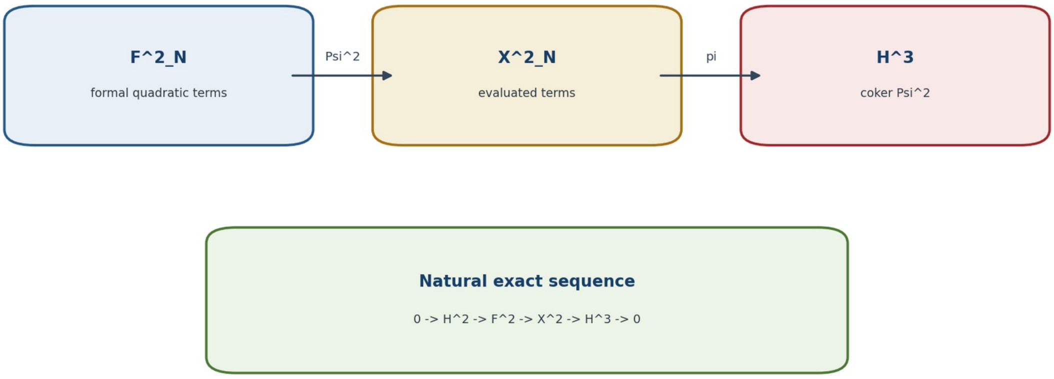


Figure 23. Minimal complex and its natural exact sequence.

12.2. Cohomologicaly and Exact Sequence

Theorem 12.2. Internal H2 and H3 [THM] $H^2(C_{min})=\ker \Psi_N^2$ and $H^3(C_{min})=\mathrm{coker}\, \Psi_N^2=X_N^2/\mathrm{im}\, \Psi_N^2$.

Theorem 12.3. Natural Exact Sequence [THM] There is a natural exact sequence $0\to H^2\to F_N^2\to X_N^2\to H^3\to 0$.

$$0 \to H^2(C_{min}) \to F_N^2 \xrightarrow{\Psi_N^2} X_N^2 \to H^3(C_{min}) \to 0.$$

Corollary 12.3.1. Finite-Dimensional Rank Formula [THM] If $\dim F_N^2=f$, $\dim X_N^2=x$, and $\mathrm{rank}\, \Psi_N^2=r$, then $\dim H^2=f-r$ and $\dim H^3=x-r$.

12.3. Functoriality and Natural Canonicity

Theorem 12.4. Minimal-Complex Functor [THM] A morphism of quadratic frames carrying formal and evaluated spaces compatibly with Psi defines a cochain map. Hence $N \mapsto C_{min}^\bullet(N)$ is a functor.

Theorem 12.5. Natural Isomorphism with O_B [THM] The obstruction-carrier functor $O_B=\mathrm{coker}\, \Psi_N^2$ is naturally isomorphic to $H^3 \circ C_{min}$.

Corollary 12.5.1. Invariant Vanishing [THM] Vanishing of the internal obstruction class is preserved by every $NAPG_q$ isomorphism. A numerical norm of a representative need not be preserved unless the morphism is isometric.

12.4. Lift Criterion and H2 Torsor

Definition 12.5. Lift [DEF-A] A lift of q in X_N^2 is f in F_N^2 such that Psi_N^2(f)=q. The set is Lift_N(q).

Theorem 12.6. Complete Internal Lift Criterion [THM] For q, the following are equivalent: q lies in im Psi_N^2; [q]=0 in H^3(C_min); Lift_N(q) is nonempty; the orthogonal residual is zero when a compatible inner product is chosen.

Theorem 12.7. Torsor of Lifts [THM] If f_0 is one lift, then Lift_N(q)=f_0+ker Psi_N^2. Thus the lift set is an affine torsor under H^2(C_min), not a unique solution.

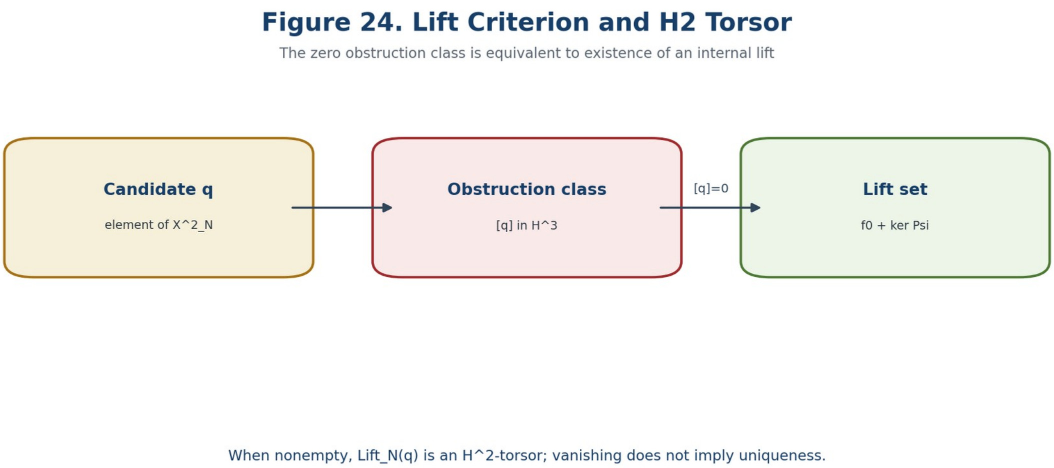


Figure 24. Lift criterion and H2 torsor of solutions.

12.5. Universal Property, Base Change, and Direct Sums

Theorem 12.8. Universal Extension into a Complex [THM] Given a cochain complex E^bullet and maps J^2:F_N^2->E^2, J^3:X_N^2->E^3 satisfying d_E J^2=J^3 Psi_N^2, there is a unique cochain map C_min^bullet(N)->E^bullet with those degree-two and degree-three components.

Theorem 12.9. Extension of Scalars [THM] For a field extension L/K, the minimal complex, its H^2, and its H^3 commute with scalar extension when tensoring is exact.

Theorem 12.10. Block-Diagonal Additivity [THM] For a direct sum of frames with Psi_{N direct_sum M}=Psi_N direct_sum Psi_M, H^2 and H^3 split as direct sums and obstruction classes add componentwise.

12.6. Canonical Class and Numerical Residual

Definition 12.6. Orthogonal Obstruction Residual [DEF-A / COMP] In a finite-dimensional real or complex sector, with Moore-Penrose pseudoinverse Psi^dagger, define r_min(q)=(I-Psi Psi^dagger)q.

$$r_{min}(q)=(I-\Psi \Psi^\dagger)q.$$

Theorem 12.11. Residual Criterion [THM] $r_{min}(q)=0$ iff $[q]=0$ in $H^3(C_{min})$. If the class vanishes, $f^*=\Psi^\dagger q$ is the minimum-norm lift.

Definition 12.7. Normalised Internal Obstruction Index [DEF-A / DIAGNOSTIC] A diagnostic index may normalise $||r_{min}(q)||$ by a predeclared scale, but its numerical value is representation- and metric-dependent. Only the zero/nonzero obstruction class is canonical under arbitrary isomorphism.

12.7. Analytic Families and Negative Prediction

Theorem 12.12. Constant-Rank Cohomology Bundles [THM] If rank Ψ_t is constant on a connected open set J, ker Ψ_t and im Ψ_t form analytic subbundles; H^2_t and H^3_t form quotient bundles and the obstruction class $o_t=[q_t]$ is an analytic section.

Corollary 12.12.1. Zeros of the Obstruction Section [THM] For one parameter, if the analytic obstruction section is not identically zero, its zeros have no interior accumulation point. Interior accumulation forces identical vanishing on the connected component.

Definition 12.8. Internal Transition Horizon [DEF-A] Δ_{min} is the union of rank-change, conditioning, type, Dom, D, chart, and bridge-failure loci for the minimal complex.

Lemma 12.13. Motion of the Residual [THM] With $P_t=\Psi_t \Psi_t^\dagger$ and $r_t=(I-P_t)q_t$, the variation of r_t is bounded by the variations of q_t and P_t in the constant-rank sector.

Theorem 12.14. Certified No-Lift Zone [THM / COMP] If $||r_{t0}||=\rho>0$ and the certified variation bound on a neighbourhood is less than ρ, then r_t remains nonzero there and no internal lift exists anywhere in that neighbourhood.

12.8. Main Conditional Predictive Theorem

Theorem 12.15. Minimal-Obstruction-Safe Predictive Theorem [COND] For a family $F_t=(N_t,\Psi_t,q_t,\rho_t,D_t,Dom_t)$, assume fixed dimensions and versioned bases, analytic or interval-certified Ψ_t and q_t, constant rank and a singular-value gap off registered horizons, typed separation of q_t from the ternary associator, valid D/Dom, a defined Reper coordinate away from poles, valid preceding atlas/tangent/holonomy/differential certificates, and restriction to the internal quadratic lift. Then H^2 and H^3 have constant ranks off Δ_{min}; $[q_t]=0$ iff an internal lift exists; the lift set is an H^2 torsor; a certified positive residual excludes the lift locally; and a zero class yields only CANDIDATE-LIFT-TO-ORDER-2.

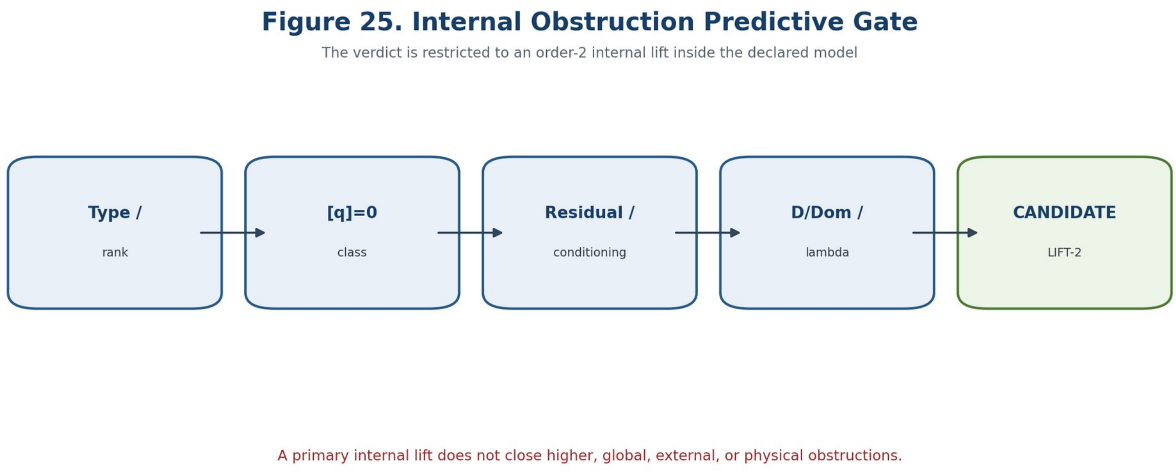


Figure 25. Blocker-safe gate for internal obstruction prediction.

12.9. Projective-Harmonic Reper Gate

> **Definition 12.9. Joint Certificate [DEF-A]** Cert_min(t)=(type_ok,[q_t],||r_t||,sigma_t^+,Valid(D_t),Dom_t,delta_truth(t),Block_t).

The strict selector admits an internal lift candidate only when [q_t]=0, the numerical residual is below its certified tolerance, the positive singular-value gap exceeds its threshold, D and Dom are valid, and Block_t is empty. The additional filter lambda=-1 or delta_truth<=tau is independent and replaces none of these conditions.

lambda=-1 does not imply [q]=0, and [q]=0 does not imply lambda=-1.

> **Countertheorem 12.16. Four Prohibited Implications [THM]** In general, H^3 nonzero does not imply a particular q is obstructed; [q]=0 does not imply uniqueness; [q]=0 does not eliminate higher or global obstructions; and H^3 nonzero implies no physical curvature, holonomy, or observable effect.

12.10. MIN-OB Computational Certificate

- TYPE: verify dimensions, bases, degrees, domains, and codomains;
- EXACT LINEAR ALGEBRA: compute rank, kernel, image, and cokernel of Psi;
- CLASS: reduce q modulo im Psi and store an exact representative;
- LIFT: solve Psi f=q or certify impossibility;
- TORSOR: store f_0+ker Psi rather than a single arbitrary lift;
- NUMERICS: compute pseudoinverse residual and positive singular-value gap with conditioning bounds;
- EVIDENCE: verify D/Dom and provenance of every matrix and basis;
- REPER: evaluate lambda only as an independent filter;
- VERDICT: NO-LIFT-IN-MODEL, CANDIDATE-LIFT-TO-ORDER-2, or ABSTAIN.

Chapter 13. External E-Complex and the Conditional Bridge Pi_E

ONTOLOGY	An internal obstruction acquires external meaning only through an explicit cochain bridge, not through a shared cohomological symbol.
EPISTEMOLOGY	The epistemic contract checks the external complex, the chain map, naturality, detection quality, and the separate associator and application bridges.
PHENOMENOLOGY	The external layer makes an internal residual visible, invisible, or supplemented by genuinely external classes.
LIMITATION	A vanishing external class implies nothing in reverse without injectivity, and no class is a physical event without a separate reduction.
AUTHORIAL NOVELTY	The authorial node is the blocker-safe bridge from the internal NAPG carrier to an external evidence-bearing complex.

The internal obstruction carrier O_B(N)=H^3(C_min(N)) does not become an external cohomology class merely because both objects use the symbol H^3. The transition requires a typed cochain map. This chapter constructs the external complex E^bullet(N), the bridge J_N, the induced map Pi_E,N, its blind and excess defects, the numerical injectivity margin, and the external transition horizon. All reverse, associator, analytic, and physical interpretations remain conditional.

Field	Controlled value
Canonical input	C_min^bullet(N): F_N^2 -> X_N^2; H^2=ker Psi_N^2; H^3=coker Psi_N^2=O_B(N); quotient map kappa_N.
Objective	Construct E^bullet(N), a cochain bridge J_N, and Pi_E,N:O_B(N)->H^3(E^bullet(N)).
Strict layer	Well-definedness, naturality, mapping cone, blind/excess defects, stable injective detection, and a parameter horizon.
Prohibition	Do not identify O_B with H^3(E), the associator, holonomy, an observable, or a physical event without separate maps.
Downstream use	Chapter 14 projectivises the nonzero obstruction carrier only after the zero and information-loss audits.

13.1. External Realisation and the B1-B8 Contract

Definition 13.1. External Realisation [DEF-A] For N in NAPG_q, an external realisation is E(N)=(E^bullet(N),d_E,Dom_E,G_E), where E^n(N) are K-modules or vector spaces, d_E has declared domains and codomains, and Dom_E and G_E record admissibility, regularity, grading, norms, and any auxiliary structures.

E(N)=(E^bullet(N), d_E, Dom_E, G_E).	T2-F046

d_E^{n+1} o d_E^n = 0 for all n.	T2-F047

Without the square-zero relation, E is only a precomplex and H^3(E^bullet) is undefined. A sequence of arrows does not create cohomology unless the compositions, domains, and closures satisfy the required identities.

Definition 13.2. Cochain Bridge J [DEF-A] A bridge from $C_{min}^\bullet(N)$ to $E^\bullet(N)$ is a cochain morphism whose essential components are $J_N^2:F_N^2\to E^2(N)$ and $J_N^3:X_N^2\to E^3(N)$.

$$J_N^2:F_N^2 \to E^2(N), \quad J_N^3:X_N^2 \to E^3(N). \tag{T2-F048}$$

$$d_E^2 J_N^2 = J_N^3 \Psi_N^2, \quad d_E^3 J_N^3 = 0. \tag{T2-F049}$$

The first identity sends internal boundaries to external boundaries. The second ensures that every external image of an evaluated quadratic object is a 3-cocycle.

Condition	Content	Status
B1	$E^\bullet(N)$ is a cochain complex; $d_E^2=0$ in every relevant degree.	THM/INPUT
B2	J_N is a typed cochain map with explicit domains and codomains.	THM/INPUT
B3	$N \to E^\bullet(N)$ is functorial for the chosen NAPG morphisms.	COND
B4	J is a natural transformation $C_{min}^\bullet \Rightarrow E^\bullet$.	COND
B5	Factorisation through κ_N and $H^3(J_N)$ is compatible with morphisms and admissible representation changes.	THM under B1-B4
B6	Reverse detection requires injective Π_E or a certified left inverse.	EXTRA
B7	The associator channel β_{Ass} is defined separately; Π_E is not called an associator.	OPEN/SEPARATE
B8	Physical, analytic, or domain interpretation requires a reduction, observable, data, and independent verification.	PHY-HYP/OPEN

Figure 26. Chain Bridge and Induced External Map

The internal quotient reaches external cohomology only through a typed cochain map

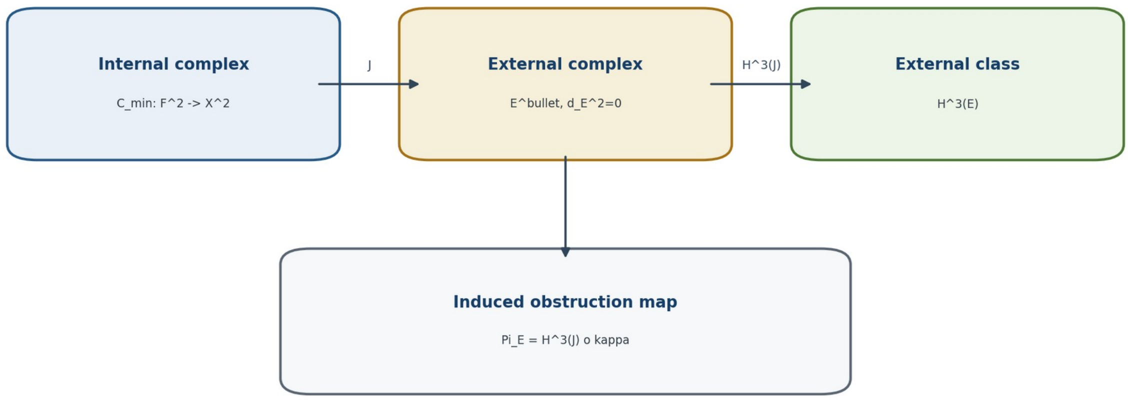


Figure 26. Chain bridge J and the induced external obstruction map Pi_E.

13.2. Well-Definedness and Naturality of Pi_E

Theorem 13.1. Descent to the Quotient [THM] Assume d_E^3 J_N^3=0. The assignment [x] -> [J_N^3 x] defines a linear map coker Psi_N^2 -> H^3(E^bullet(N)) if and only if J_N^3(Im Psi_N^2) is contained in Im d_E^2.

$[x] \mapsto [J_N^3 x].$	**T2-F050**

$J_N^3(\mathrm{Im}\ \Psi_N^2) \subset \mathrm{Im}\ d_E^2.$	**T2-F051**

Proof. Two representatives x and x+Psi_N^2 f define the same internal class. Their external images define the same cohomology class exactly when J_N^3 Psi_N^2 f is an external boundary for every f. Closedness follows from d_E^3J_N^3=0. □

The chain identity d_E^2J_N^2=J_N^3Psi_N^2 implies this condition. Conversely, a lift J_N^2 may be selected over vector spaces after choosing a section of d_E^2 onto its image. For general modules, projectivity or a splitting is a separate obligation.

Definition 13.3. External Obstruction Map [COND/THM under B1-B5] Under B1-B5, Pi_E,N is the cohomology map induced by J_N after the canonical quotient identification kappa_N.

$\Pi_{E,N} := H^3(J_N) \circ \kappa_N : O_B(N) \to H^3(E^\bullet(N)).$	**T2-F052**

$\Pi_{E,N}([x]) = [J_N^3 x].$	**T2-F053**

Theorem 13.2. Naturality [THM under B3-B5] For every admitted morphism f:N->N', the external square commutes: H^3(E(f)) Pi_E,N = Pi_E,N' O_B(f).

H^3(E(f)) Pi_E,N = Pi_E,N' O_B(f). T2-F054

13.3. One-Way, Reverse, and Complete Detection

Theorem 13.3. One-Way Detection [THM] For every correctly defined Pi_E, a nonzero image implies a nonzero internal class.

Pi_E(o) != 0 => o != 0. T2-F055

The converse is false without injectivity. Moreover, a nonzero arbitrary element of H^3(E) is not evidence of an internal obstruction unless it is certified to belong to Im Pi_E.

Theorem 13.4. Reverse Detection Criterion [THM] The following are equivalent: Pi_E is injective; Pi_E(o)=0 implies o=0; o!=0 implies Pi_E(o)!=0; and J_N^3x in Im d_E^2 implies x in Im Psi_N^2. In finite dimensions these are also equivalent to the existence of a linear left inverse S with S Pi_E=id, although S need not be canonical.

Bridge quality	Condition	Permitted conclusion
faithful	Pi_E injective	An external zero supports the reverse internal-zero conclusion.
complete	Pi_E surjective	Every external H^3 class is explained by an internal class.
exact	Pi_E is an isomorphism	Degree-3 information agrees.
degree-3 quasi-isomorphism	H^3(J) is an isomorphism	No assertion about other degrees.
quasi-isomorphism	H^n(J) is an isomorphism for all n	Full cohomological equivalence.

13.4. Mapping Cone, Blind Defect, and Excess Defect

Definition 13.5. Mapping Cone [CL] For a cochain bridge J:C_min^bullet->E^bullet, define Cone(J)^n=E^n direct-sum C_min^{n+1} with differential D_J(e,c)=(d_Ee+Jc,-delta_min c).

Cone(J)^n = E^n direct-sum C_min^{n+1}. T2-F056

D_J(e,c)=(d_E e + Jc, -delta_min c). T2-F057

Theorem 13.5. Exact Detection Sequence [THM] The mapping cone yields the exact segment H^2(C_min)->H^2(E)->H^2(Cone J)->O_B --Pi_E--> H^3(E)->H^3(Cone J)->0.

H^2(C_min)->H^2(E)->H^2(Cone J)->O_B --Pi_E--> H^3(E)->H^3(Cone J)->0. T2-F058

Blind_E(N):=Ker Pi_E,N, Excess_E(N):=Coker Pi_E,N.	**T2-F059**

Blind_E=Im(H^2(Cone J)->O_B), Excess_E isomorphic H^3(Cone J).	**T2-F061**

Blind_E measures internal obstructions invisible to the selected external realisation. Excess_E measures external degree-3 classes not explained by the internal quadratic layer. These are different failures and cannot cancel one another.

Figure 27. Mapping Cone and Detection Defects

Blind internal classes and unexplained external classes are distinct

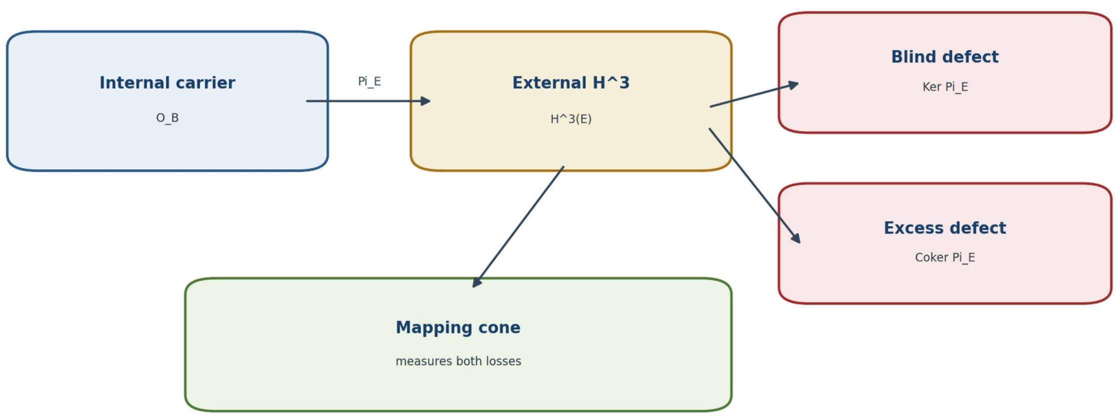


Figure 27. Mapping cone and the two defects of external detection.

13.5. Dependence on the External Realisation

> **Theorem 13.6. Chain-Homotopy Invariance [CL/THM]** If J and K are chain-homotopic maps C_min^bullet->E^bullet, then H^n(J)=H^n(K) in every degree and Pi_E^J=Pi_E^K.

H^n(J)=H^n(K) for all n; therefore Pi_E^J=Pi_E^K.	**T2-F063**

J^2-K^2=d_E^1h^2+h^3Psi^2, J^3- K^3=d_E^2h^3.	**T2-F064**

Thus Pi_E depends on the homotopy class of the bridge, not on its literal matrix. Non-homotopic bridges may detect different external information.

> **Proposition 13.6.2. Comparison of External Complexes [PROP]** If Q:E^bullet->F^bullet is a cochain map and J_F=QJ_E, then Pi_F=H^3(Q)Pi_E. Detection is preserved only when H^3(Q) is injective on Im Pi_E.

Pi_F = H^3(Q) Pi_E.	T2-F065

Definition 13.6. Category of External Realisations [DEF-A] An object of ExtReal(N) is a pair (E,J) satisfying B1-B2. A morphism (E,J)->(F,K) is a cochain map Q:E->F with QJ=K.

(E,J) |-> Pi_E:O_B(N)->H^3(E).	T2-F066

An external class is canonical relative to a declared subcategory only when the admissible realisations are connected by J-compatible quasi-isomorphisms and the resulting degree-3 classes agree. Coinciding dimensions or names are not a comparison theorem.

13.6. Finite-Dimensional Numerical Detection

In a Euclidean or Hermitian sector, choose orthogonal decompositions of the internal quotient and external cohomology. The induced bridge is represented by a finite matrix P_E from the minimal-norm internal carrier to the harmonic external carrier.

X_N^2=Im Psi_N^2 direct-sum O_N, Ker d_E^3=Im d_E^2 direct-sum H_E^3.	T2-F067

P_E:=P_{H_E^3} J_N^3 |_{O_N}.	T2-F068

Theorem 13.8. Stable Reverse Detection [THM/COMP] P_E is injective exactly when its smallest singular value is positive. If sigma_min(P_E)>=s_0>0, then ||Pi_E(o)||>=s_0||o|| for every internal class o.

sigma_min(P_E) >= s_0 > 0.	T2-F069

||Pi_E(o)|| >= s_0 ||o||.	T2-F070

eta_E([x]):=||P_{H_E^3} J_N^3 x_min||.	T2-F071

The invariant residual eta_E vanishes exactly when the external class vanishes. A certified lower bound supplies a robust one-way obstruction statement; it does not create an inverse conclusion unless the injectivity margin is also certified.

13.7. Parameter Families and the External Horizon

Delta_E=Delta_complex union Delta_chain union Delta_rankPi union Delta_sigmaPi union Delta_hom union Delta_D union Delta_Dom union Delta_glue.	**T2-F072**

The horizon records failures of the complex identity, the chain-map identity, constancy of rank, injectivity margin, homotopy class, Evidence-D, domain, and globalisation. These components are not merged into a single untyped error score.

> **Theorem 13.9. Persistence of a Nonzero External Obstruction [COND]** If the family of bridges and harmonic representatives is continuous on a connected interval, the rank profile is constant, and ||Pi_E,t(o_t)||>=epsilon_E>0, then the external obstruction cannot disappear on that interval.

||Pi_E,t(o_t)|| >= epsilon_E for all t in I.	**T2-F073**

P_E(t)=(dim H^3(E_t), rank Pi_E,t, dim Blind_E,t, dim Excess_E,t, sigma_min(P_E,t), eta_E(o_t)).	**T2-F074**

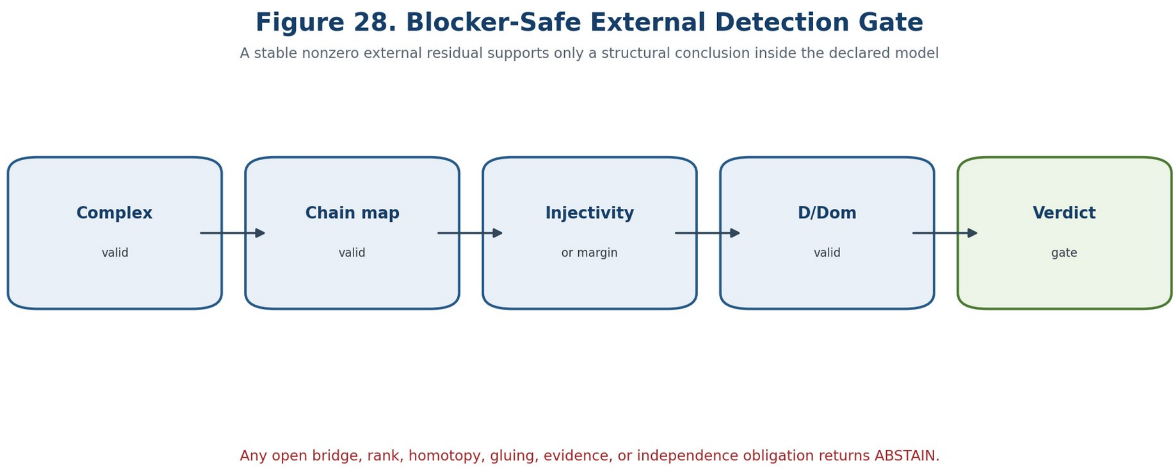


Figure 28. Blocker-safe gate for external detection.

13.8. Separate Associator Channel

beta_Ass,N:T_Ass(N)->H^3(A_Ass^bullet(N)).	**T2-F075**

The associator may be transported to its own external complex through beta_Ass. An identification with Pi_E requires an explicit comparison S on the internal side and Q on the external side, together with the commuting relation below. Without it, both channels remain mathematically distinct.

beta_Ass o S = H^3(Q) o Pi_E.	**T2-F076**

13.9. Counterexamples and EXT-E Certificate

- Pi_E=0 on a nonzero internal carrier: all internal classes are blind; an external zero proves nothing in reverse.
- An external H^3 class outside Im Pi_E: a nonzero external class need not come from the internal quadratic layer.
- Two non-homotopic bridges into the same E-complex: the external detection depends on the chosen bridge.
- A bridge with very small sigma_min: exact injectivity can coexist with severe numerical instability.
- An external class and a nonzero associator in unrelated complexes: shared dimension or notation does not define a bridge.
- A continuously varying family whose rank changes: the external profile may jump only at the registered horizon.

Certificate step	Required check
EXT-E-01	Record E^n, grading, norms, domains, and the proof that d_E^2=0.
EXT-E-02	Record J^2,J^3 and verify the chain identities exactly or with certified intervals.
EXT-E-03	Construct quotient and harmonic representatives and verify Pi_E is independent of representatives.
EXT-E-04	Compute rank, kernel, cokernel, blind/excess dimensions, and sigma_min(P_E).
EXT-E-05	Verify naturality or record the precise morphism class for which it is open.
EXT-E-06	Track the parameter horizon and continuity of the selected obstruction section.
EXT-E-07	Keep beta_Ass and every physical or analytic bridge in separate fields.
EXT-E-08	Emit NO-EXTERNAL-OBSTRUCTION-REMOVAL-IN-MODEL, CANDIDATE-EXTERNAL-TRANSITION, or ABSTAIN; store hashes.

BOUNDARY OF CHAPTER 13. A nonzero certified external image supports a nonzero internal class. A reverse conclusion requires injectivity or a left inverse. Neither direction is a physical observation.

Prior art includes cochain maps, mapping cones, exact sequences, homotopy invariance, singular-value conditioning, and functorial cohomology. The authorial contribution is the KLT-RBD arrangement of the internal NAPG carrier, the conditional Pi_E bridge, the blind/excess ledger, D/Dom controls, and the blocker-safe predictive horizon.

Chapter 14. Obstruction Spaces and Projective Carriers

ONTOLOGY	The obstruction carrier is first a vector space with a distinguished zero section; projectivisation is a later quotient of its nonzero part.
EPISTEMOLOGY	Knowledge requires an explicit audit of scale, sign, phase, provenance, lift, domain, and gluing information lost by the quotient.
PHENOMENOLOGY	The carrier appears as a direction of obstruction together with a rank/orbit stratum and a projective transition horizon.
LIMITATION	The zero class cannot be projectivised, and local projective carriers do not globalise without identification maps and effective descent.
AUTHORIAL NOVELTY	The authorial node joins the NAPG obstruction carrier, Fano firewall, Reper-lambda gate, and information-loss ledger.

Chapter 14 starts from the vector obstruction carrier and only then passes to projective directions. This order is mandatory: projectivisation removes the zero class, scale, and—depending on the scalar group—sign or phase. The chapter records the resulting losses, stratifies the nonzero carrier, constructs a Fano globalisation firewall, and defines a projective transition horizon suitable for negative structural prediction.

14.1. Vector Obstruction Carrier

O_B(N)=H^3(C_min(N))=X_N^2 / Im Psi_N^2.	**T2-F077**

Definition 14.1. Vector Carrier [DEF-A] Car_B(N)=(O_B,0_B,Fil_B,Prov_B,Dom_B), where the carrier retains the distinguished zero, a filtration, provenance, and the admissible domain.

Car_B(N)=(O_B,0_B,Fil_B,Prov_B,Dom_B).	**T2-F078**

O_B^x=O_B minus {0_B}.	**T2-F079**

The zero section encodes absence of the selected internal obstruction. It is not an ordinary projective direction. Every algorithm must test exact or certified separation from zero before projectivising.

14.2. Projectivisation and Its Exact Losses

Definition 14.2. Projective Obstruction Carrier [CL/DEF] The projective carrier is the quotient of the nonzero vector carrier by nonzero scalar multiplication.

P(O_B)=O_B^x / K^x, o~o' iff there exists a in K^x with o'=ao.	**T2-F080**

Theorem 14.1. Projective Equivalence [CL/THM] Two nonzero representatives define the same projective point exactly when they span the same one-dimensional subspace. The quotient retains direction but removes magnitude and may remove orientation or complex phase.

Proposition 14.2. Partial Functoriality [CL/PROP] A linear map f:O->O' induces P(f) only away from P(ker f).

P(f):P(O) minus P(ker f) -> P(O'), [o] |-> [f(o)].	**T2-F081**

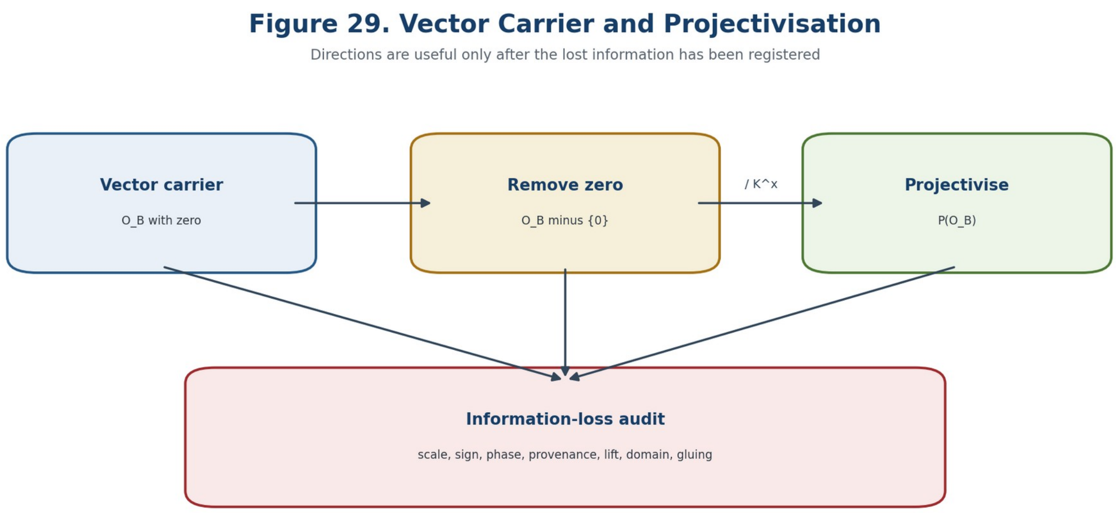


Figure 29. Vector carrier, projectivisation, and the mandatory information-loss audit.

Lost datum	Why it is lost	Repair certificate
zero class	P(O_B) is defined only on O_B minus {0}.	Exact ZERO flag and residual margin.
scale	[o]=[ao] for every admitted nonzero scalar a.	Metric and normalisation rule.
sign / orientation	Over R, [o]=[-o] in ordinary projective space.	Oriented ray or double cover.
complex phase	Over C, all nonzero phases are quotiented.	U(1) gauge or phase convention.
provenance	The point alone carries no source chain.	Evidence-D record.
lift representative	A class does not select an element of the H^2 torsor.	Lift-torsor coordinate and gauge.
domain and gluing	The same coordinates may occur in incompatible models.	Dom signature and descent certificate.

14.3. Normalised, Oriented, and Metric Carriers

$S(O_B) \to P(O_B), \quad u \mapsto [u], \quad \text{fibre}=\{u,-u\}.$	**T2-F082**

After a Hermitian or Euclidean metric is fixed, unit representatives form a spherical cover of the projective carrier. The cover remains two-to-one over R and a U(1)-bundle over C. No metric is canonical unless it belongs to the model data.

$d_P([u],[v])=\arccos(\lvert\langle u,v\rangle\rvert/(\lVert u\rVert\,\lVert v\rVert)).$	**T2-F083**

The projective metric measures angular separation. It cannot replace an absolute obstruction norm: two vectors may be projectively close while their magnitudes or conditioning differ by orders of magnitude.

14.4. Rank and Orbit-Type Stratification

$S_r=\{\ [o] \in P(O_B) : \operatorname{rank} A(o)=r\ \}.$	**T2-F084**

$G_{[o]}=\{\ g \in G : g\,o \text{ belongs to } K^\times o\ \}.$	**T2-F085**

> **Definition 14.3. Projective Structural Profile [DEF-A]** A point is recorded together with the rank of its associated operator or tensor, its stabiliser orbit type, support data, provenance, and domain signature.

Rank strata and orbit types are invariant only for homogeneous constructions. Every candidate invariant must be checked under $o \to ao$. Whitney regularity, local triviality of orbit types, and the compatibility of the selected group action remain explicit model obligations rather than automatic consequences of finite dimensionality.

14.5. Conical and Positive Projective Carriers

$P(C_B)=(C_B \setminus \{0\})/K^\times \subset P(O_B).$	**T2-F086**

$P_+(C_B)=(C_B \setminus \{0\})/R_{>0}.$	**T2-F087**

For an ordered or positive cone, quotienting only by positive scalars retains the distinction between o and $-o$. Ordinary projectivisation destroys this order information. The choice between P and P_+ is therefore part of the type, not a presentational preference.

14.6. Local Carriers and the Fano Globalisation Firewall

$O_{pre}=\bigoplus_{L \in \mathrm{Lines}(\mathrm{Fano})} O_L.$	**T2-F088**

O_glob=colim(O_L,phi_LL').	**T2-F089**

Theorem 14.5. Local-to-Global No-Go [THM] A family of projective carriers P(O_i) does not determine a global P(O). Linear identification maps, cocycle conditions, compatible zero sections, Evidence-D, and effective descent are required.

This strengthens the Fano ontological barrier: a local incidence picture does not become a global projective plane because the number of points or lines appears appropriate. A global carrier must be constructed through typed maps.

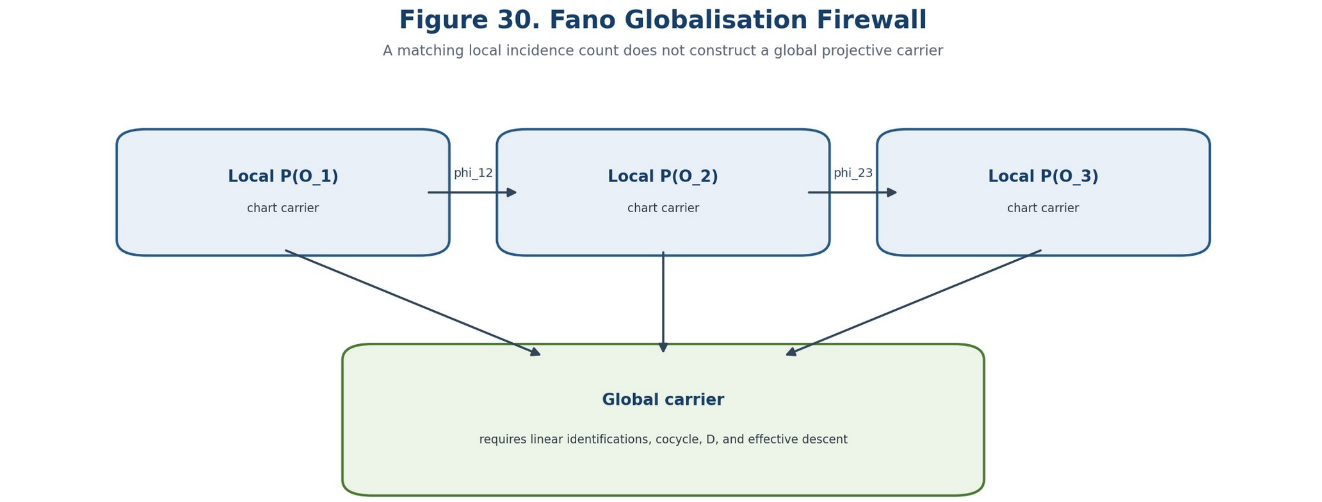


Figure 30. Fano globalisation firewall: local carriers require identification maps and effective descent.

14.7. Projective Transition Horizon

Delta_proj=Delta_zero union Delta_rank union Delta_orbit union Delta_chart union Delta_glue union Delta_D union Delta_Dom.	**T2-F090**

Component	Entry condition	Interpretation
Delta_zero	o_t=0 or loss of certified separation from zero	appearance or disappearance of the selected internal class
Delta_rank	rank A(o_t) changes	algebraic-type change
Delta_orbit	stabiliser type changes	symmetry-type change
Delta_chart	selected projective chart degenerates	coordinate defect; not necessarily structural
Delta_glue	cocycle or effective descent fails	local-to-global break
Delta_D	Evidence-D becomes invalid	epistemic blocker
Delta_Dom	admissible domain changes	change of the claim domain

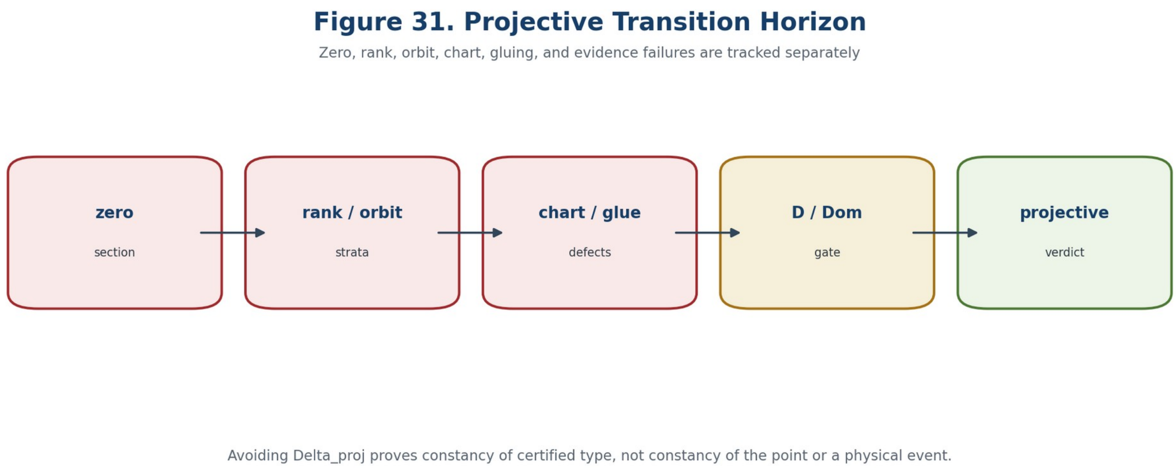


Figure 31. Components of the projective transition horizon Delta_proj.

Theorem 14.6. Constancy of Projective Type [COND] Let t->o_t be a continuous nonzero section on a connected interval. If the rank and orbit strata are locally closed, the path avoids Delta_proj, and D/Dom and gluing data remain fixed, then the certified projective profile stays in one connected stratum.

The theorem does not assert that [o_t] is a constant point. Motion inside the same certified stratum is allowed.

I intersect Delta_proj=empty => transition of certified projective type is impossible in the model.	**T2-F091**

14.8. Projective Carrier and Reper-Lambda

The Reper cross-ratio and the projective obstruction carrier are two different projective layers. The first concerns four points on P^1; the second concerns one-dimensional directions in O_B. A connection requires a separately defined rational map.

chi_lambda:P(O_B) dashedrightarrow P^1(K).	**T2-F092**

Theorem 14.7. No Automatic Lambda Bridge [THM] A point [o] in P(O_B) does not determine a canonical lambda. Four compatible homogeneous or rational functionals R,I,U,D and a proof of cross-ratio invariance are required.

lambda([o])=cr(U([o]),I([o]);R([o]),D([o])).	**T2-F093**

Even when lambda=-1, the nonzero test, Evidence-D, Dom_lambda, the absence of internal and external obstruction blockers, and the validity of chi_lambda remain separate obligations.

14.9. Information-Loss and Restoration Ledger

Cert_proj=([o],ZERO,NORM,ORIENT,PROV,LIFT,DOM,GLUE,HASH).	T2-F094

Code	Lost layer	Minimum repair	Verdict without repair
LOSS-0	zero class	ZERO flag plus exact residual	ABSTAIN
LOSS-S	scale	metric and normalisation	direction only
LOSS-SGN	sign / orientation	oriented ray or double cover	sign unknown
LOSS-PH	complex phase	U(1) gauge certificate	phase unknown
LOSS-PR	provenance	Evidence-D chain	source unknown
LOSS-LF	lift representative	H^2 torsor coordinate	lift nonunique
LOSS-DOM	domain	Dom signature	claim not transportable
LOSS-GL	globalisation	descent certificate	local only

14.10. Separating Models and Computational Certificate

Model	Data	Refuted inference
same point, different norms	o=(1,0), o'=(10^6,0)	same projective point does not mean equal quantitative risk
opposite signs	o and -o over R	ordinary projectivisation loses orientation
zero class	o=0	P(o) is undefined
map with kernel	f(x,y)=x	P(f) is undefined at [0:1]
local but not global	inconsistent phi_ij	charts do not glue automatically
small angular distance	u_n=n e_1, v_n=n e_1+e_2	angle tends to zero while absolute defect remains
lambda without bridge	same [o], different quadruples of functionals	lambda is not determined by [o]
positive cone	o and -o	ordinary P loses order type

PROJ step	Check
01-04	Build an exact basis of O_B, identify zero, fix the field/metric/action, and normalise or choose a positive ray.
05-08	Construct projective charts, verify chart changes, compute rank strata and stabilisers.
09-12	Verify homogeneity, build the ZERO/SCALE/SIGN ledger, provenance, and lift-torsor data.
13-16	Verify local-to-global cocycles, build Delta_proj, bound projective distances, and check chi_lambda and its poles.
17-18	Emit a blocker-safe verdict and preserve versions, hashes, and the machine-readable loss ledger.

14.11. Main Conditional Prediction Theorem

Theorem 14.8. Projective Obstruction-Safe Prediction [COND] Let N_t be a finite-dimensional regular family with a continuous obstruction section o_t, a projective atlas, homogeneous rank/orbit invariants, effective descent, valid D/Dom, and a reproducible PROJ certificate. If the path avoids Delta_proj and remains separated from the zero section and chart poles, the certified projective obstruction type cannot change. A transition requiring a different type is impossible inside the model; a horizon crossing yields only a candidate.

P_proj(t)=([o_t],S_rank(t),S_orbit(t),Dom_t, Glue_t). **T2-F095**

I intersect Delta_proj=empty => type(P_proj(t))=constant on I. **T2-F096**

Block_proj=B_zero union B_scale union B_sign union B_chart union B_hom union B_glue union B_D union B_Dom union B_lift union B_ind. **T2-F097**

Output	Necessary condition	Permitted interpretation
NO-PROJECTIVE-TYPE-TRANSITION-IN-MODEL	path avoids Delta_proj and blockers are empty	negative structural prediction
CANDIDATE-PROJECTIVE-TRANSITION	path meets Delta_proj and blockers are empty	target for further testing
ZERO-INTERNAL-OBSTRUCTION	o=0 exactly	vanishing of the selected internal class
ABSTAIN	at least one blocker	conclusion prohibited

BOUNDARY OF CHAPTER 14. The result is conditional and finite-dimensional. It asserts neither physical time, a causal mechanism, a transition probability, nor an experimental effect.

Prior art includes projective spaces, orbit-type and rank stratifications, projective metrics, cones, descent, and stratified geometry. The authorial contribution is their KLT-RBD integration with the NAPG obstruction carrier, Evidence-D, Reper-lambda authorisation, the Fano firewall, and the blocker-safe negative verdict.

Chapter 15. Hodge Decomposition and the Analytic NAPG Layer

ONTOLOGY	An analytic object is an operator together with Hilbert spaces, a dense domain, closure, adjoint, and boundary or interface conditions.
EPISTEMOLOGY	A harmonic representative identifies ordinary cohomology only after a closed-range or Fredholm certificate; otherwise it represents reduced cohomology.
PHENOMENOLOGY	Analytic stability appears as a spectral gap separating the harmonic sector from the positive spectrum.
LIMITATION	Nilpotency, formal symmetry, or compact individual strata do not by themselves imply ellipticity, self-adjointness, Fredholmness, or physical meaning.
AUTHORIAL NOVELTY	The authorial node is the Hodge-Fredholm certificate coupled to NAPG obstruction carriers, D/Dom, and a three-valued predictive verdict.

This chapter builds the analytic layer in which internal and external obstruction classes may acquire stable harmonic representatives. The construction distinguishes six levels: a precomplex, a Hilbert complex, a closed-range sector, an elliptic realisation, a boundary/Fredholm sector, and a predictive analytic sector. The output is three-valued: stable non-removal of a tracked obstruction, an analytic transition candidate, or ABSTAIN because the operator domain or another mandatory certificate is open.

Level	Object	Minimum certificate	Permitted conclusion
A0	precomplex	spaces and partial d_k only	cohomology prohibited
A1	Hilbert complex	closed densely defined d_k and d_{k+1}d_k=0	reduced Hodge decomposition
A2	closed-range sector	ran d_k and ran d_k* closed	ordinary cohomology is harmonic
A3	elliptic realisation	symbol sequence exact for xi!=0	regularity and finite-dimensional harmonic sector on compact base
A4	boundary/Fredholm sector	elliptic boundary conditions, closed ranges, finite kernel/cokernel	index, Green operator, spectral control
A5	predictive analytic sector	uniform gap, D/Dom, bridges, hashes	negative verdict or candidate

15.1. Hilbert Complex and Two Cohomologicalies

> **Definition 15.1. Hilbert Complex [CL/DEF]** A Hilbert complex is a sequence of Hilbert spaces H^k and densely defined closed operators d_k with ran d_k contained in ker d_{k+1}. The inclusion includes the requirement that the composition be defined on the relevant operator domain.

d_k:D(d_k) subset H^k -> H^{k+1}, ran d_k subset ker d_{k+1}.	**T2-F098**

Z^k=ker d_k, B^k=ran d_{k-1}, H^k=Z^k/B^k, Hbar^k=Z^k/closure(B^k).	**T2-F099**

Ordinary cohomology may be non-Hausdorff when B^k is not closed. Reduced cohomology always divides by a closed subspace. The analytic layer therefore uses reduced cohomology until a closed-range certificate is supplied.

> **Lemma 15.1. Adjoint Orthogonality [CL/THM]** For a densely defined closed d_k, the adjoint d_k* is closed and the standard orthogonal relations hold.

(ran d_k)^perp=ker d_k*, closure(ran d_k*)=(ker d_k)^perp. **T2-F100**

15.2. Hodge Laplacian with an Explicit Domain

> **Definition 15.3. Hodge Laplacian [CL/DEF]** In degree k, Delta_k=d_{k-1}d_{k-1}*+d_k*d_k on the domain where every composition is defined.

Delta_k=d_{k-1}d_{k-1}* + d_k* d_k. **T2-F101**

D(Delta_k)={u in D(d_k) intersect D(d_{k-1}*): d_ku in D(d_k*), d_{k-1}*u in D(d_{k-1})}. **T2-F102**

The differential expression without its domain is not an operator. Boundary and singular problems may have inequivalent closed, self-adjoint, or non-self-adjoint realisations of the same formal expression.

Harm^k=ker d_k intersect ker d_{k-1}* = ker Delta_k. **T2-F103**

<Delta_k u,u>=||d_ku||^2+||d_{k-1}*u||^2. **T2-F104**

The energy identity requires u to belong to the operator domain and the integration-by-parts formula to have no uncontrolled boundary term.

15.3. Weak and Strong Hodge Decomposition

> **Theorem 15.2. Weak Hodge Decomposition [CL/THM]** Every Hilbert complex has the orthogonal decomposition below; its harmonic sector is canonically isometric to reduced cohomology.

H^k=closure(ran d_{k-1}) direct-sum Harm^k direct-sum closure(ran d_k*). **T2-F105**

Figure 32. Hilbert Complex and Hodge Decomposition

The weak decomposition is automatic; the strong form needs closed ranges

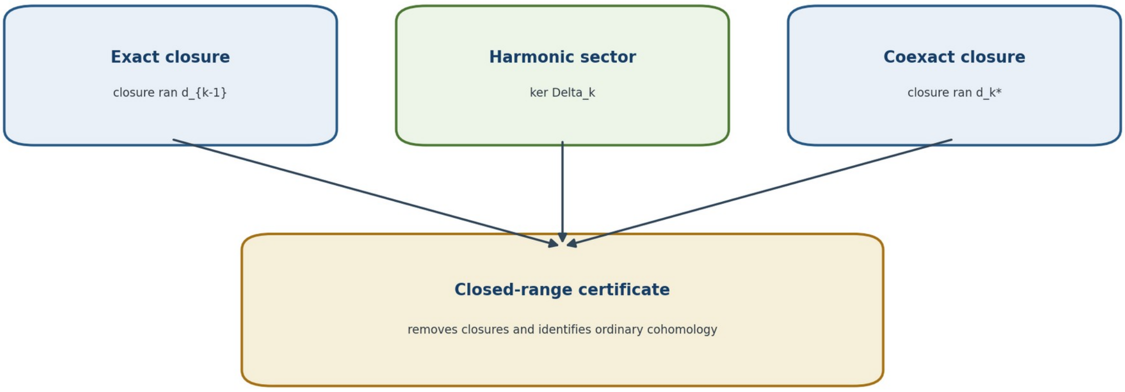


Figure 32. Hilbert complex and weak Hodge decomposition; ordinary cohomology requires closed ranges.

Theorem 15.3. Strong Decomposition Criterion [CL/THM] In a fixed degree, closedness of ran d_{k-1} and ran d_k^* is equivalent to the strong decomposition without closures, a coercive estimate on the harmonic complement, and—under a nonnegative self-adjoint realisation—isolation of zero in the spectrum.

$$\gamma_k := \inf(\operatorname{spectrum}(\Delta_k) \setminus \{0\}) > 0. \quad \text{T2-F106}$$

The positive number γ_k is the spectral gap. Its reciprocal controls the Green operator and the conditioning of analytic reconstruction.

$$G_k = (\Delta_k|_{(\mathrm{Harm}^k)^\perp})^{-1}(I - P_{\mathrm{Harm}}), \quad \|G_k\| \le 1/\gamma_k. \quad \text{T2-F107}$$

$$q = d_{k-1} a_{\min} + h, \quad h = P_{\mathrm{Harm}}\, q, \quad a_{\min} = d_{k-1}^* G_k q. \quad \text{T2-F108}$$

$$\|a_{\min}\| \le \gamma_k^{-1/2} \|q - P_{\mathrm{Harm}}\, q\|. \quad \text{T2-F109}$$

A small gap may make the minimal primitive badly conditioned even when the harmonic obstruction vanishes. Vanishing of a class and stable computation of a resolving primitive are therefore different statuses.

15.4. Elliptic Complexes and Laplace-Type Operators

0 -> E_x^0 --sigma(d_0)(x,xi)--> E_x^1 -> ... -> E_x^N -> 0, xi!=0.	T2-F110

Theorem 15.4. Ellipticity of the Hodge Laplacian [CL/THM] For an elliptic complex, the principal symbol of Delta_k is positive definite and equals the sum of the two symbol squares.

sigma_2(Delta_k)=sigma(d_{k-1})sigma(d_{k-1})* + sigma(d_k)*sigma(d_k).	T2-F111

sigma_2(L)(x,xi)=|xi|_g^2 Id.	T2-F112

On a compact manifold without boundary, a standard L^2 realisation then gives elliptic regularity, finite-dimensional harmonic spaces, and discrete spectrum. A NAPG Hodge Laplacian has this property only after the metric, principal symbols, and interface data are verified.

Countertheorem 15.5. Nilpotency Does Not Imply Ellipticity [THM] On an infinite-dimensional Hilbert space, d=0 has d^2=0 but Delta=0 has infinite-dimensional kernel, is not Fredholm, and has no positive spectral gap.

15.5. Boundary and Interface Conditions

Regime	Conditions	Cohomological type	NAPG status
relative	t omega=0 and t delta omega=0	relative cohomology	admissible after trace-space checks
absolute	n omega=0 and n d omega=0	absolute cohomology	admissible after Green-formula checks
general elliptic B	B gamma(omega)=0 plus complementing condition	depends on B	COND: self-adjoint/Fredholm certificate required

Theorem 15.6. Boundary Firewall [CL/COND] For the de Rham complex on a smooth compact manifold with smooth boundary, the standard absolute and relative realisations are elliptic self-adjoint problems. For a general NAPG operator, this conclusion requires a Green formula, trace spaces, interior-symbol ellipticity, a complementing boundary condition, and a proof of symmetry/self-adjointness or Fredholmness.

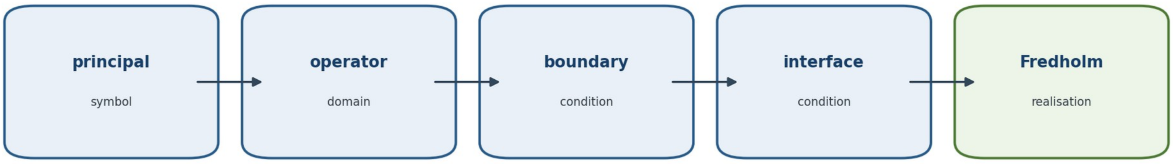
On stratified carriers, the direct sum of stratumwise complexes must additionally satisfy transmission equations across incidence interfaces. Fredholmness on every stratum does not imply Fredholmness of the total operator.

H_str^k=direct_sum_alpha L^2 Omega^k(S_alpha,E_alpha).	T2-F113

T_{alpha beta}^+u_alpha=T_{alpha beta}^-u_beta on every admitted interface.	T2-F114

Figure 33. Boundary and Interface Analytic Firewall

Interior ellipticity, domain, boundary, and transmission tests are independent obligations



The same formal differential expression may define inequivalent analytic operators on different domains.

Figure 33. Interior symbol, operator domain, boundary condition, and interface condition are separate analytic obligations.

15.6. Fredholm Sectors, Index, and Harmonic Obstruction

ind T=dim ker T - dim coker T.	T2-F115

D_H^+:H^{even}->H^{odd}, ind D_H^+=sum_k (-1)^k dim H^k.	T2-F116

Index is locally constant on a Fredholm component, but it is an alternating invariant and does not determine each harmonic rank. The predictive profile therefore retains all relevant dimensions separately.

h_E(o)=P_{Harm_E^3}q, eta_H(o)=|| h_E(o)||.	T2-F117

Theorem 15.8. Harmonic Detection of the External Class [THM/COND] For a closed representative q of Pi_E(o), eta_H(o)=dist(q,ran d_E^2), and eta_H(o)=0 exactly when Pi_E(o)=0 in the closed-range sector.

eta_H(o)=dist(q,ran d_E^2), eta_H(o)=0 iff Pi_E(o)=0.	T2-F118

Cond_H=(gamma_3^{-1},||G_3||,||P_H||,trace_constant,interface_constant).	**T2-F119**

The harmonic norm is invariant under replacement of q by an exact representative. A positive lower bound gives robust non-removal of the selected external obstruction; a zero value only removes this linear cohomological obstruction.

15.7. Spectral Stability and the Hodge-Fredholm Horizon

P_t=(2 pi i)^{-1} contour_integral_Gamma (z-Delta_{3,t})^{-1} dz.	**T2-F120**

When a zero spectral cluster is uniformly isolated, the Riesz projector varies continuously and its rank is constant. The horizon records every way this argument can fail.

Delta_HF=Delta_{d^2} union Delta_dom union Delta_ell union Delta_BC union Delta_range union Delta_gap union Delta_harm union Delta_int union Delta_D union Delta_Dom union Delta_glue.	**T2-F121**

P_HF(t)=(ind D_H,t^+,dim Harm_t^k,gamma_k(t),eta_H(t),||G_k(t)||,BC_t,Interface_t,lambda_t).	**T2-F122**

I intersect Delta_HF=empty and eta_H(t)>=epsilon_H => removal of this obstruction is impossible in the model.	**T2-F123**

Figure 34. Hodge-Fredholm Transition Horizon

Spectral stability and the tracked obstruction section are separate certificates

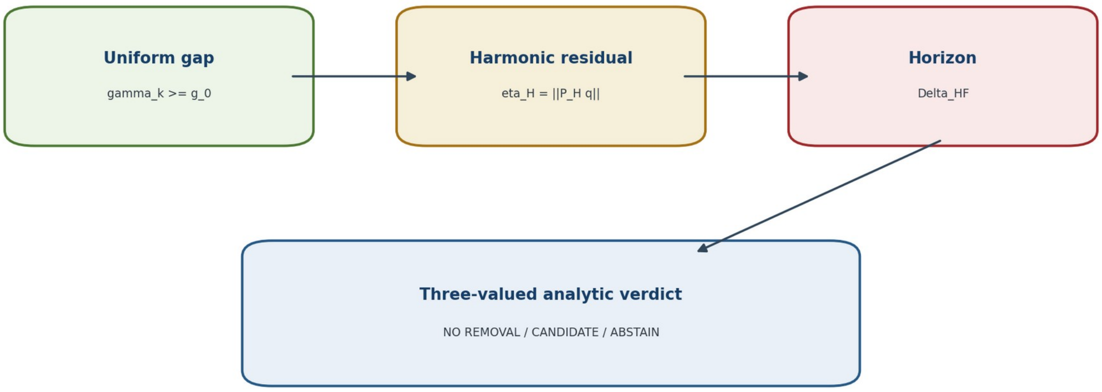


Figure 34. Hodge-Fredholm transition horizon and the three-valued analytic output.

15.8. Hodge-Reper Bridge

A harmonic representative lies in Harm_E^3. The Reper cross-ratio is defined on a quadruple of projective coordinates. There is no canonical map between them. A separate homogeneous functional package is required.

$$\chi_H=(R_H,I_H,U_H,D_H):P(\mathrm{Harm}_E^3) \dashrightarrow (P^1)^4,\quad \lambda_H=\mathrm{cr}(U_H,I_H;R_H,D_H). \qquad \text{T2-F124}$$

$$\mathrm{Cert}_{HF}=(\mathrm{COMPLEX},\mathrm{DOMAIN},\mathrm{SYMBOL},\mathrm{BC},\mathrm{INTERFACE},\mathrm{FREDHOLM},\mathrm{GAP},\mathrm{HARM},\mathrm{BRIDGE},D,\mathrm{DOM},\lambda,\mathrm{HASH}). \qquad \text{T2-F125}$$

The bridge is defined only for nonzero classes away from its poles and after the homogeneous scaling law has been checked. A zero harmonic obstruction is not projectivised.

15.9. Main Hodge-Fredholm-Safe Theorem

> **Theorem 15.12. Hodge-Fredholm-Safe Prediction [COND]** Let N_t carry external complexes and Hodge-Laplacian realisations such that the Hilbert-complex identity, elliptic symbols, boundary/transmission conditions, Fredholmness, norm-resolvent continuity, a uniform positive gap, constant harmonic ranks, a valid Π_E bridge, continuous obstruction and Evidence-D sections, fixed D/Dom and gluing data, a typed Hodge-Reper bridge, all predecessor blockers, and a reproducible HOD-AN certificate are verified. Outside Δ_{HF}, the index, harmonic rank, and certified analytic type are constant. If $\eta_H \geq \epsilon_H > 0$, the selected external obstruction cannot disappear. If $\eta_H=0$, only that linear cohomological obstruction is removed.

Block_HF=B_complex union B_domain union B_symbol union B_BC union B_interface union B_range union B_gap union B_bridge union B_D union B_Dom union B_glue union B_ind.	**T2-F126**

Output	Necessary condition	Prohibited over-interpretation
NO-OBSTRUCTION-REMOVAL-IN-MODEL	Block_HF empty and eta_H>=epsilon_H	does not exclude other transition mechanisms
CANDIDATE-ANALYTIC-TRANSITION	path meets Delta_HF with a surviving certificate	does not assert that an event occurred
ABSTAIN	a blocker is open or no uniform numerical margin exists	cannot be replaced by expert optimism

15.10. Countermodels and HOD-AN Certificate

- d^2=0 does not imply ellipticity;
- formal symmetry of Delta does not imply self-adjointness of the selected realisation;
- constant dim Harm^k does not prevent a tracked harmonic section from crossing zero;
- a small eta_H does not prove exact vanishing;
- eta_H=0 does not imply a nonlinear NAPG lift;
- Fredholmness on each stratum does not imply total Fredholmness without interface conditions;
- nonzero spectral flow is not automatically a physical transition;
- nonassociativity of the product does not imply nonzero principal-symbol curvature.

Separating model	Lesson
d=0 on an infinite-dimensional Hilbert space	nilpotent but not Fredholm; infinite harmonic sector
-d^2/dx^2 on [0,1] with Dirichlet versus Neumann domains	one formal expression yields different spectra and zero modes
Delta_t=diag(t^2,1,2,...)	a harmonic mode appears exactly when the gap closes
q_t=t h in fixed one-dimensional Harm	constant Betti number does not replace section tracking
Psi_epsilon=diag(1,epsilon)	an exact lift may be arbitrarily ill-conditioned
two strata before and after matching trace conditions	stratumwise harmonic dimensions do not add automatically

HOD group	Checks
HOD-01-05	spaces, grading, exact operator domains, d^2, adjoint domains, and principal-symbol ranks
HOD-06-09	ellipticity, boundary traces, complementing condition, and interface compatibility
HOD-10-15	kernel/cokernel, index, compact resolvent, harmonic basis, interval spectral gap, and Green bound
HOD-16-20	eta_H, Pi_E, chi_H/lambda domain, blocker-safe verdict, and source/environment/artifact hashes

BOUNDARY OF CHAPTER 15. The Hodge-Fredholm certificate establishes an analytic property of the declared operator realisation. It does not by itself establish a nonlinear lift, a causal mechanism, a probability, or a physical event.

Prior art includes Hilbert complexes, Hodge decomposition, elliptic complexes, boundary-value theory, Fredholm index, Green operators, and perturbation theory. The authorial contribution is their typed integration with the NAPG internal/external obstruction carriers, D/Dom, projective Reper authorisation, and the three-valued KLT-RBD verdict.

Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map

ONTOLOGY	A local moduli object is a deformation functor or groupoid, not merely the zero set of equations in coordinates.
EPISTEMOLOGY	Its tangent, automorphism, and obstruction directions are known through a controlling complex and small-extension lifting tests.
PHENOMENOLOGY	The Kuranishi map appears as a compressed local equation whose Taylor layers encode primary and higher obstruction data.
LIMITATION	Versal, miniversal, universal, coarse, stacky, and derived objects are not interchangeable.
AUTHORIAL NOVELTY	The authorial node is the controlled NAPG deformation machine joined to Hodge-Green contraction, Reper evidence, and an abstention gate.

The local deformation theory now passes from isolated tangent directions to functors on Artinian bases, deformation groupoids, and local moduli objects. The central question is whether a first-order class belongs to an actual miniversal family, which higher obstructions prevent continuation, and how the Hodge-Green layer produces a finite-dimensional Kuranishi reduction without turning a local moduli germ into a physical forecast.

16.1. Artinian Bases and the NAPG Deformation Groupoid

$$\mathrm{Art\_K}=\{(A,m\_A):A/m\_A \text{ isomorphic } K,\ m\_A^N=0 \text{ for some } N\}. \qquad \text{T2-F127}$$

Definition 16.1. NAPG Deformation Groupoid [DEF-A] For a fixed frame N, Def_N(A) consists of NAPG structures over A whose reduction to K is isomorphic to N, together with isomorphisms over A that are the identity on the special fibre. The set-valued functor F_N=pi_0 Def_N forgets automorphisms.

$$\mathrm{Def\_N:Art\_K}\text{->}\mathrm{Gpd},\quad \mathrm{F\_N=pi\_0\ Def\_N:Art\_K}\text{->}\mathrm{Set}. \qquad \text{T2-F128}$$

Base change must transport the partial-operation domain, grading, Evidence-D, obstruction carriers, and every selected gauge condition. A coordinate family without these structures is not the deformation functor of the declared NAPG object.

Figure 35. Deformation Functor and Local Moduli Levels

Passing to pi_0 forgets stabilisers and cannot recover the derived tangent profile

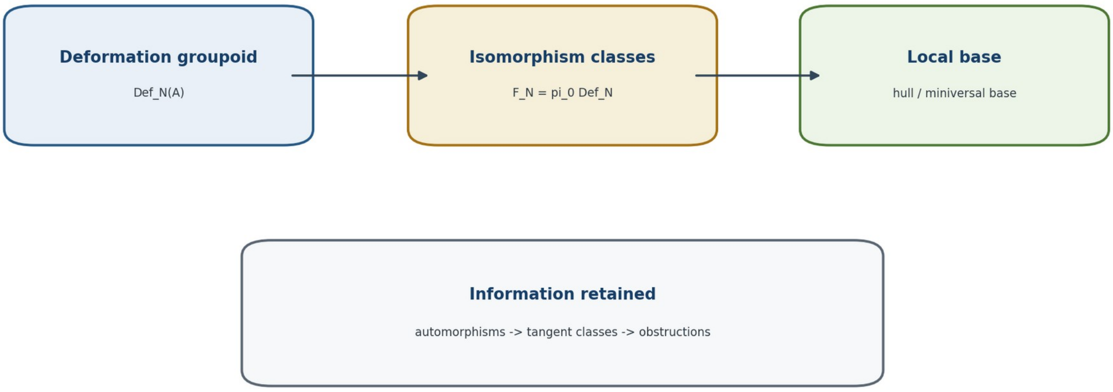


Figure 35. NAPG deformation functor and the three levels of the local moduli object.

16.2. Small Extensions and Complete Local Obstruction Theory

$0\to I\to A'\to A\to 0, \quad m_{A'} I=0.$	**T2-F129**

Definition 16.2. Complete Linear Obstruction Theory [COND/DEF] A triple (H_N^1,H_N^2,H_N^3) is complete when every small extension has a functorial obstruction in H_N^3 tensor I, vanishing exactly when a lift exists; the lift classes form an H_N^2 tensor I torsor; and infinitesimal automorphisms are controlled by H_N^1 tensor I.

This package does not follow from a cochain complex alone. It must be proved directly or derived from a controlling DGLA or L_infinity algebra.

16.3. Schlessinger Conditions and the Hull

$F(A' \times_A A'')\to F(A') \times_{F(A)} F(A'').$	**T2-F130**

Condition	Exact role	NAPG status
H1	surjectivity for a small extension	OPEN/CTRL
H2	bijectivity at the dual-number base case	OPEN/CTRL
H3	finite-dimensional tangent space	COND-FD
H4	bijectivity for identical small extensions; prorepresentability	OPEN/PROREP

Theorem 16.3. Conditional Schlessinger Package [CL/COND] If a set-valued functor satisfies H1-H3, it has a hull: a complete local algebra R and a smooth natural transformation $h_R\to F$ inducing an isomorphism on tangent spaces. H4 yields prorepresentability. Groupoid-valued problems require a stacky or derived modification.

Finite-dimensionality of the tangent space is available only in a finite-dimensional or Fredholm-reduced sector. It cannot be imported into an arbitrary infinite-dimensional NAPG model without compactness and gauge-fixing hypotheses.

16.4. Versal, Miniversal, and Universal Families

universal => miniversal => versal; the reverse implications are false.	T2-F131

A versal family induces all small deformations after some base map. A miniversal family additionally has the minimal tangent dimension and first-order uniqueness. Universality requires uniqueness of the full base map. Nontrivial automorphisms usually destroy universality while preserving miniversality; hence the correct object is generally a groupoid or stack germ.

16.5. Three-Term Deformation Complex and Derived Tangent

C_N^1 --d_N^1--> C_N^2 --d_N^2--> C_N^3, d_N^2 d_N^1=0.	T2-F132

H_N^1=infinitesimal automorphisms, H_N^2=tangent classes, H_N^3=primary obstructions.	T2-F133

H^{-1}(T_N^der)=H_N^1, H^0(T_N^der)=H_N^2, H^1(T_N^der)=H_N^3.	T2-F134

The negative degree stores stabiliser directions, degree zero stores deformations, and positive degree stores obstructions. The coarse tangent H_N^2 forgets H_N^1 and therefore cannot represent the whole local moduli problem.

16.6. Controlling L-Infinity Hypothesis and Small-Extension Lift

Hypothesis CTRL-16.1. Controlling Algebra [OPEN/COND] For the selected NAPG class there exists a complete filtered L_infinity algebra g_N=(g_N,l_1,l_2,l_3,...) whose Maurer-Cartan groupoid over every Artinian base is naturally equivalent to Def_N.

g_N=(g_N,l_1,l_2,l_3,...).	T2-F135

MC_N(A)={alpha in g_N^1 tensor m_A : sum_{n>=1}(1/n!)l_n(alpha,...,alpha)=0}.	T2-F136

Theorem 16.4. Small-Extension Lift from Maurer-Cartan [COND] Assume CTRL-16.1 and a small extension with kernel I. The curvature of any lift alpha_tilde is an l_1-cycle in g_N^2 tensor I. Its class in H^2(g_N) tensor I=H_N^3 tensor I is independent of the selected lift, vanishes exactly when an MC lift exists, and leaves an H_N^2 tensor I torsor of lift classes modulo gauge.

F(alpha_tilde)=sum_{n>=1}(1/n!)l_n(alpha_tilde^n) in g_N^2 tensor I.	T2-F137

16.7. Hodge-Green Contraction and Kuranishi Recursion

(H(g_N),0) --i--> (g_N,l_1) --p--> (H(g_N),0), id-ip=l_1h+h l_1.	T2-F138

p=P_H, i=harmonic inclusion, h=l_1* G.	T2-F139

The contraction follows from Hodge decomposition in a closed-range sector. For nonlinear recursion, h must preserve the filtration and admissible NAPG sectors, all brackets must be defined on its image, and multilinear estimates must control convergence.

Figure 36. Hodge-Green Contraction and Kuranishi Map

The local equation is certified only inside an explicit convergence radius

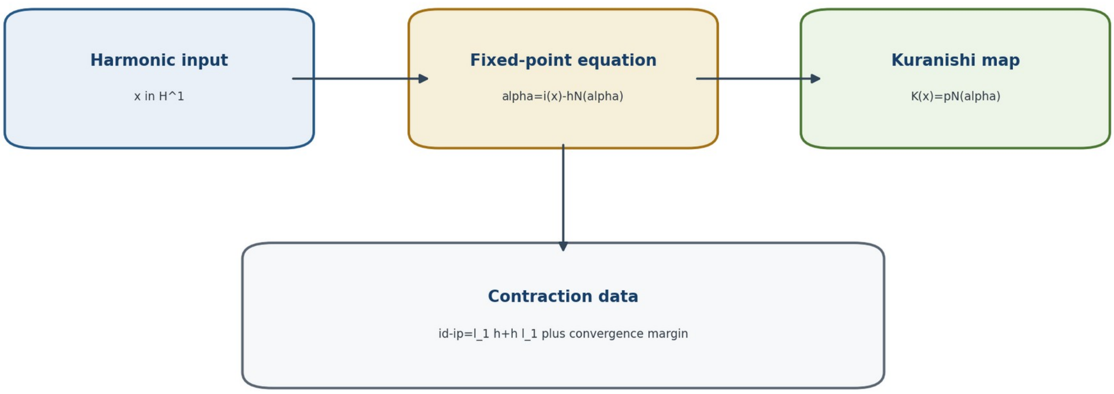


Figure 36. Hodge-Green contraction and construction of the Kuranishi map.

N(alpha)=sum_{n>=2}(1/n!)l_n(alpha^n).	T2-F140

alpha(x)=i(x)-hN(alpha(x)), h alpha(x)=0.	T2-F141

K_N(x)=pN(alpha(x)) in H^2(g_N)=H_N^3.	**T2-F142**

Theorem 16.5. Conditional Analytic Kuranishi Reduction [COND] If N(alpha) is analytic on a ball, h is bounded, and alpha->i(x)-hN(alpha) is a uniform contraction for ||x||<r_K, then the fixed-point equation has a unique solution. This solution satisfies the full MC equation exactly when K_N(x)=0.

||N(alpha)-N(beta)||<=L_R||alpha-beta||, ||h||L_R<1.	**T2-F143**

||x||<=R(1-||h||L_R)/||i||.	**T2-F144**

m_K(R)=1-||h||L_R.	**T2-F145**

The convergence margin m_K is part of the certificate. A formal recursion without a positive margin does not establish an analytic family.

16.8. Taylor Layers and Higher Obstruction Classes

K_N(x)=kappa_2(x,x)+kappa_3(x,x,x) +kappa_4(x,x,x,x)+...	**T2-F146**

kappa_2(x,x)=1/2 p l_2(ix,ix).	**T2-F147**

kappa_3(x,x,x)=1/6 p l_3(ix,ix,ix)-1/2 p l_2(ix,h l_2(ix,ix)).	**T2-F148**

nu_K(x)=min{n>=2:kappa_n(x,...,x)!=0}, nu_K=infinity if all terms vanish.	**T2-F149**

The first nonzero Taylor layer gives the obstruction order in the selected contraction and coordinate gauge. Vanishing of the quadratic term does not imply unobstructedness: a cubic or higher layer may remain.

16.9. Miniversal Base, Formal Smoothness, and Derived Boundary

R_N^min=K[[t_1,...,t_m]]/(K_1,...,K_q).	**T2-F150**

The completed local algebra is the miniversal base only after Schlessinger and control hypotheses are established. Formal smoothness means every small-extension lift exists; rigidity means the tangent space vanishes; unobstructedness means the Kuranishi map vanishes or the controlling algebra is homotopy abelian under the appropriate theorem. These notions are independent.

FormalModuli_K is equivalent to dgLie_K under characteristic-zero homotopical hypotheses.	**T2-F151**

pi_0 Def_N does not determine H^{-1}(T_N^der).	**T2-F152**

Theorem 16.7. Stabiliser No-Go [THM] A coarse moduli set or space does not determine the stabiliser directions of the deformation groupoid. A quotient stack and its coarse space may have the same underlying points but different derived tangent profiles.

16.10. Local Moduli Stratification and Transition Horizon

S_N=disjoint_union_alpha S_{N,alpha}, P_mod(x)=(dim H^1,dim H^2,dim H^3,nu_K,HS_x,dim Aut_x,[K_lead]).	**T2-F153**

Delta_mod=Delta_HF union Delta_ctrl union Delta_Sch union Delta_aut union Delta_tan union Delta_obs union Delta_Kur union Delta_conv union Delta_orb union Delta_D union Delta_Dom union Delta_glue.	**T2-F154**

eta_K(t)=||K_{N_t}(x_t)||.	**T2-F155**

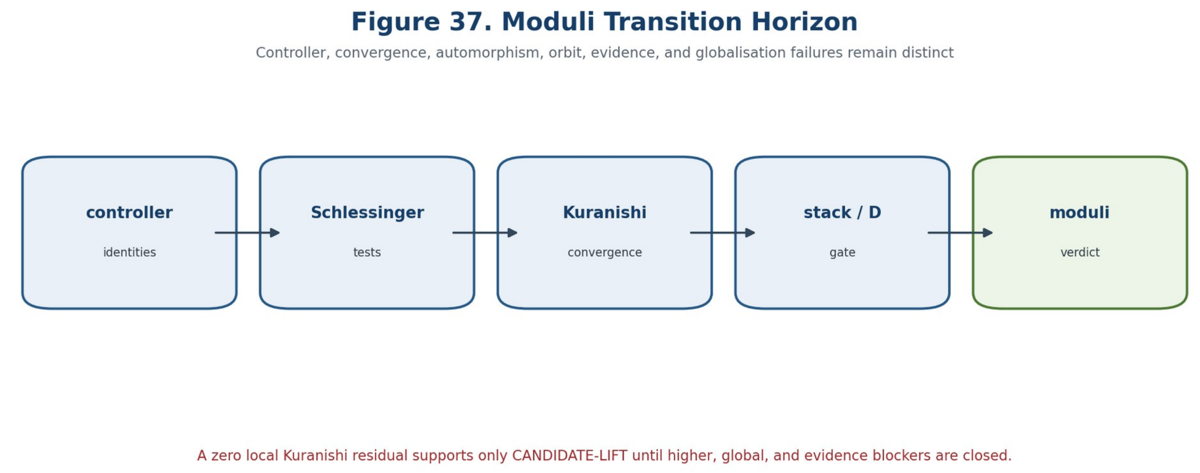


Figure 37. Moduli transition horizon and the blocker-safe local verdict.

A positive lower bound for eta_K excludes the selected tangent class from the local MC zero locus. A zero residual creates only a local candidate lift; it does not close the external bridge, globalisation, Reper-lambda, or independent-verification obligations.

16.11. Certified Trivialisation of a Family of Moduli Problems

Constancy of the dimensions of H_N^i does not determine constancy of the moduli germ. The certificate ModTriv(I) includes identifications of graded Hilbert spaces and domains, filtered L_infinity isomorphisms, compatible Hodge contractions with uniform bounds, right-equivalence of Kuranishi maps, preservation of stabiliser groupoids and D/Dom/gluing data, and a uniform Kuranishi radius separated from Delta_mod.

16.12. Main Moduli-Kuranishi-Safe Theorem

> **Theorem 16.9. Moduli-Kuranishi-Safe Prediction [COND]** Let N_t on a compact interval admit complete filtered controlling L_infinity algebras, Schlessinger H1-H3 and a miniversal hull, uniform Hodge-Green and convergence margins, a ModTriv certificate with no intersection with Delta_mod, a continuous candidate section x_t preserving Evidence-D/Dom, and closed predecessor blockers. Then the local moduli type and obstruction-order profile are constant in the certified trivialisation. If ||K_t(x_t)||>=epsilon_K>0, the selected branch does not integrate to an MC deformation in the declared Kuranishi neighbourhood.

eta_K(t)=||K_t(x_t)||>=epsilon_K>0 for all t in I.	**T2-F156**

If eta_K=0, the theorem provides only a local formal or analytic candidate lift under the remaining hypotheses. It does not assert globality, uniqueness, stability outside the radius, physical realisation, or event probability.

Block_mod=B_ctrl union B_Sch union B_HF union B_gauge union B_conv union B_Kur union B_aut union B_stack union B_D union B_Dom union B_glue union B_ind.	T2-F157

Condition	Verdict	Meaning
eta_K>=epsilon_K and Block_mod empty	NO-LIFT-IN-MODEL	the class is outside the local Kuranishi zero locus
eta_K=0 and Cert_mod complete	CANDIDATE-LIFT	local integrable candidate; downstream bridges remain
any blocker open	ABSTAIN	the proof chain is incomplete or ill-conditioned

16.13. Separating Models and MOD-KUR Certificate

- Tangent without lift: K(x)=x^2 has all first-order directions but only x=0 integrates.
- Primary obstruction zero and higher obstruction nonzero: kappa_2=0 while kappa_3(x,x,x)!=0.
- Miniversal but not universal: nontrivial H_N^1 produces several base maps related by automorphisms.
- Equal cohomology dimensions but different germs: K_1(x,y)=xy and K_2(x,y)=x^2+y^3 have different singularity types.
- Formal without analytic convergence: a formal series may have zero radius without estimates.
- Metric dependence: different Hodge contractions yield different representatives and Kuranishi maps, though the correct germs may be equivalent.
- Coarse-space blindness: a quotient stack and its coarse space have different stabiliser data.
- K=0 without dynamics: a smooth miniversal base is not a physical event.

MOD group	Checks
MOD-01-06	Artinian bases, object/morphism schemas, gauge groupoid, d^1/d^2, square-zero, and bases of H^1/H^2/H^3
MOD-07-13	small-extension generator, obstruction independence, lift torsor, Schlessinger H1-H4 flags
MOD-14-19	L_infinity identities, MC equation, gauge invariance, Hodge contraction, Green/spectral margin, and fixed-point contraction
MOD-20-24	Kuranishi Taylor coefficients, local algebra/zero locus, stabiliser strata, blocker-safe verdict, and all hashes

INPUT N,g,Artin bases,Hodge-Green,x,D/Dom; verify control and Schlessinger; solve alpha=i(x)-hN(alpha); compute K(x); emit ABSTAIN, NO-LIFT-IN-MODEL, or CANDIDATE-LIFT with proof objects and hashes.	T2-F158

BOUNDARY OF CHAPTER 16. The controlling L_infinity algebra for a general partial NAPG operation remains a proof obligation. A local Kuranishi zero is not a global object, a causal mechanism, or an empirical event.

Prior art includes Schlessinger functors, Kodaira-Spencer and Kuranishi theory, graded-Lie deformation theory, Goldman-Millson germs, and derived formal moduli. The authorial contribution is their typed integration with NAPG, Hodge-Green certificates, internal/external obstruction carriers, D/Dom, Reper authorisation, and a three-valued predictive horizon.

Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy

ONTOLOGY	A moduli space may be stratified into chambers, walls, ramification loci, and branch-monodromy orbits.
EPISTEMOLOGY	A transition is known only after branch continuation, path typing, wall certificates, and transport of invariants.
PHENOMENOLOGY	Wall crossing appears as a change of certified structural profile along a declared path.
LIMITATION	A wall is not automatically a bifurcation, branch labels need not globalise, and path dependence cannot be erased by a coarse endpoint comparison.
AUTHORIAL NOVELTY	The authorial node is the KLT-RBD branch ledger with blocker-safe wall-crossing and monodromy certificates.

A moduli carrier is generally not a single smooth manifold. Stabiliser dimension, branch count, the rank of the linearised Kuranishi map, and obstruction type may jump. This chapter treats the carrier as a certified stratified object, separates walls from bifurcation loci, tracks normalised branches and their monodromy, and defines the path-dependent wall-crossing operator and its predictive horizon.

17.1. Moduli Space as a Stratified Object

M_N=disjoint_union_{alpha in A} S_alpha, S_alpha intersect closure(S_beta)!=empty => S_alpha subset closure(S_beta).	**T2-F159**

An admissible predictive stratification has smooth locally closed strata, a constant local moduli profile on each stratum, and a verified frontier condition. Whitney (a) and (b), control data, and local topological triviality are separate obligations rather than consequences of writing a finite partition.

Figure 38. Stratified Moduli Space, Wall, and Bifurcation Locus

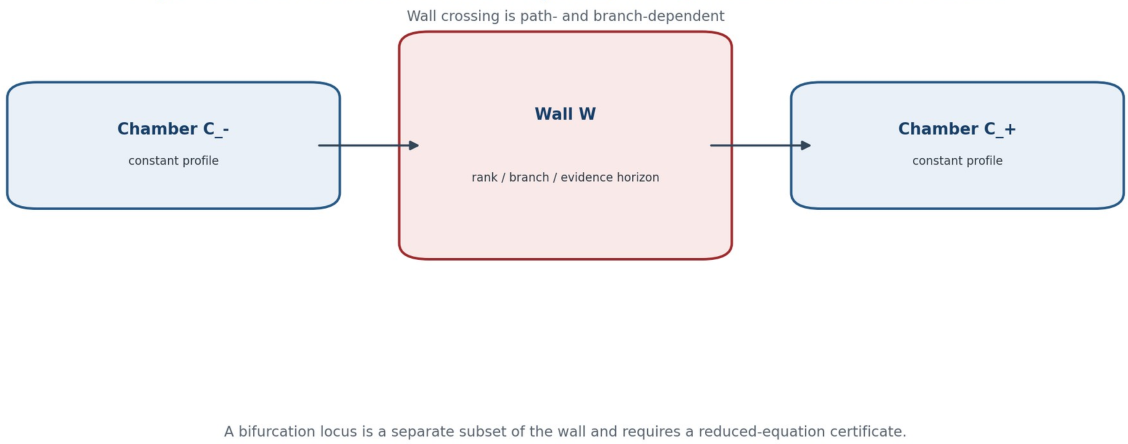


Figure 38. Stratified moduli space, wall, and bifurcation locus.

P_str(x)=(dim H^1_x,dim H^2_x,dim H^3_x,dim Aut_x,rank dK_x,mult_x,HS_x,gamma_x,lambda_x,D_x, Dom_x).	T2-F160

I_trans:M_N^reg->Lambda, I_trans|_{S_alpha}=constant.	T2-F161

The profile records local deformation, automorphism, obstruction, multiplicity, Hilbert-Samuel, spectral, Reper, evidence, and domain data. Values on adjacent strata cannot be compared, added, or ranked until a typed transport rule is supplied.

17.2. Walls, Chambers, and Wall Certificates

W=Delta_rank union Delta_aut union Delta_obs union Delta_gap union Delta_branch union Delta_D union Delta_Dom union Delta_glue.	T2-F162

A chamber is a connected component of the parameter space minus W on which the certified moduli type is constant. A wall is a locus where at least one rank, stabiliser, obstruction, spectral, branch, evidence, domain, or gluing certificate changes. A wall certificate includes a local wall equation, normal orientation or coorientation, the incident branches, one-sided invariant limits, multiplicity control, Evidence-D, and a reproducible computation.

Theorem 17.1. Constancy in a Chamber [COND] If a connected chamber carries a ModTriv certificate and does not meet W, then P_str and every certified locally constant transition invariant remain constant throughout the chamber.

17.3. Partial Wall-Crossing Operator

WC_{gamma,t*}:Inv(C_-) dashedrightarrow Inv(C_+).	T2-F163

The operator is defined only after branches on both sides are identified through a common degeneration datum. In an additive sector, the defect is typed only after a transport map has been proved.

Delta_W I=I_+ - T_{-to+}I_-.	T2-F164

Countertheorem 17.2. Equal Dimensions Do Not Define Wall Crossing [THM] Equal dimensions of invariant spaces on both sides of a wall do not determine a canonical transition operator. Branch identification and transport data are indispensable.

In a general NAPG sector, wall crossing may be a correspondence, span, or functor between groupoids rather than a numerical jump.

17.4. Bifurcation Locus and Reduced Equation

$$\mathrm{Bif}(K)=\{(t,x):K_t(x)=0,\ \mathrm{rank}\ D_xK_t<r_{reg}\}.$$	T2-F165

A singular Jacobian is only a bifurcation candidate. The number of real branches, their stability, and their observability require a Lyapunov-Schmidt reduction and verified normal-form derivatives.

$$\mathrm{fold}: g=0, g_a=0, g_{aa}\neq 0, g_t\neq 0;\ \mathrm{cusp}: g=g_a=g_{aa}=0, g_{aaa}\, g_t\neq 0.$$	T2-F166

> **Theorem 17.3. Wall Is Not Bifurcation [THM]** In general W and the bifurcation locus B do not coincide. A wall may arise from a stability, domain, or stabiliser change with a regular local equation; a bifurcation may occur inside one chamber of an external classification.

Separating situation	What it shows
wall without bifurcation	a GIT polarisation changes admitted orbits while the local branch remains smooth
bifurcation without a chosen wall	$g(t,a)=a^2-t$ has a fold at $t=0$ even if no external chamber decomposition was declared
false numerical coincidence	an apparent rank jump may disappear after interval conditioning certifies the Jacobian

17.5. Branch Normalisation and the Branch Ledger

$$\mathrm{Branch}(Z/P)=\pi_0(\tilde{Z}\setminus \mathrm{Ram}(\nu)).$$	T2-F167

For the local zero locus $Z=\{K=0\}$, a branch is a connected component of a normalised cover after removal of the ramification locus. The ledger records branch_id, local equation, multiplicity, orientation or coorientation, stabiliser, D/Dom, provenance, permitted continuations, and branch points. Without branch_id, the phrase “the same branch after the transition” has no verifiable content.

Figure 39. Branch Continuation and Monodromy

A branch label is local unless monodromy is trivial or a global section is proved

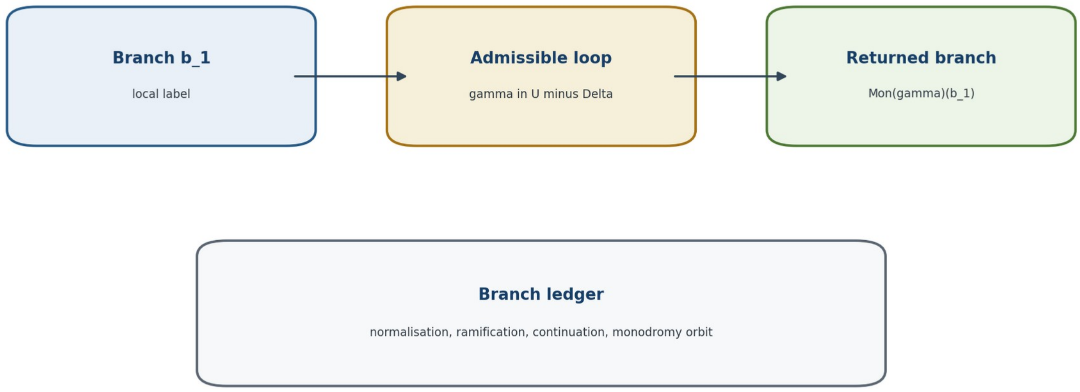


Figure 39. Continuation of branches and monodromy along an admissible loop.

17.6. Branch Monodromy and the No-Global-Label Theorem

Mon:pi_1(U,t_0)->Perm(B_{t_0}).	**T2-F168**

rho:pi_1(U,t_0)->Aut(V_{t_0}).	**T2-F169**

Monodromy depends on the punctured parameter domain and the allowed path class. It is not automatically the holonomy of Chapter 9; a comparison functor must translate branch continuation into parallel transport of a specified bundle.

Theorem 17.4. Homotopy Invariance [THM] If the branch cover is locally trivial over U, continuation along homotopic loops with fixed endpoints yields the same branch permutation; Mon therefore factors through pi_1(U,t_0).

Theorem 17.5. No Global Labelling [THM] If the image of Mon is nontrivial, there is no global continuous numbering of all branches over U.

Proof. A global numbering would trivialise the branch cover and force every loop to preserve each label, contradicting a loop with nontrivial permutation. □

KLT-RBD must therefore store monodromy orbits. It must neither create artificial new objects after a permutation nor force a label to remain fixed when the topology forbids it.

17.7. Path Dependence and Relations Between Wall Operators

T_gamma=WC_m o ... o WC_2 o WC_1.	**T2-F170**

Even with the same endpoints, T_gamma may depend on the homotopy class of the path in the complement of higher-codimension discriminants. Path independence requires a flat local system or proved commutation, braid, or higher-coherence relations.

WC_i WC_j=WC_j WC_i or WC_i WC_j WC_i=WC_j WC_i WC_j.	T2-F171

Such relations are conclusions of a specific model, not consequences of the term “wall crossing.”

17.8. Stratified Local Triviality and Stability Levels

The certificate StratTriv(U) records Whitney conditions or a declared replacement, the frontier condition, properness or local properness, submersion on each stratum, control data, and compatibility with Kuranishi charts, stabilisers, and Evidence-D. Under these hypotheses, the family is locally topologically trivial by strata and the stratified homeomorphism type is constant.

Level	Stability contract
S0	chamber constancy of a discrete invariant
S1	transport stability of a vector or class under a declared local system
S2	branch stability including normalisation, monodromy orbit, and wall operators
S3	predictive stability with D/Dom, numerical margins, and independent reproducibility

P_W(t,b)=(dist(t,W),sigma_min(D_xK_t),mult_b,MonOrb_b,eta_K,eta_H,lambda_b,CGI_b).	T2-F172

17.9. Wall-Bifurcation Transition Horizon

Delta_WB=Delta_strat union Delta_wall union Delta_bif union Delta_ram union Delta_mon union Delta_path union Delta_inv.	T2-F173

Delta_safe^{v0.14}=Delta_mod union Delta_WB.	T2-F174

The cumulative horizon records failure of the stratification, wall certificate, bifurcation test, branch normalisation, monodromy control, path typing, or invariant transport. It is combined with the Chapter 16 moduli horizon, but the individual causes remain visible.

17.10. Main Wall-Crossing-Safe Theorem

> **Theorem 17.7. Wall-Crossing-Safe Prediction [COND]** Let a family possess certified Kuranishi charts, an admissible stratification, StratTriv and ModTriv data, branch normalisation and monodromy, typed wall operators, stable transition invariants, valid D/Dom/gluing evidence, and closed predecessor blockers. If a path avoids Delta_safe^{v0.14}, no certified wall crossing occurs. If it meets the horizon, the output is only a candidate requiring post-wall branch matching and independent checks.

gamma intersect Delta_safe^{v0.14} =empty => NO-WALL-CROSSING-IN-MODEL. **T2-F175**

Block_WB=B_strat union B_Whit union B_wall union B_bif union B_branch union B_mon union B_path union B_inv union B_D union B_Dom union B_glue union B_ind. **T2-F176**

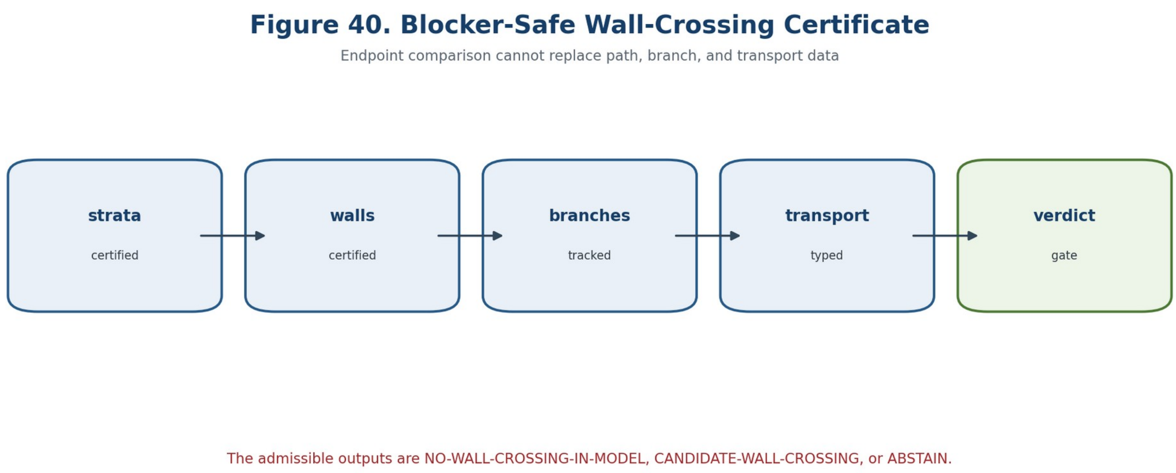


Figure 40. Blocker-safe wall-crossing certificate WC-01-WC-24.

Output	Condition	Interpretation
NO-WALL-CROSSING-IN-MODEL	gamma avoids Delta_safe and blockers are empty	certified structural profile remains in one chamber
CANDIDATE-WALL-CROSSING	gamma meets the horizon with a valid certificate	target for branch and post-wall tests
ABSTAIN	any stratification, branch, path, evidence, or independence blocker remains	no transition conclusion

17.11. Countermodels and WC-MON Certificate

- Equal endpoints with different path classes may yield different ordered wall compositions.
- A singular numerical Jacobian may be a conditioning artefact rather than a bifurcation.
- A wall generated by a domain or stability change may have no local branch bifurcation.
- A genuine fold may occur before any external wall decomposition is chosen.
- Nontrivial monodromy prohibits a global branch label even though every local chart is regular.
- A constant dimension profile does not determine multiplicity, branch topology, or monodromy orbit.
- A wall crossing in a static moduli family is not by itself a physical event or causal transition.

WC-MON group	Checks
WC-01-06	stratification, frontier and Whitney/control data, wall equations, coorientations, and chamber decomposition
WC-07-12	Kuranishi discriminant, reduced equation, branch normalisation, ramification, multiplicity, and branch IDs
WC-13-18	continuation, monodromy, path classes, wall operators, cocycle/braid relations, and transport typing
WC-19-24	Evidence-D/Dom, stability margins, cumulative horizon, blocker-safe verdict, code/data/environment hashes

INPUT K_t,stratification,path,branches,invariant, D/Dom; verify charts, strata, walls, normalisation, monodromy, transport, and margins; emit ABSTAIN, NO-WALL-CROSSING-IN-MODEL, or CANDIDATE-WALL-CROSSING.	**T2-F177**

BOUNDARY OF CHAPTER 17. Wall crossing is a certified change of classification along a path. It is not an observation that a physical event occurred, and branch monodromy is not automatically causal holonomy.

Prior art includes Whitney stratifications, isotopy lemmas, singularity and bifurcation theory, branch normalisation, monodromy, and wall-crossing formalisms. The authorial contribution is their KLT-RBD integration with the NAPG Kuranishi package, branch ledger, D/Dom, Reper coordinates, and blocker-safe predictive verdict.

Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier

ONTOLOGY	The global predictive carrier is a homotopy-coherent stacky or derived moduli object, not a collection of local charts or its coarse quotient.
EPISTEMOLOGY	Global knowledge requires effective descent, coherent coordinate changes, a perfect virtual tangent complex, branch descent, and Evidence-D/Dom compatibility.
PHENOMENOLOGY	The global object appears through a virtual tangent profile, obstruction sheaf or cone, branch stack, determinant data, and transported Reper coordinates.
LIMITATION	Local liftability does not imply a global object, and equal coarse spaces do not imply equivalent stacky or derived structures.
AUTHORIAL NOVELTY	The authorial node is the global NAPG/KLT-RBD predictive carrier with a three-valued verdict and preserved status firewall.

Local Kuranishi charts, their coarse quotient, and even locally vanishing obstruction classes do not determine a global moduli object. The final chapter of this checkpoint constructs a homotopy-coherent global carrier, its virtual tangent complex, obstruction sheaf or cone, branch stack, determinant and orientation data, Reper/Evidence-D descent, and the global transition horizon. The output remains NO-GLOBAL-TRANSITION-IN-MODEL, CANDIDATE-GLOBAL-TRANSITION, or ABSTAIN.

18.1. Three Global Moduli Levels

$$|M| \leftarrow M \leftarrow M^{der}. \qquad \textbf{T2-F178}$$

Level	Retained information	Typical loss at the next coarser level
derived moduli object M^der	higher tangent and obstruction data, homotopies, stabilisers	derived directions and higher coherence
stacky moduli object M	objects, isomorphisms, stabilisers, descent	automorphism and branch information
coarse space |M|	isomorphism classes as points	stabilisers, derived tangent profile, and higher descent

The arrows are forgetful, not equivalences. A coarse point cannot reconstruct the stacky or derived object without additional data.

18.2. Local Kuranishi Charts and Coordinate Changes

$$K_i=(U_i,E_i,s_i,G_i,\psi_i). \qquad \textbf{T2-F179}$$

$$\mathrm{vdim}(K_i)=\dim U_i-\mathrm{rank}\, E_i-\dim G_i. \qquad \textbf{T2-F180}$$

$$s_j \circ \phi_{ij} = \hat{\phi}_{ij} \circ s_i. \qquad \textbf{T2-F181}$$

A chart includes a finite-dimensional base U_i, an obstruction bundle E_i, a section s_i, an isotropy group G_i, and a footprint map psi_i. A coordinate change is not only a map of bases: it must intertwine obstruction bundles, sections, group actions, footprints, and the declared Reper/Evidence-D structures.

alpha_ijk:Phi_jk o Phi_ij => Phi_ik.	T2-F182

Triple compositions agree up to specified 2-morphisms, which must themselves satisfy a higher coherence condition on quadruple overlaps. Pairwise coordinate compatibility is not enough.

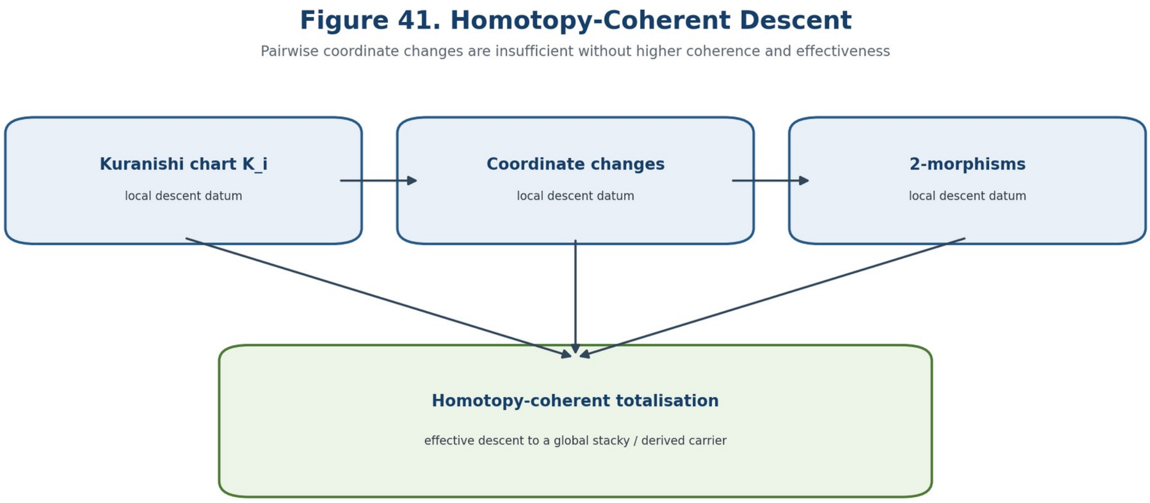


Figure 41. Homotopy-coherent descent from local Kuranishi charts to a global stacky or derived carrier.

18.3. Cech Nerve and Effective Descent

M(U) is equivalent to Tot(M(U_bullet)).	T2-F183

Definition 18.2. Effective Descent [CL/COND] A homotopy-coherent local datum is effective when its totalisation is represented by a global object with the declared universal property.

A coherent diagram may still fail to be effective in the selected category. The globalisation certificate therefore records the Cech nerve, pairwise maps, triple 2-cocycles, quadruple coherence, stabilisers, and the existence—not merely the notation—of the global object.

18.4. Virtual Tangent Complex

T_x^vir=[g_x -> T_xU_i -> E_{i,x}].	T2-F184

vdim_x=-dim H^{-1}+dim H^0-dim H^1.	T2-F185

The three cohomological degrees record infinitesimal automorphisms, deformation directions, and obstruction directions. Virtual dimension is only their alternating sum and cannot reconstruct the individual groups.

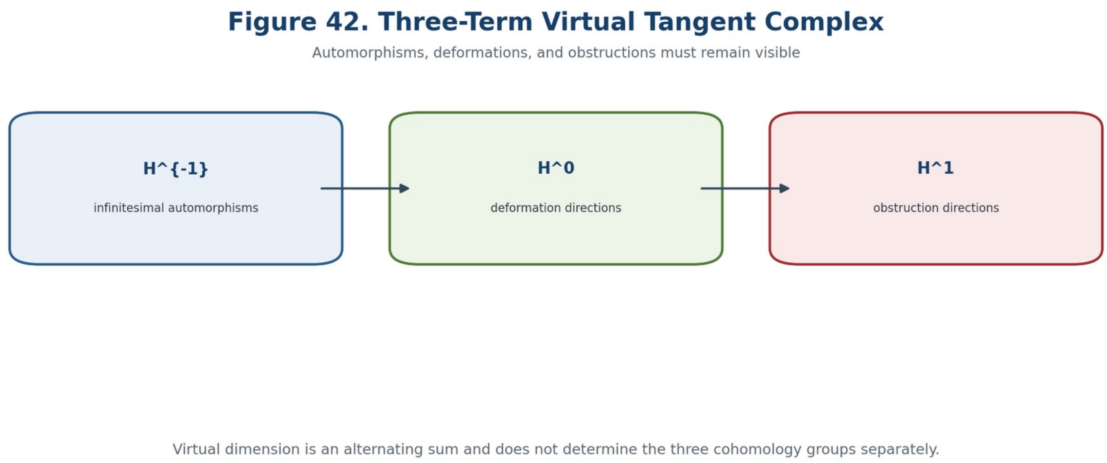


Figure 42. Virtual tangent complex: automorphisms, deformations, and obstructions remain visible.

18.5. Perfect Obstruction Theory and Intrinsic Normal Cone

$$\phi: E^\bullet \to L_M, \quad E^\bullet \text{ perfect}, \quad \mathrm{amp}(E^\bullet) \subset [-1,0]. \qquad \text{T2-F186}$$

$$Ob_M = h^1((E^\bullet)^\vee), \quad N_M = h^1/h^0(L_M^\vee). \qquad \text{T2-F187}$$

A perfect obstruction theory gives a controlled morphism from a perfect complex to the cotangent complex and supports an intrinsic normal cone construction. The selected amplitude, perfectness, compatibility with local charts, and orientation data are certificate fields; they are not inferred from a finite list of equations.

18.6. Gluing Local Obstruction Theories

$$q_{jk} \circ q_{ij} \text{ is homotopic to } q_{ik}. \qquad \text{T2-F188}$$

$$c_{ijk} = q_{ik}^{-1} q_{jk} q_{ij} \in Z, \quad [c] \in \check{H}^2(X, Z). \qquad \text{T2-F189}$$

Local obstruction complexes glue only through quasi-isomorphisms with coherent homotopies. A nontrivial central Cech class blocks the global obstruction theory even when every local chart is individually valid.

$$\det(T^{vir}) = \bigotimes_j (\det H^j(T^{vir}))^{(-1)^j}. \qquad \text{T2-F190}$$

The determinant line and orientation are additional global data. Equal virtual dimensions do not imply equal determinant, orientation, or cohomological profile.

18.7. Branch Stack and Monodromy

Mon:pi_1(P minus Delta,p_0)->Perm(B_{p_0}).	**T2-F191**

The branch stack retains local branches, isotropy, continuation maps, and monodromy. A coarse quotient forgets these data. The Chapter 17 branch ledger is therefore promoted to part of the global descent package.

18.8. Global KLT-RBD Predictive Carrier

Definition 18.4. Predictive Carrier [DEF-A] The global carrier PredCar_N combines a derived moduli family, virtual tangent complex, obstruction sheaf or cone, branch stack, Reper atlas, projective-harmonic coordinate, Evidence-D, admissible domain, and external E-complex.

PredCar_N=(M_N^der->P,T^vir,Ob_N,C_N,B_N,Rep_N,lambda_N,D_N,Dom_N,E_N).	**T2-F192**

Existence requires effective atlas descent, coherent coordinate changes, a derived/perfect enhancement, fixed amplitude and perfectness, branch descent, Reper descent, Evidence-D descent, Dom compatibility, a global lambda outside its poles, and an independently reproducible computational package.

18.9. Local-to-Global and Coarse-Moduli No-Go Theorems

c_ijk=g_ki g_jk g_ij.	**T2-F193**

Theorem 18.5. Local-to-Global No-Go [THM] Vanishing of every local obstruction class does not imply a global object. A nontrivial descent class or failure of coherent trivialisation may obstruct the global lift even when all local Kuranishi residuals vanish.

local lift + local obstruction=0 does not imply global lift.	**T2-F194**

Theorem 18.6. Coarse-Moduli No-Go [THM] A coarse moduli space does not determine the stacky or derived moduli object. The quotient stack [A^1/mu_2] and the ordinary A^1 have the same coarse type but different stabilisers and virtual tangent profiles.

|M_1| isomorphic |M_2| does not imply M_1 equivalent M_2 and does not imply M_1^der equivalent M_2^der.	**T2-F195**

18.10. Global Residuals and Transition Horizon

eta_desc=||higher descent defect||, eta_ob=||h(ob)||, eta_ext=||Pi_E(ob)||.	**T2-F196**

The three residuals live in different carriers and may not be added before an explicit normalisation and comparison theorem. The decision object is a blocker vector, not a single untyped score. A small numerical descent defect does not establish exact 2-coherence without an interval certificate.

Delta_stack=Delta_desc union Delta_coh union Delta_perf union Delta_amp union Delta_vrank union Delta_orient union Delta_branch union Delta_mon union Delta_Rep union Delta_D union Delta_Dom union Delta_ext union Delta_ind.	**T2-F197**

Delta_safe^{v0.15}=Delta_safe^{v0.14} union Delta_stack.	**T2-F198**

P_stack(p)=([amp T^vir],h^{-1},h^0,h^1,vdim,[det],[desc],MonOrb,eta_ob,eta_ext,lambda,CGI) .	**T2-F199**

The global profile is comparable only after transport between fibres and branch identification. Raw Kuranishi coordinates, numbers of local equations, and branch names are not global invariants.

18.11. Main Global-Stack-Safe Theorem

> **Theorem 18.7. Global-Stack-Safe Prediction [COND]** Let a connected parameter chamber carry a proper or controlled locally trivial stacky/derived family; effective homotopy-coherent Kuranishi descent; perfect virtual tangent complexes linked by quasi-isomorphisms of constant amplitude; certified cohomology ranks, determinant/orientation, and branch monodromy orbit; compatible descent of the Reper atlas, lambda, Evidence-D, Dom, and the external E-bridge; closed Hodge-Green, Kuranishi, wall-crossing, and globalisation blockers; a path avoiding Delta_safe^{v0.15}; and a uniform positive margin for the relevant global obstruction. Then the global profile is constant along the path up to proved transport, and a transition requiring a profile change or removal of the uniformly nonzero obstruction is impossible inside the model.

gamma intersect Delta_safe^{v0.15} =empty => NO-GLOBAL-TRANSITION-IN-MODEL.	**T2-F200**

If the path meets Delta_stack or the global obstruction residual admits zero, the only allowed positive-side output is CANDIDATE-GLOBAL-TRANSITION. A positive transition conclusion still requires a post-transition global object, branch matching, and independent verification.

Block_stack=B_atlas union B_2coc union B_eff union B_perf union B_amp union B_vtan union B_branch union B_Rep union B_D union B_Dom union B_E union B_ind.	**T2-F201**

Figure 43. Global Predictive Carrier

The global KLT-RBD carrier preserves derived structure, branches, evidence, and the right to abstain

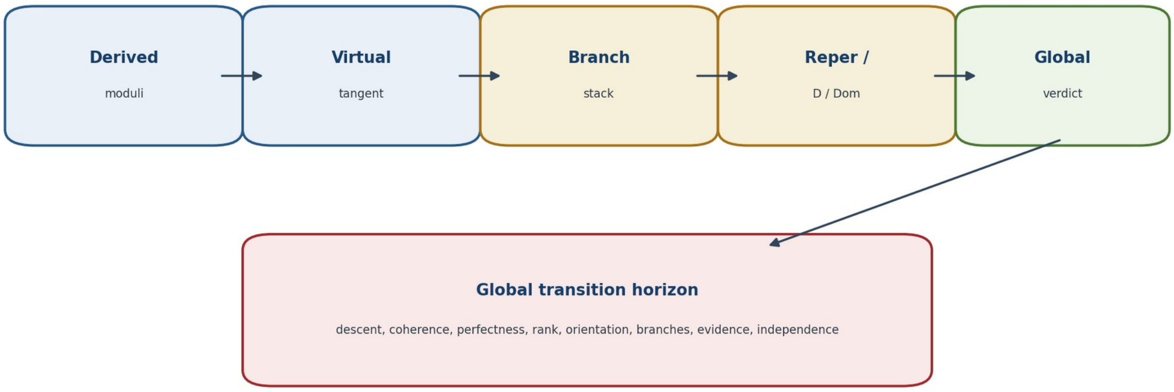


Figure 43. Global predictive carrier and blocker-safe three-valued verdict.

Output	Condition	Permitted meaning
NO-GLOBAL-TRANSITION-IN-MODEL	path avoids the cumulative horizon, residual margin positive, blockers empty	global certified profile remains constant
CANDIDATE-GLOBAL-TRANSITION	path meets the horizon or the residual admits zero with a valid certificate	requires construction of the post-transition global object
ABSTAIN	any descent, coherence, perfectness, branch, evidence, domain, external, or independence blocker remains	no global transition conclusion

18.12. Separating Models and STACK-GLOB Certificate

- All local Kuranishi maps vanish while a nontrivial gerbe or descent class blocks the global object.
- The same coarse space with different stabilisers has different stacky type.
- The same virtual dimension with different H^{-1} and H^1 hides automorphisms and obstruction directions.
- Perfect complexes with the same Euler characteristic need not be quasi-isomorphic.
- A glued stack without descended Evidence-D is a mathematical object but not an authorised Reper candidate.
- Global lambda=-1 with invalid Dom leaves the prediction gate closed.
- A nontrivial virtual class without time dynamics is an enumerative invariant, not an event.
- A numerically small descent defect without interval certification may be a badly conditioned nonzero defect.

STACK-GLOB group	Checks
STACK-01-08	atlas and footprint inventory, typed coordinate changes, pairwise/triple/quadruple coherence, stabilisers, and equivalence checks

STACK-GLOB group	Checks
STACK-09-16	Cech nerve, effective totalisation, local virtual tangent complexes, quasi-isomorphisms, amplitude, ranks, virtual dimension, determinant/orientation
STACK-17-24	local/global obstruction carriers, branch stack and monodromy, Reper/Evidence-D/Dom descent, lambda invariance and pole checks
STACK-25-28	external E/Pi_E compatibility, cumulative horizon, blocker-safe verdict, and code/data/environment hashes

BOUNDARY OF CHAPTER 18. The global carrier is a conditional mathematical construction. It preserves local-to-global, stacky/derived, evidence, and domain distinctions. It does not turn a virtual or enumerative invariant into a physical event.

Prior art includes cotangent complexes, intrinsic normal cones and perfect obstruction theories, derived and homotopical geometry, derived smooth manifolds, Kuranishi atlases, and Kuranishi 2-categories. The authorial contribution is their blocker-safe NAPG/KLT-RBD synthesis in which the global carrier simultaneously preserves derived tangent type, branch monodromy, Reper structure, Evidence-D, Dom, the external E-bridge, and the right to abstain.

Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall

ONTOLOGY	Virtual geometry supplies a cycle-theoretic carrier; probability requires a separate measurable bridge.
EPISTEMOLOGY	Knowledge is certified through a perfect obstruction package, a virtual class, insertions, orientation, properness, and an explicit probability model when probabilistic language is used.
PHENOMENOLOGY	The layer appears through signed or weighted virtual counts, localization formulas, deformation invariants, and calibrated predictive outputs.
LIMITATION	A virtual degree is not a probability measure, and an enumerative invariant does not determine event likelihood without an independently tested link.
AUTHORIAL NOVELTY	The authorial node is the two-gate virtual/probability firewall inside the Reper, D/Dom, and KLT-RBD certificate chain.

The horizon is the union of loci where rank, domain, topology, calibration, identification, or numerical certification can change. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

Controlled field	Value
Canonical input	Frozen Russian Chapter 19, inherited English Chapters 1-18, and formula/source passports.
New mathematical layer	Virtual geometry supplies a cycle-theoretic carrier; probability requires a separate measurable bridge.
Status rule	Definitions, theorems, conditional bridges, models, numerical certificates, and physical hypotheses remain distinct.
Prohibition	A virtual degree is not a probability measure, and an enumerative invariant does not determine event likelihood without an independently tested link.
Downstream role	Chapter 24 composes all certified layers and preserves ABSTAIN/FAIL as absorbing results.

19.1. Four Non-equivalent Layers of Knowledge

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

V0 -> V1 does not imply P0 -> E0.	**T2-F202**

19.2. Cycle Carrier and Virtual Dimension

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

$\varphi:E\bullet\to L\_\mathfrak{M}$, $\mathrm{amp}(E\bullet)\subset[-1,0]$.	**T2-F203**

$\mathrm{vdim}(\mathfrak{M})=\mathrm{rk}(E^\bullet)=\mathrm{rk}(E^0)-\mathrm{rk}(E^{-1})$.	**T2-F204**

19.3. Construction of the Virtual Fundamental Class

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

$[\mathfrak{M}]^{\mathrm{vir}} = 0\_\mathfrak{E}\text{^}!\ [\mathfrak{c}\_\mathfrak{M}] \in A\_\mathrm{vdim}(\mathfrak{M})$.	**T2-F205**

Figure 44. Virtual Carrier and Probability Bridge

The mathematical cycle layer and the probability layer are connected only by an explicit model

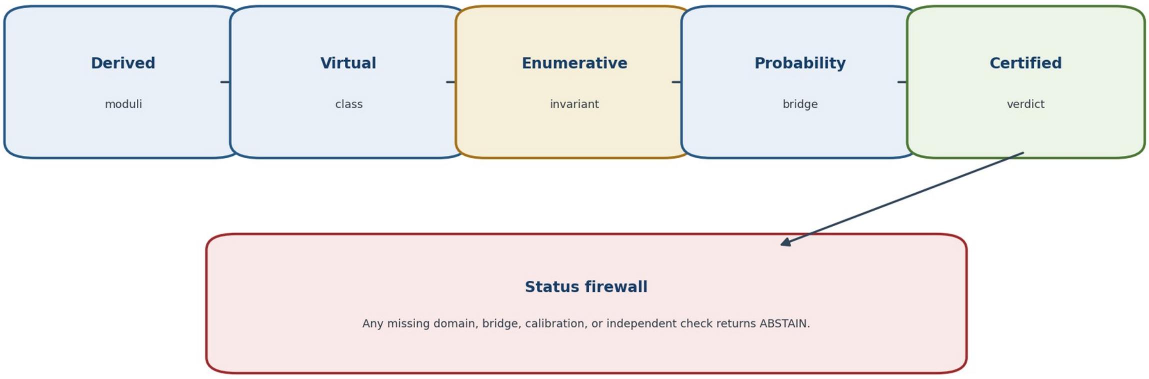


Figure 44. Virtual carrier and separate probability bridge.

19.4. Integration over the Virtual Class

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

$I^{\mathrm{vir}}(\mathfrak{M};\alpha)=\int\_[\mathfrak{M}]^{\mathrm{vir}}\ \alpha = \deg(\alpha\cap[\mathfrak{M}]^{\mathrm{vir}})$.	**T2-F206**

$\langle\alpha_1,\ldots,\alpha_n\rangle^{\mathrm{vir}} = \int\_[\mathfrak{M}]^{\mathrm{vir}} \prod_i \mathrm{ev}_i{}^*\alpha_i$.	**T2-F207**

19.5. Regular Zero Locus and Excess Intersection

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

$[Z]^{\mathrm{vir}}=[Z]$, $\mathrm{vdim}=\dim U-\mathrm{rk}\ E$.	**T2-F208**

19.6. Deformation Invariance

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

$[\mathfrak{M}_b]^{vir} = i_b^![\mathfrak{M}]^{vir}_{rel}.$	**T2-F209**

$I^{vir}(\mathfrak{M}_b;\alpha_b)=\mathrm{const}.$	**T2-F210**

19.7. Equivariant Localization

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

$[\mathfrak{M}]^{vir} = i_* \Sigma_F [F]^{vir} / e_T(N_F^{vir})$	**T2-F211**

19.8. When a Virtual Count Is Genuinely Enumerative

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

$I^{vir} = \Sigma_{[x]} m_x / \lvert\mathrm{Aut}(x)\rvert.$	**T2-F212**

19.9. Three Models Refuting the Probability Substitution

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

19.10. No Universal Probabilistic Interpretation Theorem

The statement is read under the explicitly declared hypotheses; its conclusion remains inside the mathematical model and does not acquire empirical status by translation. Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

> **Theorem 19.4. No Universal Probability Interpretation [THM]** There is no unrestricted carrier-independent rule that sends every virtual count to a probability while preserving the required probability axioms. Negative, greater-than-one, and stack-weighted examples provide separating witnesses.

virtual degree $\neq$ probability measure.	**T2-F213**

Figure 45. Probability No-Go Test

Virtual counts may violate probability-range and normalization requirements

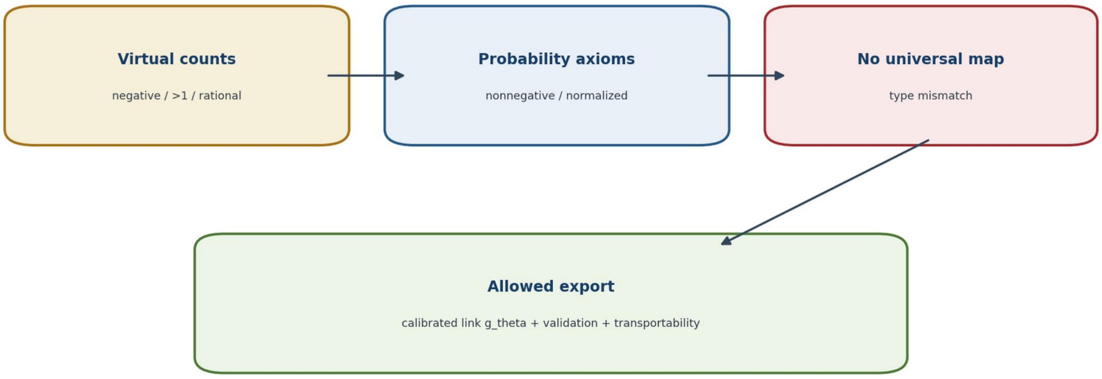


Figure 45. Probability no-go test for unrestricted virtual counts.

19.11. The Probabilistic Bridge

The bridge is an additional typed map with its own identification, calibration, and transport obligations; it is not supplied by a shared notation. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

$B_{prob}=(\Omega,\mathscr{F},P,Y,\varphi,g_\theta,\mathscr{L},Cal,Val,Ext).$	**T2-F214**

$p_\theta = g_\theta(\varphi(P_{vir}, P_{stack}, \lambda, CGI, D, Dom)).$	**T2-F215**

19.12. Calibration, Discrimination, and Transportability

The bridge is an additional typed map with its own identification, calibration, and transport obligations; it is not supplied by a shared notation. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

$E[Y \mid p_\theta]=p_\theta.$	**T2-F216**

19.13. Virtual Reper Certificate

The certificate records inputs, algorithms, tolerances, residuals, sources, code and data hashes, and the weakest evidential status supported by the chain. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

$VirtCert=(\mathfrak{M}^{der},E^\bullet,\mathfrak{c}_{\mathfrak{M}},[\mathfrak{M}]^{vir},\alpha,or,prop,src,code,D,Dom).$	**T2-F217**

$$\mathrm{Rep\_vir}=(\mathrm{R\_vir},\mathrm{I\_vir},\mathrm{U\_vir};\mathrm{D\_vir}), \tag{T2-F218}$$

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

19.14. Projective-Harmonic and Enumerative Gate

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

$$\mathrm{Gate\_vir}=1 \Leftrightarrow \mathrm{Cert\_VFC}=1 \wedge \mathrm{Valid}(D)=1 \wedge \mathrm{Dom}=1 \wedge \mathrm{Block\_vir}=\varnothing. \tag{T2-F219}$$

$$\mathrm{Gate\_prob}=1 \Leftrightarrow \mathrm{Gate\_vir}=1 \wedge \mathrm{Cert\_prob}=1 \wedge \mathrm{Ext}=1. \tag{T2-F220}$$

19.15. Virtual and Probabilistic Horizons

The horizon is the union of loci where rank, domain, topology, calibration, identification, or numerical certification can change. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

$$\Delta\_\mathrm{VFC} = \Delta\_\mathrm{POT} \cup \Delta\_\mathrm{amp} \cup \Delta\_\mathrm{prop} \cup \Delta\_\mathrm{or} \cup \Delta\_\mathrm{comp} \cup \Delta\_\mathrm{ins} \cup \Delta\_\mathrm{loc} \cup \Delta\_\mathrm{wall} \cup \Delta\_\mathrm{num}. \tag{T2-F221}$$

$$\Delta\_\mathrm{prob} = \Delta\_\Omega \cup \Delta\_\mathrm{meas} \cup \Delta\_\mathrm{link} \cup \Delta\_\mathrm{cal} \cup \Delta\_\mathrm{shift} \cup \Delta\_\mathrm{sel} \cup \Delta\_\mathrm{ext}. \tag{T2-F222}$$

$$\Delta\_\mathrm{safe}^{v0.16}=\Delta\_\mathrm{safe}^{v0.15} \cup\Delta\_\mathrm{VFC}\cup\Delta\_\mathrm{prob}. \tag{T2-F223}$$

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

19.16. Main Conditional Theorem

The statement is read under the explicitly declared hypotheses; its conclusion remains inside the mathematical model and does not acquire empirical status by translation. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

> **Theorem 19.6. Conditional Virtual-Profile Constancy [COND]** Along a path that avoids the inherited and virtual horizons, with a transported obstruction theory, orientation, properness and insertion data, the certified virtual profile is constant. This does not determine the probability of leaving that sector.

$$P\_VFC(t)=([\mathfrak{M}\_t]^{vir}, \mathrm{vdim}, I^{vir}\_t, \mathrm{supp}, \mathrm{sign}, \mathrm{denom}, \mathrm{chamber}, \lambda\_t, CGI\_t) \quad \text{T2-F224}$$

$$\gamma\cap(\Delta\_safe^{v0.15}\cup\Delta\_VFC)=\varnothing \Rightarrow \text{NO-VIRTUAL-CHANGE-IN-MODEL.} \quad \text{T2-F225}$$

19.17. Two-Stage Blocker-Safe Verdict

The allowed output is multi-valued: a certified conclusion, an explicit candidate requiring further checks, ABSTAIN with blockers, or FAIL with a witness. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

Figure 46. Two-Stage Virtual/Probability Verdict

A successful virtual gate does not automatically open the probability gate

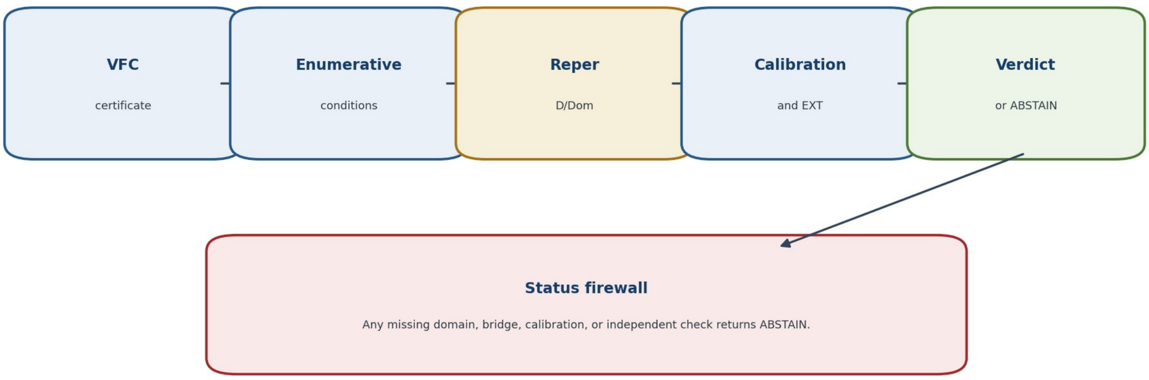


Figure 46. Two-stage virtual/probability verdict.

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

19.18. Counterexamples and Separating Models

Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

19.19. Computational Certificate VFC-ENUM-PROB

The certificate records inputs, algorithms, tolerances, residuals, sources, code and data hashes, and the weakest evidential status supported by the chain. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE

Gate component	Required check	Failure output
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

19.19.1. Pseudocode

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

19.20. Prior Art and Boundary of the Authorial Contribution

Classical constructions retain their standard attribution; the authorial contribution is the typed, blocker-safe synthesis inside KLT-RBD. Virtual intersection data and probabilistic data remain separate until a calibrated measurable link is supplied.

> **BOUNDARY OF CHAPTER 19.** A virtual degree is not a probability measure, and an enumerative invariant does not determine event likelihood without an independently tested link. truth_layer_promotion=0; independent EXT-RUN and EMP-OBS remain absent.

Chapter 20. Categorified, Motivic, and Refined Virtual Invariants

ONTOLOGY	A refined invariant first lives in a categorical or motivic carrier and only later admits decategorified and numerical realizations.
EPISTEMOLOGY	Each realization is treated as a potentially information-losing map whose domain, completion, orientation data, and specialization must be recorded.
PHENOMENOLOGY	The structure appears through Grothendieck classes, motives, vanishing cycles, refined series, CoHA/BPS carriers, and completed products.
LIMITATION	A grading, charge, coefficient index, or generating-series variable is not physical time without a state space, evolution family, observable, and empirical bridge.
AUTHORIAL NOVELTY	The authorial node is the motivic/series/dynamic firewall with a typed realization passport and an abstention rule.

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

Controlled field	Value
Canonical input	Frozen Russian Chapter 20, inherited English Chapters 1-18, and formula/source passports.
New mathematical layer	A refined invariant first lives in a categorical or motivic carrier and only later admits decategorified and numerical realizations.
Status rule	Definitions, theorems, conditional bridges, models, numerical certificates, and physical hypotheses remain distinct.
Prohibition	A grading, charge, coefficient index, or generating-series variable is not physical time without a state space, evolution family, observable, and empirical bridge.
Downstream role	Chapter 24 composes all certified layers and preserves ABSTAIN/FAIL as absorbing results.

20.1. Carrier Ladder and No-Promotion Rule

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

$$\mathbb{V}\_\gamma \in \mathscr{C}\_\gamma \to [\mathbb{V}\_\gamma] \in K_0(\mathscr{C}\_\gamma) \to \mathscr{M}\_\gamma \in R\_mot \to Real(\mathscr{M}\_\gamma) \to I\_\gamma \in R\_num. \quad \text{T2-F226}$$

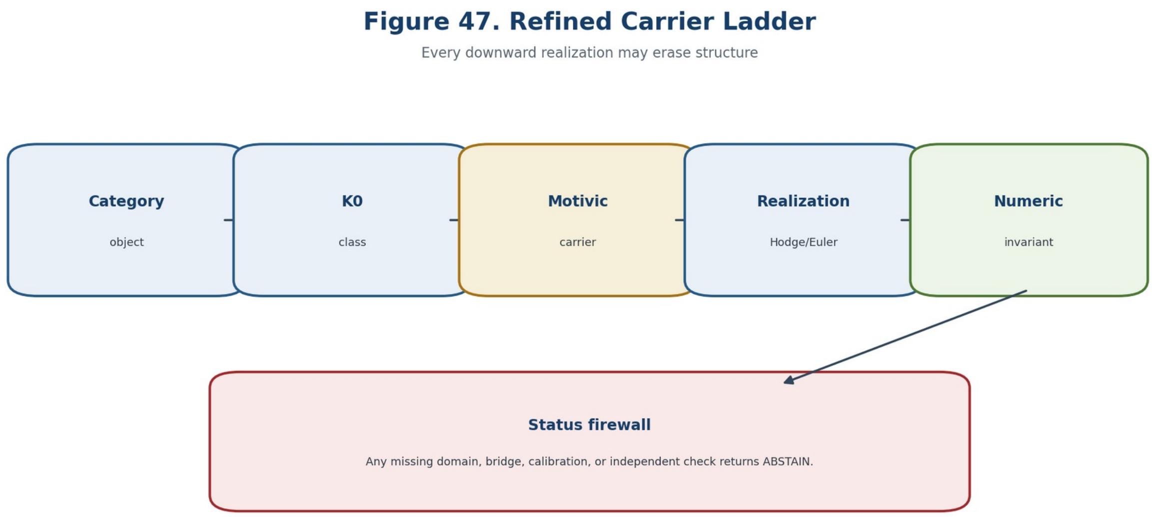


Figure 47. Refined carrier ladder and information loss.

20.2. Categorification and Decategorification

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

$$[Y]=[X]+[Z].$$

T2-F227

20.3. Motivic Carrier and the Grothendieck Ring of Varieties

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

$$[X]=[Z]+[X\setminus Z] \text{ for closed } Z \text{ subset } X, \text{ and } [X]*[Y]=[X \times Y].$$

T2-F228

$$\mathrm{MotCar}=(R\_mot, \mathbb{L}\hat{}\{1/2\}, \mathrm{Fil}, \mathrm{Comp}, \hat{\mu}, \mathrm{or}, \mathrm{src}, D, \mathrm{Dom}),$$

T2-F229

20.4. Realizations and the Numerical Indistinguishability Theorem

The statement is read under the explicitly declared hypotheses; its conclusion remains inside the mathematical model and does not acquire empirical status by translation. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

> **Theorem 20.2. Numerical Indistinguishability [THM]** Equal numerical realizations do not reconstruct equivalent categorical or motivic carriers unless the selected realization functor is proved conservative on the declared subcategory.

$\chi\_c : K_0(Var\_\mathbb{C}) \to \mathbb{Z}, E\_c : K_0(Var\_\mathbb{C}) \to \mathbb{Z}[u,v].$	**T2-F230**

20.5. Power Structures and Plethystic Operations

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

PExp(f)=exp(Σ_{r≥1} ψ_r(f)/r), PLog=PExp^{-1}.	**T2-F231**

20.6. Motivic Vanishing Cycles and Orientation Data

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

MF^φ_{U,f} ∈ 𝓜_X^{μ̂}, Real(MF^φ_{U,f}) = vanishing-cycle realization.	**T2-F232**

20.7. Refined Invariants and the Realization Passport

The certificate records inputs, algorithms, tolerances, residuals, sources, code and data hashes, and the weakest evidential status supported by the chain. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

Ω_γ^{ref}(y)=Σ_j (-1)^j dim 𝓗_γ^j · y^{j/2}.	**T2-F233**

20.8. Cohomologicalical Hall Algebra

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

CoHA=⊕_{γ∈Γ_+} H^•_{c,G_γ}(Rep_γ, φ_{Tr W}),	**T2-F234**

20.9. BPS Cohomologicaly and Integrality

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

BPS_γ ∈ MHM(M_γ), Ω_γ^{ref} =Real(BPS_γ).	T2-F235

20.10. Generating Series as Completed Graded Objects

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

Z_ref(**x**;y,𝕃)=1+Σ_{0≠γ∈Γ_+} Ω_γ^{ref}(y,𝕃) **x**^γ ∈ 1+Î.	T2-F236

20.11. Quantum Torus and Ordered Factorizations

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

x^α **x**^β = 𝕃^{⟨α,β⟩/2} **x**^{α+β}.	T2-F237

20.12. Rationality and Functional Equations

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

Z(q^{-1}) = q^a * epsilon * Z(q), or Z(q)=P(q)/Q(q).	T2-F238

20.13. Non-identifiability of Time from Coefficients

Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

> **Theorem 20.5. Time Non-identifiability from Coefficients [THM]** A graded or generating-series coefficient sequence does not identify a temporal evolution law without a time set, state embedding, evolution family, observation map, and calibration contract.

graded coefficient ≠ time-stamped state; generating series ≠ flow.	T2-F239

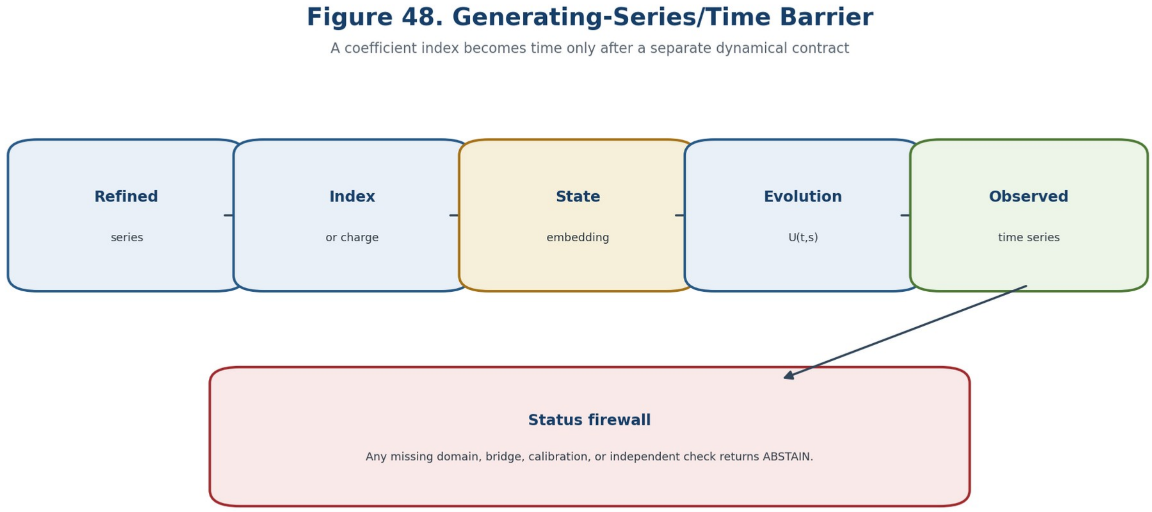


Figure 48. Barrier between a generating series and temporal dynamics.

20.14. Minimal Dynamical Bridge

The bridge is an additional typed map with its own identification, calibration, and transport obligations; it is not supplied by a shared notation. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

$B\_dyn=(T,S,\tau,U,\mathscr{G},\iota,Obs,noise,Cal,Ext,D,Dom).$	**T2-F240**

$U(t,t)=Id,\ U(t,r)\circ U(r,s)=U(t,s),\ t\geq r\geq s.$	**T2-F241**

20.15. Semigroups, Generators, and Transfer Operators

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

$Ax = \lim\_\{t\downarrow 0\}\ (U(t)x-x)/t,\ x\in Dom(A).$	**T2-F242**

20.16. Path-Space Carrier and Causal Order

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

$K\_\{t,s\}=K\_\{t,r\}\circ K\_\{r,s\}.$	**T2-F243**

20.17. Empirical Bridge and Operationalization

The bridge is an additional typed map with its own identification, calibration, and transport obligations; it is not supplied by a shared notation. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

$$Y\_t = \mathrm{Obs}(U(t,t_0)\iota(\mathscr{M}\_\mathrm{ref})) + \varepsilon\_t. \quad \text{T2-F244}$$

20.18. Motivic-Refined Reper Certificate

The certificate records inputs, algorithms, tolerances, residuals, sources, code and data hashes, and the weakest evidential status supported by the chain. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

$$\mathrm{MotRefCert}=(\mathbb{V},K_0,\mathscr{M},\mathrm{Real},\Omega\_\mathrm{ref},Z\_\mathrm{ref},B\_\mathrm{dyn},B\_\mathrm{emp},\mathrm{src},\mathrm{code},D,\mathrm{Dom}). \quad \text{T2-F245}$$

$$\mathrm{Rep\_mot}=(R\_\mathrm{mot},I\_\mathrm{mot},U\_\mathrm{mot};D\_\mathrm{mot}), \quad \text{T2-F246}$$

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

20.19. Information Residuals and Refined CGI

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

$$R\_\mathrm{ref}=(r\_\mathrm{cat},r\_K_0,r\_\mathrm{mot},r\_\mathrm{real},r\_\mathrm{spec},r\_\mathrm{series},r\_\mathrm{time},r\_\mathrm{evol},r\_\mathrm{obs},r\_\mathrm{ext}). \quad \text{T2-F247}$$

20.20. Three Transition Horizons

The horizon is the union of loci where rank, domain, topology, calibration, identification, or numerical certification can change. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

$$\Delta\_\mathrm{mot} = \Delta\_\mathrm{cat} \cup \Delta\_\mathrm{or} \cup \Delta\_\mathrm{glue} \cup \Delta\_\mathrm{comp} \cup \Delta\_\mathrm{real} \cup \Delta\_\mathrm{spec}. \quad \text{T2-F248}$$

$\Delta\_series = \Delta\_ring \cup \Delta\_order \cup \Delta\_wall \cup \Delta\_PExp \cup \Delta\_conv \cup \Delta\_func.$	**T2-F249**

$\Delta\_dyn = \Delta\_time \cup \Delta\_state \cup \Delta\_U \cup \Delta\_gen \cup \Delta\_path \cup \Delta\_obs \cup \Delta\_cal \cup \Delta\_ext.$	**T2-F250**

$\Delta\_safe^{v0.17}=\Delta\_safe^{v0.16} \cup\Delta\_mot\cup\Delta\_series\cup\Delta\_dyn.$	**T2-F251**

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

20.21. Main Conditional Theorem

The statement is read under the explicitly declared hypotheses; its conclusion remains inside the mathematical model and does not acquire empirical status by translation. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

> **Theorem 20.8. Conditional Refined-Profile Constancy [COND]** Inside a fixed motivic, series, chamber and dynamical certificate, the refined profile is transported without status promotion. Any missing temporal or empirical bridge yields FORMAL-SERIES-ONLY or ABSTAIN.

$P\_ref(t)=([\mathbb{V}\_t],\mathscr{M}\_t,Real\_t,\Omega\_t^{ref},Z\_t,chamber\_t,\lambda\_t,CGI\_ref,t)$	**T2-F252**

NO-REFINED-CHANGE-IN-MODEL or FORMAL-SERIES-ONLY.	**T2-F253**

20.22. Three-Stage Blocker-Safe Verdict

The allowed output is multi-valued: a certified conclusion, an explicit candidate requiring further checks, ABSTAIN with blockers, or FAIL with a witness. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

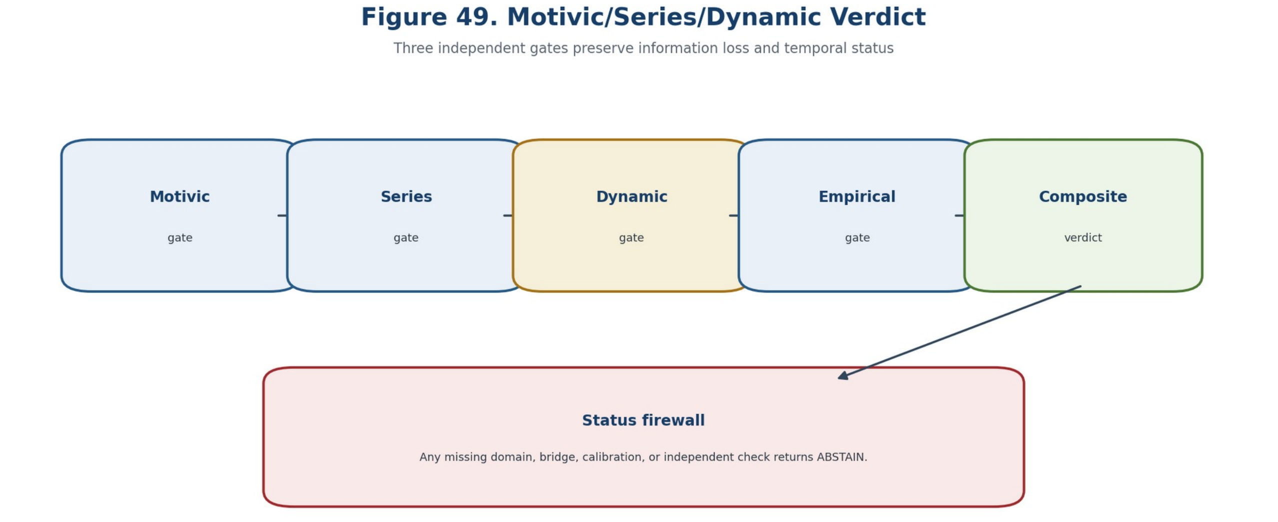


Figure 49. Motivic, series, and dynamic verdict.

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

20.23. Counterexamples and Separating Models

Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

20.24. Computational Certificate MOT-REF-SER-DYN

The certificate records inputs, algorithms, tolerances, residuals, sources, code and data hashes, and the weakest evidential status supported by the chain. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE

Gate component	Required check	Failure output
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

20.24.1. Pseudocode

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

20.25. Prior Art and Boundary of the Authorial Contribution

Classical constructions retain their standard attribution; the authorial contribution is the typed, blocker-safe synthesis inside KLT-RBD. Categorical, motivic, refined, numerical, temporal, and empirical carriers are tracked as distinct levels.

> **BOUNDARY OF CHAPTER 20.** A grading, charge, coefficient index, or generating-series variable is not physical time without a state space, evolution family, observable, and empirical bridge. truth_layer_promotion=0; independent EXT-RUN and EMP-OBS remain absent.

Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels

ONTOLOGY	Temporal prediction requires an evolution law on states and a compatible carrier on observables, measures, and paths.
EPISTEMOLOGY	Knowledge is certified through domains, semigroup or evolution-family identities, generators, kernels, path consistency, non-anticipation, and observation maps.
PHENOMENOLOGY	The dynamics appears through nonlinear flows, Koopman and transfer operators, Markov kernels, Volterra memory, and Reper trajectories.
LIMITATION	Static snapshots do not determine a unique evolution, and a transition kernel is not an intervention kernel or a physical cause.
AUTHORIAL NOVELTY	The authorial node is the temporal Reper carrier with causal typing, dynamic residuals, transition horizons, and blocker-safe output.

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

Controlled field	Value
Canonical input	Frozen Russian Chapter 21, inherited English Chapters 1-18, and formula/source passports.
New mathematical layer	Temporal prediction requires an evolution law on states and a compatible carrier on observables, measures, and paths.
Status rule	Definitions, theorems, conditional bridges, models, numerical certificates, and physical hypotheses remain distinct.
Prohibition	Static snapshots do not determine a unique evolution, and a transition kernel is not an intervention kernel or a physical cause.
Downstream role	Chapter 24 composes all certified layers and preserves ABSTAIN/FAIL as absorbing results.

21.1. Types of Time, State, and Evolution

This section fixes the carrier, domain, codomain, and status type before any computation or interpretation is permitted. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

truth_layer_promotion=0; source=T2-RP-v0.17; checkpoint=T2-RP-v0.18.	**T2-F254**

$\mathscr{U}(t,s)$: Dom_{t,s}⊆S_s → S_t.	**T2-F255**

21.1.1. Minimal Type Registry

This section fixes the carrier, domain, codomain, and status type before any computation or interpretation is permitted. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

21.2. Nonlinear Evolution Semigroup

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$\mathscr{S}(0)=\mathrm{Id}\_C,\ \mathscr{S}(t+s)=\mathscr{S}(t)\circ\mathscr{S}(s),\ \lim\_\{t\downarrow 0\}\ \mathscr{S}(t)x=x.$	**T2-F256**

21.3. Accretive and m-Accretive Generators

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$\mathscr{S}(t)x = \lim\_\{m\to\infty\}(I+(t/m)A)\hat{}\{-m\}x$	**T2-F257**

Figure 50. Nonlinear Semigroup Architecture

Generator, resolvent, and implicit approximation share one declared domain

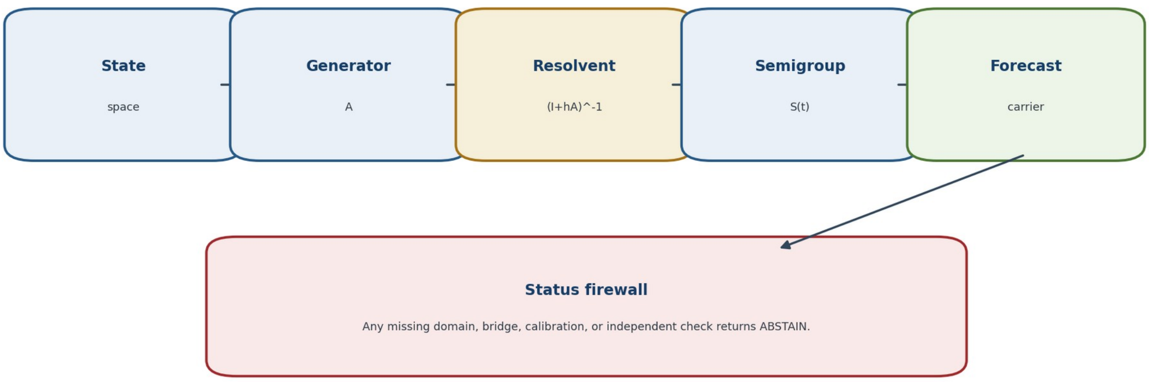


Figure 50. Nonlinear semigroup, generator, and resolvent.

21.4. Non-autonomous Evolution Families and the Kato Interface

The bridge is an additional typed map with its own identification, calibration, and transport obligations; it is not supplied by a shared notation. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$\mathscr{U}(s,s)=\mathrm{Id},\ \mathscr{U}(t,r)\circ\mathscr{U}(r,s)=\mathscr{U}(t,s).$	**T2-F258**

21.5. State Dynamics and the Koopman Operator on Observables

This section fixes the carrier, domain, codomain, and status type before any computation or interpretation is permitted. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$$(\mathscr{K}_t f)(x)=f(\Phi_t(x)).$$

T2-F259

21.6. Perron-Frobenius and Transfer Operators

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$$\mathscr{P}_t \mu=(\Phi_t)_\#\mu,\ (\mathscr{P}_t \mu)(B)=\mu(\Phi_t^{-1}(B)).$$

T2-F260

$$\int_S f\, d(\mathscr{P}_t \mu)=\int_S (\mathscr{K}_t f)d\mu.$$

T2-F261

21.7. Markov Kernels and Chapman-Kolmogorov

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$$K_{t,s}(x,B)=\int_S K_{t,r}(y,B)K_{r,s}(x,dy),\ t\geq r\geq s.$$

T2-F262

21.8. Path-Space Carrier and Cylinder Consistency

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$$\mu_{t_1,\dots,t_m}=Q\circ(X_{t_1},\dots,X_{t_m})^{-1}.$$

T2-F263

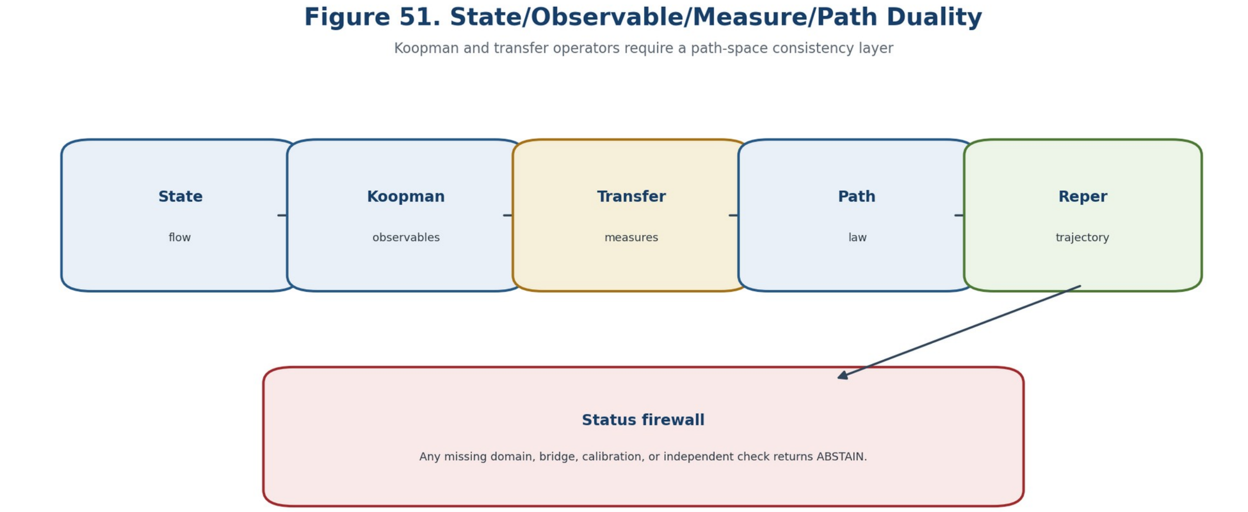


Figure 51. State, observable, measure, and path carriers.

21.9. Deterministic Path Carriers and Orbits

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$\omega\_x(t)=\mathscr{U}(t,t_0)x.$	**T2-F264**

21.10. Causal Volterra Kernels and Memory

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$x(t)=f(t)+\int\_\{t_0\}\^\{t\}\ B(t,s,x(s))\ ds.$	**T2-F265**

21.11. Non-anticipation as a Strict Causal Firewall

The horizon is the union of loci where rank, domain, topology, calibration, identification, or numerical certification can change. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$(F\omega)(t)=(F\omega')(t).$	**T2-F266**

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT

Gate component	Required check	Failure output
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

21.12. Filtrations, Adaptedness, and Observability

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

21.13. A Causal Kernel Is Not a Causal Mechanism

Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

transition kernel != intervention kernel != physical cause.	**T2-F267**

21.14. Reper Trajectory and Temporal Reper

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$\mathrm{Rep}_t=(R_t,I_t,U_t;D_t)$, $\lambda_t=\mathrm{cr}(U_t,I_t;R_t,D_t)$.	**T2-F268**

21.15. Path-Reper Carrier

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$\mathrm{PathRep}=(\Omega,Q/\mathfrak{A},\{\mathrm{Rep}_t\},\mathscr{U},K,B,\mathrm{Obs},\mathbb{F},D,\mathrm{Dom},\mathrm{src},\mathrm{code})$.	**T2-F269**

21.16. Dynamic Projective-Harmonic Coordinate

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$d\lambda_t/dt = D\lambda(\mathrm{Rep}_t)\cdot\dot{\mathrm{R}}\mathrm{ep}_t$.	**T2-F270**

21.17. Transfer Operator of the Reper Database

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$\mathscr{T}_{t,s}: \mathfrak{M}(S_s)\to\mathfrak{M}(S_t),\ \mathscr{T}_{t,r}\mathscr{T}_{r,s}=\mathscr{T}_{t,s}.$	T2-F271

21.18. Generator and Local Forecast

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$d/dt\ \mathscr{T}_t f\,|_{t=0}=Lf$	T2-F272

21.19. Perturbation Stability and Trajectory Error

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$e_{\mathscr{U}}(t,s;x)=d(\mathscr{U}(t,s)x,\tilde{U}(t,s)x).$	T2-F273

21.20. Dynamic and Causal Residual Vector

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$R_{time}=(r_{sg},r_{gen},r_{res},r_{tr},r_{path},r_{CK},r_{mem},r_{na},r_{obs},r_{cal},r_{ext}).$	T2-F274

21.21. Transition Horizons of Chapter 21

The horizon is the union of loci where rank, domain, topology, calibration, identification, or numerical certification can change. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

$\Delta_{sg}=\Delta_{dom}\cup\Delta_{cont}\cup\Delta_{comp}\cup\Delta_{accr}\cup\Delta_{res}.$	T2-F275

$\Delta_{tr}=\Delta_{pos}\cup\Delta_{mass}\cup\Delta_{dual}\cup\Delta_{spec}\cup\Delta_{inv}.$	T2-F276

$\Delta\_path=\Delta\_cons\cup\Delta\_tight\cup\Delta\_reg\cup\Delta\_branch \cup\Delta\_hist.$	**T2-F277**

$\Delta\_causal=\Delta\_order\cup\Delta\_NA\cup\Delta\_filt\cup\Delta\_interv \cup\Delta\_transport.$	**T2-F278**

$\Delta\_safe^{v0.18}=\Delta\_safe^{v0.17} \cup\Delta\_sg\cup\Delta\_tr\cup\Delta\_path\cup\Delta\_causal.$	**T2-F279**

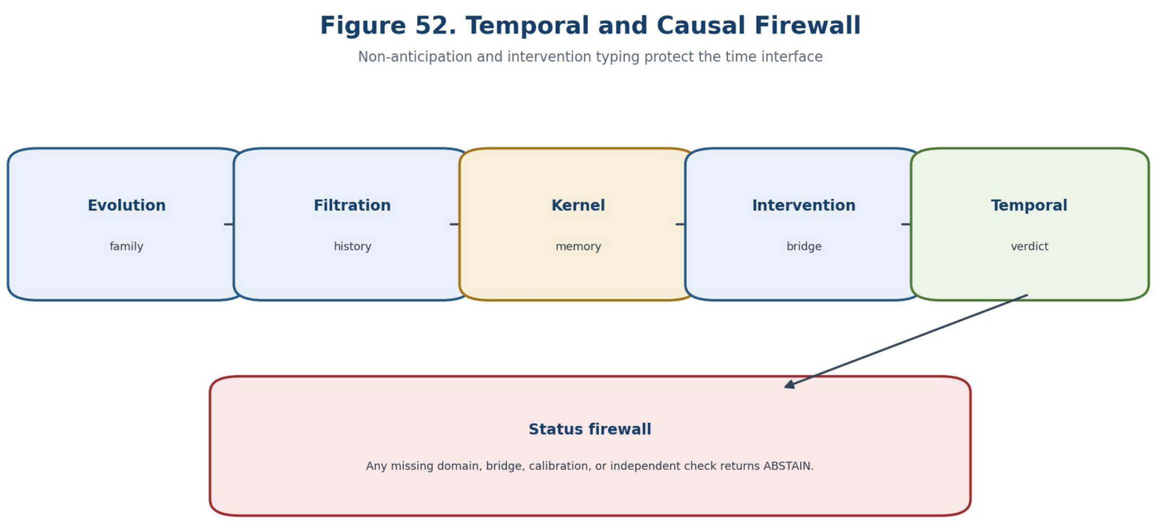


Figure 52. Temporal and causal firewall.

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

21.22. Temporal Profile Constancy Theorem

The statement is read under the explicitly declared hypotheses; its conclusion remains inside the mathematical model and does not acquire empirical status by translation. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

Theorem 21.5. Temporal Profile Constancy [COND] If the evolution family, transfer carrier, path law, observation map and Reper transport remain certified and the path avoids the temporal horizon, the temporal profile remains in the same certified class.

$$P\_time(t)=(class(\mathscr{U}\_t),class(\mathscr{T}\_t),class(Q\_t),\ rank/stratum,\lambda\_t,CGI\_time,t) \quad \text{T2-F280}$$

$$\text{NO-TEMPORAL-TRANSITION-IN-MODEL.} \quad \text{T2-F281}$$

21.23. Negative Theorem on Static Snapshots

The statement is read under the explicitly declared hypotheses; its conclusion remains inside the mathematical model and does not acquire empirical status by translation. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

Theorem 21.6. Static-Snapshot No-Go [THM] A family of one-time marginals or static snapshots does not in general identify a unique path law, generator, memory kernel, or causal mechanism.

21.24. Counterexamples and Separating Models

Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

21.25. Computational Certificate EVOL-TRANSFER-PATH

The certificate records inputs, algorithms, tolerances, residuals, sources, code and data hashes, and the weakest evidential status supported by the chain. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

21.25.1. Pseudocode

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

21.26. Prior Art and Boundary of the Authorial Contribution

Classical constructions retain their standard attribution; the authorial contribution is the typed, blocker-safe synthesis inside KLT-RBD. Evolution on states, observables, measures, and paths is synchronized only through declared duality and consistency contracts.

> **BOUNDARY OF CHAPTER 21.** Static snapshots do not determine a unique evolution, and a transition kernel is not an intervention kernel or a physical cause. truth_layer_promotion=0; independent EXT-RUN and EMP-OBS remain absent.

Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference

ONTOLOGY	A stochastic law is a probability measure on adapted paths together with a filtration, generator, martingale problem, and declared interventions.
EPISTEMOLOGY	Knowledge is established by existence and uniqueness, domain-rich test functions, stopping-time conditions, barrier certificates, and causal identification assumptions.
PHENOMENOLOGY	The layer appears through Markov semigroups, SDEs, martingale residuals, hitting probabilities, controls, HJB equations, and sequential evidence.
LIMITATION	Observational prediction, control under a policy, and intervention are different laws; optional stopping and Girsanov changes require their exact hypotheses.
AUTHORIAL NOVELTY	The authorial node is the stochastic Reper-path and forecast-control-intervention firewall with an anytime-valid evidence gate.

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

Controlled field	Value
Canonical input	Frozen Russian Chapter 22, inherited English Chapters 1-18, and formula/source passports.
New mathematical layer	A stochastic law is a probability measure on adapted paths together with a filtration, generator, martingale problem, and declared interventions.
Status rule	Definitions, theorems, conditional bridges, models, numerical certificates, and physical hypotheses remain distinct.
Prohibition	Observational prediction, control under a policy, and intervention are different laws; optional stopping and Girsanov changes require their exact hypotheses.
Downstream role	Chapter 24 composes all certified layers and preserves ABSTAIN/FAIL as absorbing results.

22.1. Stochastic Basis and Usual Conditions

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

truth_layer_promotion=0; source=T2-RP-v0.18; checkpoint=T2-RP-v0.19.	**T2-F282**

22.1.1. Registry of Stochastic Types

This section fixes the carrier, domain, codomain, and status type before any computation or interpretation is permitted. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

22.2. Markov Kernels and Markov Semigroup

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

$(P_t f)(x)=\int_E f(y)p_t(x,dy)=E_x[f(X_t)].$	T2-F283

22.3. Feller Sector, Generator, and Positive Maximum Principle

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

$Lf = \lim_{t\downarrow 0}(P_t f-f)/t,\ f\in Dom(L).$	T2-F284

22.4. Resolvent and Kolmogorov Equations

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

$R_\alpha f = \int_0^\infty e^{-\alpha t}P_t f\, dt.$	T2-F285

22.5. Stroock-Varadhan Martingale Problem

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

$M_t^f = f(X_t)-f(X_0)-\int_0^t Lf(X_s)ds$	T2-F286

Figure 53. Markov Triangle

Semigroup, generator, and martingale problem must be mutually compatible

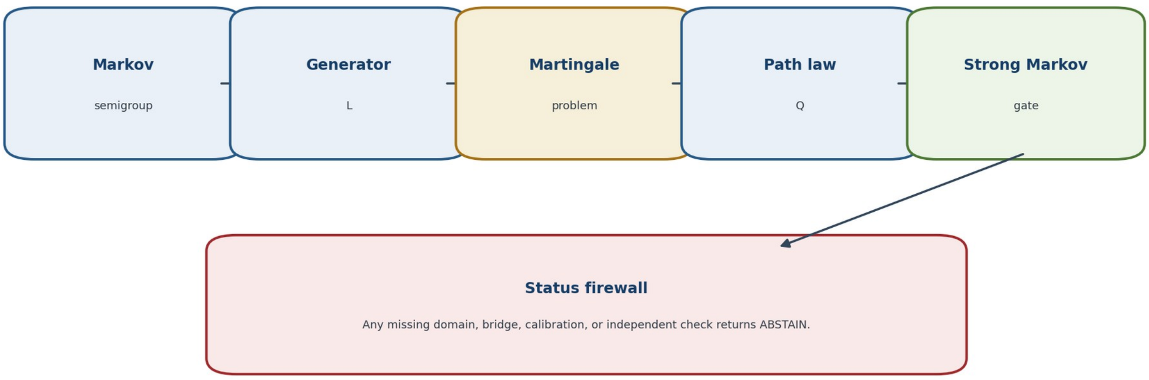


Figure 53. Markov semigroup, generator, and martingale problem.

22.6. Existence, Uniqueness, and the Strong Markov Firewall

The horizon is the union of loci where rank, domain, topology, calibration, identification, or numerical certification can change. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

22.7. Diffusion Generator and Stochastic Differential Equation

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

$$dX_t=b(t,X_t)dt+\sigma(t,X_t)dW_t \qquad \text{T2-F287}$$

$$L_t f(x)=b(t,x)\cdot\nabla f(x)+(1/2)\mathrm{Tr}(a(t,x)\nabla^2 f(x)),\quad a=\sigma\sigma^T. \qquad \text{T2-F288}$$

22.8. Weak and Strong Solutions and the Uniqueness Hierarchy

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

22.9. Girsanov Transform and the Intervention Firewall

The horizon is the union of loci where rank, domain, topology, calibration, identification, or numerical certification can change. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

$$Z_t=\exp(\int_0^t \theta_s\cdot dW_s-(1/2)\int_0^t||\theta_s||^2ds) \quad \text{T2-F289}$$

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

22.10. Stopping Times and the Stopped Process

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

$$\tau_A = \inf\{t\geq t_0 : X_t\in A\}. \quad \text{T2-F290}$$

22.11. Optional Sampling: Exact Domain of Applicability

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

22.12. Counterexample to Naive Optional Stopping

Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

22.13. Hitting Probabilities and First-Passage Prediction

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

$$p_A(T,x)=P_x(\tau_A\leq T). \quad \text{T2-F291}$$

22.14. Stochastic Barrier Certificate

The certificate records inputs, algorithms, tolerances, residuals, sources, code and data hashes, and the weakest evidential status supported by the chain. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

$$(\partial_t+L_t)V(t,x) \le 0 \text{ on } [0,T] \times (E\setminus A). \quad \text{T2-F292}$$

$$P_{x_0}(\tau_A \le T) \le V(0,x_0). \quad \text{T2-F293}$$

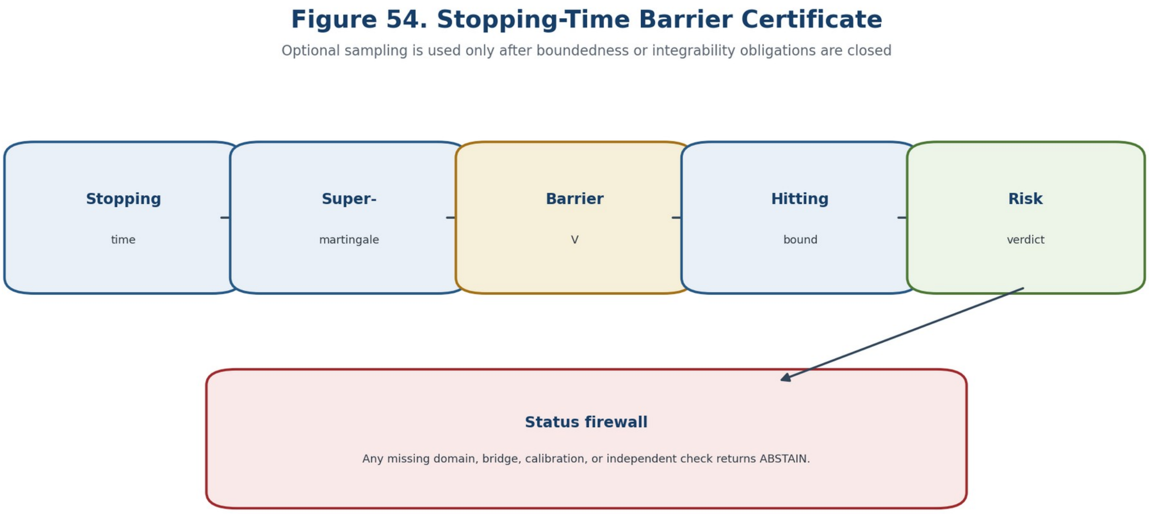


Figure 54. Stopping-time barrier certificate.

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

22.15. Robust Barrier for All Admissible Controls

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

$$\sup_{a\in A(t,x)} (\partial_t+L_t^a)V(t,x)\le 0, \quad \text{T2-F294}$$

22.16. Controlled Markov Family and Policy Law

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

$$J(\pi;x)=E_x^\pi\left[\int_0^T c(t,X_t,a_t)\,dt+g(X_T)\right].$$

T2-F295

22.17. Dynamic Programming and the HJB Layer

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

$$\partial_t V^*+\inf_{a\in A}\{L^a V^*+c(t,x,a)\}=0,\quad V^*(T,x)=g(x).$$

T2-F296

22.18. Forecast, Control, and Intervention as Three Different Laws

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

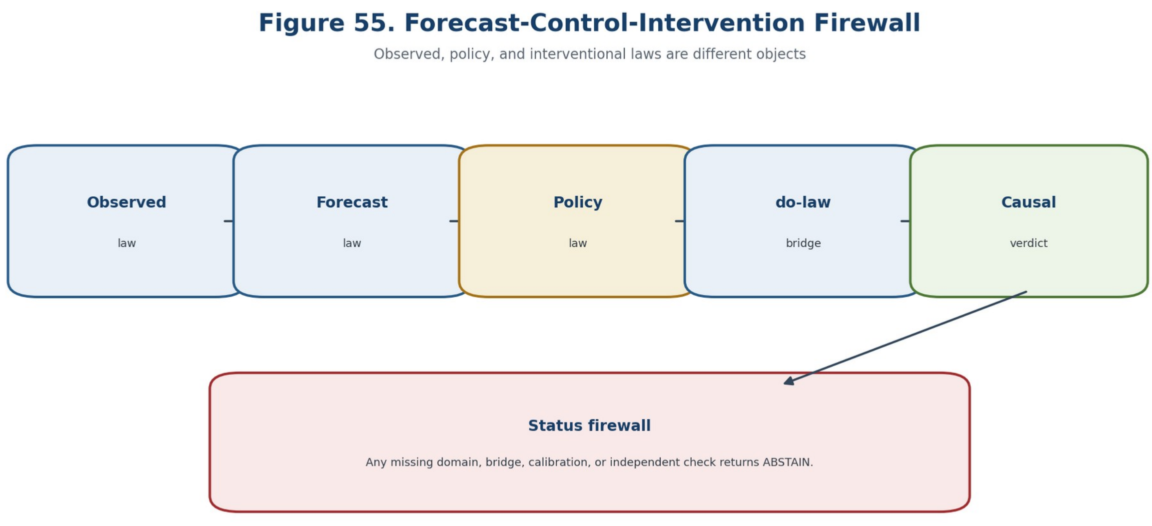


Figure 55. Forecast-control-intervention firewall.

22.19. An Observational Markov Law Does Not Identify an Intervention Law

Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

22.20. Structural Causal Kernel and the do-Operator

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

$X_{t+1}=F_t(X_{\le t},A_t,U_{t+1}),\ Y_t=G_t(X_{\le t},U_t).$	T2-F297

22.21. The g-Formula and Identification Conditions

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

$p(y^{\bar{a}}) = \int \prod_t p(l_{t+1}\mid\bar{l}_t,\bar{a}_t)\, p(y\mid\bar{l}_T,\bar{a}_T)\, d(\bar{l}).$	T2-F298

22.22. Counterfactual Carrier

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

22.23. Stochastic Reper-Path

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

$Rep_t(\omega)=(R_t(\omega),I_t(\omega),U_t(\omega);D_t(\omega)).$	T2-F299

22.24. Ito Formula for the Harmonic Defect

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

$d\varphi(X_t)=L\varphi(X_t)dt+\nabla\varphi(X_t)\sigma(X_t)dW_t.$	T2-F300

$Lq=2\varphi L\varphi+\|\sigma^T\nabla\varphi\|^2.$	T2-F301

22.25. Conditions for Stochastic Invariance of the Harmonic Locus

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

sigma_j(x) dot grad phi(x)=0 for all j, and L phi(x)=0 for x in M.	T2-F302

22.26. Martingale Residuals as Computational Generator Tests

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

R_{s,t}^{f_k}=f_k(X_t)-f_k(X_s)-∫_s^t Lf_k(X_r)dr.	T2-F303

22.27. Sequential Evidence and the Optional-Stopping-Safe Layer

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

P(sup_t E_t ≥ 1/α)≤α.	T2-F304

22.28. Stochastic Transition Horizon

The horizon is the union of loci where rank, domain, topology, calibration, identification, or numerical certification can change. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

Δ_stoch = Δ_MP ∪ Δ_Feller ∪ Δ_gen ∪ Δ_stop ∪ Δ_hit ∪ Δ_bar ∪ Δ_ctrl ∪ Δ_HJB ∪ Δ_do ∪ Δ_id ∪ Δ_λ ∪ Δ_cal ∪ Δ_ext.	T2-F305

Δ_safe^{v0.19}=Δ_safe^{v0.18} ∪Δ_stoch.	T2-F306

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

22.29. Main Conditional Theorem

The statement is read under the explicitly declared hypotheses; its conclusion remains inside the mathematical model and does not acquire empirical status by translation. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

> **Theorem 22.7. Conditional Stochastic Safety [COND]** Under a well-posed martingale problem, valid stopping and barrier hypotheses, certified policy or intervention law, and sequential evidence control, the reported hitting or risk bound is valid inside the model.

$$V(0,x)=0 \Rightarrow \text{NO-HIT-IN-MODEL}; \quad 0<V(0,x)\leq\alpha \Rightarrow \text{RISK-BOUND}\leq\alpha. \tag{T2-F307}$$

22.30. Blocker-Safe Verdict

The allowed output is multi-valued: a certified conclusion, an explicit candidate requiring further checks, ABSTAIN with blockers, or FAIL with a witness. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

$$\text{Block\_stoch}=\text{B\_basis}\cup\text{B\_MP}\cup\text{B\_gen}\cup\text{B\_stop}\cup\text{B\_bar}\cup\text{B\_ctrl}\cup\text{B\_do}\cup\text{B\_id}\cup\text{B\_}\lambda\cup\text{B\_cal}\cup\text{B\_ext}. \tag{T2-F308}$$

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

22.31. Separating Countermodels

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

22.32. Computational Certificate STOCH-CAUSAL

The certificate records inputs, algorithms, tolerances, residuals, sources, code and data hashes, and the weakest evidential status supported by the chain. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN

Gate component	Required check	Failure output
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

22.32.1. Pseudocode

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

22.33. Prior Art and Boundary of the Authorial Contribution

Classical constructions retain their standard attribution; the authorial contribution is the typed, blocker-safe synthesis inside KLT-RBD. The stochastic conclusion is limited by the martingale domain, stopping conditions, policy law, and causal identification bridge.

> **BOUNDARY OF CHAPTER 22.** Observational prediction, control under a policy, and intervention are different laws; optional stopping and Girsanov changes require their exact hypotheses. truth_layer_promotion=0; independent EXT-RUN and EMP-OBS remain absent.

Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification

ONTOLOGY	Rare-event analysis separates asymptotic rate geometry, risk-sensitive dynamics, simulation efficiency, and finite-sample coverage.
EPISTEMOLOGY	Knowledge is certified through topology, speed, exponential tightness, a good rate function, robust ambiguity sets, and finite-sample guarantees.
PHENOMENOLOGY	The layer appears through actions, quasipotentials, Feynman-Kac and logarithmic semigroups, importance sampling, splitting, and risk bounds.
LIMITATION	An asymptotic exponent is not a finite-sample probability, and an unobserved rare event does not imply zero risk.
AUTHORIAL NOVELTY	The authorial node is the robust rare-event Reper certificate joining large deviations to coverage-valid finite-sample decisions.

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

Controlled field	Value
Canonical input	Frozen Russian Chapter 23, inherited English Chapters 1-18, and formula/source passports.
New mathematical layer	Rare-event analysis separates asymptotic rate geometry, risk-sensitive dynamics, simulation efficiency, and finite-sample coverage.
Status rule	Definitions, theorems, conditional bridges, models, numerical certificates, and physical hypotheses remain distinct.
Prohibition	An asymptotic exponent is not a finite-sample probability, and an unobserved rare event does not imply zero risk.
Downstream role	Chapter 24 composes all certified layers and preserves ABSTAIN/FAIL as absorbing results.

23.1. Four Levels of Rare-Event Inference

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

truth_layer_promotion=0; source=T2-RP-v0.19; checkpoint=T2-RP-v0.20.	**T2-F309**

23.1.1. Typed Ladder

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

23.2. Definition of the Large-Deviation Principle

This section fixes the carrier, domain, codomain, and status type before any computation or interpretation is permitted. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

-inf_{x∈A°} I(x) ≤ liminf_n a_n^{-1}log P(Z_n∈A) ≤ limsup_n a_n^{-1}log P(Z_n∈A) ≤ -inf_{x∈cl A}I(x).	**T2-F310**

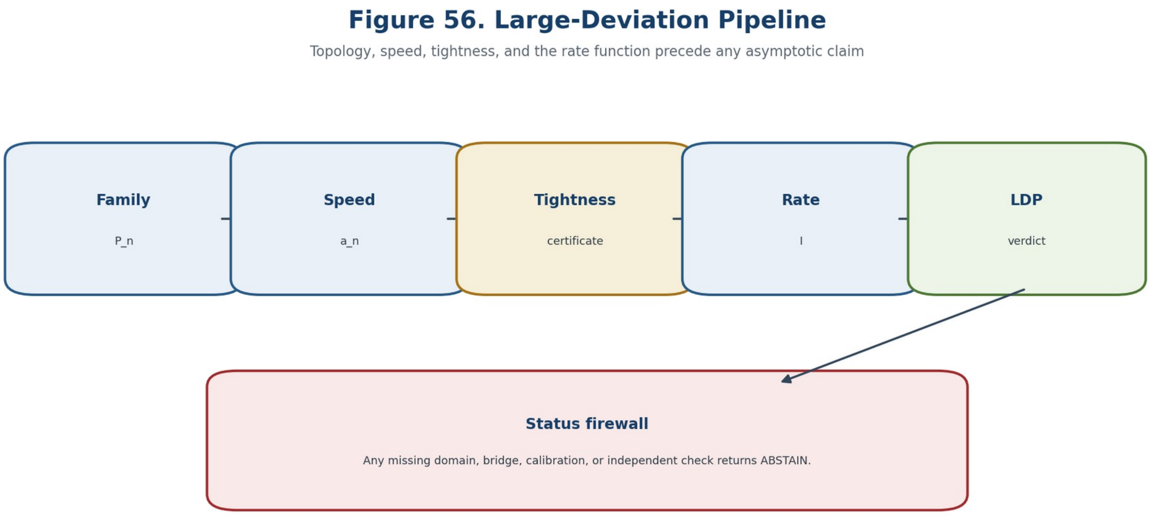


Figure 56. Large-deviation pipeline and evidence firewall.

23.3. Exponential Tightness and a Good Rate Function

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

limsup_n a_n^{-1}log P(Z_n∉K_M) ≤ -M.	**T2-F311**

23.4. Contraction Principle

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

J(y)=inf{I(x):F(x)=y}, inf∅=∞.	**T2-F312**

23.5. Laplace Principle and Varadhan Lemma

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

lim_n a_n^{-1}log E exp(a_n F(Z_n)) = sup_{x∈𝒳}{F(x)-I(x)}.	**T2-F313**

23.6. Gartner-Ellis Theorem and Its Limits

The statement is read under the explicitly declared hypotheses; its conclusion remains inside the mathematical model and does not acquire empirical status by translation. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$\Lambda(\theta)=\lim_n a_n^{-1}\log E \exp(a_n\langle\theta,Z_n\rangle).$	**T2-F314**

23.7. Sanov Layer: Empirical Measure and Relative Entropy

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$I(Q)=D(Q\|\|P),$	**T2-F315**

23.8. Path-Space LDP and the Topology Ledger

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

23.9. Freidlin-Wentzell Action for Small-Noise Diffusions

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$dX_t^\varepsilon=b(X_t^\varepsilon)dt+\sqrt{\varepsilon}\,\sigma(X_t^\varepsilon)dW_t$	**T2-F316**

$S_{0T}(\varphi)=1/2 \int_0^T \langle\dot{\varphi}-b(\varphi), a(\varphi)^{-1}(\dot{\varphi}-b(\varphi))\rangle\, dt,$	**T2-F317**

23.10. Quasipotential and Geometry of Metastable Transitions

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$V(x,y)=\inf_{T>0} \inf_{\varphi(0)=x,\, \varphi(T)=y} S_{0T}(\varphi).$	**T2-F318**

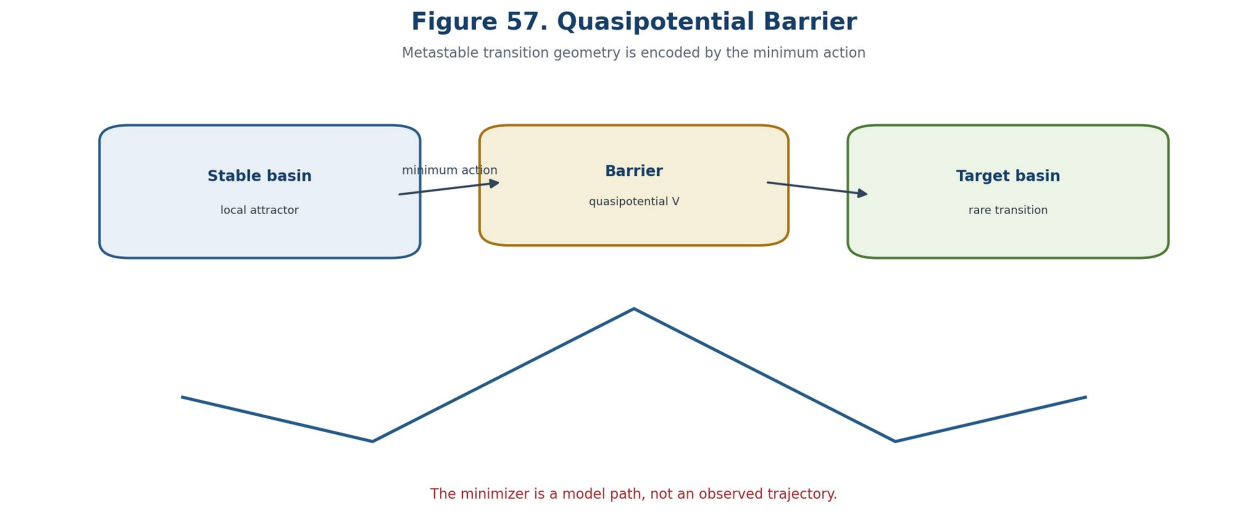


Figure 57. Quasipotential barrier and minimum-action path.

23.11. Rare-Event Geometry of the Reper-Path

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$$z=(Rep, \mu, Ass, o, \lambda, D, Dom). \quad \text{T2-F319}$$

$$A_{\varepsilon,\eta}=\{z(\cdot): \inf_t |\lambda_t+1|\le\varepsilon, ||o_t||\le\eta, \mathrm{Valid}(D_t)=1, \mathrm{Block}_t=\varnothing\}. \quad \text{T2-F320}$$

$$c_{\varepsilon,\eta}=\inf_{z(\cdot)\in \mathrm{cl}\, A_{\varepsilon,\eta}} I_{path}(z). \quad \text{T2-F321}$$

23.12. Lambda Poles and the Extended Contraction Firewall

The horizon is the union of loci where rank, domain, topology, calibration, identification, or numerical certification can change. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

23.13. Donsker-Varadhan Layer for Empirical Measures of a Markov Process

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

L_T=(1/T)∫_0^T δ_{X_t}dt	T2-F322

I_DV(μ)= -inf_{u>0} ∫ (Lu/u)dμ.	T2-F323

23.14. Feynman-Kac Semigroup

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

(Q_t^V f)(x)=E_x[exp(∫_0^t V(X_s)ds) f(X_t)].	T2-F324

23.15. Risk-Sensitive Logarithmic Semigroup

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

(S_t^{θ,V}g)(x)=θ^{-1} log E_x exp(θ[g(X_t)+∫_0^t V(X_s)ds]).	T2-F325

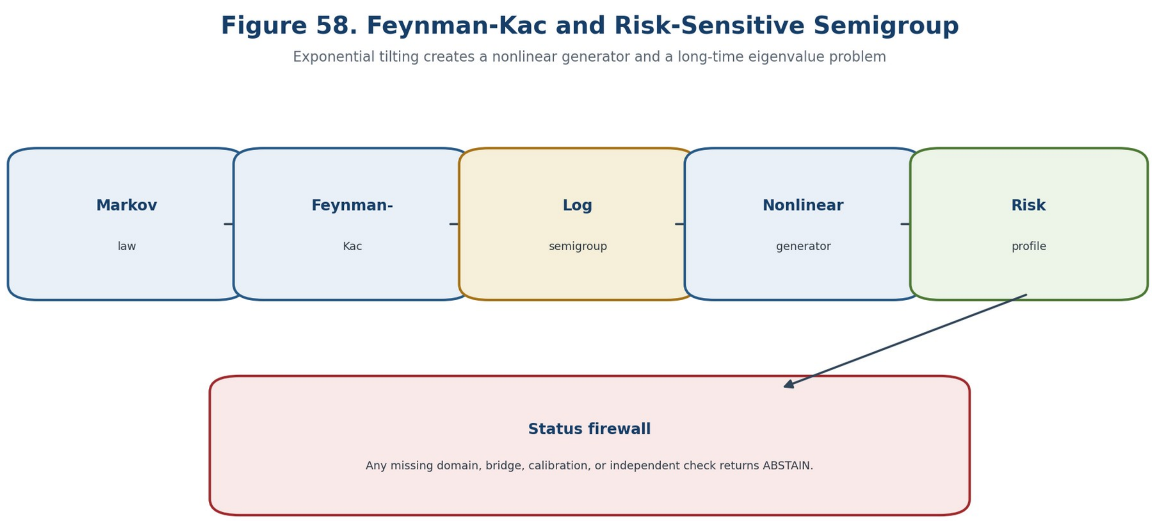


Figure 58. Feynman-Kac and risk-sensitive semigroup.

23.16. Nonlinear Generator of the Risk-Sensitive Layer

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$H_\theta f = \theta^{-1}e^{-\theta f}L(e^{\theta f})+V.$	T2-F326

$H_\theta f = Lf +(\theta/2)\|\|\sigma^T\nabla f\|\|^2+V.$	T2-F327

23.17. Long-Time Eigenvalue and Multiplicative Ergodic Limit

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$\rho(\theta)=\lim_{t\to\infty}(1/t)\log E_x \exp(\theta\int_0^t V(X_s)ds).$	T2-F328

23.18. Entropic Variational Formula

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$\log E_P e^F = \sup_{Q\ll P}\{E_Q F-D(Q\|\|P)\}.$	T2-F329

23.19. Risk-Sensitive Control and the HJB Eigenproblem

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$J_\theta(a)=\limsup_{T\to\infty}(1/(\theta T))\log E^a \exp(\theta\int_0^T c(X_t,a_t)dt)$	T2-F330

$\rho+\inf_a\{L^a v+c(x,a)+(\theta/2)\|\|\sigma_a^T\nabla v\|\|^2\}=0.$	T2-F331

23.20. An Asymptotic Exponent Is Not a Finite-n Probability

Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$\lim_n a_n^{-1}\log p_n=-c, c>0$	T2-F332

23.21. Importance Sampling and an Unbiased Rare-Event Estimator

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$p=P(A)=E_Q[1_A L].$	T2-F333

23.22. Logarithmic and Bounded-Relative-Error Efficiency

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

23.23. Splitting and Adaptive Levels

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

23.24. Ambiguity Sets: Robust Layer

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$U_N(\rho)=\{Q: d(Q,\hat{P}_N)\le\rho,\ Q\in\mathscr{P}_{adm}\}.$	T2-F334

23.25. KL and f-Divergence Ambiguity

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$\sup_{D(Q\|\hat{P})\le\rho} E_Q\ell \le \inf_{\eta>0} \{\eta\rho+\eta \log E_{\hat{P}} \exp(\ell/\eta)\}.$	T2-F335

23.26. Wasserstein Ambiguity and Geometry of New States

This section fixes the carrier, domain, codomain, and status type before any computation or interpretation is permitted. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$\sup_{W_c(Q,\hat{P})\le\rho}E_Q\ell = \inf_{\eta\ge 0} \{\eta\rho+E_{\hat{P}}[\sup_z(\ell(z)-\eta c(z,\xi))]\}.$	T2-F336

23.27. Finite-Sample Coverage Ambiguity Set

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$P\_data(P\_* \in U\_N(\rho\_N(\beta))) \geq 1-\beta.$	**T2-F337**

$P\_*(A) \leq \sup\_\{Q \in U\_N\} Q(A).$	**T2-F338**

23.28. Distributionally Robust Chance Certificate

The certificate records inputs, algorithms, tolerances, residuals, sources, code and data hashes, and the weakest evidential status supported by the chain. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$P\_data(P\_*(A) \leq B\_N(A)) \geq 1-\beta.$	**T2-F339**

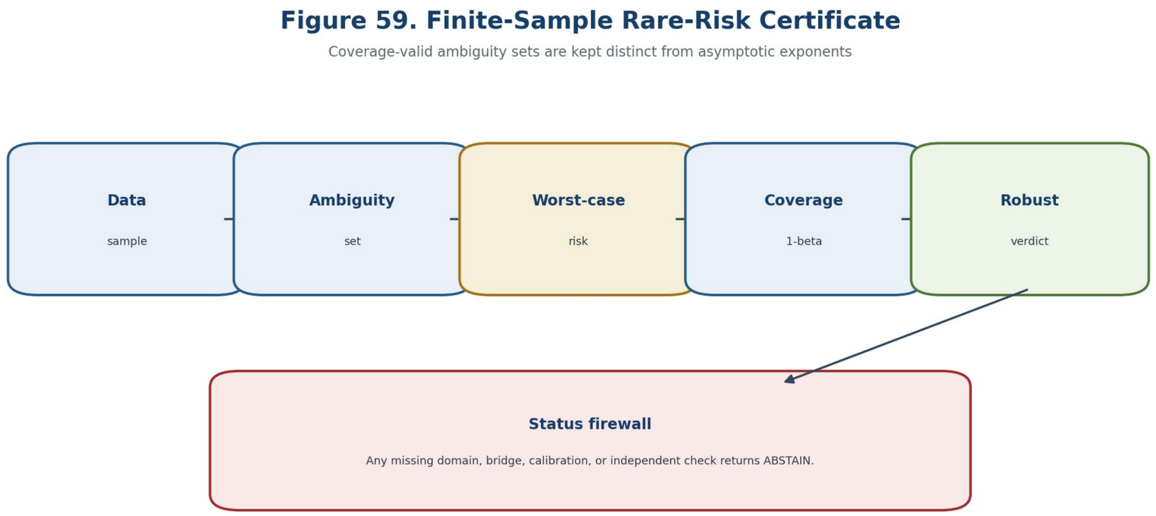


Figure 59. Finite-sample robust rare-risk certificate.

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

23.29. Exact Binomial Certificate for a Rare Event

The certificate records inputs, algorithms, tolerances, residuals, sources, code and data hashes, and the weakest evidential status supported by the chain. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$$p_U=1-\alpha^{1/N},\ \text{coverage} \geq 1-\alpha. \quad \text{T2-F340}$$

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

23.30. Bounded-Loss Concentration and Empirical Risk

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$$E[X]\leq \bar{X}_N+\sqrt{\log(1/\beta)/(2N)}. \quad \text{T2-F341}$$

23.31. Anytime-Valid and Sequential Certification

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

23.32. Fusion of Asymptotic and Finite-Sample Layers

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

$$p_n(A) \leq \min\{B_N^{rob}(A),\ C_n \exp[-a_n(c_A-\delta)]\}, \quad \text{T2-F342}$$

23.33. Non-identifiability of the Tail from a Finite Sample

Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

23.34. Rate-Function Estimation and Epistemic Uncertainty

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

Rep_rate=(I_hat, topology, speed, solver, residuals; D_rate).	T2-F343

23.35. Robust Rare-Event Reper Certificate

The certificate records inputs, algorithms, tolerances, residuals, sources, code and data hashes, and the weakest evidential status supported by the chain. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

Cert_LD=(𝒳,τ,a_n,P_n,I,A,c_A,R_n,U_N,B_N,IS,λ,D,Dom,src,code,hash).	T2-F344

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

23.36. Large-Deviation and Finite-Sample Horizons

The horizon is the union of loci where rank, domain, topology, calibration, identification, or numerical certification can change. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

Δ_LD=Δ_speed∪Δ_top∪Δ_tight∪Δ_rate∪Δ_contract∪Δ_pole∪Δ_action∪Δ_inst.	T2-F345

Δ_RS=Δ_FK∪Δ_expint∪Δ_eig∪Δ_HJB∪Δ_tilt∪Δ_IS.	T2-F346

Δ_FS=Δ_iid∪Δ_dep∪Δ_tail∪Δ_amb∪Δ_cov∪Δ_sel∪Δ_stop∪Δ_shift∪Δ_ext.	T2-F347

Δ_safe^{v0.20}=Δ_safe^{v0.19} ∪Δ_LD∪Δ_RS∪Δ_FS.	**T2-F348**

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

23.37. Main Conditional Theorem

The statement is read under the explicitly declared hypotheses; its conclusion remains inside the mathematical model and does not acquire empirical status by translation. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

> **Theorem 23.8. Rare-Event Dual Certificate [COND]** When the LDP hypotheses and a coverage-valid ambiguity set are both certified, the release may report the asymptotic exponent and the finite-sample robust bound as separate components. Neither component may replace the other.

23.38. Counterexamples and Prohibitions

Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

23.39. Computational Certificate LD-RISK

The certificate records inputs, algorithms, tolerances, residuals, sources, code and data hashes, and the weakest evidential status supported by the chain. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

23.39.1. Pseudocode

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

23.40. Prior Art and Boundary of the Authorial Contribution

Classical constructions retain their standard attribution; the authorial contribution is the typed, blocker-safe synthesis inside KLT-RBD. Asymptotic rate statements and finite-sample risk bounds are reported separately and may not be substituted for one another.

> **BOUNDARY OF CHAPTER 23.** An asymptotic exponent is not a finite-sample probability, and an unobserved rare event does not imply zero risk. truth_layer_promotion=0; independent EXT-RUN and EMP-OBS remain absent.

Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability

ONTOLOGY	The end-to-end predictor is a composition of certified partial operators, not a single total black-box map.
EPISTEMOLOGY	Knowledge is carried by typed inputs, preconditions, postconditions, proof objects, uncertainty budgets, hash-linked provenance, and absorbing ABSTAIN/FAIL branches.
PHENOMENOLOGY	The architecture appears as a lattice-valued verdict and a set of certified continuations rather than an unsupported point prophecy.
LIMITATION	Local correctness does not imply global compatibility; incompatible budgets, interfaces, causal bridges, or release evidence close the gate.
AUTHORIAL NOVELTY	The authorial node is the CertKLT category and the blocker-safe KLT-RBD release operator with monotone abstention and explicit falsifiers.

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

Controlled field	Value
Canonical input	Frozen Russian Chapter 24, inherited English Chapters 1-18, and formula/source passports.
New mathematical layer	The end-to-end predictor is a composition of certified partial operators, not a single total black-box map.
Status rule	Definitions, theorems, conditional bridges, models, numerical certificates, and physical hypotheses remain distinct.
Prohibition	Local correctness does not imply global compatibility; incompatible budgets, interfaces, causal bridges, or release evidence close the gate.
Downstream role	Chapter 24 composes all certified layers and preserves ABSTAIN/FAIL as absorbing results.

24.1. Four Incompatible Meanings of Prediction

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

truth_layer_promotion=0; source=T2-RP-v0.20; checkpoint=T2-RP-v0.21.	**T2-F349**

24.2. Predictive Query as a Typed Object

This section fixes the carrier, domain, codomain, and status type before any computation or interpretation is permitted. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

$Q = (S\_src, \Omega, T, Y, A, Loss, Mode, \alpha, \beta, L, D, Dom, Split, Policy).$	**T2-F350**

24.3. Certified Computational State

This section fixes the carrier, domain, codomain, and status type before any computation or interpretation is permitted. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

$Z_j = (X_j, P_j, B_j, C_j, G_j, H_j, V_j),$	**T2-F351**

24.4. Homogeneous Reper Coordinate without an Artificial Pole

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

$\Lambda\_Rep = [N:Q] = [(U-R)(I-D) : (U-D)(I-R)] \in P^1,$	**T2-F352**

24.5. Result Type: OK, ABSTAIN, and FAIL

The allowed output is multi-valued: a certified conclusion, an explicit candidate requiring further checks, ABSTAIN with blockers, or FAIL with a witness. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

$Result(Y)=OK(Y,Cert,B) \sqcup ABSTAIN(Block) \sqcup FAIL(Witness).$	**T2-F353**

24.6. Category of Certified Partial Operators

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

$F=(f, Pre\_F, Post\_F, T\_F, E\_F, Audit\_F),$	**T2-F354**

Figure 62. CertKLT Composition

Interfaces transport values, certificates, and budgets while preserving absorbing branches

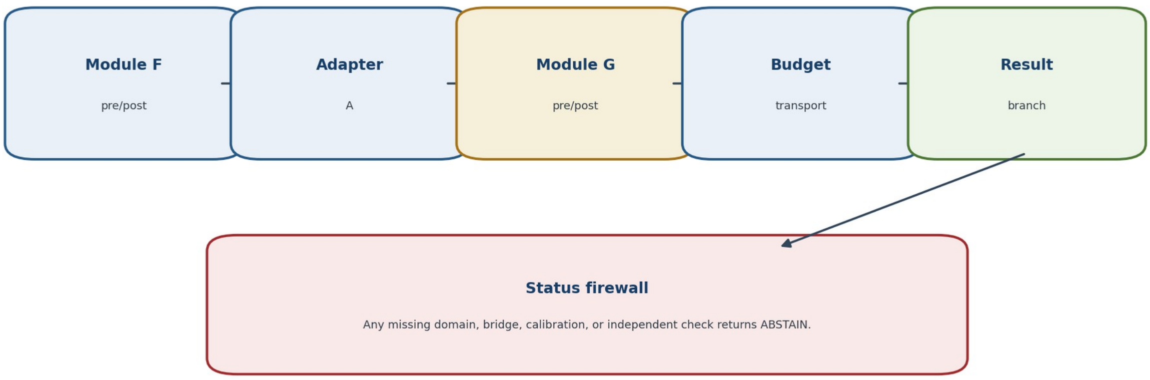


Figure 62. Composition in the CertKLT category.

24.7. Operator Composition and Absorbing Branches

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

$(G \circ F)(x)=G(y)$ if $F(x)=OK(y,C\_F,B\_F)$; otherwise return the same ABSTAIN or FAIL branch.	**T2-F355**

$B\_\{G\odot F\}=T\_G(T\_F(B\_in) \oplus E\_F) \oplus E\_G.$	**T2-F356**

24.8. Soundness Theorem for the CertKLT Category

The statement is read under the explicitly declared hypotheses; its conclusion remains inside the mathematical model and does not acquire empirical status by translation. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

> **Theorem 24.1. Soundness of CertKLT Composition [THM]** Certified partial operators with compatible interfaces form a category under absorbing composition; identity operators preserve values, certificates, budgets and result branches.

24.9. Vector Uncertainty Budget

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

$B=(b\_type,b\_dom,b\_alg,b\_top,b\_num,\alpha\_stat,\mathscr{U}\_shift,b\_causal,b\_ext,\sigma\_proof).$	**T2-F357**

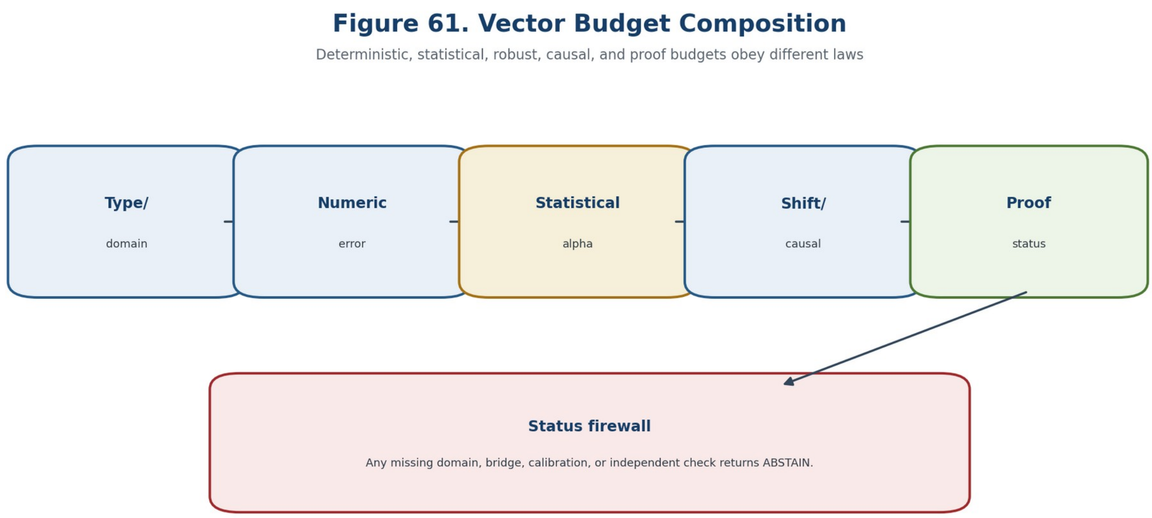


Figure 61. Vector budget composition.

24.10. Deterministic Error Transport

The bridge is an additional typed map with its own identification, calibration, and transport obligations; it is not supplied by a shared notation. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

$$\varepsilon_{out} \le \left(\Pi_{k=1}^m L_k\right)\varepsilon_{in} + \Sigma_{j=1}^m \left(\Pi_{k=j+1}^m L_k\right) \varepsilon_j. \quad \text{T2-F358}$$

24.11. Probabilistic Budget without Independence

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

$$P\left(\cup_{j=1}^m E_j\right) \le \Sigma_{j=1}^m \alpha_j, \quad \alpha_{tot}=\min(1,\Sigma\alpha_j). \quad \text{T2-F359}$$

24.12. Sequential Budget and Optional Stopping

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

$$P_{H0}(\exists t: E_t \ge 1/\alpha) \le \alpha. \quad \text{T2-F360}$$

24.13. Robust and Transport Budget

The bridge is an additional typed map with its own identification, calibration, and transport obligations; it is not supplied by a shared notation. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

$\mathscr{U}\_out \supseteq F\_\#(\mathscr{U}\_in) \oplus \mathscr{V}\_F$.	T2-F361

24.14. Computational Budget and Proof-Carrying Output

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

C_comp=(value, interval, residual, dual_gap, discretization, seed, environment, code_hash, data_hash).	T2-F362

24.15. Lattice of Evidential Statuses

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

OPEN <= CONJ <= MODEL <= COMP <= COND <= THM; PHY-HYP is a separate branch.	T2-F363

24.16. No Canonical Scalarization Theorem

The statement is read under the explicitly declared hypotheses; its conclusion remains inside the mathematical model and does not acquire empirical status by translation. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

> **Theorem 24.2. No Canonical Scalarization [THM]** No canonical order-preserving scalar summarizes all deterministic, statistical, robust, causal, evidential and proof-status budget coordinates without additional preferences or loss data.

24.17. Local Algorithmic Contract

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

24.18. Interface Contract between Modules

The bridge is an additional typed map with its own identification, calibration, and transport obligations; it is not supplied by a shared notation. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

Interface(F,G;A)=PASS iff Post_F implies Pre_G o A and Budget_G o A is defined.	T2-F364

24.19. Global Release Contract

The certificate records inputs, algorithms, tolerances, residuals, sources, code and data hashes, and the weakest evidential status supported by the chain. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

M_rel=(Q, Modules, Edges, Notation, Budgets, Policies, Sources, Code, Data, Env, HashRoot).	T2-F365

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

24.20. Definition of the End-to-End KLT-RBD Operator

This section fixes the carrier, domain, codomain, and status type before any computation or interpretation is permitted. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

𝔓_KLT(Q)=Gate_release ⊙ F_10 ⊙ ⋯ ⊙ F_1 ⊙ F_0 (Q).	T2-F366

𝔓_KLT = Release ⊙ Validate ⊙ Robust ⊙ Rare ⊙ Causal ⊙ Stoch ⊙ Evol ⊙ Global ⊙ Obstruct ⊙ NAPG ⊙ Reper ⊙ Ingest.	T2-F367

Figure 60. End-to-End KLT-RBD Architecture

Each module is partial, typed, budgeted, and proof-carrying

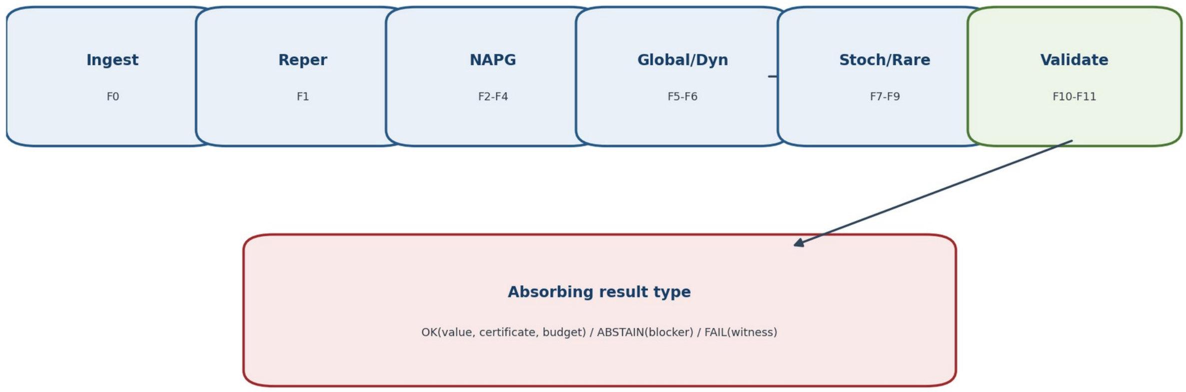


Figure 60. End-to-end KLT-RBD architecture.

24.21. Modular Decomposition F0-F11

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

24.22. F0: Source, Identity, and Provenance

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

F0(S)=OK(S*,Cert_src,B0), or FAIL(HASH-MISMATCH), or ABSTAIN(SOURCE-AMBIGUOUS).	**T2-F368**

24.23. F1: Reper Lift and D/Dom Authorization

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

F1(x)=OK(Rep_x,Lambda_x,Cert_D) only if Valid(D_x) and Admissible(Dom_x).	**T2-F369**

24.24. F2-F3: Algebraic-Geometric NAPG Core

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

Cert_NAPG=(Ass_⊙, nuclei, invariants, atlas, cocycle, ∇,R_∇,Hol_D; Dom).	T2-F370

24.25. F4: Obstructions, Cohomologicaly, and the External E-Bridge

The bridge is an additional typed map with its own identification, calibration, and transport obligations; it is not supplied by a shared notation. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

Pi_E: O_B partial-> H^3(E), with status(Pi_E)<=COND until B1-B8 are closed.	T2-F371

24.26. F5: Global, Derived, and Virtual Layer

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

GlobalOK ⇔ Descent∧Coherence∧Orientation∧Transport∧NoRequiredBlocker.	T2-F372

24.27. F6: Temporal Interface and Evolution

The bridge is an additional typed map with its own identification, calibration, and transport obligations; it is not supplied by a shared notation. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

U(t,r)U(r,s)=U(t,s), s<=r<=t, under compatible domains.	T2-F373

24.28. F7-F8: Stochastic Law and Causal Firewall

The horizon is the union of loci where rank, domain, topology, calibration, identification, or numerical certification can change. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

P_obs(Y|X) != P(Y|do(X)) without a structural bridge.	T2-F374

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT

Gate component	Required check	Failure output
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

24.29. F9: Rare-Event and Robust Finite-Sample Layer

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

$$V\_rare \in \{IMPOSSIBLE\text{-}IN\text{-}MODEL, FINITE\text{-}SAMPLE\text{-}RISK\text{-}BOUND, EXPONENTIALLY\text{-}SUPPRESSED\text{-}IN\text{-}MODEL, CANDIDATE\text{-}RARE\text{-}TRANSITION, ABSTAIN\}. \quad \text{T2-F375}$$

24.30. F10-F11: External Validation and Release Gate

The certificate records inputs, algorithms, tolerances, residuals, sources, code and data hashes, and the weakest evidential status supported by the chain. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

$$Release=OK \Leftrightarrow Required(V,Q)=PASS \wedge B\le B^* \wedge Block\_required=\varnothing \wedge HashChain=VALID. \quad \text{T2-F376}$$

24.31. Composite Verdict instead of a Single Label

The allowed output is multi-valued: a certified conclusion, an explicit candidate requiring further checks, ABSTAIN with blockers, or FAIL with a witness. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

$$V=(V\_struct,V\_geom,V\_ob,V\_global,V\_dyn,V\_prob,V\_causal,V\_phys). \quad \text{T2-F377}$$

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

24.32. Prediction as a Set of Certified Continuations

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

$$\mathrm{Pred}(Q)= \{z\in\mathscr{C}(Q): \mathrm{margin}(z,\Delta\_\mathrm{safe})\geq m^*, B(z)\preccurlyeq B^*, \mathrm{Valid}(D\_z), \mathrm{Dom}\_z\}. \quad \text{T2-F378}$$

24.33. Monotonicity of ABSTAIN

The statement is read under the explicitly declared hypotheses; its conclusion remains inside the mathematical model and does not acquire empirical status by translation. Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

> **Theorem 24.3. Monotonicity of ABSTAIN [THM]** Adding an unresolved required blocker cannot turn an ABSTAIN result into OK. Closing blockers may refine ABSTAIN, but only through a new certificate and change-set.

24.34. General Conditional End-to-End Safety Theorem

The statement is read under the explicitly declared hypotheses; its conclusion remains inside the mathematical model and does not acquire empirical status by translation. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

> **Theorem 24.4. Conditional End-to-End Safety [COND]** If all required module contracts, budget transports, provenance links, status constraints and release predicates pass, the end-to-end output is type-correct and carries no stronger evidential status than its weakest required component.

24.35. Proof of Theorem 24.4

The statement is read under the explicitly declared hypotheses; its conclusion remains inside the mathematical model and does not acquire empirical status by translation. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

24.36. What Theorem 24.4 Does Not Prove

The statement is read under the explicitly declared hypotheses; its conclusion remains inside the mathematical model and does not acquire empirical status by translation. Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

24.37. Counterexample: Locally Correct but Globally Incompatible Modules

Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

24.38. Counterexample: Inflation of the Probability Budget

Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

$$10 * 0.05 = 0.50, \text{ not } 0.05. \tag{T2-F379}$$

24.39. Counterexample: Small Local Error and Unbounded Amplification

Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

24.40. Counterexample: Scalar Lambda near a Projective Pole

Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

24.41. Counterexample: Observational Accuracy without Causal Identification

Separating models show that the prohibited inference fails even when the upstream mathematical object is well defined. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

24.42. Falsifiability Protocol

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

Figure 63. Falsifiability and Release Gate

A failed required witness produces FAIL; an unresolved obligation produces ABSTAIN

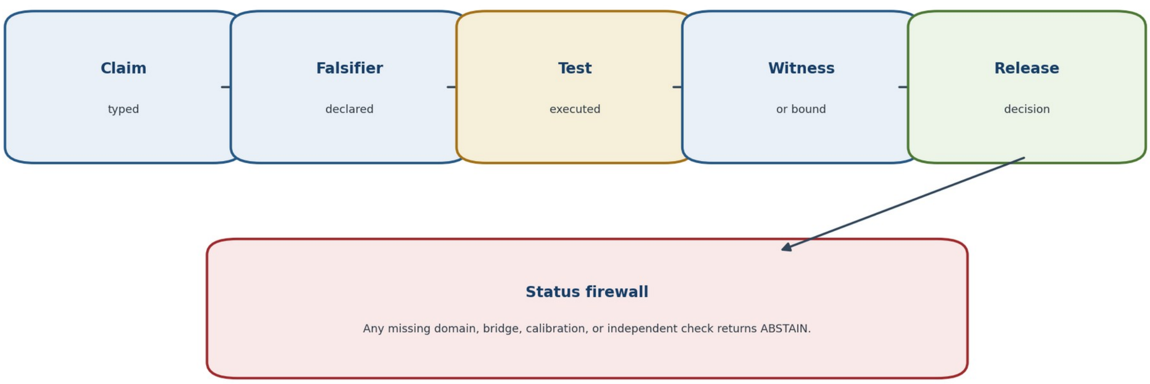


Figure 63. Falsifiability witnesses and release gate.

24.43. Final Falsifiability Matrix for Chapters 1-24

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

24.43.1. Matrix 24-A: Chapters 1-8

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

24.43.2. Matrix 24-B: Chapters 9-16

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

24.43.3. Matrix 24-C: Chapters 17-24

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

24.44. Final Status Matrix of Volume II

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

24.45. Computational Certificate E2E-KLT

The certificate records inputs, algorithms, tolerances, residuals, sources, code and data hashes, and the weakest evidential status supported by the chain. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

Gate component	Required check	Failure output
Type and domain	All Dom/Cod and admissibility predicates are defined.	ABSTAIN-DOMAIN
Mathematical certificate	Hypotheses, residuals, and representative independence are verified.	ABSTAIN-CERT
Bridge and transport	The relevant realization, temporal, causal, or empirical bridge is identified.	ABSTAIN-BRIDGE
Independent evidence	Required external data or EXT-RUN is present and hash-linked.	ABSTAIN-EXT

24.46. Canonical Pseudocode

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

RETURN OK(V, Pred(Q), Cert, HashRoot); truth_layer_promotion=0.	**T2-F380**

24.47. Reproducibility and Root Hash

The certificate records inputs, algorithms, tolerances, residuals, sources, code and data hashes, and the weakest evidential status supported by the chain. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

h_j = H(h_{j-1} || module_id || input_hash || output_hash || cert_hash || budget_hash).	**T2-F381**

24.48. Prior Art and Boundary of the Authorial Synthesis

Classical constructions retain their standard attribution; the authorial contribution is the typed, blocker-safe synthesis inside KLT-RBD. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

24.49. Checkpoint, Conclusion of Volume II, and Boundary of Inference

The source construction is restated in controlled English with its hypotheses, invariants, loss channels, and forbidden status transfers kept explicit. Composition preserves certificates, budgets, and absorbing failure branches; release uses the weakest required component.

BOUNDARY OF CHAPTER 24. Local correctness does not imply global compatibility; incompatible budgets, interfaces, causal bridges, or release evidence close the gate. truth_layer_promotion=0; independent EXT-RUN and EMP-OBS remain absent.

Appendix T2-A. Synchronized Register of Formal Statements

Total: 339 numbered formal objects. Cross-type collisions of the bare number: 44; duplicate typed identifiers within one type: 0. The register preserves the source identifiers and explicit statuses.

STATUS FRAME. The appendix registries preserve the authority relation Authority(T2-RU v1.0) > Authority(T2-EN). A registry row records a source object, obligation, formula, locator, or release check; it does not strengthen its mathematical or physical status. truth_layer_promotion=0; independent EXT-RUN and EMP-OBS remain absent.

Typed ID	Type	Short title	Explicit status	Primary section
T2-DEF-5.1	Definition	Domain of the Associator	DEF-A	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-LEM-5.2	Lemma	Trilinearity on the Full Domain	THM	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-DEF-5.3	Definition	Three Nuclei and the Nucleus	DEF-A	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-PROP-5.4	Proposition	Linearity of the Nuclei	THM	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-DEF-5.5	Definition	Commutant and Center	DEF-A	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-DEF-5.6	Definition	Associator Ideal	DEF-A	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-THM-5.7	Theorem	Universal Associative Reflection	THM	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-THM-5.8	Theorem	Degree No-Go	THM	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-THM-5.9	Theorem	Even the Cubic Diagonal Is Insufficient	THM	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-DEF-5.10	Definition	Three Quadratic Pencils	DEF-A	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-DEF-5.11	Definition	Alternating Component	DEF-A	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-THM-5.12	Theorem	Completeness of the Quadratic-Alternating Certificate	THM	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-DEF-5.13	Definition	Strict Realisation of R⋆R	DEF-A	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-PROP-5.14	Proposition	Profile of Model $\mathscr{A}_2$	THM	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-DEF-5.15	Definition	Basic Profile	DEF-A	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants

STATUS FRAME. The appendix registries preserve the authority relation Authority(T2-RU v1.0) > Authority(T2-EN). A registry row records a source object, obligation, formula, locator, or release check; it does not strengthen its mathematical or physical status. truth_layer_promotion=0; independent EXT-RUN and EMP-OBS remain absent.

Typed ID	Type	Short title	Explicit status	Primary section
T2-THM-5.16	Theorem	Isomorphism Invariance of the Profile	THM	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-DEF-5.17	Definition	Profile Pseudodistance	DEF-A	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-DEF-5.18	Definition	Polynomial Family of Algebras	DEF-A	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-DEF-5.19	Definition	Determinantal Horizon	DEF-A	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-THM-5.20	Theorem	Localisation of Structural Transitions	THM	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-COR-5.21	Corollary	Negative Prediction Theorem	THM	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-DEF-5.22	Definition	Predictive Horizon along a Path	DEF-A	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-DEF-5.23	Definition	Harmonic Transition Candidate	DEF-A	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-THM-5.24	Theorem	Projective Invariance of a Harmonic Candidate	THM	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-PROP-5.25	Proposition	Finiteness of the Construction of J_Ass	THM	Chapter 5. Associator, R⋆R, Nuclei, Centers, and Invariants
T2-DEF-6.1	Definition	Representable Duality	DEF-A	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-DEF-6.2	Definition	Spatial Duality	DEF-A	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-THM-6.3	Theorem	Yoneda-Safe Anti-Equivalence	THM	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-DEF-6.4	Definition	Rep_A(T)	DEF-A	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-PROP-6.5	Proposition	Functoriality of Reper Configurations	THM	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-COR-6.6	Corollary	Isomorphism Invariance	THM	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-HYP-6.7	Hypothesis	Spatial Realisation	COND	Chapter 6. Packet-Reper Algebraic-Geometric Duality

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Typed ID	Type	Short title	Explicit status	Primary section
T2-DEF-6.8	Definition	Algebraic Defect	DEF-A	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-DEF-6.9	Definition	Geometric Defect	DEF-A	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-THM-6.10	Theorem	Restricted Reconstruction Theorem	THM under hypothesis 6.7	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-COR-6.11	Corollary	Preservation of Isomorphism Invariants	THM under hypothesis 6.7	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-THM-6.12	Theorem	Character-Spectrum No-Go	THM	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-PROP-6.14	Proposition	No-Dynamics Principle	THM	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-DEF-6.15	Definition	Projective Reper Atlas	DEF-A	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-THM-6.16	Theorem	Globalisation of λ	THM	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-COR-6.17	Corollary	Global Harmonic Locus	THM	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-DEF-6.18	Definition	Projective-Reper Morphism	DEF-A	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-THM-6.19	Theorem	Invariance of the Harmonic Locus	THM	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-HYP-6.20	Hypothesis	Conjugacy Bridge	COND	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-THM-6.21	Theorem	Coincidence of Rank Horizons	THM under hypothesis 6.20	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-COR-6.22	Corollary	Double Negative-Prediction Theorem	THM under hypotheses 6.7 and 6.20	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-DEF-6.23	Definition	Dual Mismatch Set	DEF-A	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-DEF-6.24	Definition	Block_dual	DEF-A	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-DEF-6.25	Definition	Dual Harmonic Candidate	DEF-A	Chapter 6. Packet-Reper Algebraic-Geometric Duality

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Typed ID	Type	Short title	Explicit status	Primary section
T2-THM-6.26	Theorem	Functorial Predictive Transport	COND	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-PROP-6.27	Proposition	Representability of the Associative Reflection	THM	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-PROP-6.28	Proposition	Functoriality of Nucleus Loci	THM	Chapter 6. Packet-Reper Algebraic-Geometric Duality
T2-DEF-7.1	Definition	Local NAPG Model	DEF-A	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-DEF-7.2	Definition	NAPG Atlas	DEF-A	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-DEF-7.3	Definition	Structural Groupoid	DEF-A	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-THM-7.4	Theorem	Associative Transition Groupoid Is Necessary	THM	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-DEF-7.5	Definition	Projective-Reper Chart	DEF-A	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-THM-7.6	Theorem	Globality of lambda	THM	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-DEF-7.7	Definition	Descent Datum	CL/DEF-A	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-DEF-7.8	Definition	Effective Descent	CL/COND	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-THM-7.9	Theorem	Gluing of an NAPG Bundle	THM	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-DEF-7.11	Definition	Bundle of NAPG Algebras	DEF-A	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-THM-7.12	Theorem	Descent of the Operation	THM	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-DEF-7.13	Definition	Operation Descent Defect	DEF-A	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-DEF-7.14	Definition	Reper Bundle	DEF-A	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-THM-7.15	Theorem	Double Descent of Reper	COND	Chapter 7. Atlases, Bundles, and Globalisation Obstructions

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Typed ID	Type	Short title	Explicit status	Primary section
T2-DEF-7.16	Definition	Hodge-Compatible Atlas	DEF-A	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-THM-7.17	Theorem	Descent of the Hodge Star	THM	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-THM-7.19	Theorem	Central Obstruction Class	THM/COND	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-DEF-7.20	Definition	Globalisation Defect Vector	DEF-A	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-THM-7.21	Theorem	Cellular Obstruction Tower	CL/COND	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-DEF-7.22	Definition	Parametric NAPG Bundle	DEF-A	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-THM-7.23	Theorem	Homotopy Constancy	THM	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-COR-7.24	Corollary	Negative Global Prediction	THM	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-DEF-7.25	Definition	Globalisation Horizon	DEF-A	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-THM-7.26	Theorem	Localisation of a Possible Global Transition	COND	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-DEF-7.27	Definition	Predictive Reper Bundle	DEF-A	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-DEF-7.28	Definition	Globally Admissible Scenario	DEF-A	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-DEF-7.29	Definition	Global Structural Candidate	DEF-A	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-THM-7.30	Theorem	No Local-to-Global Substitution	THM	Chapter 7. Atlases, Bundles, and Globalisation Obstructions
T2-DEF-8.1	Definition	Dual-Number Tangent	CL/DEF-A	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-LEM-8.2	Lemma	Derivation Representation	THM	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-DEF-8.3	Definition	Curve Tangent	CL/COND	Chapter 8. Tangent and Cotangent Objects of NAPG

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Typed ID	Type	Short title	Explicit status	Primary section
T2-DEF-8.4	Definition	Kahler Cotangent Module	CL/COND	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-DEF-8.5	Definition	Cotangent at a Rational Point	CL	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-DEF-8.6	Definition	Algebraic Tangent Cone	CL	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-PROP-8.7	Proposition	Cone-to-Tangent Inclusion	CL	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-DEF-8.10	Definition	Ambient Operation Space	DEF-A	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-DEF-8.11	Definition	Linearised Structure Space	DEF-A	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-THM-8.12	Theorem	Differential of the Associator	THM	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-COR-8.13	Corollary	Associative Tangent Equation	CL/THM	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-DEF-8.14	Definition	Gauge Differential	DEF-A	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-THM-8.15	Theorem	Stabiliser-Derivation Identity	THM	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-DEF-8.16	Definition	Reduced Tangent Space	DEF-A	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-DEF-8.17	Definition	Tangent Complex	DEF-A	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-THM-8.18	Theorem	No Canonical Self-Duality	CL/THM	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-COR-8.19	Corollary	NAPG Duality Boundary	THM/COND	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-DEF-8.20	Definition	Second-Order Obstruction Class	DEF-A	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-THM-8.21	Theorem	Second-Order Lift Criterion	THM	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-DEF-8.23	Definition	Formally Smooth Point	DEF-A	Chapter 8. Tangent and Cotangent Objects of NAPG

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Typed ID	Type	Short title	Explicit status	Primary section
T2-DEF-8.24	Definition	Finite-Dimensional Regular Sector	DEF-A	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-DEF-8.26	Definition	Linearisation Horizon	DEF-A	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-THM-8.27	Theorem	Local Constancy Outside the Horizon	COND	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-THM-8.28	Theorem	Differential of the Cross-Ratio	THM	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-COR-8.29	Corollary	Tangent Space to the Harmonic Locus	THM/COND	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-DEF-8.30	Definition	Smooth Harmonic Risk	DEF-A	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-THM-8.31	Theorem	First-Order Blindness at Exact Harmony	THM	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-DEF-8.32	Definition	Structural Constraint Map	DEF-A	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-DEF-8.33	Definition	Integrable Predictive Direction	DEF-A	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-THM-8.34	Theorem	Tangent-Safe Predictive Transport	COND	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-THM-8.35	Theorem	No Event from Tangent Data Alone	THM	Chapter 8. Tangent and Cotangent Objects of NAPG
T2-DEF-9.1	Definition	Algebraic NAPG Bundle	DEF-A	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-DEF-9.2	Definition	D-Admissible Path Category	DEF-A	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-DEF-9.3	Definition	NAPG Connection	DEF-A	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-DEF-9.4	Definition	Parallel Transport	CL/DEF-A	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-THM-9.5	Theorem	Associativity of Transport Composition	THM	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-COR-9.6	Corollary	First No-Go	THM	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature

STATUS FRAME. The appendix registries preserve the authority relation Authority(T2-RU v1.0) > Authority(T2-EN). A registry row records a source object, obligation, formula, locator, or release check; it does not strengthen its mathematical or physical status. truth_layer_promotion=0; independent EXT-RUN and EMP-OBS remain absent.

Typed ID	Type	Short title	Explicit status	Primary section
T2-DEF-9.7	Definition	Curvature	CL	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-DEF-9.8	Definition	Small-Loop Certificate	DEF-A	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-THM-9.9	Theorem	Small Loops Localise Curvature	CL/THM	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-DEF-9.10	Definition	D-Holonomy	DEF-A	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-PROP-9.11	Proposition	Base-Point Change	THM	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-THM-9.12	Theorem	Ambrose-Singer: Classical Layer	CL	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-HYP-9.13	Hypothesis	D-Ambrose-Singer Bridge	COND/OPEN	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-DEF-9.14	Definition	Product Defect	DEF-A	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-DEF-9.15	Definition	Product-Compatible Connection	DEF-A	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-THM-9.16	Theorem	Transport Preserves the Product	THM	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-COR-9.17	Corollary	Holonomy Preserves Structure	THM	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-DEF-9.18	Definition	Finite Multiplication Holonomy Defect	DEF-A	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-DEF-9.19	Definition	Finite Associator Holonomy Defect	DEF-A	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-THM-9.20	Theorem	Derivative of the Associator through C_nabla	THM	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-COR-9.21	Corollary	Vanishing Associator Curvature and Trivial Associator Holonomy	THM	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-DEF-9.22	Definition	Associator Curvature K_Ass	DEF-A	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-THM-9.23	Theorem	Necessary Condition for Parallelism	THM	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature

STATUS FRAME. The appendix registries preserve the authority relation Authority(T2-RU v1.0) > Authority(T2-EN). A registry row records a source object, obligation, formula, locator, or release check; it does not strengthen its mathematical or physical status. truth_layer_promotion=0; independent EXT-RUN and EMP-OBS remain absent.

Typed ID	Type	Short title	Explicit status	Primary section
T2-DEF-9.25	Definition	Full Associator-Holonomy Bridge Package	DEF-A	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-THM-9.26	Theorem	Holonomy Principle for the Associator	CL/THM	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-THM-9.32	Theorem	Universal-Equality No-Go	THM	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-DEF-9.33	Definition	Akivis Algebra	CL	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-DEF-9.34	Definition	Bridge Datum beta	DEF-A	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-DEF-9.36	Definition	D-Holonomy Signature	DEF-A	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-DEF-9.37	Definition	Finite Holonomy Certificate	DEF-A	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-THM-9.38	Theorem	Local Constancy of Certified Rank	THM	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-DEF-9.40	Definition	Connection-Holonomy Horizon	DEF-A	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-THM-9.41	Theorem	Negative Holonomy Prediction	COND	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-THM-9.42	Theorem	Common Projective Transport Invariance	THM	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-COR-9.43	Corollary	Relative Transport Is Necessary	THM	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-DEF-9.44	Definition	Relative Reper Connection	DEF-A	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-THM-9.46	Theorem	Holonomy-Associator-Safe Predictive Theorem	COND	Chapter 9. Connections, Curvature, Holonomy, and Associator Curvature
T2-DEF-10.1	Definition	Internal Packet Forms	DEF-A	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.2	Definition	Internal Differential Candidate	DEF-A	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.3	Definition	External E-Operator	DEF-A/COND	Chapter 10. NAPG Differential Forms and Typed Differentials

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Typed ID	Type	Short title	Explicit status	Primary section
T2-DEF-10.4	Definition	Hodge Operators	CL/DEF-A	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-PRINC-10.5	Principle	Notation Firewall	THM/PROTOCOL	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.6	Definition	Leibniz Defect	DEF-A	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.7	Definition	Graded Derivation	CL/DEF-A	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-LEM-10.8	Lemma	Value on the Unit	THM	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-THM-10.9	Theorem	Closure of Derivations	THM	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-COR-10.10	Corollary	Square of an Odd Derivation	THM	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-THM-10.11	Theorem	Associator Leibniz Identity	THM	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-COR-10.12	Corollary	Stability of the Associative Sector	THM	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.13	Definition	Differential Curvature	DEF-A	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-LEM-10.14	Lemma	Operator Bianchi Identity	THM	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.15	Definition	Precomplex and Complex	DEF-A	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.20	Definition	Sheaf-Local Operator	DEF-A	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-LEM-10.21	Lemma	Support Nonincrease	THM	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-THM-10.22	Theorem	Gluing of Local Differentials	THM	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.23	Definition	Differential Gluing Defect	DEF-A	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.25	Definition	Bigraded Bridge Object	DEF-A/COND	Chapter 10. NAPG Differential Forms and Typed Differentials

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Typed ID	Type	Short title	Explicit status	Primary section
T2-THM-10.26	Theorem	Square Decomposition	THM	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.28	Definition	Differential Bridge Certificate	DEF-A	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.30	Definition	Hodge Sector	CL/COND	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.31	Definition	Codifferential	CL/COND	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.32	Definition	Hodge Laplacian	CL/COND	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-THM-10.33	Theorem	Nilpotency Transfer	THM	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.35	Definition	Hodge Transport Defect	DEF-A	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.36	Definition	Formal-Adjoint Defect	DEF-A	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.37	Definition	Differential Reper	DEF-A	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.38	Definition	Differential Defect Vector	DEF-A	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-PRINC-10.39	Principle	Harmonic Insufficiency Principle	THM/PROTOCOL	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.40	Definition	Relaxed Differential Candidate	DEF-A	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.41	Definition	Finite Differential Signature	DEF-A	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-10.42	Definition	Differential Horizon	DEF-A	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-THM-10.43	Theorem	Rank Constancy	THM	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-THM-10.44	Theorem	Differential Negative Prediction	COND	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-COR-10.45	Corollary	Horizon Crossing Is Only a Candidate	COND	Chapter 10. NAPG Differential Forms and Typed Differentials

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Typed ID	Type	Short title	Explicit status	Primary section
T2-CTHM-10.46	Countertheorem	Triple Independence Countertheorem	THM	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-THM-10.47	Theorem	Differential-Calculus-Safe Predictive Theorem	COND	Chapter 10. NAPG Differential Forms and Typed Differentials
T2-DEF-12.1	Definition	NAPG Quadratic Frame	DEF-A	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-DEF-12.2	Definition	Internal Minimal Complex	THM/IMPORT	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-LEM-12.1	Lemma	Nilpotency	THM	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-DEF-12.3	Definition	Canonical Map Theta_min	THM/IMPORT	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-DEF-12.4	Definition	Internal Obstruction Class	DEF-A	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-THM-12.2	Theorem	Internal H2 and H3	THM	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-THM-12.3	Theorem	Natural Exact Sequence	THM	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-COR-12.3	Corollary	1. Finite-Dimensional Rank Formula	THM	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-THM-12.4	Theorem	Minimal-Complex Functor	THM	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-THM-12.5	Theorem	Natural Isomorphism with O_B	THM	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-COR-12.5	Corollary	1. Invariant Vanishing	THM	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-DEF-12.5	Definition	Lift	DEF-A	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-THM-12.6	Theorem	Complete Internal Lift Criterion	THM	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-THM-12.7	Theorem	Torsor of Lifts	THM	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-THM-12.8	Theorem	Universal Extension into a Complex	THM	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min

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Typed ID	Type	Short title	Explicit status	Primary section
T2-THM-12.9	Theorem	Extension of Scalars	THM	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-THM-12.10	Theorem	Block-Diagonal Additivity	THM	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-DEF-12.6	Definition	Orthogonal Obstruction Residual	DEF-A/COMP	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-THM-12.11	Theorem	Residual Criterion	THM	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-DEF-12.7	Definition	Normalised Internal Obstruction Index	DEF-A/DIAGNOSTIC	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-THM-12.12	Theorem	Constant-Rank Cohomology Bundles	THM	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-COR-12.12	Corollary	1. Zeros of the Obstruction Section	THM	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-DEF-12.8	Definition	Internal Transition Horizon	DEF-A	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-LEM-12.13	Lemma	Motion of the Residual	THM	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-THM-12.14	Theorem	Certified No-Lift Zone	THM/COMP	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-THM-12.15	Theorem	Minimal-Obstruction-Safe Predictive Theorem	COND	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-DEF-12.9	Definition	Joint Certificate	DEF-A	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-CTHM-12.16	Countertheorem	Four Prohibited Implications	THM	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min
T2-DEF-13.1	Definition	External Realisation	DEF-A	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-DEF-13.2	Definition	Cochain Bridge J	DEF-A	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-THM-13.1	Theorem	Descent to the Quotient	THM	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-COR-13.1	Corollary	Injective-Bridge Corollary	THM	Chapter 13. External E-Complex and the Conditional Bridge Pi_E

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Typed ID	Type	Short title	Explicit status	Primary section
T2-DEF-13.3	Definition	External Obstruction Map	COND/THM under B1-B5	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-THM-13.2	Theorem	Naturality	THM under B3-B5	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-THM-13.3	Theorem	One-Way Detection	THM	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-THM-13.4	Theorem	Reverse Detection Criterion	THM	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-DEF-13.4	Definition	Bridge Quality	DEF-A	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-DEF-13.5	Definition	Mapping Cone	CL	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-THM-13.5	Theorem	Exact Detection Sequence	THM	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-THM-13.6	Theorem	Chain-Homotopy Invariance	CL/THM	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-DEF-13.6	Definition	Category of External Realisations	DEF-A	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-THM-13.7	Theorem	Canonical External-Class Criterion	THM	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-DEF-13.7	Definition	Canonical External Class	COND; canonical external class	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-THM-13.8	Theorem	Stable Reverse Detection	THM/COMP	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-LEM-13.9	Lemma	Local Constancy of Ranks	THM	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-THM-13.10	Theorem	Compact-Interval External Detection	THM/COMP	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-THM-13.11	Theorem	External-Detection-Safe Predictive Theorem	COND	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-DEF-13.8	Definition	Associator Test Channel	OPEN/DEF-A	Chapter 13. External E-Complex and the Conditional Bridge Pi_E
T2-CTHM-13.12	Countertheorem	False External Implications Without Additional Hypotheses	THM	Chapter 13. External E-Complex and the Conditional Bridge Pi_E

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Typed ID	Type	Short title	Explicit status	Primary section
T2-DEF-15.1	Definition	Hilbert Complex	CL/DEF	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-DEF-15.2	Definition	Cycles, Boundaries, and Two Cohomology Spaces	CL/DEF	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-LEM-15.1	Lemma	Adjoint Orthogonality	CL/THM	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-DEF-15.3	Definition	Hodge Laplacian	CL/DEF	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-DEF-15.4	Definition	Harmonic Sector	CL/DEF	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-THM-15.2	Theorem	Weak Hodge Decomposition	CL/THM	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-THM-15.3	Theorem	Strong Decomposition Criterion	CL/THM	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-THM-15.4	Theorem	Ellipticity of the Hodge Laplacian	CL/THM	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-DEF-15.5	Definition	Laplacian-Type Operator	CL/DEF	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-CTHM-15.5	Countertheorem	Nilpotency Does Not Imply Ellipticity	THM	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-THM-15.6	Theorem	Boundary Firewall	CL/COND	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-CTHM-15.7	Countertheorem	Formal Symmetry Does Not Imply Self-Adjointness	THM	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-DEF-15.6	Definition	Interface Domain	DEF-A/COND	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-DEF-15.7	Definition	Fredholm Operator	CL/DEF	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-THM-15.8	Theorem	Harmonic Detection of the External Class	CL/THM	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-DEF-15.8	Definition	Compact Resolvent	CL/DEF; compact-resolvent sector	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-THM-15.9	Theorem	Exact Analytic Detection	THM/COND	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer

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Typed ID	Type	Short title	Explicit status	Primary section
T2-DEF-15.9	Definition	Analytic Transition Horizon	DEF-A; analytic conditioning ledger	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-THM-15.10	Theorem	Stable Nonzero Obstruction	THM/COMP	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-COR-15.10	Corollary	Stable-Obstruction Corollary	UNMARKED	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-THM-15.11	Theorem	Necessity of Intersecting the Analytic Horizon	THM/COND	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-DEF-15.10	Definition	Hodge-Reper Certificate	DEF-A	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-THM-15.12	Theorem	Hodge-Fredholm-Safe Prediction	COND	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-CTHM-15.13	Countertheorem	Invalid Analytic Implications Without Additional Hypotheses	THM	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer
T2-DEF-16.1	Definition	NAPG Deformation Groupoid	DEF-A	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map
T2-DEF-16.2	Definition	Complete Linear Obstruction Theory	DEF-A	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map
T2-THM-16.3	Theorem	Conditional Schlessinger Package	UNMARKED	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map
T2-THM-16.4	Theorem	Small-Extension Lift from Maurer-Cartan	UNMARKED	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map
T2-THM-16.5	Theorem	Conditional Analytic Kuranishi Reduction	UNMARKED	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map
T2-DEF-16.6	Definition	Kuranishi Convergence Radius	Kuranishi conditioning margin	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map
T2-DEF-16.7	Definition	Order of the First Nonzero Obstruction	DEF-A	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map
T2-CTHM-16.8	Countertheorem	Coarse Moduli Cannot Recover a Stack Germ Without Stabiliser Data	UNMARKED	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map
T2-THM-16.9	Theorem	Moduli-Kuranishi-Safe Prediction	COND	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map
T2-THM-17.1	Theorem	Constancy in a Chamber	UNMARKED	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy

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Typed ID	Type	Short title	Explicit status	Primary section
T2-CTHM-17.2	Countertheorem	Equal Dimensions Do Not Define Wall Crossing	UNMARKED	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy
T2-THM-17.3	Theorem	Wall Is Not Bifurcation	UNMARKED	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy
T2-THM-17.4	Theorem	Homotopy Invariance	UNMARKED	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy
T2-THM-17.5	Theorem	No Global Labelling	UNMARKED	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy
T2-THM-17.7	Theorem	Wall-Crossing-Safe Prediction	COND	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy
T2-DEF-18.1	Definition	Global Stacky/Derived NAPG Moduli Object	DEF-A	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier
T2-THM-18.2	Theorem	Descent No-Shortcut Theorem	THM in selected 2-category	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier
T2-THM-18.3	Theorem	Presentation Invariance	THM	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier
T2-DEF-18.4	Definition	Predictive Carrier	DEF-A	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier
T2-THM-18.5	Theorem	Local-to-Global No-Go	THM	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier
T2-THM-18.6	Theorem	Coarse-Moduli No-Go	THM	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier
T2-THM-18.7	Theorem	Global-Stack-Safe Prediction	COND	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier
T2-THM-19.1	Theorem	Conditional Presentation Independence	COND	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall
T2-LEM-19.2	Lemma	Transverse Reduction	THM in finite-dimensional oriented models	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall
T2-THM-19.3	Theorem	Conditional Deformation Invariance of the Virtual Invariant	COND	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall
T2-THM-19.4	Theorem	No Universal Probability Interpretation	THM	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall
T2-DEF-19.5	Definition	Probabilistic Bridge to an Applied Event	DEF-A	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall

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Typed ID	Type	Short title	Explicit status	Primary section
T2-THM-19.6	Theorem	Conditional Virtual-Profile Constancy	COND; Virtual-cycle-safe predictive theorem	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall
T2-DEF-20.1	Definition	Refined-Carrier Ladder	DEF-A	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants
T2-DEF-20.2	Definition	Categorification and Decategorification Data	DEF-A	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants
T2-THM-20.1	Theorem	Decategorification No-Go Theorem	THM	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants
T2-DEF-20.3	Definition	Motivic Carrier of a NAPG Candidate	DEF-A	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants
T2-THM-20.2	Theorem	Numerical Indistinguishability	THM	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants
T2-LEM-20.3	Lemma	Plethystic Exponential and Logarithm Bijection	THM	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants
T2-DEF-20.4	Definition	Series Certificate	Γ,R,completion,pairing,ordering,chamber,PExp/PLog,convergence_status,D,Dom	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants
T2-THM-20.4	Theorem	Coefficient-Time Non-Identifiability	THM	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants
T2-DEF-20.5	Definition	Minimal Dynamic Bridge	DEF-A	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants
T2-DEF-20.6	Definition	Complete Chapter Certificate	DEF-A	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants
T2-THM-20.5	Theorem	Time Non-identifiability from Coefficients	COND	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants
T2-DEF-21.1	Definition	Temporal Carrier	DEF-A	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels
T2-DEF-21.2	Definition	Nonlinear Evolution Semigroup	DEF-A	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels
T2-THM-21.1	Theorem	Specialised Crandall-Liggett Generation Theorem	THM/prior art	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels
T2-COR-21.1	Corollary	Certified Discretised Transition Corollary	UNMARKED	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-

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Typed ID	Type	Short title	Explicit status	Primary section
				Space Carriers, and Causal Kernels
T2-DEF-21.3	Definition	Non-Autonomous Evolution Family	DEF-A	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels
T2-THM-21.2	Theorem	No-State-Reconstruction Theorem	THM	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels
T2-DEF-21.4	Definition	Markov Transition Kernel	DEF-A	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels
T2-THM-21.3	Theorem	Kolmogorov Consistency	THM/prior art	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels
T2-COR-21.2	Corollary	One-Time Marginals Do Not Determine a Path Law	UNMARKED	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels
T2-DEF-21.5	Definition	Non-Anticipating Path Operator	DEF-A	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels
T2-THM-21.4	Theorem	Kernel Non-Anticipation	THM	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels
T2-DEF-21.6	Definition	Temporal Reper	DEF-A	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels
T2-THM-21.5	Theorem	Temporal Profile Constancy	COND	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels
T2-THM-21.6	Theorem	Static-Snapshot No-Go	THM	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels
T2-DEF-22.1	Definition	Stochastic Basis	DEF-A	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference
T2-THM-22.1	Theorem	Well-Posed Martingale Problem	THM/prior art	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference

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Typed ID	Type	Short title	Explicit status	Primary section
T2-THM-22.2	Theorem	Measure Change Is Not Intervention	THM	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference
T2-THM-22.3	Theorem	Finite-Horizon Barrier Bound	THM	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference
T2-THM-22.4	Theorem	Observational-Interventional Non-Identifiability	THM	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference
T2-COR-22.1	Corollary	Positive Local Drift of the Harmonic Defect	UNMARKED	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference
T2-THM-22.5	Theorem	Stochastic Prediction-Control-Causality Safety Theorem	COND	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference
T2-THM-23.1	Theorem	Contraction Principle	THM/prior art	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification
T2-THM-23.2	Theorem	Asymptotic-Probability Firewall	THM	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification
T2-THM-23.3	Theorem	Coverage-to-Risk Theorem	THM	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification
T2-THM-23.4	Theorem	Finite-Sample Tail No-Go Theorem	THM	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification
T2-THM-23.5	Theorem	Rare-Event Predictive Safety Theorem	COND	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification
T2-DEF-24.1	Definition	Predictive Query	DEF-A	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability
T2-DEF-24.2	Definition	Certified State at Step j	DEF-A	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability
T2-LEM-24.1	Lemma	Homogeneous Reper Coordinate Without	UNMARKED	Chapter 24. End-to-End KLT-RBD Predictive

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Typed ID	Type	Short title	Explicit status	Primary section
		Artificial Poles		Operator, Budget Composition, and Final Falsifiability
T2-DEF-24.3	Definition	Objects of the Category CertKLT	DEF-A	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability
T2-THM-24.1	Theorem	Soundness of CertKLT Composition	UNMARKED	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability
T2-DEF-24.4	Definition	Complete Uncertainty Budget	DEF-A	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability
T2-COR-24.1	Corollary	Deterministic Transport Error Bound	UNMARKED	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability
T2-LEM-24.2	Lemma	Weakest-Link Rule	UNMARKED	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability
T2-THM-24.2	Theorem	No Canonical Scalarization	UNMARKED	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability
T2-COR-24.2	Corollary	Prohibition of an Undefined Scalar Validity Percentage	UNMARKED	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability
T2-DEF-24.5	Definition	Release Manifest	DEF-A	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability
T2-DEF-24.6	Definition	Composite Final Verdict	DEF-A	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability
T2-THM-24.3	Theorem	Monotonicity of ABSTAIN	UNMARKED	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability
T2-THM-24.4	Theorem	Conditional End-to-End Safety	COND	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability

Appendix T2-B. Complete Register of Evidence Obligations T2-PO-001-T2-PO-500

The source status is preserved. The normalized class is an analytic aid and does not replace the obligation text or its required evidence. OPEN and COND entries remain blockers unless a later version records a valid closure witness.

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-001	The definitions and objects of the chapter are typed and supplied with Dom/Cod.	OPEN	OPEN	Definition/typing dossier ∣ Collect the canonical inputs and verify collisions. ∣ Ch. 1
T2-PO-002	The main transition of the chapter is proved or explicitly retained as conditional together with a counterexample.	OPEN	OPEN	Proof or countermodel dossier ∣ Construct a proof, a negative model, and a closure criterion. ∣ Ch. 1
T2-PO-003	Complete NOTATION LEDGER, types and reservation symbols.	CLOSED	CLOSED/THM	§10.1-10.3 ∣ Maintain this item for every new chapter.
T2-PO-004	Collisions ⊙/⋆/⋆_Hdg/δ/δ_min eliminated.	CLOSED	CLOSED/THM	Lemma 2.1; counterexample 2.1-2.2 ∣ Automatic notation audit in the appendix.
T2-PO-005	Objects, morphisms, identities and composition NAPG_q defined.	CLOSED	CLOSED/THM	Def. 3.1-3.2; Thm. 3.1 ∣ Extend to topological frames.
T2-PO-006	Constructed countermodels to M1-M4 and Dom.	CLOSED	CLOSED/THM	Counterexamples 3.1-3.6 ∣ Add machine tests.
T2-PO-007	Graded bilinear algebra and formal language typed.	CLOSED ALG	CLOSED/THM	§12.1-12.3 ∣ Analytic norms are treated separately.
T2-PO-008	The main transition of the chapter is proved or explicitly retained as conditional together with a counterexample.	OPEN	OPEN	Proof or countermodel dossier ∣ Construct a proof, a negative model, and a closure criterion. ∣ Ch. 4
T2-PO-009	General bridge Ass_⊙ ↔ curvature/Hol_D	OPEN	OPEN	first specify geometric connection and types both carriers
T2-PO-010	Natural associator invariant/β_Ass.	OPEN	OPEN	Counterexample 4.5 ∣ tom2_v0_3; do not conflate it with O_B.
T2-PO-011	Typed nuclei, center and J_Ass	CLOSED	CLOSED/THM	transfer to the final Chapter 5
T2-PO-012	Universality associative factor	CLOSED	CLOSED/THM	add a categorical formulation as a left adjoint functor
T2-PO-013	No-go for diagonal encoding	CLOSED	CLOSED/THM	computational tests on the octonions
T2-PO-014	Complete R⋆R-certificate	CLOSED/COND	COND	char≠2,3; investigate characteristics 2 and 3
T2-PO-015	Determinantal horizon transition	CLOSED	CLOSED/THM	implement a symbolic certificate

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-016	Complete exactness representable NAPG-functor	CLOSED	CLOSED/THM	Preserve type discipline when extending the category.
T2-PO-017	Naturality Adm and Valid(D)	COND	COND	Formalize the classes of admissible test morphisms.
T2-PO-018	Global existence Spec_R/Gamma_R	OPEN	OPEN	Choose concrete spectrum and structural sheaf for target podkategorii.
T2-PO-019	Reconstruction unit/counit	COND	COND	Construct eta and epsilon on the explicit models A2, M2, and the octonion layer.
T2-PO-020	Faithfulness point-set spectrum	CLOSED-NEG	CLOSED/THM	Preserve the no-go result as a mandatory countertest.
T2-PO-021	Projective Reper atlas	CLOSED-FORMAL	CLOSED/THM	Construct a nontrivial atlas with several charts.
T2-PO-022	Non-PGL chart counterexample	CLOSED	CLOSED/THM	Include in the automatic test TEST-NONPGL-07.
T2-PO-023	Conjugacy bridge algebra-geometry	OPEN	OPEN	Define the geometric structure maps of Chapters 7-9.
T2-PO-024	Dual horizon equality	COND	COND	Close after T2-PO-023 on an explicit family.
T2-PO-025	Banach/Hilbert completion	OPEN	OPEN	Transfer to the analytic layer after Chapter 11.
T2-PO-026	Independent predictive certificate	OPEN	OPEN	Preregister a computational test without physical claims.
T2-PO-027	Topology/smoothness Aut_NAPG(F) for model fibres	OPEN	OPEN	construct for A2, M2, and the octonion layer
T2-PO-028	Effective descent category NAPG_q	OPEN	OPEN	specify a stack/pseudofunctor and prove effectiveness
T2-PO-029	Cocycle gluing theorem	CLOSED	CLOSED/THM	theorem 7.9
T2-PO-030	No-go for nonassociative composition transition	CLOSED	CLOSED/THM	theorem 7.4
T2-PO-031	Descent of the Operation and J_Ass	CLOSED	CLOSED/THM	theorem 7.12
T2-PO-032	Global λ	CLOSED	CLOSED/THM	theorem 7.6
T2-PO-033	Descent Evidence-D	OPEN	OPEN	formalize the provenance category
T2-PO-034	Descent of the Hodge Star	CLOSED	CLOSED/THM	theorem 7.17

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-035	Central lifting obstruction	CLOSED/LOCAL	CLOSED/THM	theorem 7.19; choose concrete Z
T2-PO-036	Relation $\mathcal{O}$_B with Čech obstruction	OPEN	OPEN	do not identify them; construct a natural transformation
T2-PO-037	Section obstruction tower for predictive bundle	OPEN	OPEN	specify the fibre F and pi_k(F)
T2-PO-038	Homotopy Invariance	CLOSED	CLOSED/THM	theorem 7.23
T2-PO-039	Computational atlas/cocycle certificate	OPEN	OPEN	implement TEST-ATLAS-01 through TEST-HASH-14
T2-PO-040	Independent global prediction run	OPEN	OPEN	after the domain adapter; do not promote the status
T2-PO-041	Comparison curve/dual-number/derivation tangent	CLOSED/LOCAL	CLOSED/THM	theorem 8.2; globalize over the atlas
T2-PO-042	Cotangent module NAPG outside commutative envelope	OPEN	OPEN	specify a universal bimodule differential
T2-PO-043	Formula linearization Ass	CLOSED	CLOSED/THM	theorem 8.12
T2-PO-044	Gauge complex and Der-stabilizer	CLOSED	CLOSED/THM	theorem 8.15
T2-PO-045	Finite-projective tangent/cotangent duality	CLOSED/COND	COND	verify on models
T2-PO-046	Tangent cone for spaces NAPG-operations	OPEN	OPEN	compute the initial ideals for A2/M2/octonions
T2-PO-047	Second-order obstruction map	OPEN	OPEN	link Q with Theta_min and O_B
T2-PO-048	Integrability H^2_red classes	OPEN	OPEN	construct formal arcs and a versal model
T2-PO-049	Smooth locus quotient NAPG	OPEN	OPEN	verify free/proper action or provide a stacky replacement
T2-PO-050	Differential/Hessian λ	CLOSED/LOCAL	CLOSED/THM	theorem 8.28 and 8.31
T2-PO-051	Linearization horizon Δ_lin	DEFINED/OPEN	OPEN	compute on parametric models
T2-PO-052	Tangent-safe predictive certificate	OPEN	OPEN	implement TEST-TAN-01 through TEST-HASH-14
T2-PO-053	Independent domain run	OPEN	OPEN	only after the adapter and preregistration
T2-PO-054	Strict category D-admissible paths and existence transport	COND	COND	partially closed
T2-PO-055	Associativity transport composition and no-	THM	CLOSED/THM	closed

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PO	Description	Source status	Normalized class	Evidence / next step
	go Hol=Ass			
T2-PO-056	D-Ambrose-Singer for restricted system paths	COND	OPEN	OPEN
T2-PO-057	Equivalence C_∇=0 and preservation μ transport	THM	CLOSED/THM	closed
T2-PO-058	Formula ∇Ass through C_∇	THM	CLOSED/THM	closed
T2-PO-059	Definition and natural K_Ass	THM/DEF-A	CLOSED/THM	closed in typed sector
T2-PO-060	Existence Akivis/Sabinin-bridge β	OPEN	OPEN	not closed
T2-PO-061	Independent β from charts and gauges	OPEN	OPEN	not closed
T2-PO-062	Octonionic compatible model	MODEL/THM	CLOSED/THM	closed
T2-PO-063	Universal-equality no-go	THM	CLOSED/THM	closed
T2-PO-064	Completeness finite certificate G_N	COND	OPEN	OPEN
T2-PO-065	Local constancy rank G_N	THM	CLOSED/THM	closed
T2-PO-066	Common-PGL_2 invariance of λ	THM	CLOSED/THM	closed
T2-PO-067	Relative Reper connection	DEF-A/OPEN	OPEN	defined; realization remains open
T2-PO-068	Holonomy-associator-safe theorem	COND	COND	formulated
T2-PO-069	Independent domain run HOL-ASS	OPEN	OPEN	not executed
T2-PO-070	Typed sheaf Ω_N^• and partial product	DEF-A	SPECIFIED	defined
T2-PO-071	Leibniz defect and graded derivation package	THM	CLOSED/THM	closed
T2-PO-072	Closedness derivations and d^2 as even derivation	THM	CLOSED/THM	closed
T2-PO-073	Associator differential identity	THM	CLOSED/THM	closed
T2-PO-074	No-go: Leibniz not implies d^2=0	THM	CLOSED/THM	closed
T2-PO-075	Sheaf-locality and support property	THM	CLOSED/THM	closed in sheaf sector
T2-PO-076	Gluing theorem for local d_i	THM	CLOSED/THM	closed
T2-PO-077	Čech obstruction class from K_ij	COND	OPEN	OPEN coefficient sheaf
T2-PO-078	Mixed internal/E compatibility	OPEN	OPEN	not closed

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-079	Cert_E and Π_E well-definedness	OPEN	OPEN	not closed
T2-PO-080	Hodge codifferential and sign convention	COND	COND	closed locally
T2-PO-081	Hodge decomposition on strata	OPEN	OPEN	analytic blockers
T2-PO-082	Differential Reper certificate	DEF-A/COMP	COMP	specified
T2-PO-083	Rank constancy and Δ_diff	THM	CLOSED/THM	closed in the finite analytic sector
T2-PO-084	Differential-safe predictive theorem	COND	COND	formulated
T2-PO-085	Banach/Hilbert extension	OPEN	OPEN	not constructed
T2-PO-086	Independent run DIFF-NAPG	OPEN	OPEN	not executed
T2-PO-087	Typed C_min and nilpotency	THM	CLOSED/THM	§84; F077-F078
T2-PO-088	H^2=ker Ψ and H^3=coker Ψ	THM	CLOSED/THM	Theorem 12.2
T2-PO-089	Natural exact sequence	THM	CLOSED/THM	Theorem 12.3
T2-PO-090	Functoriality C_min	THM	CLOSED/THM	Theorem 12.4
T2-PO-091	Natural κ:O_B ≅ H^3	THM	CLOSED/THM	Theorem 12.5
T2-PO-092	Criterion lift	THM	CLOSED/THM	Theorem 12.6
T2-PO-093	H^2-torsor lifts	THM	CLOSED/THM	Theorem 12.7
T2-PO-094	Universal chain-map property	THM	CLOSED/THM	Theorem 12.8 | existence external J^2,J^3 separately
T2-PO-095	Field base-change	THM	CLOSED/THM	Theorem 12.9 | ring non-flat base-change not covered
T2-PO-096	Block-sum additivity	THM	OPEN	Theorem 12.10 | mixed blocks open
T2-PO-097	Residual and minimal-norm lift	THM/COMP	CLOSED/THM	Theorem 12.11 | are required norms/convention
T2-PO-098	Obstruction bundle constant rank	THM	OPEN	Theorem 12.12 | infinite-dimensional cases open
T2-PO-099	Stable zone NO-LIFT	THM/COMP	CLOSED/THM	Theorem 12.14 | requires certified bounds
T2-PO-100	Main predictive theorem v0.9	COND	COND	Theorem 12.15 | H1-H8
T2-PO-101	Higher obstructions after C_min	OPEN	OPEN	Chapter 16 | is required obstruction tower / MC-package
T2-PO-102	External E-bridge Π_E	OPEN	OPEN	Next assembly | B1-B8

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-103	Banach/Hilbert Fredholm-version	OPEN	OPEN	closed image, complemented kernels
T2-PO-104	Independent domain run	OPEN	OPEN	data and preregistration
T2-PO-105	Physical interpretation	PHY-HYP/OPEN	OPEN	Volume III ∣ independent verification
T2-PO-106	E^• is complex	THM/INPUT	CLOSED/THM	§101.1 ∣ B1
T2-PO-107	J is chain map	THM/INPUT	CLOSED/THM	§101.2 ∣ B2
T2-PO-108	Criterion well-definedness Π_E	THM	CLOSED/THM	Theorem 13.1
T2-PO-109	Natural Π_E	THM under B3-B5	CLOSED/THM	Theorem 13.2 ∣ B3-B5
T2-PO-110	One-sided detection	THM	CLOSED/THM	Theorem 13.3
T2-PO-111	Reverse detection	THM/COND	COND	Theorem 13.4 ∣ injectivity B6
T2-PO-112	Mapping cone and exact sequence	THM	CLOSED/THM	Theorem 13.5
T2-PO-113	Blind/Excess defects	THM	CLOSED/THM	§104.2
T2-PO-114	Chain-homotopy invariance	THM	CLOSED/THM	Theorem 13.6
T2-PO-115	Category external implement	THM/DEF-A	CLOSED/THM	Theorem 13.7
T2-PO-116	Canonical external class	COND	COND	§106 ∣ quasi-isomorphic realization category
T2-PO-117	Stable reverse detection	THM/COMP	CLOSED/THM	Theorem 13.8 ∣ norm/basis ledger
T2-PO-118	Parametric external horizon	THM/COMP	CLOSED/THM	§108 ∣ constant ranks/bounds
T2-PO-119	Stable external obstruction	THM/COMP	CLOSED/THM	Theorem 13.10 ∣ ε_E certificate
T2-PO-120	Main predictive theorem v0.10	COND	COND	Theorem 13.11 ∣ B1-B8 + previous blockers
T2-PO-121	Associator β_Ass-bridge	OPEN	OPEN	§110 ∣ B7
T2-PO-122	Physical reduction	PHY-HYP/OPEN	OPEN	Volume III ∣ B8 + data
T2-PO-123	Banach/Hilbert external layer	OPEN	OPEN	closed range/Fredholm
T2-PO-124	Independent domain run	OPEN	OPEN	preregistration/data
T2-PO-125	Machine-verifiable EXT-E certificate	COMP/OPEN	OPEN	E-01-E-16 ∣ implementation audit
T2-PO-126	correctness P(O_B) on O_B\{0}	CLOSED	CLOSED/THM	
T2-PO-127	partial functoriality P(f)	CLOSED	CLOSED/THM	

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-128	no-go natural choice representative	CLOSED	CLOSED/THM	
T2-PO-129	exact information-loss ledger	CLOSED	CLOSED/THM	
T2-PO-130	spherical/oriented model	CLOSED finite-dim	CLOSED/THM	
T2-PO-131	projective metric stability	CLOSED local	CLOSED/THM	
T2-PO-132	homogeneity criterion for invariant	CLOSED	CLOSED/THM	
T2-PO-133	Whitney (a) for rank strata	OPEN model	OPEN	
T2-PO-134	Whitney (b) for orbit strata	OPEN model	OPEN	
T2-PO-135	frontier/local finiteness	OPEN model	OPEN	
T2-PO-136	positive projectivization order cone	CLOSED	CLOSED/THM	
T2-PO-137	Fano local-to-global no-go	CLOSED	CLOSED/THM	
T2-PO-138	effective descent global carrier	OPEN	OPEN	
T2-PO-139	projective horizon construction	CLOSED finite family	CLOSED/THM	
T2-PO-140	profile constancy theorem	CLOSED under H1-H8	CLOSED/THM	
T2-PO-141	canonical χ_λ bridge	OPEN	OPEN	
T2-PO-142	interval-certified distance to Δ_proj	OPEN computation	OPEN	
T2-PO-143	Banach projective carrier	OPEN	OPEN	
T2-PO-144	independent domain run	OPEN	OPEN	
T2-PO-145	physical reduction	OPEN / Volume III	OPEN	
T2-PO-146	Hilbert-complex domains and closedness	CLOSED	CLOSED/THM	operator specification (15.1)
T2-PO-147	weak Hodge decomposition	CLOSED/CL	CLOSED/THM	theorem Hilbert-complex
T2-PO-148	strong Hodge decomposition	CLOSED/COND	COND	closed-range hypothesis
T2-PO-149	harmonic = reduced cohomology	CLOSED/CL	CLOSED/THM	orthogonal decomposition
T2-PO-150	ordinary cohomology = harmonic	CLOSED/COND	COND	ran d closed
T2-PO-151	Poincare estimate and spectral gap	CLOSED/COND	COND	self-adjoint closed-range sector

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-152	Green operator and lift estimate	CLOSED/COND	COND	uniform gap
T2-PO-153	elliptic symbol theorem	CLOSED/CL	CLOSED/THM	exact symbol sequence
T2-PO-154	Laplace-type identification	OPEN/COND	OPEN	model-specific principal symbol
T2-PO-155	absolute/relative boundary realization	CLOSED/CL	CLOSED/THM	smooth compact boundary
T2-PO-156	general NAPG boundary Fredholmness	OPEN	OPEN	Lopatinski-Shapiro / APS data
T2-PO-157	stratified interface domain	OPEN/COND	OPEN	transmission maps required
T2-PO-158	Fredholm index constancy	CLOSED/CL	CLOSED/THM	continuous Fredholm family
T2-PO-159	compact resolvent on NAPG strata	OPEN/COND	OPEN	compactness and ideal BC
T2-PO-160	harmonic residual formula	CLOSED/COND	COND	closed range
T2-PO-161	spectral projector stability	CLOSED/COND	COND	norm-resolvent continuity and gap
T2-PO-162	analytic obstruction bundle	COND	COND	constant harmonic rank
T2-PO-163	Hodge-Reper bridge chi_H	OPEN	OPEN	homogeneous functionals and pole audit
T2-PO-164	Cheeger-type singular Hodge sector	OPEN	OPEN	stratified pseudomanifold hypotheses
T2-PO-165	mezzoperversity / ideal BC choice	OPEN	OPEN	domain classification
T2-PO-166	uniform interval spectral certification	OPEN/COMP	OPEN	validated eigensolver
T2-PO-167	compatibility with Pi_E and Blind_E	COND	COND	B1-B6
T2-PO-168	compatibility with beta_Ass	OPEN	OPEN	separate chain bridge
T2-PO-169	independent domain run	OPEN	OPEN	no EXT-RUN supplied
T2-PO-170	Hodge-Fredholm predictive theorem	COND	COND	H1-H12 and certificate HOD-AN
T2-PO-171	Define Art_K and base-change for partial NAPG-operations.	CLOSED-FD	CLOSED/THM	Finite-dimensional typed sector.
T2-PO-172	Construct groupoid-valued Def_N, preserves D/Dom.	COND	COND	Is required complete morphism specification.
T2-PO-173	Prove small-extension obstruction class.	COND	COND	Follows from CTRL-16.1.
T2-PO-174	Prove lift torsor H_N^2⊗I.	COND	COND	Complete obstruction theory.
T2-PO-175	Identifi infinitesimal automorphisms with H_N^1.	COND	COND	Gauge completeness.
T2-PO-176	Construct controlling filtered L_infinity	OPEN	OPEN	Main algebraic blocker.

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PO	Description	Source status	Normalized class	Evidence / next step
	algebra NAPG.			
T2-PO-177	Verify Schlessinger H1.	OPEN	OPEN	Fiber-product lifting.
T2-PO-178	Verify Schlessinger H2.	OPEN	OPEN	Dual-number compatibility.
T2-PO-179	Prove H3 finite tangent.	COND-FD	COND	Fredholm/finite sector.
T2-PO-180	Verify H4 or explicitly ABSTAIN from universality.	OPEN	OPEN	Automorphism-sensitive.
T2-PO-181	Align shift g=C[1] and derived tangent degrees.	CLOSED	CLOSED/THM	Fixed convention.
T2-PO-182	Prove compatibility bracket maps with domains.	OPEN	OPEN	Unbounded/partial maps.
T2-PO-183	Construct Hodge contraction p,i,h.	COND-HF	COND	Relies on v0.12.
T2-PO-184	Prove homotopy-transfer convergence.	OPEN	OPEN	Uniform multilinear estimates.
T2-PO-185	Construct Kuranishi recursion.	COND	COND	Contraction margin m_K>0.
T2-PO-186	Prove MC iff K=0 in selected neighborhood.	COND	COND	Gauge and convergence.
T2-PO-187	Compute κ_2,κ_3 on models A_2.	OPEN-COMP	OPEN	Are required structural constants.
T2-PO-188	Construct miniversal local algebra.	COND	COND	After T2-PO-176/185.
T2-PO-189	Prove independence to right-equivalence.	OPEN	OPEN	Change metric/splitting.
T2-PO-190	Classify stabilizer strata.	OPEN	OPEN	Stack-level data.
T2-PO-191	Define derived formal NAPG problem.	OPEN	OPEN	Nilcomplete/infinitesimal cohesive.
T2-PO-192	Construct ModTriv(I) certificate.	OPEN-COMP	OPEN	Parameter family data.
T2-PO-193	Certify interval bound for ||K(x)||.	OPEN-COMP	OPEN	Validated numerics.
T2-PO-194	Align Kuranishi carrier with Π_E and β_Ass.	OPEN	OPEN	Bridge theorem.
T2-PO-195	Perform independent moduli run.	OPEN-IND	OPEN	External code and data.
T2-PO-196	Preserve physical status lock.	CLOSED	CLOSED/THM	truth_layer_promotion=0.
T2-PO-197	Construct finite admissible stratification moduli carrier	OPEN	OPEN	Close in v0.15 or specialized certificate
T2-PO-198	Verify frontier condition	OPEN	OPEN	Close in v0.15 or specialized certificate
T2-PO-199	Prove Whitney (a)	OPEN	OPEN	Close in v0.15 or specialized certificate

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-200	Prove Whitney (b) or substituting control package	OPEN	OPEN	Close in v0.15 or specialized certificate
T2-PO-201	Construct StratTriv outside discriminant	COND	COND	Close in v0.15 or specialized certificate
T2-PO-202	Define wall equations and coorientation	MODEL	CLOSED/THM	Close in v0.15 or specialized certificate
T2-PO-203	Prove chamber constancy	THM under ModTriv	CLOSED/THM	Close in v0.15 or specialized certificate
T2-PO-204	Typed wall operator	OPEN	OPEN	Close in v0.15 or specialized certificate
T2-PO-205	Prove branch normalization	OPEN	OPEN	Close in v0.15 or specialized certificate
T2-PO-206	Certify multiplicities	OPEN	OPEN	Close in v0.15 or specialized certificate
T2-PO-207	Construct ramification locus	OPEN	OPEN	Close in v0.15 or specialized certificate
T2-PO-208	Compute branch monodromy	COMP	CLOSED/THM	Close in v0.15 or specialized certificate
T2-PO-209	Prove homotopy invariance continuation	THM under a cover	CLOSED/THM	Close in v0.15 or specialized certificate
T2-PO-210	Verify no-global-label criterion	THM	CLOSED/THM	Close in v0.15 or specialized certificate
T2-PO-211	Distinguish wall and bifurcation loci	THM/EX	CLOSED/THM	Close in v0.15 or specialized certificate
T2-PO-212	Prove reduced bifurcation normal form	MODEL	CLOSED/THM	Close in v0.15 or specialized certificate
T2-PO-213	Verify path-independence or braid relations	OPEN	OPEN	Close in v0.15 or specialized certificate
T2-PO-214	Construct transport for transition invariant	OPEN	OPEN	Close in v0.15 or specialized certificate
T2-PO-215	Certify level stable S0-S3	OPEN	OPEN	Close in v0.15 or specialized certificate
T2-PO-216	Align λ with branch transport	OPEN	OPEN	Close in v0.15 or specialized certificate
T2-PO-217	Align Δ_WB with Δ_mod	COND	COND	Close in v0.15 or specialized certificate
T2-PO-218	Interval certify distance to wall	OPEN	OPEN	Close in v0.15 or specialized certificate
T2-PO-219	Align wall layer with Π_E and β_Ass	OPEN	OPEN	Close in v0.15 or specialized certificate
T2-PO-220	Construct independent domain wall-run	OPEN	OPEN	Close in v0.15 or specialized certificate
T2-PO-221	Verify physical reduction separately	PHY-HYP	PHY-HYP	Close in v0.15 or specialized certificate
T2-PO-222	Freez WC-MON certificate and hashes	COMP	CLOSED/THM	Close in v0.15 or specialized certificate
T2-PO-223	Define 2-category local NAPG-Kuranishi charts.	COND	COND	Complete specification objects, 1- and 2-morphism.
T2-PO-224	Prove coverage footprints.	MODEL-CLOSED	CLOSED/THM	Finite atlas certificate.

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-225	Typed coordinate changes.	MODEL-CLOSED	CLOSED/THM	Check (18.4) on each models.
T2-PO-226	Construct triple 2-cocycle.	OPEN	OPEN	Explicit α_{ijk}.
T2-PO-227	Verify quadruple coherence.	OPEN	OPEN	Pentagon/higher homotopy certificate.
T2-PO-228	Classify stabilizers.	COND	COND	Stacky local models.
T2-PO-229	Prove Morita/presentation invariance.	COND	COND	Equivalence of atlases.
T2-PO-230	Construct global derived enhancement.	OPEN	OPEN	Controlling ∞/L∞-model.
T2-PO-231	Construct virtual tangent complex.	MODEL-CLOSED	CLOSED/THM	Local three-term sector.
T2-PO-232	Prove existence perfect obstruction theory.	OPEN	OPEN	BF-type morphism E•→L_𝔐.
T2-PO-233	Record Tor-amplitude.	COND	COND	Check perfectness.
T2-PO-234	Construct obstruction sheaf and cone.	COND	COND	Global POT/derived enhancement.
T2-PO-235	Glue local obstruction theories.	OPEN	OPEN	Homotopy-coherent quasi-isomorphisms.
T2-PO-236	Compute descent obstruction.	COND	COND	Central band or full totalization.
T2-PO-237	Prove preserves perfectness under descent.	COND	COND	Derived descent theorem in selected category.
T2-PO-238	Construct determinant/orientation data.	OPEN	OPEN	Orientation line certificate.
T2-PO-239	Construct branch stack.	COND	COND	Normalization/étale sector.
T2-PO-240	Compute monodromy.	MODEL-CLOSED	CLOSED/THM	Finite branch cover.
T2-PO-241	Prove Reper descent.	OPEN	OPEN	Compatibility four points.
T2-PO-242	Prove Evidence-D descent.	OPEN	OPEN	Provenance functor and cocycle.
T2-PO-243	Prove Dom descent.	OPEN	OPEN	Compatibility admissible domains.
T2-PO-244	Prove global λ.	COND	COND	Projective transitions and pole exclusion.
T2-PO-245	Align global carrier with Π_E.	OPEN	OPEN	Natural transformation on stack.
T2-PO-246	Prove existence PredCar_N.	OPEN	OPEN	Close PO-223-245.
T2-PO-247	Prove invariant profile theorem.	COND	COND	Local triviality + transport.
T2-PO-248	Record local-to-global no-go.	CLOSED	CLOSED/THM	Theorem 18.5.
T2-PO-249	Prove global horizon theorem.	COND	COND	Uniform family hypotheses.
T2-PO-250	Construct interval/numerical descent	OPEN	OPEN	Validated numerics.

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PO	Description	Source status	Normalized class	Evidence / next step
	certificate.			
T2-PO-251	Perform independent STACK-RUN.	OPEN	OPEN	Independent code, data and hashes.
T2-PO-252	Block automatic physical export.	CLOSED	CLOSED/THM	truth_layer_promotion=0; B8.
T2-PO-253	Record cycle/homology carrier for virtual class.	CLOSED/CL	CLOSED/THM	Chow/homology specification.
T2-PO-254	Construct global virtual fundamental class NAPG.	COND	COND	Global POT + intrinsic cone.
T2-PO-255	Define virtual dimension and grading.	CLOSED/CL	CLOSED/THM	Rank/Euler characteristic.
T2-PO-256	Prove properness or compact-support substitute.	OPEN	OPEN	Domain-specific compactness theorem.
T2-PO-257	Typed insertions and degree matching.	CLOSED/CL	CLOSED/THM	Formulas (19.5)-(19.6).
T2-PO-258	Prove base-change compatibility.	COND	COND	Relative POT and refined Gysin.
T2-PO-259	Prove deformation invariance.	COND	COND	Theorem 19.3 hypotheses.
T2-PO-260	Construct equivariant virtual localization.	COND	COND	T-action + equivariant POT.
T2-PO-261	Certify virtual normal Euler classes.	OPEN	OPEN	No zero denominators in localization.
T2-PO-262	Record orientation/determinant data.	OPEN	OPEN	Global compatible orientation.
T2-PO-263	Account for stabilizer weights.	COND	COND	Stack integration convention.
T2-PO-264	Align VFC with PredCar v0.15.	COND	COND	Compatibility diagram.
T2-PO-265	Define VirtCert and Reper_vir.	MODEL-CLOSED	CLOSED/THM	Formulas (19.16)-(19.17).
T2-PO-266	Construct canonical λ-bridge to virtual data.	OPEN	OPEN	Is required χ_vir; automatic inference no.
T2-PO-267	Prove additivity-probability no-go.	CLOSED	CLOSED/THM	Theorem 19.4.
T2-PO-268	Specify space outcomes Ω and σ-algebra.	OPEN/EMP	OPEN	Domain-specific event protocol.
T2-PO-269	Specify/estimate probability measure P.	OPEN/EMP	OPEN	Sampling/model assumptions.
T2-PO-270	Record link model g_θ.	OPEN/EMP	OPEN	Pre-registered functional form.
T2-PO-271	Prove or verify calibration.	OPEN/EMP	OPEN	Frozen calibration protocol.
T2-PO-272	Verify discrimination separately.	OPEN/EMP	OPEN	Pre-specified metric.
T2-PO-273	Verify transportability/domain shift.	OPEN/EMP	OPEN	External target domain.

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-274	Execute independent external run.	OPEN/EMP	OPEN	EXT-RUN with frozen code/data.
T2-PO-275	Construct Δ_VFC.	MODEL-CLOSED	CLOSED/THM	Horizon ledger (19.20).
T2-PO-276	Construct Δ_prob.	MODEL-CLOSED	CLOSED/THM	Horizon ledger (19.21).
T2-PO-277	Prove virtual-profile constancy.	COND	COND	Theorem 19.6 H1-H8.
T2-PO-278	Verify wall-crossing jump formula.	OPEN	OPEN	Domain-specific comparison.
T2-PO-279	Construct interval VFC computation.	COMP/OPEN	OPEN	Exact arithmetic or certified bounds.
T2-PO-280	Freez VFC-ENUM-PROB certificate.	COMP	COMP	VFC-01-VFC-30 and hashes.
T2-PO-281	Block automatic physical/probability export.	CLOSED	CLOSED/THM	Probability firewall; B8.
T2-PO-282	Close main theorem v0.16.	COND	COND	All mathematical and empirical bridges.
T2-PO-283	Define category carrier general NAPG.	OPEN	OPEN	Concrete stable/dg/∞ category.
T2-PO-284	Construct functorial K_0.	COND	COND	Exact/triangulated structure and naturality.
T2-PO-285	Prove tensor compatibility decategorification.	OPEN	OPEN	Monoidal enhancement.
T2-PO-286	Record motivic coefficient ring.	MODEL-CLOSED	CLOSED/THM	Ring/localization/completion passport.
T2-PO-287	Construct motivic measure NAPG.	OPEN	OPEN	Scissors/product theorem.
T2-PO-288	Verify 𝕃^{1/2} convention.	COND	COND	Orientation and coefficient extension.
T2-PO-289	Construct motivic vanishing cycles.	OPEN	OPEN	Critical charts + orientation data.
T2-PO-290	Prove chart independence.	OPEN	OPEN	d-critical/derived comparison theorem.
T2-PO-291	Construct realization functors.	COND	COND	Hodge/weight/ℓ-adic realization.
T2-PO-292	Maintain information-loss ledger.	CLOSED/PROTO	CLOSED/THM	MOT-15 tests.
T2-PO-293	Define refined invariant.	MODEL-CLOSED	CLOSED/THM	Grading, sign, shift, duality.
T2-PO-294	Construct CoHA_NAPG.	OPEN	OPEN	Extension stacks and pull-push.
T2-PO-295	Prove associativity CoHA.	OPEN	OPEN	Correspondence composition.
T2-PO-296	Construct BPS-cohomology carrier.	OPEN	OPEN	PBW/integrality package.
T2-PO-297	Record grading monoid Γ.	CLOSED/TYPE	CLOSED/THM	Positive cone and support.
T2-PO-298	Define completed series ring.	CLOSED/TYPE	CLOSED/THM	Filtration and completeness.

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-299	Verify PExp/PLog.	COND	COND	λ-ring/Adams hypotheses.
T2-PO-300	Construct quantum-torus pairing.	OPEN	OPEN	Skew form and ordering.
T2-PO-301	Prove wall-crossing factorization.	OPEN	OPEN	Stability structure and transport.
T2-PO-302	Classify formal/analytic status series.	MODEL-CLOSED	CLOSED/THM	Convergence ledger.
T2-PO-303	Prove no-time theorem.	CLOSED	CLOSED/THM	Theorem 20.4.
T2-PO-304	Specify time map τ.	OPEN-DOMAIN	OPEN	External temporal semantics.
T2-PO-305	Specify state space S.	OPEN-DOMAIN	OPEN	Domain-specific states.
T2-PO-306	Construct evolution family U(t,s).	OPEN	OPEN	Cocycle and regularity.
T2-PO-307	Construct generator/path kernel.	OPEN	OPEN	Semigroup or nonautonomous theorem.
T2-PO-308	Prove NAPG-compatibility evolution.	OPEN	OPEN	Preservation of D/Dom/⊙.
T2-PO-309	Specify observation map.	OPEN-DOMAIN	OPEN	Operational measurement model.
T2-PO-310	Perform calibration/validation.	OPEN-EMP	OPEN	Frozen protocol and data.
T2-PO-311	Perform independent EXT-RUN.	OPEN-EMP	OPEN	External preregistered run.
T2-PO-312	Align λ and CGI_ref.	COND	COND	Weight/source sensitivity certificate.
T2-PO-313	Implement MOT-REF-SER-DYN code.	OPEN-COMP	OPEN	Exact/interval executable package.
T2-PO-314	Close main theorem v0.17.	COND	COND	All categorified, series, dynamic and empirical bridges.
T2-PO-315	Typed temporal carrier and order	CLOSED	CLOSED/THM	Definition 21.1
T2-PO-316	Typed state bundle and evolution domains	CLOSED	CLOSED/THM	(21.2)
T2-PO-317	Nonlinear semigroup axioms	CLOSED	CLOSED/THM	(21.3)
T2-PO-318	m-accretivity specific NAPG-generator	OPEN	OPEN	Is required model
T2-PO-319	Crandall-Liggett generation for selected A	COND	COND	After PO-318
T2-PO-320	Invariance admissible sector under resolvent	OPEN	OPEN	NAPG-specific
T2-PO-321	Non-autonomous Kato stability	OPEN	OPEN	Family A(t)
T2-PO-322	Transport-domain compatibility	OPEN	OPEN	Check composition
T2-PO-323	Koopman functoriality	CLOSED	CLOSED/THM	(21.6)

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-324	Perron-Frobenius pushforward and duality	CLOSED	CLOSED/THM	(21.7)-(21.8)
T2-PO-325	Positivity and preserves mass	COND	COND	Depends from regime
T2-PO-326	Lasota-Yorke-type estimate for RBD/NAPG	OPEN	OPEN	New estimate
T2-PO-327	Markov-kernel measurability	OPEN	OPEN	Domain model
T2-PO-328	Chapman-Kolmogorov consistency	COND	COND	(21.9)
T2-PO-329	Kolmogorov path-space extension	COND	COND	Standard Borel sector
T2-PO-330	Tightness/regularity path law	OPEN	OPEN	Moment estimates
T2-PO-331	Deterministic orbit carrier	CLOSED	CLOSED/THM	(21.11)
T2-PO-332	Volterra-kernel existence/uniqueness	OPEN	OPEN	Kernel-specific
T2-PO-333	Resolvent memory kernel	OPEN	OPEN	Analytic package
T2-PO-334	Non-anticipation theorem	CLOSED	CLOSED/THM	Theorem 21.4
T2-PO-335	Filtration and adaptedness	COND	COND	Probability bridge
T2-PO-336	Observability of Reper state	OPEN	OPEN	Obs-specific
T2-PO-337	Parameter identifiability	OPEN	OPEN	Data-specific
T2-PO-338	Reper trajectory transport	OPEN	OPEN	NAPG-specific
T2-PO-339	Global definition of λ_t	COND	COND	Projective atlas
T2-PO-340	Hitting-time well-posedness	OPEN	OPEN	Path law required
T2-PO-341	RBD transfer operator	OPEN	OPEN	Software/data model
T2-PO-342	Generator inference error bound	OPEN	OPEN	Independent data
T2-PO-343	Perturbation/resolvent convergence	OPEN	OPEN	Model-specific
T2-PO-344	Dynamic residual weights W_time	OPEN	OPEN	Sensitivity analysis
T2-PO-345	Temporal-profile stability theorem	COND	COND	H1-H9
T2-PO-346	Snapshot no-go	CLOSED	CLOSED/THM	Theorem 21.6
T2-PO-347	Empirical calibration and EXT-RUN	OPEN	OPEN	Independent run
T2-PO-348	Physical/causal interpretation	OPEN	OPEN	Separate bridge
T2-PO-349	Stochastic basis and usual conditions	CLOSED	CLOSED/THM	Definition 22.1

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-350	Markov kernel measurability	COND	COND	State/domain specific
T2-PO-351	Semigroup and conservativity tests	COND	COND	STOCH-05-08
T2-PO-352	Feller strong continuity	OPEN	OPEN	Concrete model
T2-PO-353	Generator domain and core	OPEN	OPEN	Model-specific
T2-PO-354	Positive maximum principle	OPEN	OPEN	Model-specific
T2-PO-355	Resolvent identities	COND	COND	After PO-353
T2-PO-356	Martingale problem formulation	CLOSED	CLOSED/THM	(22.5)
T2-PO-357	Existence martingale problem	OPEN	OPEN	Concrete generator
T2-PO-358	Uniqueness/well-posedness	OPEN	OPEN	Concrete generator
T2-PO-359	Strong Markov consequence	COND	COND	After PO-357-358
T2-PO-360	SDE-to-generator identification	COND	COND	Regular diffusion sector
T2-PO-361	Weak/strong solution hierarchy	CLOSED	CLOSED/THM	Type specification
T2-PO-362	Girsanov integrability	OPEN	OPEN	Model-specific
T2-PO-363	Measure-change no-intervention theorem	CLOSED	CLOSED/THM	Theorem 22.2
T2-PO-364	Stopping-time measurability	COND	COND	Target/path regularity
T2-PO-365	Optional sampling assumptions	OPEN	OPEN	Stopping rule specific
T2-PO-366	Naive optional-stopping counterexample	CLOSED	CLOSED/THM	Section 303
T2-PO-367	Hitting probability well-posedness	OPEN	OPEN	Boundary problem
T2-PO-368	Barrier theorem	CLOSED	CLOSED/THM	Theorem 22.3
T2-PO-369	Computable barrier construction	OPEN	OPEN	SOS/PDE/interval method
T2-PO-370	Robust controlled barrier	COND	COND	(22.13)
T2-PO-371	Controlled Markov family	OPEN	OPEN	Control model
T2-PO-372	Dynamic programming principle	OPEN	OPEN	Policy/compactness package
T2-PO-373	HJB solution and verification	OPEN	OPEN	Model-specific
T2-PO-374	Forecast/control/intervention typing	CLOSED	CLOSED/THM	Section 310
T2-PO-375	Observational-interventional no-go	CLOSED	CLOSED/THM	Theorem 22.4

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-376	Structural intervention kernel	OPEN	OPEN	SCM/domain specific
T2-PO-377	Sequential exchangeability	OPEN	OPEN	Evidence-D required
T2-PO-378	Positivity and consistency	OPEN	OPEN	Evidence-D required
T2-PO-379	g-formula identification	COND	COND	After PO-377-378
T2-PO-380	Counterfactual carrier	OPEN	OPEN	Structural model
T2-PO-381	Stochastic Reper adaptedness	OPEN	OPEN	NAPG-specific
T2-PO-382	λ Itô formula and pole control	COND	COND	Smooth chart sector
T2-PO-383	Harmonic-locus stochastic invariance	COND	COND	(22.21)
T2-PO-384	Martingale residual external test	OPEN	OPEN	Independent data
T2-PO-385	Main safe theorem v0.19	COND	COND	All H1-H12
T2-PO-386	Physical/causal export and EXT-RUN	OPEN	OPEN	Independent bridge
T2-PO-387	State/path carrier and topology	COND	COND	Domain-specific
T2-PO-388	Speed a_n and law family	COND	COND	Model-specific
T2-PO-389	LDP lower bound	OPEN	OPEN	Concrete family
T2-PO-390	LDP upper bound	OPEN	OPEN	Concrete family
T2-PO-391	Exponential tightness	OPEN	OPEN	Path-space compactness
T2-PO-392	Good rate function	OPEN	OPEN	Level-set compactness
T2-PO-393	Contraction map continuity	COND	COND	Away from poles
T2-PO-394	λ pole-set repair	OPEN	OPEN	Projective graph/exponential negligibility
T2-PO-395	Laplace principle equivalence	COND	COND	Polish-space package
T2-PO-396	Gärtner-Ellis differentiability/steepness	OPEN	OPEN	SCGF-specific
T2-PO-397	Sanov empirical-measure layer	COND	COND	IID sector
T2-PO-398	Freidlin-Wentzell action	OPEN	OPEN	Concrete diffusion
T2-PO-399	Degenerate action/control representation	OPEN	OPEN	Controllability
T2-PO-400	Quasipotential existence	OPEN	OPEN	Compactness/minimizer
T2-PO-401	Instanton uniqueness or multiplicity ledger	OPEN	OPEN	Numerical/analytic

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-402	Donsker-Varadhan functional	OPEN	OPEN	Ergodic Markov model
T2-PO-403	Feynman-Kac semigroup realization	OPEN	OPEN	Exponential integrability
T2-PO-404	Risk-sensitive nonlinear generator	COND	COND	Domain of exponential transform
T2-PO-405	Principal eigenvalue limit	OPEN	OPEN	Spectral/ergodic package
T2-PO-406	Risk-sensitive HJB verification	OPEN	OPEN	Controlled model
T2-PO-407	Asymptotic-probability firewall	CLOSED	CLOSED/THM	Theorem 23.2
T2-PO-408	Importance-sampling unbiasedness	OPEN	OPEN	Proposal and likelihood ratio
T2-PO-409	Importance-sampling efficiency	OPEN	OPEN	Second-moment bound
T2-PO-410	Splitting estimator validity	OPEN	OPEN	Level/adaptation model
T2-PO-411	KL ambiguity duality	COND	COND	Orientation/support assumptions
T2-PO-412	Wasserstein ambiguity duality	COND	COND	Growth/duality assumptions
T2-PO-413	Finite-sample ambiguity coverage	OPEN	OPEN	Concentration theorem
T2-PO-414	Coverage-to-risk theorem	CLOSED	CLOSED/THM	Theorem 23.3
T2-PO-415	Exact zero-count binomial bound	CLOSED	CLOSED/THM	Formula (23.32)
T2-PO-416	Dependence correction	OPEN	OPEN	Cluster/mixing/effective sample size
T2-PO-417	Sequential rare-event validity	OPEN	OPEN	E-process/confidence sequence
T2-PO-418	Finite-n LDP remainder	OPEN	OPEN	Model-specific sharp asymptotics
T2-PO-419	Tail non-identifiability theorem	CLOSED	CLOSED/THM	Theorem 23.4
T2-PO-420	Rate-function numerical certificate	OPEN	OPEN	Interval/optimization solver
T2-PO-421	Robust rare-event Reper certificate	COND	COND	Cert_LD schema
T2-PO-422	Large-deviation horizons	CLOSED	CLOSED/THM	Definitions (23.37)-(23.40)
T2-PO-423	Main safety theorem v0.20	COND	COND	H1-H14
T2-PO-424	Physical interpretation bridge	OPEN	OPEN	Separate reduction
T2-PO-425	Independent rare-event EXT-RUN	OPEN	OPEN	Preregistered external data
T2-PO-426	Cross-domain transportability	OPEN	OPEN	Domain adapters and evidence
T2-PO-427	Category CertKLT formaliz in selected foundational system	COND	COND	provide machine-verif definition

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-428	Result semantics align with partial charts	THM-text	CLOSED/THM	formalize cases
T2-PO-429	Budget transformers form associative system	COND	COND	verify each type budget
T2-PO-430	Homogeneous Λ compatib with all Reper-morphism	COND	COND	naturality proof
T2-PO-431	Harmonic locus N+Q=0 invariant	THM-local	CLOSED/THM	global carrier proof
T2-PO-432	Degenerate locus [0:0] correct is blocked	COMP	COMP	property-based tests
T2-PO-433	Unit/type adapters certified	OPEN	OPEN	adapter library
T2-PO-434	Affine deterministic bound implement interval arithmetic	COMP	COMP	exact test suite
T2-PO-435	Condition numbers comput/are bounded	OPEN	OPEN	domain-specific bounds
T2-PO-436	α-ledger protected from post-selection	COND	COND	pre-registration mechanism
T2-PO-437	e-process merge uses common zero model	COND	COND	filtration audit
T2-PO-438	Robust set pushforward correct	COND	COND	metric-specific proof
T2-PO-439	Shift radius has coverage status	OPEN	OPEN	external calibration
T2-PO-440	Status lattice and meet machine-readable	COMP	COMP	schema + tests
T2-PO-441	PHY-HYP separated from mathematical status	COMP	COMP	release policy tests
T2-PO-442	Ingest distinguishes copies and version	COMP	COMP	hash/content tests
T2-PO-443	D/Dom blockers not are scalarized	COMP	COMP	negative tests
T2-PO-444	NAPG module exports complete invariants	OPEN	OPEN	canonical invariant set
T2-PO-445	Geometry module handles higher coherence	OPEN	OPEN	2-categorical implementation
T2-PO-446	Obstruction quotient independent of representative	COND	COND	general proof/finite tests
T2-PO-447	Π_E ledger enforces B1-B8	COMP	COMP	gate tests
T2-PO-448	Global descent certificate compositional	COND	COND	Čech/stack proof
T2-PO-449	Kuranishi charts version-compatible	OPEN	OPEN	coordinate-change validator
T2-PO-450	Virtual orientation data audited	OPEN	OPEN	orientation package

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-451	Refined invariant never auto-cast to probability	COMP	COMP	type firewall
T2-PO-452	Evolution module proves existence domain	COND	COND	generator-specific proof
T2-PO-453	Path laws preserve nonanticipation	COND	COND	filtration tests
T2-PO-454	Martingale core/uniqueness status exported	OPEN	OPEN	solver/theorem integration
T2-PO-455	Optional stopping assumptions explicit	COMP	COMP	ledger tests
T2-PO-456	Causal module stores SCM equivalence class	OPEN	OPEN	schema + identification engine
T2-PO-457	Observational and interventional laws separated	COMP	COMP	type tests
T2-PO-458	LDP result stores topology/speed/rate	COMP	COMP	certificate schema
T2-PO-459	Finite-n remainder required for finite-n claim	COMP	COMP	release tests
T2-PO-460	Ambiguity coverage externally validated	OPEN	OPEN	calibration run
T2-PO-461	Importance weights audited	COND	COND	absolute-continuity tests
T2-PO-462	Tail assumptions machine-readable	OPEN	OPEN	domain ontology
T2-PO-463	External split immutable before tuning	OPEN	OPEN	sealed split protocol
T2-PO-464	Leakage detector has known sensitivity	OPEN	OPEN	benchmark
T2-PO-465	Release policy matches requested Mode	COMP	COMP	cross-mode tests
T2-PO-466	Verdict vector schema stable	COMP	COMP	serialization tests
T2-PO-467	Set-valued forecast supports Pareto output	COMP	COMP	algorithm + tests
T2-PO-468	No canonical scalarization enforced	COMP	COMP	forbidden-field audit
T2-PO-469	ABSTAIN monotonicity implementation verified	COMP	COMP	metamorphic tests
T2-PO-470	FAIL witness preserved to final report	COMP	COMP	trace tests
T2-PO-471	Proof chain links stable IDs	COMP	COMP	reference integrity
T2-PO-472	Hash chain canonical serialization fixed	OPEN	OPEN	canonical encoding
T2-PO-473	Nondeterministic parallel runs	OPEN	OPEN	deterministic reduction or interval

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PO	Description	Source status	Normalized class	Evidence / next step
	reproducible			
T2-PO-474	Environment capture sufficient	OPEN	OPEN	container lockfile
T2-PO-475	Independent verifier implemented	OPEN	OPEN	separate codebase
T2-PO-476	Adversarial integrated test suite complete	OPEN	OPEN	red-team corpus
T2-PO-477	Theorem 24.4 formally proved	COND	COND	Lean/Coq/Isabelle target
T2-PO-478	Completeness limits documented per domain	OPEN	OPEN	domain dossiers
T2-PO-479	Falsifiability matrix linked to all theorem IDs	COMP	COMP	cross-reference audit
T2-PO-480	EXT-RUN for F-1-F-14 executed	OPEN/PHY-HYP	OPEN	independent preregistered run
T2-PO-481	Completeness register formal statements	CLOSED	CLOSED/THM	339 numbered statements extracted; typed IDs assigned.
T2-PO-482	Elimination ambiguity bare numbers statements	CLOSED	CLOSED/THM	44 cross-type collisions neutralized ID form T2-THM/DEF/LEM-...
T2-PO-483	Uniqueness formula ID	CLOSED	CLOSED/THM	404 formula labels unique within Volume II.
T2-PO-484	Continuity register T2-PO	CLOSED	CLOSED/THM	T2-PO-001-T2-PO-500 form continuous range.
T2-PO-485	Internal links theorem/formula/PO registers	CLOSED	CLOSED/THM	In DOCX established bookmark/anchor links; PDF-check holds under conversion.
T2-PO-486	Complete bibliographic verification all external URI/DOI	COND	COND	Is required separate network link-check before public derivation.
T2-PO-487	Alt text for all figures	CLOSED	CLOSED/THM	Alt text is formed from nearest captions; portrait author described separately.
T2-PO-488	Header rows tables	CLOSED	CLOSED/THM	First rows tables marked as repeating header rows.
T2-PO-489	Logical hierarchy headings	CLOSED/LOCAL	CLOSED/THM	Heading 1/2 audit performed; historical direct markup title preserved as design.
T2-PO-490	Searchable text layer PDF	COND	COND	Clos after final conversion and pdftotext-verif.
T2-PO-491	PDF outline and internal navigation	COND	COND	Clos after final conversion and verif outline/annotations.

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PO	Description	Source status	Normalized class	Evidence / next step
T2-PO-492	Absence broken external links	OPEN	OPEN	Is required separate online-audit on date publication.
T2-PO-493	Metadata author, title and version	CLOSED	CLOSED/THM	Core properties and headers and footers synchron with v0.22.
T2-PO-494	Legal status lock register documents	CLOSED	CLOSED/THM	Register not is interpreted as confirmation theorems or physical hypotheses.
T2-PO-495	Mathematical/physical truth-layer firewall	CLOSED	CLOSED/THM	truth_layer_promotion=0; F-1-F-14 and EXT-RUN not promoted.
T2-PO-496	Register freeze-blockers	CLOSED	OPEN	Open and conditional obligations preserves in publication gate.
T2-PO-497	Release manifest and rollback lineage	CLOSED	COND	source=T2-RP-v0.21; checkpoint=T2-RP-v0.22; next conditional freeze.
T2-PO-498	Independent external EXT-RUN	OPEN/PHY-HYP	OPEN	Not executed; empirical-physical gate not passed.
T2-PO-499	Preservation point rollback v0.21	CLOSED	CLOSED/THM	v0.21 is preserved as a separate DOCX/PDF pair.
T2-PO-500	Decision about freez Volume II	COND	COND	Editorial freezing is admissible; scientific and empirical completeness is not claimed.

Appendix T2-C. Formula Index

The canonical appendix contains 404 defining formula identifiers. The sequential English ID is a derivative locator; the Russian source ID and the formula/object are preserved. Formula text is not translated by semantic conjecture.

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English ID	RU source ID	Formula / object	Primary section	Link
T2-F001	T2-F-10.1	$\Omega_N^\bullet = \oplus_{p\geq 0} \Omega_N^p$, $\lvert\alpha\rvert=p$ for $\alpha\in\Omega_N^p$.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F002	T2-F-10.2	$d_N^p: \mathrm{Dom}(d_N^p) \subset \Omega_N^p \to \Omega_N^{p+1}$.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F003	T2-F-10.3	$\delta_E: E^q \to E^{q+1}$, $\delta_E^2=0$ only after certificate.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F004	T2-F-10.4	$L_d(\alpha,\beta)=d_N(\alpha\odot\beta)-d_N\alpha\odot\beta-(-1)^{\lvert\alpha\rvert}\alpha\odot d_N\beta$.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator

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English ID	RU source ID	Formula / object	Primary section	Link
T2-F005	T2-F-10.5	$[D,E]=D\circ E-(-1)^{\lvert D\rvert\lvert E\rvert}E\circ D$	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F006	T2-F-10.6	$d_N^2(\alpha\odot\beta)=d_N^2\alpha\odot\beta+\alpha\odot d_N^2\beta$.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F007	T2-F-10.7	$d_N \mathrm{Ass}(\alpha,\beta,\gamma)=\mathrm{Ass}(d_N\alpha,\beta,\gamma)+(-1)^{\lvert\alpha\rvert}\mathrm{Ass}(\alpha,d_N\beta,\gamma)+(-1)^{\lvert\alpha\rvert+\lvert\beta\rvert}\mathrm{Ass}(\alpha,\beta,d_N\gamma)$.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F008	T2-F-10.8	$\Omega_d:= d_N^2: \Omega_N^p \to \Omega_N^{p+2}$.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F009	T2-F-10.9	$[d_N,\Omega_d]=0$.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F010	T2-F-10.10	$d^2(a)=c\neq 0$.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F011	T2-F-10.11	$d_\nabla^2 \alpha = R_\nabla \wedge \alpha$.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F012	T2-F-10.12	$A^2 = d\omega + \omega\wedge\omega$.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F013	T2-F-10.13	$(d_U \alpha)\rvert_V = d_V(\alpha\rvert_V)$.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F014	T2-F-10.14	$g_{ij} \circ d_j = d_i \circ g_{ij}$,	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F015	T2-F-10.15	$K_{ij}:= g_{ij} d_j - d_i g_{ij}$.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F016	T2-F-10.16	$D_{tot} = d_N + (-1)^p \delta_E$.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F017	T2-F-10.17	$D_{tot}^2 = \Omega_{int} + \Omega_E + (-1)^p M_{mix}$,	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F018	T2-F-10.18	$Cert_E=(\delta_E^2=0$, well-defined Π_E, representative independence, naturality, mixed compatibility).	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F019	T2-F-10.19	$\star_{Hdg}: \Omega^p(U) \to \Omega^{n-p}(U)$.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F020	T2-F-10.20	$\delta_{Hdg} = (-1)^{n(p+1)+1} \star_{Hdg} d_N \star_{Hdg}$.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F021	T2-F-10.21	$\Delta_{Hdg} = d_N \delta_{Hdg} + \delta_{Hdg} d_N$.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F022	T2-F-10.22	$H_{ij} = g_{ij} \star_j - \star_i g_{ij}$.	Chapter 10. NAPG Differential Forms and	internal locator

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English ID	RU source ID	Formula / object	Primary section	Link
			Typed Differentials	
T2-F023	T2-F-10.23	A_Hdg = δ_Hdg - d_N^*.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F024	T2-F-10.24	Rep_diff(d_N)=(R_d,I_d,U_d;D_d),	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F025	T2-F-10.25	Def_diff=(‖L_d‖,‖Ω_d‖,‖K_glue‖,‖M_mix‖,‖H‖,pole_λ,Block_Dom).	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F026	T2-F-10.26	C_diff(τ,η)={x: δ_truth(x)≤τ, ‖Def_diff(x)‖≤η, Valid(D)=1, Dom=1}.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F027	T2-F-10.27	Σ_diff(t)=(rank d_t^p, rank(d_t^{p+1}d_t^p), rank L_{d_t}, rank K_t, rank M_t, rank H_t, dim H_t^p when defined).	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F028	T2-F-10.28	Δ_safe^{++} = Δ_safe^+ ∪ Δ_diff.	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F029	T2-F-10.29	dim H_t^p = dim Ω^p - rank d_t^p - rank d_t^{p-1}	Chapter 10. NAPG Differential Forms and Typed Differentials	internal locator
T2-F030	T2-F-12.1	N=(K,A^•,⊙,G,R; F²_N, X²_N, Ψ²_N).	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F031	T2-F-12.2	φ_X ∘ Ψ²_N = Ψ²_N′ ∘ φ_F.	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F032	T2-F-12.3	C_min^n(N)=F²_N for n=2; C_min^n(N)=X²_N for n=3; C_min^n(N)=0 for n≠2,3.	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F033	T2-F-12.4	δ_min²(N)=Ψ²_N; δ_min^n(N)=0 for n≠2.	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F034	T2-F-12.5	Θ_min,N:X²_N→C_min³(N), Θ_min,N=id_{X²_N}.	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F035	T2-F-12.6	o_min,N(q)=π_N(Θ_min,N(q))=[q] ∈ H³(C_min^•(N)).	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F036	T2-F-12.7	H²(C_min(N))=Ker Ψ²_N, H³(C_min(N))=Coker Ψ²_N=O_B(N).	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F037	T2-F-12.8	0→H²(C_min)→F²_N —Ψ²_N→ X²_N —π_N→ H³(C_min)→0.	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F038	T2-F-12.9	dim H²=f-r, dim H³=x-r, dim H²-dim H³=f-x.	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F039	T2-F-12.10	C_min^•:NAPG_q→CoCh_K.	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator

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English ID	RU source ID	Formula / object	Primary section	Link
T2-F040	T2-F-12.11	$\kappa_N:O_B(N)\to H^3(C_{min}(N)), \kappa_N([x])=[x],$	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F041	T2-F-12.12	$Lift_N(q)=f_0+\mathrm{Ker}\,\Psi^2_N=f_0+H^2(C_{min}(N)).$	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F042	T2-F-12.13	$\delta_E^2\circ J^2 = J^3\circ\Psi^2_N.$	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F043	T2-F-12.14	$H^i(C_{min}(N)\otimes_K L) \cong H^i(C_{min}(N))\otimes_K L, i=2,3.$	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F044	T2-F-12.15	$H^i(C_{min}(N\oplus M)) \cong H^i(C_{min}(N))\oplus H^i(C_{min}(M)), i=2,3.$	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F045	T2-F-12.16	$r_{min}(q)=(I-\Psi^2_N(\Psi^2_N)^\dagger)q.$	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F046	T2-F-12.17	$\lVert f^*\rVert \le \lVert q\rVert/\sigma^+(\Psi^2_N),$	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F047	T2-F-12.18	$OCI_{min}(q)=\lVert r_{min}(q)\rVert/(\lVert q\rVert+\varepsilon), \varepsilon>0.$	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F048	T2-F-12.19	$H^2_t=\mathrm{Ker}\,\Psi_t, H^3_t=X_t/\mathrm{Im}\,\Psi_t$	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F049	T2-F-12.20	$\Delta_{min} = \Delta_{rank} \cup \Delta_{cond} \cup \Delta_{Dom} \cup \Delta_D \cup \mathrm{Pole}(\lambda),$	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F050	T2-F-12.21	$\lVert r_t-r_s\rVert \le \lVert q_t-q_s\rVert + \lVert P_t-P_s\rVert\cdot\lVert q_s\rVert.$	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F051	T2-F-12.22	$\lVert q_t-q_{t_0}\rVert + \lVert P_t-P_{t_0}\rVert\cdot\lVert q_{t_0}\rVert < \rho,$	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F052	T2-F-12.23	$F_t=(N_t,\Psi_t,q_t,\rho_t,D_t,Dom_t), t\in I,$	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F053	T2-F-12.24	$Cert_{min}(t)=(type_{ok}, [q_t], \lVert r_t\rVert, \sigma^+_t, Valid(D_t), Dom_t, \delta_{truth}(t), Block_t).$	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F054	T2-F-12.25	$[q_t]=0, \lVert r_t\rVert\le\varepsilon_{num}, \sigma^+_t\ge s_0, Valid(D_t)=1, Dom_t=1, Block_t=\varnothing.$	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F055	T2-F-12.26	$\lambda=-1 \not\Rightarrow [q]=0, [q]=0 \not\Rightarrow \lambda=-1.$	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F056	T2-F-12.27	truth_layer_promotion=0; checkpoint=T2-RP-v0.9; next=T2-RP-v0.10.	Chapter 12. Internal Construction of C_min^bullet, delta_min, and Theta_min	internal locator
T2-F057	T2-F-13.1	$E(N)=(E^\bullet(N), d_E, Dom_E, G_E),$	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator

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English ID	RU source ID	Formula / object	Primary section	Link
T2-F058	T2-F-13.2	$d_E^{n+1} \circ d_E^n = 0$ for all n.	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F059	T2-F-13.3	$J^2_N:F^2_N \to E^2(N)$, $J^3_N:X^2_N \to E^3(N)$,	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F060	T2-F-13.4	$d_E^2 J^2_N = J^3_N \Psi^2_N$, $d_E^3 J^3_N = 0$.	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F061	T2-F-13.5	$[x] \mapsto [J^3_N x]$	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F062	T2-F-13.6	$J^3_N(\mathrm{Im}\, \Psi^2_N) \subseteq \mathrm{Im}\, d_E^2$.	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F063	T2-F-13.7	$\Pi_{E,N} := H^3(J_N) \circ \kappa_N: O_B(N) \to H^3(E^\bullet(N))$,	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F064	T2-F-13.8	$\Pi_{E,N}([x]) = [J^3_N x]$.	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F065	T2-F-13.9	$H^3(E(f))\, \Pi_{E,N} = \Pi_{E,N'}\, O_B(f)$.	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F066	T2-F-13.10	$\Pi_E(o) \neq 0 \Rightarrow o \neq 0$.	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F067	T2-F-13.11	$\mathrm{Cone}(J)^n = E^n \oplus C_{min}^{n+1}$,	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F068	T2-F-13.12	$D_J(e,c) = (d_E e + Jc, -\delta_{min} c)$.	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F069	T2-F-13.13	$H^2(C_{min}) \to H^2(E) \to H^2(\mathrm{Cone}\, J) \to O_B \xrightarrow{\Pi_E} H^3(E) \to H^3(\mathrm{Cone}\, J) \to 0$.	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F070	T2-F-13.14	$\mathrm{Blind}_E(N) := \mathrm{Ker}\, \Pi_{E,N}$,	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F071	T2-F-13.15	$\mathrm{Excess}_E(N) := \mathrm{Coker}\, \Pi_{E,N}$.	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F072	T2-F-13.16	$\mathrm{Blind}_E = \mathrm{Im}(H^2(\mathrm{Cone}\, J) \to O_B)$,	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F073	T2-F-13.17	$\mathrm{Excess}_E \cong H^3(\mathrm{Cone}\, J)$.	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F074	T2-F-13.18	$H^n(J)=H^n(K)$ for all n; consequently $\Pi_E^J=\Pi_E^K$.	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F075	T2-F-13.19	$J^2-K^2 = d_E^1 h^2 + h^3 \Psi^2$, $J^3-K^3 = d_E^2 h^3$.	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator

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English ID	RU source ID	Formula / object	Primary section	Link
T2-F076	T2-F-13.20	$\Pi\_F = H^3(Q)\ \Pi\_E.$	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F077	T2-F-13.21	$(E,J) \mapsto \Pi\_E{:}O\_B(N) \to H^3(E)$	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F078	T2-F-13.22	$X^2\_N = \mathrm{Im}\ \Psi^2\_N \oplus O\_N$, $\mathrm{Ker}\ d\_E^3 = \mathrm{Im}\ d\_E^2 \oplus H\_E^3.$	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F079	T2-F-13.23	$P\_E{:}= P\_\{H\_E^3\}\ J^3\_N\ \|\_\{O\_N\}.$	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F080	T2-F-13.24	$\sigma\_\min(P\_E) \geq s\_0 > 0,$	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F081	T2-F-13.25	$\|\|\Pi\_E(o)\|\| \geq s\_0\ \|\|o\|\|.$	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F082	T2-F-13.26	$\eta\_E([x]){:}= \|\|P\_\{H\_E^3\}\ J^3\_N\ x\_\min\|\|,$	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F083	T2-F-13.27	$\Delta\_E = \Delta\_\{complex\} \cup \Delta\_\{chain\} \cup \Delta\_\{rank\ \Pi\} \cup \Delta\_\{\sigma\Pi\} \cup \Delta\_\{hom\} \cup \Delta\_D \cup \Delta\_Dom \cup \Delta\_\{glue\}.$	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F084	T2-F-13.28	$\|\|\Pi\_\{E,t\}(o\_t)\|\| \geq \varepsilon\_E$ for all $t\in I.$	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F085	T2-F-13.29	$P\_E(t)=(\dim H^3(E\_t), \mathrm{rank}\ \Pi\_\{E,t\}, \dim Blind\_\{E,t\}, \dim Excess\_\{E,t\}, \sigma\_\min(P\_\{E,t\}), \eta\_E(o\_t))$	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F086	T2-F-13.30	$\beta\_Ass,N{:}T\_Ass(N) \to H^3(A\_Ass^\wedge\bullet(N)).$	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F087	T2-F-13.31	$\beta\_Ass \circ S = H^3(Q) \circ \Pi\_E.$	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F088	T2-F-13.32	truth_layer_promotion=0; checkpoint=T2-RP-v0.10; next=T2-RP-v0.11.	Chapter 13. External E-Complex and the Conditional Bridge Pi_E	internal locator
T2-F089	T2-F-14.1	$O\_B(N) = H^3(C\_\min(N)) = X\_N^2 / \mathrm{Im}\ \Psi\_N^2.$	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F090	T2-F-14.2	$Car\_B(N) = (O\_B, 0\_B, Fil\_B, Prov\_B, Dom\_B).$	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F091	T2-F-14.3	$O\_B^\wedge\times = O\_B \setminus \{0\_B\}.$	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F092	T2-F-14.4	$P(O\_B) = O\_B^\wedge\times / K^\wedge\times$, $o \sim o' \Leftrightarrow \exists a\in K^\wedge\times{:}\ o'=ao.$	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F093	T2-F-14.5	$P(f){:}\ P(O) \setminus P(\ker f) \to P(O'), [o] \mapsto [f(o)].$	Chapter 14. Obstruction Spaces and Projective	internal locator

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English ID	**RU source ID**	**Formula / object**	**Primary section**	**Link**
			Carriers	
T2-F094	T2-F-14.6	S(O_B) → P(O_B), u ↦ [u], fibre={u,-u}.	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F095	T2-F-14.7	d_P([u],[v]) = arccos(|⟨u,v⟩| / (||u||·||v||)).	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F096	T2-F-14.8	S_r = { [o]∈P(O_B): rank A(o)=r }.	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F097	T2-F-14.9	G_[o] = { g∈G: g·o ∈ K^×o }.	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F098	T2-F-14.10	P(C_B) = (C_B \ {0}) / K^× ⊆ P(O_B).	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F099	T2-F-14.11	P_+(C_B) = (C_B \ {0}) / R_{>0}.	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F100	T2-F-14.12	O_pre = ⊕_{L∈Lines(Fano)} O_L.	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F101	T2-F-14.13	O_glob = colim(O_L, φ_{LL'}).	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F102	T2-F-14.14	Δ_proj = Δ_zero ∪ Δ_rank ∪ Δ_orbit ∪ Δ_chart ∪ Δ_glue ∪ Δ_D ∪ Δ_Dom.	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F103	T2-F-14.15	I ∩ Δ_proj=∅ ⇒ transition of certified projective type is impossible in model.	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F104	T2-F-14.16	χ_λ: P(O_B) ⇢ P¹(K),	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F105	T2-F-14.17	λ([o]) = cr(U([o]), I([o]); R([o]), D([o])).	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F106	T2-F-14.18	Cert_proj = ([o], ZERO, NORM, ORIENT, PROV, LIFT, DOM, GLUE, HASH).	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F107	T2-F-14.19	P_proj(t)=([o_t], S_rank(t), S_orbit(t), Dom_t, Glue_t).	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F108	T2-F-14.20	I ∩ Δ_proj=∅ ⇒ type(P_proj(t))=const on I.	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F109	T2-F-14.21	Block_proj = B_zero ∪ B_scale ∪ B_sign ∪ B_chart ∪ B_hom ∪ B_glue ∪ B_D ∪ B_Dom ∪ B_lift ∪ B_ind.	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator
T2-F110	T2-F-14.22	truth_layer_promotion=0; checkpoint=T2-RP-v0.11; next=T2-RP-v0.12.	Chapter 14. Obstruction Spaces and Projective Carriers	internal locator

<table>
<tr><td colspan="5">STATUS FRAME. The appendix registries preserve the authority relation Authority(T2-RU v1.0) > Authority(T2-EN). A registry row records a source object, obligation, formula, locator, or release check; it does not strengthen its mathematical or physical status. truth_layer_promotion=0; independent EXT-RUN and EMP-OBS remain absent.</td></tr>
<tr><th>English ID</th><th>RU source ID</th><th>Formula / object</th><th>Primary section</th><th>Link</th></tr>
<tr><td>T2-F111</td><td>T2-F-15.1</td><td>d_k: D(d_k) ⊂ H^k → H^{k+1}, ran d_k ⊂ ker d_{k+1}.</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
<tr><td>T2-F112</td><td>T2-F-15.2</td><td>Z^k = ker d_k, B^k = ran d_{k-1}, H^k = Z^k/B^k, H̄^k = Z^k/closure(B^k).</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
<tr><td>T2-F113</td><td>T2-F-15.3</td><td>(ran d_k)⊥ = ker d_k*, closure(ran d_k*) = (ker d_k)⊥.</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
<tr><td>T2-F114</td><td>T2-F-15.4</td><td>Δ_k = d_{k-1} d_{k-1}* + d_k* d_k,</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
<tr><td>T2-F115</td><td>T2-F-15.5</td><td>D(Δ_k)={u∈D(d_k)∩D(d_{k-1}*): d_ku∈D(d_k*), d_{k-1}*u∈D(d_{k-1})}.</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
<tr><td>T2-F116</td><td>T2-F-15.6</td><td>ℋk = ker d_k ∩ ker d_{k-1}* = ker Δ_k.</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
<tr><td>T2-F117</td><td>T2-F-15.7</td><td>⟨Δ_ku,u⟩ = ||d_ku||² + ||d_{k-1}*u||².</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
<tr><td>T2-F118</td><td>T2-F-15.8</td><td>H^k = closure(ran d_{k-1}) ⊕ ℋ^k ⊕ closure(ran d_k*).</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
<tr><td>T2-F119</td><td>T2-F-15.9</td><td>γ_k:= inf(spectrum(Δ_k) \ {0}) > 0.</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
<tr><td>T2-F120</td><td>T2-F-15.10</td><td>G_k = (Δ_k |_{(ℋ^k)⊥})^{-1}(I-P_{ℋ^k}), ||G_k|| ≤ 1/γ_k.</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
<tr><td>T2-F121</td><td>T2-F-15.11</td><td>q = d_{k-1}a_min + h, h=P_{ℋ^k}q, a_min=d_{k-1}*G_kq.</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
<tr><td>T2-F122</td><td>T2-F-15.12</td><td>||a_min|| ≤ γ_k^{-1/2} ||q-P_{ℋ^k}q||.</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
<tr><td>T2-F123</td><td>T2-F-15.13</td><td>0 → E_x^0 --σ(d_0)(x,ξ)→ E_x^1 →... → E_x^N → 0.</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
<tr><td>T2-F124</td><td>T2-F-15.14</td><td>σ_2(Δ_k)(x,ξ)=σ(d_{k-1})σ(d_{k-1})* + σ(d_k)*σ(d_k), ξ≠0.</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
<tr><td>T2-F125</td><td>T2-F-15.15</td><td>σ_2(L)(x,ξ)=|ξ|_g² Id.</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
<tr><td>T2-F126</td><td>T2-F-15.16</td><td>H_str^k = direct_sum_α L²Ω^k(S_α,E_α).</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
<tr><td>T2-F127</td><td>T2-F-15.17</td><td>T_{αβ}^+ u_α = T_{αβ}^- u_β on every admissible incidence interface.</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
<tr><td>T2-F128</td><td>T2-F-15.18</td><td>ind T = dim ker T - dim coker T.</td><td>Chapter 15. Hodge Decomposition and the Analytic NAPG Layer</td><td>internal locator</td></tr>
</table>

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English ID	RU source ID	Formula / object	Primary section	Link
T2-F129	T2-F-15.19	D_H^+: H^{even} → H^{odd}, ind D_H^+ = sum_k (-1)^k dim H^k.	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer	internal locator
T2-F130	T2-F-15.20	h_E(o)=P_{ℋ_E^3}q, η_H(o)=||h_E(o)||.	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer	internal locator
T2-F131	T2-F-15.21	η_H(o) = dist(q, ran d_E^2), η_H(o)=0 ⇔ Π_E(o)=0.	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer	internal locator
T2-F132	T2-F-15.22	Cond_H = (γ_3^{-1}, ||G_3||, ||P_H||, trace_constant, interface_constant).	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer	internal locator
T2-F133	T2-F-15.23	P_t = (2πi)^{-1} contour_integral_Γ (z-Δ_{3,t})^{-1} dz	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer	internal locator
T2-F134	T2-F-15.24	Δ_HF = Δ_{d^2} ∪ Δ_{dom} ∪ Δ_{ell} ∪ Δ_{BC} ∪ Δ_{range} ∪ Δ_{gap} ∪ Δ_{harm} ∪ Δ_{int} ∪ Δ_D ∪ Δ_Dom ∪ Δ_{glue}.	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer	internal locator
T2-F135	T2-F-15.25	P_HF(t)=(ind D_H,t^+, dim ℋ_t^k, γ_k(t), η_H(t), ||G_k(t)||, BC_t, Interface_t, λ_t)	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer	internal locator
T2-F136	T2-F-15.26	I ∩ Δ_HF = empty and η_H(t) ≥ ε_H ⇒ removal of this obstruction is impossible in model.	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer	internal locator
T2-F137	T2-F-15.27	χ_H = (R_H,I_H,U_H,D_H): P(ℋ_E^3) ⇢ (P^1)^4, λ_H=cr(U_H,I_H;R_H,D_H).	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer	internal locator
T2-F138	T2-F-15.28	Cert_HF=(COMPLEX, DOMAIN, SYMBOL, BC, INTERFACE, FREDHOLM, GAP, HARM, BRIDGE, D, DOM, λ, HASH).	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer	internal locator
T2-F139	T2-F-15.29	Block_HF = B_complex ∪ B_domain ∪ B_symbol ∪ B_BC ∪ B_interface ∪ B_range ∪ B_gap ∪ B_bridge ∪ B_D ∪ B_Dom ∪ B_glue ∪ B_ind.	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer	internal locator
T2-F140	T2-F-15.30	truth_layer_promotion=0; checkpoint=T2-RP-v0.12; next=T2-RP-v0.13.	Chapter 15. Hodge Decomposition and the Analytic NAPG Layer	internal locator
T2-F141	T2-F-16.1	Art_K = { (A,m_A): A/m_A ≅ K, m_A^N=0 for some N }.	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F142	T2-F-16.2	Def_N: Art_K → Gpd, F_N = π_0 Def_N: Art_K → Set.	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F143	T2-F-16.3	0 → I → A′ → A → 0, m_{A′} I = 0.	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F144	T2-F-16.4	F(A′×_A A″) → F(A′) ×_{F(A)} F(A″).	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F145	T2-F-16.5	universal ⇒ miniversal ⇒ versal; the converse	Chapter 16. Deformation Functors, Moduli	internal locator

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		implications fail.	Spaces, and the Kuranishi Map	
T2-F146	T2-F-16.6	C_N^1 −d_N^1→ C_N^2 −d_N^2→ C_N^3, d_N^2 d_N^1 = 0.	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F147	T2-F-16.7	H_N^1 = infinitesimal automorphisms, H_N^2 = tangent classes, H_N^3 = primary obstructions.	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F148	T2-F-16.8	H^{-1}(T_N^der)=H_N^1, H^0(T_N^der)=H_N^2, H^1(T_N^der)=H_N^3.	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F149	T2-F-16.9	g_N=(g_N,l_1,l_2,l_3,...)	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F150	T2-F-16.10	MC_N(A)={α∈g_N^1⊗m_A: Σ_{n≥1}(1/n!) l_n(α,...,α)=0 }.	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F151	T2-F-16.11	F(α̃)=Σ_{n≥1}(1/n!)l_n(α̃^n) ∈ g_N^2⊗I	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F152	T2-F-16.12	(H(g_N),0) −i→ (g_N,l_1) −p→ (H(g_N),0), id-ip=l_1h+hl_1.	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F153	T2-F-16.13	p=P_H, i=harmonic inclusion, h=l_1^* G.	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F154	T2-F-16.14	N(α)=Σ_{n≥2}(1/n!)l_n(α^n).	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F155	T2-F-16.15	α(x)=i(x)-hN(α(x)), hα(x)=0.	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F156	T2-F-16.16	K_N(x)=pN(α(x)) ∈ H^2(g_N)=H_N^3.	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F157	T2-F-16.17	$\|N(\alpha)-N(\beta)\| \le L\_R \|\alpha-\beta\|, \|h\| L\_R < 1.$	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F158	T2-F-16.18	$\|x\| \le R(1-\|h\|L\_R)/\|i\|.$	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F159	T2-F-16.19	$m\_K(R)=1-\|h\|L\_R.$	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F160	T2-F-16.20	K_N(x)=κ_2(x,x)+κ_3(x,x,x)+κ_4(x,x,x,x)+...	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F161	T2-F-16.21	κ_2(x,x)=1/2·p l_2(ix,ix).	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F162	T2-F-16.22	κ_3(x,x,x)=1/6·p l_3(ix,ix,ix)-1/2·p l_2(ix,h l_2(ix,ix)).	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator

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T2-F163	T2-F-16.23	ν_K(x)=min{n≥2: κ_n(x,...,x)≠0}, ν_K=∞ if all terms vanish.	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F164	T2-F-16.24	R_N^min = K[[t_1,...,t_m]]/(K_1,...,K_q).	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F165	T2-F-16.25	FormalModuli_K ≃ dgLie_K (under char K=0 and the corresponding homotopical hypotheses).	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F166	T2-F-16.26	π_0Def_N does not determine H^{-1}(T_N^der).	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F167	T2-F-16.27	S_N = ⊔_α S_{N,α}, P_mod(x)=(dim H^1,dim H^2,dim H^3,ν_K,HS_x,dim Aut_x,[K_lead]).	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F168	T2-F-16.28	Δ_mod = Δ_HF ∪ Δ_ctrl ∪ Δ_Sch ∪ Δ_aut ∪ Δ_tan ∪ Δ_obs ∪ Δ_Kur ∪ Δ_conv ∪ Δ_orb ∪ Δ_D ∪ Δ_Dom ∪ Δ_glue.	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F169	T2-F-16.29	η_K(t)=‖K_{N_t}(x_t)‖.	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F170	T2-F-16.30	η_K(t)=‖K_t(x_t)‖ ≥ ε_K > 0 for all t∈I,	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F171	T2-F-16.31	Block_mod = B_ctrl ∪ B_Sch ∪ B_HF ∪ B_gauge ∪ B_conv ∪ B_Kur ∪ B_aut ∪ B_stack ∪ B_D ∪ B_Dom ∪ B_glue ∪ B_ind.	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F172	T2-F-16.32	INPUT NAPG frame N, controlling data g, Artin bases, Hodge-Green package, candidate x, D/Dom CHECK l_infinity_identities; compute H1,H2,H3; test small extensions and Schlessinger maps BUILD contraction (p,i,h); verify id-ip=l1h+hl1 and uniform bounds SOLVE alp	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F173	T2-F-16.33	truth_layer_promotion=0; checkpoint=T2-RP-v0.13; next=T2-RP-v0.14.	Chapter 16. Deformation Functors, Moduli Spaces, and the Kuranishi Map	internal locator
T2-F174	T2-F-17.1	M_N = ⊔_{α∈A} S_α, S_α ∩ overline(S_β) ≠∅ ⇒ S_α ⊂ overline(S_β).	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F175	T2-F-17.2	P_str(x) = (dim H^1_x, dim H^2_x, dim H^3_x, dim Aut_x, rank dK_x, mult_x, HS_x, γ_x, λ_x, D_x, Dom_x).	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F176	T2-F-17.3	I_trans: M_N^reg → Λ, I_trans|_{S_α}=const.	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F177	T2-F-17.4	W = Δ_rank ∪ Δ_aut ∪ Δ_obs ∪ Δ_gap ∪ Δ_branch ∪ Δ_D ∪ Δ_Dom ∪ Δ_glue.	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator

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T2-F178	T2-F-17.5	WC_{γ,t*}: Inv(C_-) → Inv(C_+).	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F179	T2-F-17.6	Δ_W I = I_+ - T_{-→+}I_-,	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F180	T2-F-17.7	Bif(K) = {(t,x): K_t(x)=0, rank D_xK_t < r_reg}.	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F181	T2-F-17.8	fold: g=0, g_a=0, g_{aa}≠0, g_t≠0; cusp: g=g_a=g_{aa}=0, g_{aaa}g_t≠0.	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F182	T2-F-17.9	Branch(Z/P) = π_0(Z~ \ Ram(ν)).	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F183	T2-F-17.10	Mon: $\pi_1(U,t_0)$ → Perm(B_{t_0}).	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F184	T2-F-17.11	ρ: $\pi_1(U,t_0)$ → Aut(V_{t_0}).	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F185	T2-F-17.12	T_γ = WC_m ∘... ∘ WC_2 ∘ WC_1.	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F186	T2-F-17.13	WC_i WC_j = WC_j WC_i or WC_i WC_j WC_i = WC_j WC_i WC_j	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F187	T2-F-17.14	P_W(t,b)=(dist(t,W), σ_min(D_xK_t), mult_b, MonOrb_b, η_K, η_H, λ_b, CGI_b).	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F188	T2-F-17.15	Δ_WB = Δ_strat ∪ Δ_wall ∪ Δ_bif ∪ Δ_ram ∪ Δ_mon ∪ Δ_path ∪ Δ_inv.	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F189	T2-F-17.16	Δ_safe^{v0.14} = Δ_mod ∪ Δ_WB.	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F190	T2-F-17.17	γ ∩ Δ_safe^{v0.14}=∅ ⇒ NO-WALL-CROSSING-IN-MODEL.	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F191	T2-F-17.18	Block_WB = B_strat ∪ B_Whit ∪ B_wall ∪ B_bif ∪ B_branch ∪ B_mon ∪ B_path ∪ B_inv ∪ B_D ∪ B_Dom ∪ B_glue ∪ B_ind.	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F192	T2-F-17.19	INPUT family K_t, stratification candidate, path γ, branch data, invariant I, D/Dom CHECK Kuranishi charts; verify frontier/Whitney/control data; compute discriminant and chambers NORMALIZE zero locus; assign branch_id; continue branches; compute Mon and wall	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator
T2-F193	T2-F-17.20	truth_layer_promotion=0; checkpoint=T2-RP-v0.14; next=T2-RP-v0.15.	Chapter 17. Stratified Moduli Spaces, Wall Crossing, and Monodromy	internal locator

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T2-F194	T2-F-18.1	$\lvert\mathfrak{M}\rvert \leftarrow \mathfrak{M} \leftarrow \mathfrak{M}^{der}$.	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F195	T2-F-18.2	$\mathscr{K}_i=(U_i,E_i,s_i,G_i,\psi_i)$,	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F196	T2-F-18.3	$\mathrm{vdim}(\mathscr{K}_i)=\dim U_i-\mathrm{rank}\ E_i-\dim G_i$	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F197	T2-F-18.4	$s_j\circ\varphi_{ij} = \hat{h}\varphi_{ij}\circ s_i$.	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F198	T2-F-18.5	$\alpha_{ijk}: \Phi_{jk}\circ\Phi_{ij} \Rightarrow \Phi_{ik}$,	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F199	T2-F-18.6	$\mathfrak{M}(U) \simeq \mathrm{Tot}(\mathfrak{M}(U\_\bullet))$.	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F200	T2-F-18.7	$\mathbb{T}_x^{vir}=[\ \underset{x}{\rightarrowtail}\ T_xU_i\ \square\ E_{i,x}\ ]$,	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F201	T2-F-18.8	$\mathrm{vdim}_x = -\dim H^{-1} + \dim H^0 - \dim H^1$.	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F202	T2-F-18.9	$\varphi:E\bullet\to L\_\mathfrak{M}$, $E\bullet$ perfect, $\mathrm{amp}(E\bullet)\subset[-1,0]$,	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F203	T2-F-18.10	$Ob\_\mathfrak{M} = h^1((E\bullet)\vee)$, $\mathfrak{N}\_\mathfrak{M}=h^1/h^0(L\_\mathfrak{M}\vee)$.	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F204	T2-F-18.11	$q_{jk}\circ q_{ij} \simeq q_{ik}$,	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F205	T2-F-18.12	$c_{ijk}=q_{ik}^{-1}\ q_{jk}\ q_{ij} \in Z$, $[c]\in$Čech $H^2(X,Z)$.	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F206	T2-F-18.13	$\det(\mathbb{T}^{vir})=\otimes_j(\det H^j(\mathbb{T}^{vir}))$^{(-1)^j}.	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F207	T2-F-18.14	$\mathrm{Mon}:\pi_1(P\backslash\Delta,p_0)\to\mathrm{Perm}(\mathfrak{B}\_\{p_0\})$.	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F208	T2-F-18.15	PredCar_N=($\mathfrak{M}$_N$^{der}\to$P, $\mathbb{T}^{vir}$, Ob_N, $\mathfrak{c}$_N, $\mathfrak{B}$_N, Rep_N, λ_N, D_N, Dom_N, E_N).	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F209	T2-F-18.16	$c_{ijk}=g_{ki}\ g_{jk}\ g_{ij}$.	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F210	T2-F-18.17	local lift + local obstruction=0 $\nRightarrow$ global lift.	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F211	T2-F-18.18	$\lvert\mathfrak{M}_1\rvert\cong\lvert\mathfrak{M}_2\rvert \nRightarrow \mathfrak{M}_1\simeq\mathfrak{M}_2$ and $\nRightarrow \mathfrak{M}_1^{der}\simeq\mathfrak{M}_2^{der}$.	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator

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T2-F212	T2-F-18.19	η_desc = ∣∣defect of higher descent∣∣, η_ob = ∣∣h(ob)∣∣, η_ext = ∣∣Π_E(ob)∣∣.	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F213	T2-F-18.20	Δ_stack = Δ_desc ∪ Δ_coh ∪ Δ_perf ∪ Δ_amp ∪ Δ_vrank ∪ Δ_orient ∪ Δ_branch ∪ Δ_mon ∪ Δ_Rep ∪ Δ_D ∪ Δ_Dom ∪ Δ_ext ∪ Δ_ind.	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F214	T2-F-18.21	Δ_safe^{v0.15}=Δ_safe^{v0.14}∪Δ_stack.	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F215	T2-F-18.22	P_stack(p)=([amp $\mathbb{T}^{vir}$], h^{-1},h^0,h^1, vdim, [det], [desc], MonOrb, η_ob, η_ext, λ, CGI).	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F216	T2-F-18.23	γ ∩ Δ_safe^{v0.15}=∅ ⇒ NO-GLOBAL-TRANSITION-IN-MODEL.	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F217	T2-F-18.24	Block_stack=B_atlas∪B_2coc∪B_eff∪B_perf∪B_amp∪B_vtan∪B_branch∪B_Rep∪B_D∪B_Dom∪B_E∪B_ind.	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F218	T2-F-18.25	truth_layer_promotion=0; checkpoint=T2-RP-v0.15; next=T2-RP-v0.16.	Chapter 18. Global Derived/Stacky Moduli Spaces and the Predictive Carrier	internal locator
T2-F219	T2-F-19.1	V0 → V1 does not imply P0 → E0.	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F220	T2-F-19.2	φ:E•→L_𝔐, amp(E•)⊂[-1,0].	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F221	T2-F-19.3	vdim(𝔐)=rk(E•)=rk(E^0)-rk(E^{-1}).	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F222	T2-F-19.4	$[𝔐]^{vir}$ = 0_𝔈^! [c_𝔐] ∈ A_vdim(𝔐).	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F223	T2-F-19.5	I^{vir}(𝔐;α)=∫_$[𝔐]^{vir}$ α = deg(α∩$[𝔐]^{vir}$).	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F224	T2-F-19.6	$\langle\alpha_1,\ldots,\alpha_n\rangle^{vir}$ = ∫_$[𝔐]^{vir}$ $\prod_i ev_i^*\alpha_i$.	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F225	T2-F-19.7	$[Z]^{vir}$=[Z], vdim=dim U-rk E.	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F226	T2-F-19.8	$[𝔐\_b]^{vir}$ = i_b^!$[𝔐]^{vir}$_rel.	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F227	T2-F-19.9	I^{vir}(𝔐_b;α_b)=const.	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F228	T2-F-19.10	$[𝔐]^{vir}$ = i_* Σ_F $[F]^{vir}$ / e_T(N_F^{vir})	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator

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T2-F229	T2-F-19.11	I^{vir} = Σ_[x] m_x / |Aut(x)|.	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F230	T2-F-19.12	virtual degree ≠ probability measure.	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F231	T2-F-19.13	B_prob=(Ω,ℱ,P,Y,φ,g_θ,ℒ,Cal,Val,Ext).	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F232	T2-F-19.14	p_θ = g_θ(φ(P_vir, P_stack, λ, CGI, D, Dom)).	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F233	T2-F-19.15	E[Y | p_θ]=p_θ.	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F234	T2-F-19.16	VirtCert=($\mathfrak{M}^{der}$,E•,𝔠_𝔐, $[\mathfrak{M}]^{vir}$,α,or,prop,src,code,D,Dom).	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F235	T2-F-19.17	Rep_vir=(R_vir,I_vir,U_vir;D_vir),	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F236	T2-F-19.18	Gate_vir=1 ⇔ Cert_VFC=1 ∧ Valid(D)=1 ∧ Dom=1 ∧ Block_vir=∅.	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F237	T2-F-19.19	Gate_prob=1 ⇔ Gate_vir=1 ∧ Cert_prob=1 ∧ Ext=1.	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F238	T2-F-19.20	Δ_VFC = Δ_POT ∪ Δ_amp ∪ Δ_prop ∪ Δ_or ∪ Δ_comp ∪ Δ_ins ∪ Δ_loc ∪ Δ_wall ∪ Δ_num.	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F239	T2-F-19.21	Δ_prob = Δ_Ω ∪ Δ_meas ∪ Δ_link ∪ Δ_cal ∪ Δ_shift ∪ Δ_sel ∪ Δ_ext.	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F240	T2-F-19.22	Δ_safe^{v0.16}=Δ_safe^{v0.15} ∪Δ_VFC∪Δ_prob.	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F241	T2-F-19.23	P_VFC(t)=($[\mathfrak{M}\_t]^{vir}$, vdim, I^{vir}_t, supp, sign, denom, chamber, λ_t, CGI_t)	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F242	T2-F-19.24	γ ∩ (Δ_safe^{v0.15} ∪ Δ_VFC)=∅ ⇒ NO-VIRTUAL-CHANGE-IN-MODEL.	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F243	T2-F-19.25	truth_layer_promotion=0; checkpoint=T2-RP-v0.16; next=T2-RP-v0.17.	Chapter 19. Virtual Cycles, Enumerative Invariants, and the Probability Firewall	internal locator
T2-F244	T2-F-20.1	𝕍_γ ∈→_γ 𝕍 [∈_γ] →K_0(∈_γ) → □ _γ □ R_mot □ Real(→γ) ∈ I_γ □ R_num.	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F245	T2-F-20.2	[Y]=[X]+[Z].	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F246	T2-F-20.3	[X]=[Z]+[XZ] for closed Z□ X, [X]·[Y]=[X×Y].	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator

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T2-F247	T2-F-20.4	MotCar=(R_mot, 𝕃^{1/2}, Fil, Comp, μ̂, or, src, D, Dom),	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F248	T2-F-20.5	χ_c: K_0(Var_ℂ) → ℤ, E_c: K_0(Var_ℂ) → ℤ[u,v].	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F249	T2-F-20.6	PExp(f)=exp(Σ_{r≥1} ψ_r(f)/r), PLog=PExp^{-1}.	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F250	T2-F-20.7	MF^φ_{U,f} ∈ □_X^{μ̂}, Real(MF^φ_{U,f}) = vanishing-cycle realization.	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F251	T2-F-20.8	Ω_γ^{ref}(y)=Σ_j (-1)^j dim ℋ_γ^j · y^{j/2}.	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F252	T2-F-20.9	CoHA=⊕_{γ∈Γ_+} H^•_{c,G_γ}(Rep_γ, φ_{Tr W}),	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F253	T2-F-20.10	BPS_γ ∈ MHM(M_γ), Ω_γ^{ref}=Real(BPS_γ).	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F254	T2-F-20.11	Z_ref(𝕃;y,∈)=1+Σ_{0≠γ𝕀Γ_+} Ω_γ^{ref}(y,∈) □^γ □ 1+Î.	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F255	T2-F-20.12	**x**^α **x**^β = 𝕃^{⟨α,β⟩/2} **x**^{α+β}.	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F256	T2-F-20.13	Z(q^{-1}) = q^a · ε · Z(q) or Z(q)=P(q)/Q(q).	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F257	T2-F-20.14	graded coefficient ≠ time-stamped state; generating series ≠ flow.	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F258	T2-F-20.15	B_dyn=(T,S,τ,U,𝒢,ι,Obs,noise,Cal,Ext,D,Dom).	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F259	T2-F-20.16	U(t,t)=Id, U(t,r)∘U(r,s)=U(t,s), t≥r≥s.	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F260	T2-F-20.17	Ax = lim_{t↓0} (U(t)x-x)/t, x∈Dom(A).	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F261	T2-F-20.18	K_{t,s}=K_{t,r}∘K_{r,s}.	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F262	T2-F-20.19	Y_t = Obs(U(t,t_0)ι(□_ref)) + ε_t.	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F263	T2-F-20.20	MotRefCert=(𝕍,K_0,ℳ,Real,Ω_ref,Z_ref,B_dyn,B_emp,src,code,D,Dom).	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F264	T2-F-20.21	Rep_mot=(R_mot,I_mot,U_mot;D_mot),	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator

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T2-F265	T2-F-20.22	R_ref=(r_cat,r_K0,r_mot,r_real,r_spec,r_series,r_time,r_evol,r_obs,r_ext).	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F266	T2-F-20.23	Δ_mot = Δ_cat ∪ Δ_or ∪ Δ_glue ∪ Δ_comp ∪ Δ_real ∪ Δ_spec.	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F267	T2-F-20.24	Δ_series = Δ_ring ∪ Δ_order ∪ Δ_wall ∪ Δ_PExp ∪ Δ_conv ∪ Δ_func.	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F268	T2-F-20.25	Δ_dyn = Δ_time ∪ Δ_state ∪ Δ_U ∪ Δ_gen ∪ Δ_path ∪ Δ_obs ∪ Δ_cal ∪ Δ_ext.	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F269	T2-F-20.26	Δ_safe^{v0.17}=Δ_safe^{v0.16} ∪Δ_mot∪Δ_series∪Δ_dyn.	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F270	T2-F-20.27	P_ref(t)=([𝕍_t],𝓜_t,Real_t,Ω_t^{ref},Z_t,chamber_t,λ_t,CGI_ref,t)	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F271	T2-F-20.28	NO-REFINED-CHANGE-IN-MODEL or FORMAL-SERIES-ONLY.	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F272	T2-F-20.29	truth_layer_promotion=0; checkpoint=T2-RP-v0.17; next=T2-RP-v0.18.	Chapter 20. Categorified, Motivic, and Refined Virtual Invariants	internal locator
T2-F273	T2-F-21.1	truth_layer_promotion=0; source=T2-RP-v0.17; checkpoint=T2-RP-v0.18.	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F274	T2-F-21.2	ℭ(t,s): Dom_{t,s}→S_s [illegible] S_t.	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F275	T2-F-21.3	𝒮(0)=Id_C, 𝒮(t+s)=𝒮(t)∘𝒮(s), lim_{t↓0}𝒮(t)x=x.	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F276	T2-F-21.4	𝒮(t)x = lim_{m→∞}(I+(t/m)A)^{-m}x	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F277	T2-F-21.5	𝒰(s,s)=Id, 𝒰(t,r)∘𝒰(r,s)=𝒰(t,s).	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F278	T2-F-21.6	(𝒦_t f)(x)=f(Φ_t(x)).	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F279	T2-F-21.7	𝒫_t μ=(Φ_t)_#μ, (𝒫_t μ)(B)=μ(Φ_t^{-1}(B)).	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F280	T2-F-21.8	∫_S f d(𝒫_t μ)=∫_S (𝒦_t f)dμ.	Chapter 21. Nonlinear Evolution Semigroups,	internal locator

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English ID	RU source ID	Formula / object	Primary section	Link
			Transfer Operators, Path-Space Carriers, and Causal Kernels	
T2-F281	T2-F-21.9	$K_{t,s}(x,B)=\int_S K_{t,r}(y,B)K_{r,s}(x,dy),\ t\ge r\ge s.$	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F282	T2-F-21.10	$\mu_{t_1,\dots,t_m}=Q\circ(X_{t_1},\dots,X_{t_m})^{-1}.$	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F283	T2-F-21.11	$\omega_x(t)=\mathcal{U}(t,t_0)x.$	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F284	T2-F-21.12	$x(t)=f(t)+\int_{t_0}^{t} B(t,s,x(s))\,ds.$	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F285	T2-F-21.13	$(F\omega)(t)=(F\omega')(t).$	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F286	T2-F-21.14	transition kernel ≠ intervention kernel ≠ physical cause.	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F287	T2-F-21.15	$Rep_t=(R_t,I_t,U_t;D_t),\ \lambda_t=cr(U_t,I_t;R_t,D_t).$	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F288	T2-F-21.16	$PathRep=(\Omega,Q/\mathfrak{A},\{Rep_t\},\mathcal{U},K,B,Obs,\mathbb{F},D,Dom,src,code).$	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F289	T2-F-21.17	$d\lambda_t/dt = D\lambda(Rep_t)\cdot\dot{Rep}_t.$	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F290	T2-F-21.18	$\mathcal{T}_{t,s}: \mathfrak{M}(S_s)\to\mathfrak{M}(S_t),\ \mathcal{T}_{t,r}\mathcal{T}_{r,s}=\mathcal{T}_{t,s}.$	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F291	T2-F-21.19	$d/dt\, \mathcal{T}_t f \,\vert_{t=0}=Lf$	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F292	T2-F-21.20	$e_{\mathcal{U}}(t,s;x)=d(\mathcal{U}(t,s)x,\tilde{U}(t,s)x).$	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F293	T2-F-21.21	$R_{time}=(r_{sg},r_{gen},r_{res},r_{tr},r_{path},r_{CK},r_{me}$	Chapter 21. Nonlinear Evolution Semigroups,	internal locator

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English ID	RU source ID	Formula / object	Primary section	Link
		m,r_na,r_obs,r_cal,r_ext).	Transfer Operators, Path-Space Carriers, and Causal Kernels	
T2-F294	T2-F-21.22	Δ_sg=Δ_dom∪Δ_cont∪Δ_comp∪Δ_accr∪Δ_res.	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F295	T2-F-21.23	Δ_tr=Δ_pos∪Δ_mass∪Δ_dual∪Δ_spec∪Δ_inv.	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F296	T2-F-21.24	Δ_path=Δ_cons∪Δ_tight∪Δ_reg∪Δ_branch∪Δ_hist.	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F297	T2-F-21.25	Δ_causal=Δ_order∪Δ_NA∪Δ_filt∪Δ_interv∪Δ_transport.	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F298	T2-F-21.26	Δ_safe^{v0.18}=Δ_safe^{v0.17} ∪Δ_sg∪Δ_tr∪Δ_path∪Δ_causal.	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F299	T2-F-21.27	P_time(t)=(class(𝒰_t),class(𝒯_t),class(Q_t),rank/stratum,λ_t,CGI_time,t)	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F300	T2-F-21.28	NO-TEMPORAL-TRANSITION-IN-MODEL.	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F301	T2-F-21.29	truth_layer_promotion=0; checkpoint=T2-RP-v0.18; next=T2-RP-v0.19.	Chapter 21. Nonlinear Evolution Semigroups, Transfer Operators, Path-Space Carriers, and Causal Kernels	internal locator
T2-F302	T2-F-22.1	truth_layer_promotion=0; source=T2-RP-v0.18; checkpoint=T2-RP-v0.19.	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F303	T2-F-22.2	(P_t f)(x)=∫_E f(y)p_t(x,dy)=E_x[f(X_t)].	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F304	T2-F-22.3	Lf = lim_{t↓0}(P_t f-f)/t, f∈Dom(L).	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F305	T2-F-22.4	R_α f = ∫_0^∞ e^{-αt}P_t f dt.	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F306	T2-F-22.5	M_t^f = f(X_t)-f(X_0)-∫_0^t Lf(X_s)ds	Chapter 22. Stochastic Evolutions, Martingale	internal locator

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English ID	RU source ID	Formula / object	Primary section	Link
			Problems, Stopping Times, Control, and Causal Inference	
T2-F307	T2-F-22.6	dX_t=b(t,X_t)dt+σ(t,X_t)dW_t	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F308	T2-F-22.7	L_t f(x)=b(t,x)·∇f(x)+(1/2)Tr(a(t,x)∇²f(x)), a=σσᵀ.	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F309	T2-F-22.8	Z_t=exp(∫_0^t θ_s·dW_s-(1/2)∫_0^t‖θ_s‖²ds)	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F310	T2-F-22.9	τ_A = inf{t≥t_0: X_t∈A}.	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F311	T2-F-22.10	p_A(T,x)=P_x(τ_A≤T).	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F312	T2-F-22.11	(∂_t+L_t)V(t,x)≤0 on [0,T]×(E\A).	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F313	T2-F-22.12	P_{x_0}(τ_A≤T)≤V(0,x_0).	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F314	T2-F-22.13	sup_{a∈A(t,x)} (∂_t+L_t^a)V(t,x)≤0,	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F315	T2-F-22.14	J(π;x)=E_x^π[∫_0^T c(t,X_t,a_t)dt+g(X_T)].	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F316	T2-F-22.15	∂_tV^*+inf_{a∈A}{L^aV^*+c(t,x,a)}=0, V^*(T,x)=g(x).	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F317	T2-F-22.16	X_{t+1}=F_t(X_{≤t},A_t,U_{t+1}), Y_t=G_t(X_{≤t},U_t).	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F318	T2-F-22.17	p(y^{a-bar}) = ∫ ∏_t p(l_{t+1}|l-bar_t,a-bar_t) p(y|l-bar_T,a-bar_T) d(l-bar).	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F319	T2-F-22.18	Rep_t(ω)=(R_t(ω),I_t(ω),U_t(ω);D_t(ω)).	Chapter 22. Stochastic Evolutions, Martingale	internal locator

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			Problems, Stopping Times, Control, and Causal Inference	
T2-F320	T2-F-22.19	$d\varphi(X_t)=L\varphi(X_t)dt+\nabla\varphi(X_t)\sigma(X_t)dW_t$.	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F321	T2-F-22.20	$Lq=2\varphi L\varphi+\|\|\sigma^T\nabla\varphi\|\|^2$.	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F322	T2-F-22.21	$\sigma_j(x)\cdot\nabla\varphi(x)=0$ for all j, $L\varphi(x)=0$, $x\in M$.	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F323	T2-F-22.22	$R_{s,t}^{f_k}=f_k(X_t)-f_k(X_s)-\int_s^t Lf_k(X_r)dr$.	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F324	T2-F-22.23	$P(\sup_t E_t \geq 1/\alpha)\leq\alpha$.	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F325	T2-F-22.24	$\Delta_{stoch} = \Delta_{MP} \cup \Delta_{Feller} \cup \Delta_{gen} \cup \Delta_{stop} \cup \Delta_{hit} \cup \Delta_{bar} \cup \Delta_{ctrl} \cup \Delta_{HJB} \cup \Delta_{do} \cup \Delta_{id} \cup \Delta_\lambda \cup \Delta_{cal} \cup \Delta_{ext}$.	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F326	T2-F-22.25	$\Delta_{safe}^{v0.19}=\Delta_{safe}^{v0.18}\cup\Delta_{stoch}$.	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F327	T2-F-22.26	$V(0,x)=0$ => NO-HIT-IN-MODEL; $0<V(0,x)\leq\alpha$ => RISK-BOUND≤α.	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F328	T2-F-22.27	$Block_{stoch}=B_{basis}\cup B_{MP}\cup B_{gen}\cup B_{stop}\cup B_{bar}\cup B_{ctrl}\cup B_{do}\cup B_{id}\cup B_\lambda\cup B_{cal}\cup B_{ext}$.	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F329	T2-F-22.28	truth_layer_promotion=0; checkpoint=T2-RP-v0.19; next=T2-RP-v0.20.	Chapter 22. Stochastic Evolutions, Martingale Problems, Stopping Times, Control, and Causal Inference	internal locator
T2-F330	T2-F-23.1	truth_layer_promotion=0; source=T2-RP-v0.19; checkpoint=T2-RP-v0.20.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F331	T2-F-23.2	$-\inf_{x\in A^\circ} I(x) \leq \liminf_n a_n^{-1}\log P(Z_n\in A) \leq \limsup_n a_n^{-1}\log P(Z_n\in A) \leq -\inf_{x\in \mathrm{cl}\, A}I(x)$.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F332	T2-F-23.3	$\limsup_n a_n^{-1}\log P(Z_n\notin K_M) \leq -M$.	Chapter 23. Large Deviations, Risk-Sensitive	internal locator

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English ID	RU source ID	Formula / object	Primary section	Link
			Semigroups, Rare-Event Geometry, and Finite-Sample Certification	
T2-F333	T2-F-23.4	J(y)=inf{I(x):F(x)=y}, inf∅=∞.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F334	T2-F-23.5	lim_n a_n^{-1}log E exp(a_n F(Z_n)) = sup_{x∈𝒳}{F(x)-I(x)}.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F335	T2-F-23.6	Λ(θ)=lim_n a_n^{-1}log E exp(a_n⟨θ,Z_n⟩).	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F336	T2-F-23.7	I(Q)=D(Q||P),	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F337	T2-F-23.8	dX_t^ε=b(X_t^ε)dt+√ε σ(X_t^ε)dW_t	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F338	T2-F-23.9	S_{0T}(φ)=1/2 ∫_0^T ⟨φ_dot-b(φ), a(φ)^{-1}(φ_dot-b(φ))⟩ dt,	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F339	T2-F-23.10	V(x,y)=inf_{T>0} inf_{φ(0)=x, φ(T)=y} S_{0T}(φ).	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F340	T2-F-23.11	z=(Rep, μ, Ass, o, λ, D, Dom).	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F341	T2-F-23.12	A_{ε,η}={z(·): inf_t |λ_t+1|≤ε, ||o_t||≤η, Valid(D_t)=1, Block_t=∅}.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F342	T2-F-23.13	c_{ε,η}=inf_{z(·)∈cl A_{ε,η}} I_path(z).	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F343	T2-F-23.14	L_T=(1/T)∫_0^T δ_{X_t}dt	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F344	T2-F-23.15	I_DV(μ)= -inf_{u>0} ∫ (Lu/u)dμ.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F345	T2-F-23.16	(Q_t^V f)(x)=E_x[exp(∫_0^t V(X_s)ds) f(X_t)].	Chapter 23. Large Deviations, Risk-Sensitive	internal locator

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English ID	RU source ID	Formula / object	Primary section	Link
			Semigroups, Rare-Event Geometry, and Finite-Sample Certification	
T2-F346	T2-F-23.17	$(S_t^{\theta,V}g)(x)=\theta^{-1}\log E_x \exp(\theta[g(X_t)+\int_0^t V(X_s)ds])$.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F347	T2-F-23.18	$H_\theta f = \theta^{-1}e^{-\theta f}L(e^{\theta f})+V$.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F348	T2-F-23.19	$H_\theta f = Lf +(\theta/2)\lVert\sigma^T\nabla f\rVert^2+V$.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F349	T2-F-23.20	$\rho(\theta)=\lim_{t\to\infty}(1/t)\log E_x \exp(\theta\int_0^t V(X_s)ds)$.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F350	T2-F-23.21	$\log E_P e^F = \sup_{Q\ll P}\{E_Q F-D(Q\Vert P)\}$.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F351	T2-F-23.22	$J_\theta(a)=\limsup_{T\to\infty}(1/(\theta T))\log E^a \exp(\theta\int_0^T c(X_t,a_t)dt)$	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F352	T2-F-23.23	$\rho+\inf_a\{L^a v+c(x,a)+(\theta/2)\lVert\sigma_a^T\nabla v\rVert^2\}=0$.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F353	T2-F-23.24	$\lim_n a_n^{-1}\log p_n=-c, c>0$	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F354	T2-F-23.25	$p=P(A)=E_Q[1_A L]$.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F355	T2-F-23.26	$U_N(\rho)=\{Q: d(Q,\hat P_N)\le\rho, Q\in\mathscr{P}_{adm}\}$.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F356	T2-F-23.27	$\sup_{D(Q\Vert\hat P)\le\rho} E_Q\ell \le \inf_{\eta>0}\{\eta\rho+\eta\log E_{\hat P}\exp(\ell/\eta)\}$.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F357	T2-F-23.28	$\sup_{W_c(Q,\hat P)\le\rho}E_Q\ell = \inf_{\eta\ge0}\{\eta\rho+E_{\hat P}[\sup_z(\ell(z)-\eta c(z,\xi))]\}$.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F358	T2-F-23.29	$P_{data}(P_*\in U_N(\rho_N(\beta)))\ge1-\beta$.	Chapter 23. Large Deviations, Risk-Sensitive	internal locator

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English ID	RU source ID	Formula / object	Primary section	Link
			Semigroups, Rare-Event Geometry, and Finite-Sample Certification	
T2-F359	T2-F-23.30	P_*(A)≤sup_{Q∈U_N}Q(A).	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F360	T2-F-23.31	P_data(P_*(A)≤B_N(A))≥1-β.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F361	T2-F-23.32	p_U=1-α^{1/N}, coverage ≥1-α.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F362	T2-F-23.33	E[X]≤X_bar_N+sqrt(log(1/β)/(2N)).	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F363	T2-F-23.34	p_n(A) ≤ min{B_N^{rob}(A), C_n exp[-a_n(c_A-δ)]},	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F364	T2-F-23.35	Rep_rate=(I_hat, topology, speed, solver, residuals; D_rate).	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F365	T2-F-23.36	Cert_LD=(𝒳,τ,a_n,P_n,I,A,c_A,R_n,U_N,B_N,IS,λ,D,Dom,src,code,hash).	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F366	T2-F-23.37	Δ_LD=Δ_speed∪Δ_top∪Δ_tight∪Δ_rate∪Δ_contract∪Δ_pole∪Δ_action∪Δ_inst.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F367	T2-F-23.38	Δ_RS=Δ_FK∪Δ_expint∪Δ_eig∪Δ_HJB∪Δ_tilt∪Δ_IS.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F368	T2-F-23.39	Δ_FS=Δ_iid∪Δ_dep∪Δ_tail∪Δ_amb∪Δ_cov∪Δ_sel∪Δ_stop∪Δ_shift∪Δ_ext.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F369	T2-F-23.40	Δ_safe^{v0.20}=Δ_safe^{v0.19} ∪Δ_LD∪Δ_RS∪Δ_FS.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F370	T2-F-23.41	truth_layer_promotion=0; checkpoint=T2-RP-v0.20; next=T2-RP-v0.21.	Chapter 23. Large Deviations, Risk-Sensitive Semigroups, Rare-Event Geometry, and Finite-Sample Certification	internal locator
T2-F371	T2-F-24.1	truth_layer_promotion=0; source=T2-RP-v0.20;	Chapter 24. End-to-End KLT-RBD Predictive	internal locator

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English ID	RU source ID	Formula / object	Primary section	Link
		checkpoint=T2-RP-v0.21.	Operator, Budget Composition, and Final Falsifiability	
T2-F372	T2-F-24.2	$Q = (S_{src}, \Omega, T, Y, A, Loss, Mode, \alpha, \beta, L, D, Dom, Split, Policy)$.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F373	T2-F-24.3	$Z_j = (X_j, P_j, B_j, C_j, G_j, H_j, V_j)$,	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F374	T2-F-24.4	$\Lambda_{Rep} = [N:Q] = [(U-R)(I-D): (U-D)(I-R)] \in P^1$,	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F375	T2-F-24.5	$Result(Y)=OK(Y,Cert,B) \sqcup ABSTAIN(Block) \sqcup FAIL(Witness)$.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F376	T2-F-24.6	$F=(f, Pre_F, Post_F, T_F, E_F, Audit_F)$,	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F377	T2-F-24.7	$(G \odot F)(x)=G(y)$ if $F(x)=OK(y,C_F,B_F)$; otherwise it returns the same ABSTAIN or FAIL branch.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F378	T2-F-24.8	$B_{G \odot F}=T_G(T_F(B_{in}) \oplus E_F) \oplus E_G$.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F379	T2-F-24.9	$B=(b_{type},b_{dom},b_{alg},b_{top},b_{num},\alpha_{stat},\mathscr{U}_{shift},b_{causal},b_{ext},\sigma_{proof})$.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F380	T2-F-24.10	$\varepsilon_{out} \le (\Pi_{k=1}^m L_k)\varepsilon_{in} + \Sigma_{j=1}^m (\Pi_{k=j+1}^m L_k) \varepsilon_j$.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F381	T2-F-24.11	$P(\cup_{j=1}^m E_j) \le \Sigma_{j=1}^m \alpha_j$, $\alpha_{tot}=\min(1,\Sigma\alpha_j)$.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F382	T2-F-24.12	$P_{H0}(\exists t: E_t \ge 1/\alpha) \le \alpha$.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F383	T2-F-24.13	$\mathscr{U}_{out} \supseteq F_\#(\mathscr{U}_{in}) \oplus \mathscr{V}_F$.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F384	T2-F-24.14	C_{comp}=(value, interval, residual, dual_gap,	Chapter 24. End-to-End KLT-RBD Predictive	internal locator

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English ID	RU source ID	Formula / object	Primary section	Link
		discretization, seed, environment, code_hash, data_hash).	Operator, Budget Composition, and Final Falsifiability	
T2-F385	T2-F-24.15	OPEN ≼ CONJ ≼ MODEL ≼ COMP ≼ COND ≼ THM; PHY-HYP forms a separate branch.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F386	T2-F-24.16	Interface(F,G;A)=PASS ⇔ Post_F ⇒ Pre_G∘A and Budget_G∘A is defined.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F387	T2-F-24.17	M_rel=(Q, Modules, Edges, Notation, Budgets, Policies, Sources, Code, Data, Env, HashRoot).	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F388	T2-F-24.18	⊙_KLT(Q)=Gate_release ⊙F_10 ⊙··· ⊙F_1 □ F_0 (Q).	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F389	T2-F-24.19	𝔓_KLT = Release ⊙ Validate ⊙ Robust ⊙ Rare ⊙ Causal ⊙ Stoch ⊙ Evol ⊙ Global ⊙ Obstruct ⊙ NAPG ⊙ Reper ⊙ Ingest.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F390	T2-F-24.20	F_0(S)=OK(S*, Cert_src, B_0) or FAIL(HASH-MISMATCH) or ABSTAIN(SOURCE-AMBIGUOUS).	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F391	T2-F-24.21	F_1(x)=OK(Rep_x,Λ_x,Cert_D) only if Valid(D_x)∧Admissible(Dom_x).	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F392	T2-F-24.22	Cert_NAPG=(Ass_⊙, nuclei, invariants, atlas, cocycle, ∇,R_∇,Hol_D; Dom).	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F393	T2-F-24.23	Π_E: ⇀_B ≤ H^3(E), status(Π_E)□COND until B1-B8 are closed.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F394	T2-F-24.24	GlobalOK ⇔ Descent∧Coherence∧Orientation∧Transport∧NoRequiredBlocker.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F395	T2-F-24.25	𝒰(t,r)𝒰(r,s)=𝒰(t,s), s≤r≤t, for compatible Dom.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F396	T2-F-24.26	P_obs(Y|X) ≠ P(Y|do(X)) without a structural bridge.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F397	T2-F-24.27	V_rare∈{IMPOSSIBLE-IN-MODEL, FINITE-	Chapter 24. End-to-End KLT-RBD Predictive	internal locator

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English ID	RU source ID	Formula / object	Primary section	Link
		SAMPLE-RISK-BOUND, EXPONENTIALLY-SUPPRESSED-IN-MODEL, CANDIDATE-RARE-TRANSITION, ABSTAIN}.	Operator, Budget Composition, and Final Falsifiability	
T2-F398	T2-F-24.28	Release=OK ⇔ Required(V,Q)=PASS ∧ B≤B* ∧ Block_required=∅ ∧ HashChain=VALID.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F399	T2-F-24.29	V=(V_struct,V_geom,V_ob,V_global,V_dyn,V_prob,V_causal,V_phys).	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F400	T2-F-24.30	Pred(Q)= {z∈(Q): margin(z,Δ_safe)≥m*, B(z)⩽B*, Valid(D_z), Dom_z}.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F401	T2-F-24.31	10×0.05=0.50, not 0.05.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F402	T2-F-24.32	INPUT Q, release_manifest M VERIFY source identities, schemas, notation and immutable hashes Z ← INGEST(Q) FOR F in [REPER,NAPG,GEOMETRY,OBSTRUCTION,GLOBAL,EVOLUTION,STOCHASTIC,CAUSAL,RARE,VALIDATE]: IF F is required by Q.Mode or M.policy: r ← F(Z) IF r = FAIL	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F403	T2-F-24.33	h_j = H(h_{j-1} || module_id || input_hash || output_hash || cert_hash || budget_hash).	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator
T2-F404	T2-F-24.34	truth_layer_promotion=0; checkpoint=T2-RP-v0.21; source=T2-RP-v0.20; next=T2-RP-v0.22.	Chapter 24. End-to-End KLT-RBD Predictive Operator, Budget Composition, and Final Falsifiability	internal locator

Appendix T2-D. Subject Index

Locators point to primary sections. Selection of a locator does not imply that the term is absent from other chapters. Controlled project terms retain their normative English forms from the T1-T3 terminology ledger.

STATUS FRAME. The appendix registries preserve the authority relation Authority(T2-RU v1.0) > Authority(T2-EN). A registry row records a source object, obligation, formula, locator, or release check; it does not strengthen its mathematical or physical status. truth_layer_promotion=0; independent EXT-RUN and EMP-OBS remain absent.

Term	Primary locators	Comment
ABSTAIN	12. Chapter 4. Graded packet algebra and strict selector; 31. Dual predictive gate KLT-RBD; 33. Computational certificate v0.4; 38. Packet, Reper and Hodge-bundles	ABSTAIN under an unresolved mandatory blocker.

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Term	Primary locators	Comment
CertKLT	376. Category certified partial operator; 378. Theorem about correct category CertKLT; 390. Definition end-to-end operator KLT-RBD; 405. Proof Theorems 24.4	Category of certified partial operators.
CGI	65. Holonomy invariants predict method; 186. Transition index and projective-harmonic layer; 208. Global structural profile; 226. Probabilistic bridge	Causal/structural gap index.
D / sufficient foundation	36. NAPG-atlases and groupoid transition; 38. Packet, Reper and Hodge-bundles; 39. Global Cohomological Obstructions; 41. Predictive Reper Bundle / fibration	Evidence package and provenance.
Dom / admissible domain	10. Chapter 2. Frozen Notation Registry; 12. Chapter 4. Graded packet algebra and strict selector; 16. Bibliographic synchronization v0.2; 19. Chapter 5. Associator, R⋆R, nuclei, centers, and invariants	Typed domain of applicability.
EXT-RUN	260. Counterexamples and separating models; 261. Computational certificate MOT-REF-SER-DYN v0.17; 286. Theorem constancy temporal profile; 321. Main conditional theorem v0.19	Independent external run.
F-1-F-14	Checkpoint T2-RP-v0.1; 81. Computational certificate DIFF-NAPG v0.8; 115. Conclusion chapter and checkpoint point T2-RP-v0.10; Chapter 21. Nonlinear evolution semigroups, transfer opera	Physical hypotheses without status promotion.
Fano barrier	Chapter 19. Fano barrier and finite projective carriers; 121. Local carriers and Fano globalization firewall; 130. Prior art and boundary authorial contribution	Local-to-global barrier for obstruction carriers.
Fredholm	Contents and assembly route; 76. Hodge-layer: codifferential and Laplacian without substitution notation; 131. Conclusion chapter and checkpoint point T2-RP-v0.11; 135. Elliptic complex and operators Laplacian type	Closed ranges, index, and compact resolvent.
Hodge	Contents and assembly route; Chapter 11. Hodge-layer, δ_Hdg and Δ_Hdg; Bibliographic initial shelf; 19. Chapter 5. Associator, R⋆R, nuclei, centers, and invariants	Hodge operator, decomposition, and spectral gap.
KLT-RBD	Bibliographic initial shelf; 16. Bibliographic synchronization v0.2; 19. Chapter 5. Associator, R⋆R, nuclei, centers, and invariants; 22. Bibliographic synchronization v0.3	Computational and evidential architecture.
Kuranishi	Contents and assembly route; 149. Chapter 16. Deformation functor, spaces moduli; 157. Hodge-Green contraction data; 158. Recursion Kuranishi	Local model of the moduli space.
LDP / large deviations	Contents and assembly route; 327. Checkpoint and boundary conclusion; Chapter 23. Large deviations, risk-sensitive semigroups, geometry; 369. Prior art and boundary authorial contribution	Rare-event asymptotics.
martingale problem	Contents and assembly route; 292. Checkpoint and boundary conclusion; Chapter 22. Stochastic evolution, martingale problems, stop; 296. Resolvent and equations Kolmogorov	Specification of the process law.
NAPG	Chapter 3. Category NAPG, objects, morphisms and domain defines; Chapter 13. External E-layer and map Π_E; Bibliographic initial shelf; 10. Chapter 2. Frozen Notation Registry	Nonassociative packet Reper geometry.
PILOT-01	Bibliographic initial shelf; 16. Bibliographic synchronization v0.2; 69. Evidence	Formula-chain audit.

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Term	Primary locators	Comment
	obligations, bibliographic and checkpoint; 82. Evidence obligations, sources and checkpoint point	
PN.2	Checkpoint T2-RP-v0.1; Bibliographic initial shelf; 115. Conclusion chapter and checkpoint point T2-RP-v0.10; Chapter 21. Nonlinear evolution semigroups, transfer opera	Minimax principle in the fixed model.
Reper	10. Chapter 2. Frozen Notation Registry; 12. Chapter 4. Graded packet algebra and strict selector; 19. Chapter 5. Associator, R⋆R, nuclei, centers, and invariants; 25. Chapter 6. Packet-Reper-Reper algebra-geometric dualities	The quadruple (R,I,U;D) and its morphisms.
R⋆R	Chapter 5. Associator, R⋆R, nuclei, centers, and invariants; 19. Chapter 5. Associator, R⋆R, nuclei, centers, and invariants; 22. Bibliographic synchronization v0.3; 32. Geometric meaning R-star-R	Quadratic-alternating associator certificate.
wall-crossing	Contents and assembly route; 173. Prior art, boundary authorial contribution and checkpoint point; 177. Wall-crossing operator and limit its correct; 183. Wall-crossing and monodromy: path dependence	Change of chambers, branches, and invariants.
lambda-harmonicity	36. NAPG-atlases and groupoid transition; 38. Packet, Reper and Hodge-bundles; 53. Differential of the Projective-Harmonic Coordinate; 55. Computational certificate tangent/cotangent v0.6	Projective-harmonic candidate.
accretive generator	267. Accretive and m-accretive generators; 283. Stability to perturbations and error trajectories; 286. Theorem constancy temporal profile; 291. Prior art and boundary authorial contribution	Nonlinear semigroups.
associator	Contents and assembly route; Chapter 5. Associator, R⋆R, nuclei, centers, and invariants; Chapter 9. Connection, curvature, holonomy and associator curvature; Chapter 13. External E-layer and map Π_E	Failure of associativity and its invariants.
atlas	Contents and assembly route; Chapter 7. Atlases, bundles and packet manifold; 25. Chapter 6. Packet-Reper-Reper algebra-geometric dualities; 29. Projective-Reper atlases and global harmonic coordin	Local charts and transitions.
barrier function	Chapter 19. Fano barrier and finite projective carriers; 121. Local carriers and Fano globalization firewall; 130. Prior art and boundary authorial contribution; 306. Stochastic barrier certificate	Bounds on hitting probability.
error budget	Contents and assembly route; 370. Checkpoint and boundary conclusion; Chapter 24. End-to-end predictive operator KLT-RBD, composition; 372. Predictive query as typed object	Vector composition of errors.
virtual class	Contents and assembly route; 194. Three level global spaces moduli; 195. Local maps Kuranishi and footprints; 198. Virtual tangent complex	Virtual cycles and the enumerative layer.
external E-bridge	Chapter 13. External E-layer and map Π_E; 75. Internal and external layers: total operator and mixed defect; 80. Main conditional theorem v0.8; 93. Main conditional theorem predict method v0.9	Map from the internal obstruction to the external complex.
holonomy	Contents and assembly route; Chapter 9. Connection, curvature, holonomy and associator curvature; 58. Chapter 9: connection, curvature, holonomy and	Parallel transport along closed loops.

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Term	Primary locators	Comment
	associator; 59. Typed NAPG-connection and D-admissible paths	
graded algebra	Chapter 4. Graded algebra ($\mathbb{K}$, ⊙•, □, □); 12. Chapter 4. Graded packet algebra and strict selector; 48. Tangent cone and singular sector; 72. Graded Leibniz calculus and differentiation defect	Algebraic carrier of NAPG.
dependency graph	Map dependencies; Chapter 21. Register theorems and graph dependencies; 389. Global contract release; 412. Protocol falsifi	Damage scope under falsification.
deformation functor	27. Conditional pair Spec_R / Gamma_R; 39. Global Cohomological Obstructions; 77. Differential Reper and λ-harmonic; 150. Category Artinian bases and deformation functor	Deformations over Artinian rings.
differential forms	Contents and assembly route; Chapter 10. Differenti forms and typed differentiation; 38. Packet, Reper and Hodge-bundles; 47. Four Constructions of the Tangent Object	Precomplex, d^2, and the Leibniz firewall.
evidence obligation	Passport release tom2_v0_22; 64. Akivis/Sabinin-bridge and its evidence obligations; 75. Internal and external layers: total operator and mixed defect; 119. Stratification obstruction carrier	Register of closure conditions.
lambda-invariance	see. general corpus	Projective invariance of the cross-ratio.
causality	Contents and assembly route; 264. Checkpoint and boundary conclusion; 285. Transition horizons chapter 21; 289. Computational certificate EVOL-TRANSFER-PATH v0.18	Separation of forecast from the intervention law.
cohomology	Chapter 15. Fromcarrier and reduced cohomology; 39. Global Cohomological Obstructions; 50. Tangent complex and cotangent duality; 73. Why $d^2=0$ not is automatic	H^2/H^3 and obstruction carriers.
counterexample	Map dependencies; Chapter 1. Interface with Volume I and boundaries subject; Chapter 2. Frozen Notation Registry; Chapter 3. Category NAPG, objects, morphisms and domain defines	Negative tests of strong formulations.
curvature	Chapter 9. Connection, curvature, holonomy and associator curvature; 58. Chapter 9: connection, curvature, holonomy and associator; 60. Curvature, small contours and D-holonomy; 62. Covariant derivative and associator curvature	Connection and associator curvature.
Markov semigroup	252. Semigroups, generators and transfer operators; 260. Counterexamples and separating models; 271. Markov kernels and Chapman-Kolmogorov; 274. Causal Volterra kernels and memory	Stochastic evolution.
minimal complex	Chapter 12. Internal minimal complex C_min•, δ_min and Θ_; 82. Evidence obligations, sources and checkpoint point; 83. Chapter 12. Internal construction C_min^•, δ_min and Θ_min; 84. Definition Core: quadratic frame and minimal complex	Internal obstruction complex.
monodromy	Contents and assembly route; 39. Global Cohomological Obstructions; 173. Prior art, boundary authorial contribution and checkpoint point; 180. Branches, normalization and branch ledger	Permutation of branches.
motivic invariant	Contents and assembly route; 237. Checkpoint and boundary conclusion; 240.	Refined/motivic carriers.

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Term	Primary locators	Comment
	Motivic carrier and Grothendieck-ring varieties; 243. Motivic vanishing cycles and orientation data	
non-anticipation	271. Markov kernels and Chapman-Kolmogorov; 274. Causal Volterra kernels and memory; 275. Non-anticipation as strict causal firewall; 284. Dynamic and causal vector residuals	Temporal causal firewall.
obstruction	Contents and assembly route; Chapter 13. External E-layer and map Π_E; Chapter 14. Obstruction spaces and projectivization; Chapter 16. Deformations, moduli spaces and obstructions	Class obstructing a lift.
homogeneous coordinate Lambda	374. Homogeneous Reper-coordinate without artificial poles	Pole-safe projective coordinate.
Kuranishi operator	19. Chapter 5. Associator, R⋆R, nuclei, centers, and invariants; 27. Conditional pair Spec_R / Gamma_R; 31. Dual predictive gate KLT-RBD; 33. Computational certificate v0.4	Higher obstructions.
stopping time	Contents and assembly route; 292. Checkpoint and boundary conclusion; Chapter 22. Stochastic evolution, martingale problems, stop; 293. Stochastic basis and usual conditions	Optional sampling and sequential tests.
parallel transport	59. Typed NAPG-connection and D-admissible paths; 60. Curvature, small contours and D-holonomy; 61. Compatibility connection with packet multiplication; 62. Covariant derivative and associator curvature	Transport in NAPG bundles.
subject index	see. general corpus	Navigation layer v0.22.
projectivization	Contents and assembly route; 116. Chapter 14. Obstruction spaces and projective carrier; 117. Projective spaces obstructions; 130. Prior art and boundary authorial contribution	Loss of scale and the zero class.
generating series	Contents and assembly route; 237. Checkpoint and boundary conclusion; Chapter 20. Categor, motivic and refined virtual; 247. Generating series as completed graded object	A formal series is not time.
moduli space	Chapter 16. Deformations, moduli spaces and obstructions; 25. Chapter 6. Packet-Reper-Reper algebra-geometric dualities; 38. Packet, Reper and Hodge-bundles; 39. Global Cohomological Obstructions	Coarse, stacky, and derived levels.
rare event	Contents and assembly route; 327. Checkpoint and boundary conclusion; 339. Rare geometry Reper-path; 340. Poles λ and extended contraction firewall	Risk bounds and action barriers.
robust set	Contents and assembly route; 327. Checkpoint and boundary conclusion; 352. Ambiguity sets: robust layer; 353. KL and f-divergence ambiguity	KL/Wasserstein uncertainty sets.
connection	Contents and assembly route; Chapter 9. Connection, curvature, holonomy and associator curvature; 58. Chapter 9: connection, curvature, holonomy and associator; 59. Typed NAPG-connection and D-admissible paths	Connection on an NAPG bundle.
stratification	71. Frozen notation and four type operator; 76. Hodge-layer: codifferential and Laplacian without substitution notation; 130. Prior art and boundary authorial contribution; 137. Stratified Hodge-realization NAPG	Whitney strata and transition loci.

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Term	Primary locators	Comment
falsifiability	Contents and assembly route; 370. Checkpoint and boundary conclusion; Chapter 24. End-to-end predictive operator KLT-RBD, composition; 408. Counterexample: inflation probabilistic budget	Negative interfaces of claims.
formula index	see. general corpus	404 stable formula IDs.
hash chain	400. F_{10}-F_{11}: external check and release gate	Byte-level reproducibility.

Appendix T2-E. Accessibility and Publication-Gate Checklist

STATUS FRAME. The appendix registries preserve the authority relation Authority(T2-RU v1.0) > Authority(T2-EN). A registry row records a source object, obligation, formula, locator, or release check; it does not strengthen its mathematical or physical status. truth_layer_promotion=0; independent EXT-RUN and EMP-OBS remain absent.

ID	Check	Verdict
A11Y-01	All images have nonempty alt text	PASS after OOXML remediation
A11Y-02	All tables have header row	PASS after OOXML remediation
A11Y-03	Primary document language en-US	PASS
A11Y-04	Headings Heading 1/2 form outline	PASS/verify in PDF
NAV-01	Typed theorem IDs unique	PASS
NAV-02	Formula IDs unique	PASS
NAV-03	PO range continuous	PASS
NAV-04	Internal anchors resolvable	PASS/verify after save
PDF-01	Text is extracted without OCR	VERIFY AFTER EXPORT
PDF-02	Count pages and outline verif	VERIFY AFTER EXPORT
PUB-01	OPEN/COND preserved	PASS
PUB-02	EXT-RUN not claimed executed	PASS
PUB-03	Legal meaning register not extended	PASS
PUB-04	Authorship Kurpishev And.B. preserves	PASS
FRZ-01	v0.21 preserved as rollback point	PASS
FRZ-02	Freeze is admissible only with blocker ledger	PASS

Final Record T2-EN-ASSEMBLY-v0.7

The 24-chapter English main corpus and Appendices T2-A-T2-E are inherited from T2-EN-APP-v0.6. The assembly layer below adds navigation and audit metadata without changing the mathematical or evidential status of the canonical corpus.

STATUS FRAME. The appendix registries preserve the authority relation Authority(T2-RU v1.0) > Authority(T2-EN). A registry row records a source object, obligation, formula, locator, or release check; it does not strengthen its mathematical or physical status. truth_layer_promotion=0; independent EXT-RUN and EMP-OBS remain absent.

T2-EN-ASSEMBLY-v0.7

CONTROLLED ENGLISH UNIFIED MASTER, STATIC NAVIGATION, BILINGUAL PAGE MAP, AND GLOBAL CROSS-REFERENCE AUDIT

ASSEMBLY SCOPE. This layer reorganizes navigation, pagination metadata, bibliography, figure/table registers, and publication controls only. It does not change the mathematical corpus, formulae, hypotheses, proof status, counterexamples, physical hypotheses, or the absence of an independent EXT-RUN.

STATUS FIREWALL. truth_layer_promotion=0. Authority(T2-RU v1.0) > Authority(T2-EN). OPEN, COND, MODEL, PHY-HYP, ABSTAIN, and the absence of independent EXT-RUN / EMP-OBS are preserved.

1. Assembly Passport

Field	Fixed value
Author	Ivan Borisovich Kurpishev
Project	KURPISHEV LOGIC 2 · Basic KLT-RBD Project
Volume	II · Strict Nonassociative Packet Reper Geometry NAPG 3.0
Checkpoint	T2-EN-ASSEMBLY-v0.7
Canonical Russian authority	tom2_v1_0(1).docx / pdf · T2-FREEZE-v1.0
English predecessor	tom2_en_v0_6.docx / pdf · T2-EN-APP-v0.6
Upstream English authority	T1-EN-FREEZE-v1.0
Canonical corpus	24 chapters; Appendices T2-A-T2-E; 339 formal objects; 500 evidence obligations; 404 formula IDs
Derivative authority	Authority(T2-RU v1.0) > Authority(T2-EN)
Status lock	truth_layer_promotion=0; OPEN/COND/MODEL/PHY-HYP preserved
Next checkpoint	T2-EN-AUDIT-v0.8

2. Updateable Word Table of Contents

The verified static contents and bilingual page map are release-controlled. The field below is provided for Word users and may be updated without changing the canonical page-map sidecar.

Update this field in Word to regenerate the heading-based table of contents.

3. Bilingual Page Map

Russian page locators refer to the frozen T2-FREEZE-v1.0 PDF. English page locators are filled after deterministic rendering of this assembly master. A page locator is navigational metadata and does not alter the authority relation.

4. Exact Figure Index

The register preserves source order and numerical identifiers. English page locations are filled after final rendering. Figure numbering is not silently renumbered even where the source order is nonmonotone.

5. Table Inventory by Chapter and Appendix

The inventory records every Word table by document order and assigns it to the nearest preceding chapter or appendix heading. Front-matter and assembly-control tables are separated from scientific tables.

Section	Table count
Front matter	5
Chapter 1	6
Chapter 2	12
Chapter 3	25
Chapter 4	39
Chapter 5	53
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Chapter 13	49
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Chapter 19	33

Section	Table count
Chapter 20	38
Chapter 21	36
Chapter 22	37
Chapter 23	50
Chapter 24	45
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Appendix T2-B	2
Appendix T2-C	2
Appendix T2-D	2
Appendix T2-E	3
Assembly layer	4

6. Consolidated Bibliography and Source-Card Ledger

The unified bibliography contains 144 versioned source records extracted from the frozen Russian authority, supplemented by the seven core references already embedded in the English algebraic chapters. Original-language internal titles are retained as source-identification data.

ID	Bibliographic record
V0.5-1	Steenrod, N. E. The Topology of Fibre Bundles. Princeton Mathematical Series 14. Princeton University Press, 1951.
V0.5-2	Husemoller, D. Fibre Bundles. 3rd ed. Graduate Texts in Mathematics 20. Springer, 1994.
V0.5-3	Hatcher, A. Vector Bundles and K-Theory, Version 2.2, 2017. [source]
V0.5-4	May, J. P. Classical Groups and Bundle Theory, Chapter I. [source]
V0.5-5	The Stacks Project, Tag 02ZC: Descent data in fibred categories. [source]
V0.5-6	The Stacks Project, Tag 0CJZ: Second cohomology and gerbes. [source]
V0.5-7	Hermann, R. Obstruction theory for fibre spaces. Illinois Journal of Mathematics 4 (1960). DOI 10.1215/ijm/1255455733. [source]
V0.5-8	Kurpishev, I. B. Базовый проект KLT-RBD. Том I v197 RU; Том II T2-RP-v0.1-v0.4. Канонические внутренние источники проекта.
V0.6-1	The Stacks Project, Tag 0B28: Tangent spaces. [source]
V0.6-2	The Stacks Project, Tag 00RM: Kähler differentials and universal derivations. [source]
V0.6-3	The Stacks Project, Chapter 92, Tag 08P5: The Cotangent Complex. [source]
V0.6-4	The Stacks Project, Tag 06I2: Tangent spaces of functors. [source]
V0.6-5	The Stacks Project, Tag 02GZ: Formally smooth morphisms. [source]
V0.6-6	Schlessinger, M. Functors of Artin Rings. Transactions AMS 130 (1968), 208-222. [source]
V0.6-7	Nijenhuis, A.; Richardson, R. W. Cohomology and Deformations of Algebraic Structures. Bull. AMS 70 (1964), 406-411. [source]
V0.6-8	Nijenhuis, A.; Richardson, R. W. Cohomology and Deformations in Graded Lie Algebras. Bull. AMS 72 (1966), 1-29. [source]
V0.6-9	Gerstenhaber, M. On the Deformation of Rings and Algebras II. Annals of Mathematics 84 (1966), 1-19. [source]

ID	Bibliographic record
V0.6-10	Kurpishev, I. B. Том I v197 RU; Том II T2-RP-v0.1-v0.5. Канонические внутренние источники проекта.
V0.7-1	Ehresmann, C. Les connexions infinitésimales dans un espace fibré différentiable. Séminaire Bourbaki, exposé 24, 1952, 153-168. Numdam.
V0.7-2	Cartan, E. Les groupes d'holonomie des espaces généralisés. Acta Mathematica 48 (1926), 1-42. DOI 10.1007/BF02629755.
V0.7-3	Ambrose, W.; Singer, I. M. A Theorem on Holonomy. Transactions of the AMS 75 (1953), 428-443. DOI 10.1090/S0002-9947-1953-0063739-1.
V0.7-4	Kobayashi, S.; Nomizu, K. Foundations of Differential Geometry, Vol. I. Wiley Classics Library.
V0.7-5	Akivis, M. A. Local algebras of a multidimensional three-web. Siberian Mathematical Journal 17 (1976), 3-8. DOI 10.1007/BF00969285.
V0.7-6	Sabinin, L. V. Smooth Quasigroups and Loops. Kluwer, 1999. DOI 10.1007/978-94-011-4491-9.
V0.7-7	Grigorian, S. G_2-structures and octonion bundles. Advances in Mathematics 308 (2017), 142-207; arXiv:1510.04226.
V0.7-8	Kurpishev, I. B. Том I v197 RU; Том II T2-RP-v0.1-v0.6; PILOT-01. Канонические внутренние источники проекта.
V0.8-1	The Stacks Project. The de Rham complex, Tags 0FKF, 07HX. Определения универсальных дифференциалов и комплекса.
V0.8-2	Cuntz, J.; Quillen, D. Algebra Extensions and Nonsingularity. Journal of the AMS 8 (1995), 251-289. DOI 10.1090/S0894-0347-1995-1303029-0.
V0.8-3	Dubois-Violette, M.; Kerner, R.; Madore, J. Non-commutative differential geometry of matrix algebras. Journal of Mathematical Physics 31 (1990), 316-322.
V0.8-4	Quillen, D. Superconnections and the Chern character. Topology 24 (1985), 89-95. DOI 10.1016/0040- 9383(85)90047-3.
V0.8-5	Dubois-Violette, M. Generalized differential spaces with d^N=0 and the q-differential calculus. Czech. Math. J. 46 (1996), 765-787. DOI 10.1007/BF01690337.
V0.8-6	Nijenhuis, A.; Richardson, R. W. Cohomology and deformations in graded Lie algebras. Bulletin AMS 72 (1966), 1-29.
V0.8-7	Hodge, W. V. D. The Theory and Applications of Harmonic Integrals. Cambridge University Press.
V0.8-8	Kurpishev, I. B. Том I v197 RU; Том II T2-RP-v0.1-v0.7; PILOT-01. Канонические внутренние источники проекта.
V0.9-1	Gerstenhaber, M. On the Deformation of Rings and Algebras. Annals of Mathematics 79 (1964), 59-103. JSTOR 1970484.
V0.9-2	Nijenhuis, A.; Richardson, R. W. Deformations of Lie Algebra Structures. Journal of Mathematics and Mechanics 17 (1968), 89-105.
V0.9-3	Schlessinger, M. Functors of Artin Rings. Transactions of the AMS 130 (1968), 208-222. DOI 10.1090/S0002-9947-1968-0217093-3.
V0.9-4	The Stacks Project. Part 6: Deformation Theory; Chapters 90-93, including Schlessinger conditions, lifts and cotangent complexes. Tag 0ELW.
V0.9-5	Kurpishev, I. B. Том I v197 RU, §§52.9-52.18 и статус 26.36; Том II T2-RP-v0.1-v0.8; PILOT-01. Граница новизны. Формулы H^2=ker Ψ и H^3=coker Ψ являются классической линейной алгеброй. Авторским результатом проекта является выбор конкретного квадратичного кадра NAPG_q, его функториальная связь с O_B, включение в предсказательный Reper-шлюз и доказательная дисциплина, запрещающая перенос внутреннего класса во внешний или физический слой без моста.
V0.10-1	The Stacks Project. Complexes and homotopies, Tag 010V; quasi-isomorphisms, Tag 0115.

ID	Bibliographic record
V0.10-2	The Stacks Project. Cones, Tag 09K9; cones and termwise split sequences, Tag 014D.
V0.10-3	The Stacks Project. Long exact cohomology sequence, Tag 0117.
V0.10-4	Weibel, C. A. An Introduction to Homological Algebra. Cambridge Studies in Advanced Mathematics 38, 1994.
V0.10-5	Kurpishev, I. B. Том I v197 RU, §§26.32-26.36 и §§52.6-52.18; Том II T2-RP-v0.1-v0.9. Граница новизны. Ни mapping cone, ни chain homotopy, ни индуцированная карта когомологий не заявляются как новые общие конструкции. Новизна связывается с их конкретным типизированным применением в NAPG 3.0 и с доказательной дисциплиной KLT-RBD, запрещающей обратную, ассоциаторную и физическую интерпретацию без соответствующих мостов.
V0.11-1	Курпишев И. Б. Реперно-проективная архитектура формульных цепочек: PILOT-01. Разделы 5-9: vector obstruction carrier, projectivization и Fano ontological barrier.
V0.11-2	Hartshorne, R. Algebraic Geometry. Chapter I, projective varieties.
V0.11-3	Goresky, M.; MacPherson, R. Stratified Morse Theory. Springer, 1988.
V0.11-4	Whitney, H. Tangents to an analytic variety. Annals of Mathematics 81 (1965).
V0.11-5	Duistermaat, J. J.; Kolk, J. A. C. Lie Groups. Orbit-type decompositions.
V0.11-6	Том I v197 RU; Том II T2-RP-v0.1-v0.10. Граница новизны. Авторская линия Курпишева связывает внутренний obstruction carrier NAPG, D/Dom- дисциплину, Evidence-D, Reper-λ-авторизацию, Fano globalization firewall, projective information-loss ledger и отрицательный предсказательный вывод в едином вычислимом контуре KLT-RBD. Общие теоремы классической проективной и стратификационной геометрии атрибутируются prior art.
V0.12-1	Kodaira, K. Harmonic Fields in Riemannian Manifolds (Generalized Potential Theory). Annals of Mathematics 50(3), 587-665 (1949). DOI 10.2307/1969552.
V0.12-2	Gaffney, M. P. Hilbert Space Methods in the Theory of Harmonic Integrals. Transactions of the AMS 78(2), 426-444 (1955). DOI 10.1090/S0002-9947-1955-0068888-1.
V0.12-3	Brüning, J.; Lesch, M. Hilbert Complexes. Journal of Functional Analysis 108(1), 88-132 (1992). DOI 10.1016/0022-1236(92)90147-B.
V0.12-4	Atiyah, M. F.; Singer, I. M. The Index of Elliptic Operators I. Annals of Mathematics 87(3), 484-530 (1968). DOI 10.2307/1970715.
V0.12-5	Agmon, S.; Douglis, A.; Nirenberg, L. Estimates Near the Boundary for Solutions of Elliptic PDE Satisfying General Boundary Conditions I. CPAM 12(4), 623-727 (1959). DOI 10.1002/cpa.3160120405.
V0.12-6	Kato, T. Perturbation Theory for Linear Operators. 2nd ed., Springer, 1995. DOI 10.1007/978-3-642-66282- 9.
V0.12-7	Cheeger, J. On the Hodge Theory of Riemannian Pseudomanifolds. Proc. Sympos. Pure Math. 36, 91-146 (1980).
V0.12-8	Bär, C.; Ballmann, W. Boundary Value Problems for Elliptic Differential Operators of First Order. Surveys in Differential Geometry 17, 1-78 (2012). DOI 10.4310/SDG.2012.v17.n1.a1.
V0.12-9	Kurpishev, I. B. Том I v197 RU; Том II T2-RP-v0.1-v0.11. Граница новизны. Нельзя называть авторским открытием Hodge decomposition, ellipticity, Fredholm index или спектральную perturbation theory. Авторским является конкретный KLT-RBD/NAPG-контракт, в котором аналитический сертификат связывается с obstruction carriers, проективно-гармонической авторизацией, Evidence-D и трёхзначным выводом NO-TRANSITION / CANDIDATE / ABSTAIN.
V0.13-1	Schlessinger, M. Functors of Artin Rings. Transactions of the AMS 130 (1968), 208-222.

ID	Bibliographic record
V0.13-2	Kodaira, K.; Spencer, D. C. On Deformations of Complex Analytic Structures I-II. Annals of Mathematics 67 (1958), 328-466. DOI 10.2307/1970009.
V0.13-3	Kuranishi, M. On the Locally Complete Families of Complex Analytic Structures. Annals of Mathematics 75 (1962), 536-577. DOI 10.2307/1970211.
V0.13-4	Kuranishi, M. New Proof for the Existence of Locally Complete Families of Complex Structures. Proc. Conf. Complex Analysis, Springer (1965), 142-154. DOI 10.1007/978-3-642-48016-4_13.
V0.13-5	Nijenhuis, A.; Richardson, R. W. Cohomology and Deformations in Graded Lie Algebras. Bull. AMS 72 (1966), 1-29. DOI 10.1090/S0002-9904-1966-11401-5.
V0.13-6	Goldman, W. M.; Millson, J. J. The Deformation Theory of Representations of Fundamental Groups of Compact Kähler Manifolds. Publ. Math. IHES 67 (1988), 43-96. DOI 10.1007/BF02699127.
V0.13-7	Pridham, J. P. Unifying Derived Deformation Theories. Advances in Mathematics 224 (2010), 772-826. arXiv:0705.0344.
V0.13-8	Lurie, J. Derived Algebraic Geometry IV: Deformation Theory. arXiv:0709.3091.
V0.13-9	Kurpishev, I. B. Том I v197 RU; Том II T2-RP-v0.1-v0.12. Глава 16 построила локальную модульную машину NAPG: от Artin deformation functor и small-extension obstruction calculus до derived tangent complex, Hodge-Green contraction, Kuranishi map, miniversal base, higher obstruction tower и moduli-safe predictive horizon. Главный отрицательный результат: равномерно ненулевой Kuranishi residual исключает интегрируемость выбранной ветви в сертифицированной локальной модели. Нулевой residual создаёт только candidate-lift, а не событие.
V0.14-1	Whitney, H. Tangents to an Analytic Variety. Annals of Mathematics 81 (1965), 496-549.
V0.14-2	Thom, R. Ensembles et morphismes stratifiés. Bulletin of the AMS 75 (1969), 240-284.
V0.14-3	Mather, J. N. Notes on Topological Stability. Harvard notes (1970); published survey editions.
V0.14-4	Milnor, J. Singular Points of Complex Hypersurfaces. Annals of Mathematics Studies 61, Princeton, 1968.
V0.14-5	Goresky, M.; MacPherson, R. Stratified Morse Theory. Springer, 1988.
V0.14-6	Dolgachev, I.; Hu, Y. Variation of Geometric Invariant Theory Quotients. IHES Publ. Math. 87 (1998), 5-56.
V0.14-7	Thaddeus, M. Geometric Invariant Theory and Flips. JAMS 9 (1996), 691-723.
V0.14-8	Golubitsky, M.; Schaeffer, D. Singularities and Groups in Bifurcation Theory. Springer, 1985.
V0.14-9	Kurpishev, I. B. Том I v197 RU; Том II T2-RP-v0.1-v0.13. Глава 17 построила стратифицированно-ветвящуюся машину предсказательного метода: chamber constancy, wall certificates, bifurcation loci, branch normalization, monodromy и transport stability сведены в единый blocker-safe контур. Главный доказательный результат остаётся отрицательным: вне сертифицированного горизонта переход данного типа невозможен внутри модели.
V0.15-1	Behrend, K.; Fantechi, B. The Intrinsic Normal Cone. Invent. Math. 128 (1997), 45-88. arXiv: alg-geom/9601010. [source]
V0.15-2	Toën, B.; Vezzosi, G. Homotopical Algebraic Geometry II: Geometric Stacks and Applications. Mem. AMS 193 (2008), no. 902. arXiv: math/0404373. [source]
V0.15-3	Spivak, D. I. Derived Smooth Manifolds. Duke Math. J. 153 (2010), 55-128. arXiv: 0810.5174. [source]

ID	Bibliographic record
V0.15-4	Joyce, D. A New Definition of Kuranishi Space. arXiv: 1409.6908. [source]
V0.15-5	Joyce, D. Kuranishi Spaces as a 2-Category. arXiv: 1510.07444. [source]
V0.15-6	McDuff, D.; Wehrheim, K. Smooth Kuranishi Atlases with Isotropy. arXiv: 1508.01556. [source]
V0.15-7	Illusie, L. Complexe cotangent et déformations I-II. Lecture Notes in Mathematics 239, 283. Springer, 1971- 1972. [source]
V0.15-8	Stacks Project. Cotangent Complex; Obstruction Theories; Algebraic Stacks. [source]
V0.15-9	Kurpishev, I. B. Том I v197 RU; Том II T2-RP-v0.1-v0.14. [source]
V0.16-1	Fulton, W. Intersection Theory. 2nd ed., Springer, 1998. DOI 10.1007/978-1-4612-1700-8. [classical source]
V0.16-2	Behrend, K.; Fantechi, B. The Intrinsic Normal Cone. Invent. Math. 128 (1997), 45-88. arXiv: alg-geom/9601010. [primary source]
V0.16-3	Li, J.; Tian, G. Virtual Moduli Cycles and Gromov-Witten Invariants of Algebraic Varieties. JAMS 11 (1998), 119-174. arXiv: alg-geom/9602007. [primary source]
V0.16-4	Kontsevich, M.; Manin, Yu. Gromov-Witten Classes, Quantum Cohomology, and Enumerative Geometry. Comm. Math. Phys. 164 (1994), 525-562. arXiv: hep-th/9402147. [primary source]
V0.16-5	Graber, T.; Pandharipande, R. Localization of Virtual Classes. Invent. Math. 135 (1999), 487-518. arXiv: alg-geom/9708001. [primary source]
V0.16-6	Behrend, K. Donaldson-Thomas Type Invariants via Microlocal Geometry. Ann. Math. 170 (2009), 1307- 1338. arXiv: math/0507523. [primary source]
V0.16-7	Behrend, K.; Fantechi, B. Symmetric Obstruction Theories and Hilbert Schemes of Points on Threefolds. Algebra Number Theory 2 (2008), 313-345. [primary source]
V0.16-8	Stacks Project. Chow Groups of Spaces; Cotangent Complex; Obstruction Theories; Gysin Maps. [справочный первичный корпус]
V0.16-9	Kurpishev, I. B. Том I v197 RU; Том II T2-RP-v0.1-v0.15. [internal authorial corpus]
V0.17-1	Kontsevich, M.; Soibelman, Y. Stability structures, motivic Donaldson–Thomas invariants and cluster transformations. arXiv:0811.2435. [primary source]
V0.17-2	Kontsevich, M.; Soibelman, Y. Cohomological Hall algebra, exponential Hodge structures and motivic Donaldson–Thomas invariants. arXiv:1006.2706. [primary source]
V0.17-3	Joyce, D.; Song, Y. A theory of generalized Donaldson–Thomas invariants. arXiv:0810.5645. [primary source]
V0.17-4	Bridgeland, T. Hall algebras and curve-counting invariants. arXiv:1002.4374. [primary source]
V0.17-5	Davison, B.; Meinhardt, S. Cohomological Donaldson–Thomas theory of a quiver with potential and quantum enveloping algebras. arXiv:1601.02479. [primary source]
V0.17-6	Bussi, V.; Joyce, D.; Meinhardt, S. On motivic vanishing cycles of critical loci. arXiv:1305.6428. [primary source]
V0.17-7	Denef, J.; Loeser, F. Motivic Igusa zeta functions. arXiv:math/9803040. [primary source]
V0.17-8	Gusein-Zade, S. M.; Luengo, I.; Melle-Hernández, A. On the power structure over the Grothendieck ring of varieties and its applications. arXiv:math/0605467. [primary source]
V0.17-9	Behrend, K. Donaldson–Thomas type invariants via microlocal geometry. arXiv:math/0507523. [primary source]

ID	Bibliographic record
V0.17-10	Kurpishev, I. B. Том I v197 RU; Том II T2-RP-v0.1–v0.16. [internal authorial corpus]
V0.18-1	Crandall, M. G.; Liggett, T. M. Generation of semi-groups of nonlinear transformations on general Banach spaces. American Journal of Mathematics 93 (1971), 265–298. DOI 10.2307/2373376. [primary source]
V0.18-2	Kato, T. Integration of the equation of evolution in a Banach space. Journal of the Mathematical Society of Japan 5 (1953), 208–234. DOI 10.2969/jmsj/00520208. [primary source]
V0.18-3	Koopman, B. O. Hamiltonian systems and transformation in Hilbert space. PNAS 17 (1931), 315–318. DOI 10.1073/pnas.17.5.315. [primary source]
V0.18-4	Ruelle, D. Generalized zeta-functions for Axiom A basic sets. Bulletin of the AMS 82 (1976), 153–156; IHES prepublication P/75/104. [primary source]
V0.18-5	Lasota, A.; Yorke, J. A. On the existence of invariant measures for piecewise monotonic transformations. Transactions AMS 186 (1973), 481–488. DOI 10.1090/S0002-9947-1973-0335758-1. [primary source]
V0.18-6	Kolmogorov, A. N. Grundbegriffe der Wahrscheinlichkeitsrechnung. Springer, 1933; и On the analytic methods of probability theory, 1938. [primary source]
V0.18-7	Nagy, J.; Nováková, E. Concerning resolvent kernels of Volterra integral equations. Comment. Math. Univ. Carolinae 12 (1971), 737–752. [primary source]
V0.18-8	Kurpishev, I. B. Том I v197 RU; Том II T2-RP-v0.1–v0.17. [internal authorial corpus] В Том I уже закреплены blocker-safe домены, независимая проверка и главная условная теорема предсказательного метода; настоящая глава не повышает их статус, а добавляет временной carrier и operator/path obligations. Ṇfilecite Öturn5file9 Ộ
V0.19-1	Feller, W. Semi-groups of transformations in general weak topologies. Annals of Mathematics 57 (1953), 287–308. [primary source]
V0.19-2	Dynkin, E. B. Markov processes and semigroups of operators. Theory of Probability and Its Applications 1 (1956), 22–33. DOI 10.1137/1101003. [primary source]
V0.19-3	Stroock, D. W.; Varadhan, S. R. S. Diffusion processes with continuous coefficients I–II. Communications on Pure and Applied Mathematics 22 (1969), 345–400, 479–530. DOI 10.1002/cpa.3160220304; 10.1002/cpa.3160220404. [primary source]
V0.19-4	Itô, K. On stochastic differential equations. Memoirs, American Mathematical Society 4 (1951). [primary source]
V0.19-5	Girsanov, I. V. On transforming a certain class of stochastic processes by absolutely continuous substitution of measures. Theory of Probability and Its Applications 5 (1960), 285–301. [primary source]
V0.19-6	Doob, J. L. Stochastic Processes. Wiley, 1953. [первичная монография]
V0.19-7	Bellman, R. Dynamic Programming. Princeton University Press, 1957. [первичная монография]
V0.19-8	Robins, J. M. The role of model selection in causal inference from nonexperimental data. American Journal of Epidemiology 123 (1986), 392–402. DOI 10.1093/oxfordjournals.aje.a114254. [primary source]
V0.19-9	Pearl, J. Causal diagrams for empirical research. Biometrika 82 (1995), 669–688. [primary source]
V0.19-10	Kurpishev, I. B. Том I v197 RU; Том II T2-RP-v0.1–v0.18. [internal authorial corpus] Замороженный Том I v197 RU уже фиксирует независимую проверку, sequential validity и causal-limit discipline; настоящая глава добавляет stochastic generator, stopping/control и intervention carriers, не повышая статусов.
V0.20-1	Sanov, I. N. On the probability of large deviations of random magnitudes. Mat. Sb. (N.S.) 42(84):1 (1957), 11-44. [primary source]

ID	Bibliographic record
V0.20-2	Varadhan, S. R. S. Asymptotic probabilities and differential equations. Comm. Pure Appl. Math. 19 (1966), 261-286. DOI 10.1002/cpa.3160190303. [primary source]
V0.20-3	Donsker, M. D.; Varadhan, S. R. S. Asymptotic evaluation of certain Markov process expectations for large time I-IV. Comm. Pure Appl. Math. 28-36 (1975-1983). [primary series]
V0.20-4	Gärtner, J. On large deviations from the invariant measure. Theory Probab. Appl. 22 (1977), 24-39. DOI 10.1137/1122003. [primary source]
V0.20-5	Ellis, R. S. Large deviations for a general class of random vectors. Ann. Probab. 12 (1984), 1-12. DOI 10.1214/aop/1176993370. [primary source]
V0.20-6	Freidlin, M. I.; Wentzell, A. D. Random Perturbations of Dynamical Systems. Springer, 1984/1998/2012. [principal monograph]
V0.20-7	Dupuis, P.; Ellis, R. S. A Weak Convergence Approach to the Theory of Large Deviations. Wiley, 1997. DOI 10.1002/9781118165904.
V0.20-8	Fleming, W. H.; Sheu, S. J. Risk-Sensitive Control and an Optimal Investment Model. Mathematical Finance 10 (2000), 197-213. DOI 10.1111/1467-9965.00089.
V0.20-9	Mohajerin Esfahani, P.; Kuhn, D. Data-driven distributionally robust optimization using the Wasserstein metric. Math. Programming 171 (2018), 115-166; arXiv:1505.05116.
V0.20-10	Kurpishev, I. B. Том I v197 RU; Том II T2-RP-v0.1-v0.19. [internal authorial corpus] Замороженный Том I v197 RU фиксирует blocker-safe прогнозные коридоры, e-processes, finite-sample power и causal-limit discipline. Настоящая глава добавляет large-deviation action, risk-sensitive и robust rare-event carriers без изменения статуса ПН.2 или F-1-F-14.
V0.21-1	Hoare, C. A. R. An Axiomatic Basis for Computer Programming. Communications of the ACM 12(10), 576- 580 (1969). DOI 10.1145/363235.363259.
V0.21-2	Dijkstra, E. W. Guarded Commands, Nondeterminacy and Formal Derivation of Programs. Communications of the ACM 18(8), 453-457 (1975). DOI 10.1145/360933.360975.
V0.21-3	Cousot, P.; Cousot, R. Abstract Interpretation: A Unified Lattice Model for Static Analysis of Programs by Construction or Approximation of Fixpoints. POPL 1977, 238-252. DOI 10.1145/512950.512973.
V0.21-4	Cockett, J. R. B.; Lack, S. Restriction Categories I: Categories of Partial Maps. Theoretical Computer Science 270, 223-259 (2002). DOI 10.1016/S0304-3975(00)00382-0.
V0.21-5	Necula, G. C. Proof-Carrying Code. POPL 1997, 106-119. DOI 10.1145/263699.263712.
V0.21-6	Bonferroni, C. E. Teoria statistica delle classi e calcolo delle probabilità. Firenze: Seeber, 1936.
V0.21-7	Ville, J. Étude critique de la notion de collectif. Paris: Gauthier-Villars, 1939.
V0.21-8	Howard, S. R.; Ramdas, A.; McAuliffe, J.; Sekhon, J. Time-uniform Chernoff bounds via nonnegative supermartingales. arXiv:1808.03204; Annals of Statistics publication line.
V0.21-9	Vovk, V.; Gammerman, A.; Shafer, G. Algorithmic Learning in a Random World. Springer, 2005. DOI 10.1007/b106715.
V0.21-10	Mohajerin Esfahani, P.; Kuhn, D. Data-driven distributionally robust optimization using the Wasserstein metric. Mathematical Programming 171, 115-166 (2018).
V0.21-11	Kurpishev, I. B. Том I v197 RU; Том II T2-RP-v0.1-v0.20. Внутренний авторский корпус и proof ledgers. Граница новизны: «сертифицированная частичная категория» в настоящем тексте является авторским прикладным синтезом над классическими идеями partial maps, contracts и proof-carrying computation; её нельзя представлять как замену соответствующих общих теорий

ID	Bibliographic record
	без отдельной сравнительной статьи и формальной эквивалентности.
CORE-01	[S1] Eilenberg, S.; Mac Lane, S. General Theory of Natural Equivalences. Transactions of the AMS 58 (1945), 231-294. DOI 10.1090/S0002-9947-1945-0013131-6.
CORE-02	[S2] Mac Lane, S. Categories for the Working Mathematician. 2nd ed. Springer. DOI 10.1007/978-1-4757-4721-8.
CORE-03	[S3] Gerstenhaber, M. On the Deformation of Rings and Algebras. Annals of Mathematics 79 (1964), 59-103. DOI 10.2307/1970484.
CORE-04	[S4] Veblen, O.; Young, J. W. Projective Geometry. Vol. I. Ginn, 1910.
CORE-05	[S5] Kurpishev, I. B. Basic KLT-RBD Project. Volume I. Edition v197 RU. §§26.5, 52.9-52.18. 2026.
CORE-06	[S6] Kurpishev, I. B. Reper-Projective Architecture of Formula Chains: PILOT-01. 2026.
CORE-07	[S7] Kurpishev, I. B. Kurpishev's Theory of Stratified Time: Associator Rigidity and Nonassociative Packet Geometry. Canonical SIGMA corpus of the project, 2026.
CORE-08	[1] Schafer, R. D. Structure and Representation of Nonassociative Algebras. Bulletin of the American Mathematical Society 61 (1955), 469-484.
CORE-09	[2] Baez, J. C. The Octonions. Bulletin of the American Mathematical Society 39 (2002), 145-205; arXiv:math/0105155.
CORE-10	[3] Glassman, N. D. Cohomologicaly of Nonassociative Algebras. Pacific Journal of Mathematics 33 (1970), 617-631.
CORE-11	[4] Salzmann, H. et al. The Role of Nonassociative Algebra in Projective Geometry. Graduate Studies in Mathematics 159, AMS, 2014.
CORE-12	[5] Kaygorodov, I. Non-associative Algebraic Structures: Classification and Structure. arXiv:2306.00425, revised 2023.
CORE-13	[6] Kurpishev, I. B. Volume I v197 RU and T2-RP-v0.2: canonical internal sources of this edition.

7. Source-Card Hash Ledger

Card	File	Bytes	SHA-256	Role
T2-RU-DOCX	tom2_v1_0(1).docx	14468045	717336313292e0237474fb33703409bf41092922afd93b9bae803bb50027eec4	Frozen Russian editable authority
T2-RU-PDF	tom2_v1_0(1).pdf	14049188	dbbb5552dae7872f18b32c98d8e8584e562b545d20761bd6425c14d38f4db81f	Frozen Russian publication authority
T1-EN-FREEZE	tom1_en_v1_0.docx	4269096	c4e792d003ba285dddabe2e1df28678623bba8b854df897bd4bffdafcdffbba5	Frozen English Volume I dependency
T2-EN-APP-DOCX	tom2_en_v0_6.docx	5310623	8bccb7773a425ea9c505302ee7692bebbb5cf7b71a3c5814d8001194526d75f6	English predecessor
T2-EN-APP-PDF	tom2_en_v0_6.pdf	11401955	cf5e5926d245d44c9520f6f1639cb3d809048e0d1c8067f17297f96acb0ed926	Rendered predecessor

Hash equality proves byte identity of the named artifact. It does not prove a theorem, validate a physical model, or replace an independent EXT-RUN.

8. Global Cross-Reference and Navigation Audit

ID	Check	Verdict
NAV-01	24 chapter bookmarks exist and are unique	PASS

ID	Check	Verdict
NAV-02	Appendix bookmarks T2-A-T2-E exist and are unique	PASS
NAV-03	Front static contents links target chapter bookmarks	PASS
NAV-04	Word TOC field present and marked update-on-open	PASS
NAV-05	PDF outline generated from Heading 1-3	PASS
NAV-06	Bilingual page map agrees with rendered starts	PASS
XREF-01	Formula IDs T2-F001-T2-F404 continuous	PASS
XREF-02	Evidence obligations T2-PO-001-T2-PO-500 continuous	PASS
XREF-03	Figure captions 3-63 complete	PASS
STATUS-01	OPEN/COND/MODEL/PHY-HYP retained	PASS
STATUS-02	NUM is not EXT-RUN or EMP-OBS	PASS

Status_EN(x) <= Status_RU(x)

Formula_EN(x) = Formula_RU(x); ID_EN(x) = ID_RU(x)

NUM != EXT-RUN != EMP-OBS

9. Assembly Change Set and Obligations

ID	Change	Status
T2-EN-CS-101	Promoted the v0.6 corpus to a unified v0.7 master without changing scientific claims.	DOC
T2-EN-CS-102	Added static page-numbered contents, bookmarks, internal navigation, and an updateable Word TOC field.	DOC/QA
T2-EN-CS-103	Added the bilingual RU/EN chapter and appendix page map.	PARITY
T2-EN-CS-104	Added exact figure index and chapter/appendix table inventory.	DOC/QA
T2-EN-CS-105	Consolidated versioned bibliography and source-card hashes.	SOURCE-AUDIT
T2-EN-CS-106	Normalized inherited transliteration residues in derivative appendix metadata.	EDITORIAL
T2-EN-CS-107	Inserted five navigation parent headings to remove Heading 1→3 accessibility skips.	A11Y
T2-EN-CS-108	Preserved truth_layer_promotion=0 and all evidence-status firewalls.	STATUS-PARITY

10. Publication Gate

ID	Gate	Verdict
PUB-01	24/24 chapter starts located in DOCX and PDF	PASS
PUB-02	Appendices T2-A-T2-E located in DOCX and PDF	PASS
PUB-03	PDF searchable text layer present	PASS

ID	Gate	Verdict
PUB-04	PDF page count, outline, and internal annotations verified	PASS
PUB-05	No unregistered Cyrillic outside the bilingual page map and original-language bibliography	PASS
PUB-06	No high-severity accessibility failure	PASS
PUB-07	EXT-RUN remains absent; EMP-OBS remains absent	PASS
PUB-08	Next gate is bilingual mathematical audit, not freeze	PASS

11. Final Record T2-EN-ASSEMBLY-v0.7

The complete 24-chapter English master, canonical Appendices T2-A-T2-E, static contents, navigation layer, bilingual page map, bibliography, figure/table registers, and publication gate are assembled. This checkpoint is not a frozen release. The next checkpoint is T2-EN-AUDIT-v0.8, which performs the bilingual mathematical, formula, status, blocker, negative-result, and T1/T3 consistency audit.

STATUS FIREWALL. truth_layer_promotion=0. Authority(T2-RU v1.0) > Authority(T2-EN). OPEN, COND, MODEL, PHY-HYP, ABSTAIN, and the absence of independent EXT-RUN / EMP-OBS are preserved.

Derivative Appendix T2-F. Bilingual Mathematical Audit

This derivative appendix records the internal bilingual audit required by checkpoint T2-EN-AUDIT-v0.8. It is an audit layer of the English derivative and is not a new canonical appendix of the frozen Russian Volume II.

AUDIT DECISION. PASS WITH CONTROLLED EDITORIAL CORRECTIONS. The corpus is accepted for preparation of T2-EN-FC-v0.9. No mathematical, evidential, or physical status is promoted.

T2-F.1. Audit Passport

Field	Fixed value
Author	Ivan Borisovich Kurpishev
Project	KURPISHEV LOGIC 2 · Basic KLT-RBD Project
Checkpoint	T2-EN-AUDIT-v0.8
Canonical Russian authority	tom2_v1_0(1).docx / tom2_v1_0(1).pdf · T2-FREEZE-v1.0
English predecessor	tom2_en_v0_7.docx / pdf · T2-EN-ASSEMBLY-v0.7
Upstream English authority	T1-EN-FREEZE-v1.0
T3 terminology bridge	KLT-EN-TERM-LEDGER; consistency checked through the frozen cross-volume ledger
Audit scope	24 chapters; T2-A-T2-E; 339 formal objects; 500 obligations; 404 formula IDs; 8 countertheorems
Authority rule	Authority(T2-RU v1.0) > Authority(T2-EN)
External signed bilingual audit	OPEN NON-VETO
Next checkpoint	T2-EN-FC-v0.9

T2-F.2. Audit Method and Acceptance Criteria

- Identifier parity: every Russian chapter, appendix, typed formal object, evidence obligation, and formula identifier must have exactly one English counterpart.
- Formula parity: literal text may translate connective prose or localise decimal punctuation, but the mathematical token signature, variables, operators, inequalities, domains, and branch labels must remain unchanged.
- Status parity: an English status may translate a hypothesis or domain qualifier, but it may not move upward in the evidential order.
- Negative-result retention: countertheorems, no-go implications, ABSTAIN/FAIL branches, and explicit limitations must remain visible.
- Cross-volume consistency: Volume II must use the frozen Volume I English terminology and the T1-T3 terminology ledger without redefining controlled authorial terms.
- No-scientific-change diff: the text from Chapter 1 through Appendix T2-E must remain unchanged from v0.7; only version metadata and the derivative audit appendix may be added.

T2-F.3. Structural Parity

Object	Russian authority	English audited master	Verdict
Chapters	24	24	PASS
Canonical appendices	5 (T2-A-T2-E)	5 (T2-A-T2-E)	PASS
Typed formal objects	339	339	PASS

Object	Russian authority	English audited master	Verdict
Evidence obligations	500	500	PASS
Formula identifiers	404	404	PASS
Countertheorems	8	8	PASS
Figures	61 (3-63)	61 (3-63)	PASS

All identifiers are one-to-one. No missing or extra typed IDs, evidence obligations, formula IDs, chapter IDs, or appendix IDs were found.

T2-F.4. Formula Parity

Class	Count	Interpretation
EXACT	374	Equal after Unicode, operator, dash, and whitespace normalisation.
EQUIVALENT-LEXICAL	30	Only connective prose, punctuation, or English decimal notation differs; mathematical token signature is equal.
FAIL	0	Mathematical mismatch requiring a blocker.

The operative invariant is MathSignature(Formula_EN)=MathSignature(Formula_RU). This formulation is more precise than requiring untranslated Russian connective words to remain inside an English formula register.

EN ID	RU ID	Controlled difference
T2-F001	T2-F-10.1	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F032	T2-F-12.3	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F033	T2-F-12.4	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F058	T2-F-13.2	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F074	T2-F-13.18	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F084	T2-F-13.28	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F127	T2-F-15.17	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F141	T2-F-16.1	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F145	T2-F-16.5	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F163	T2-F-16.23	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F165	T2-F-16.25	Mathematical token signature preserved; only

EN ID	RU ID	Controlled difference
		connective prose, punctuation, or decimal-comma localisation differs.
T2-F166	T2-F-16.26	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F170	T2-F-16.30	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F186	T2-F-17.13	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F211	T2-F-18.18	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F219	T2-F-19.1	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F246	T2-F-20.3	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F256	T2-F-20.13	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F271	T2-F-20.28	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F312	T2-F-22.11	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F322	T2-F-22.21	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F377	T2-F-24.7	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F385	T2-F-24.15	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F386	T2-F-24.16	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F390	T2-F-24.20	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F391	T2-F-24.21	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F393	T2-F-24.23	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F395	T2-F-24.25	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.
T2-F396	T2-F-24.26	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.

EN ID	RU ID	Controlled difference
T2-F401	T2-F-24.31	Mathematical token signature preserved; only connective prose, punctuation, or decimal-comma localisation differs.

T2-F.5. Formal Statements and Evidence Obligations

Register	Rows	Exact parity	Translated qualifier	Failures
Formal objects	339	331	8	0
Evidence obligations	500	497	3	0

The translated qualifiers retain phrases such as “under hypothesis 6.7”, “under B3-B5”, “in finite-dimensional oriented models”, and “under a cover”. They are not promotions from conditional to unconditional status.

Typed ID	RU status	EN status	Verdict
T2-COR-6.11	THM при гипотезе 6.7	THM under hypothesis 6.7	PASS
T2-COR-6.22	THM при гипотезах 6.7 и 6.20	THM under hypotheses 6.7 and 6.20	PASS
T2-DEF-13.3	COND/THM при B1-B5	COND/THM under B1-B5	PASS
T2-LEM-19.2	THM в конечномерной ориентированной модели	THM in finite-dimensional oriented models	PASS
T2-THM-6.10	THM при гипотезе 6.7	THM under hypothesis 6.7	PASS
T2-THM-6.21	THM при гипотезе 6.20	THM under hypothesis 6.20	PASS
T2-THM-13.2	THM при B3-B5	THM under B3-B5	PASS
T2-THM-18.2	THM в выбранной 2-категории	THM in selected 2-category	PASS
PO	**RU status**	**EN status**	**Class**
T2-PO-109	THM при B3-B5	THM under B3-B5	CLOSED/THM
T2-PO-203	THM при ModTriv	THM under ModTriv	CLOSED/THM
T2-PO-209	THM при cover	THM under a cover	CLOSED/THM

T2-F.6. Negative Results and Status Firewall

Typed ID	Countertheorem	Status
T2-CTHM-10.46	Triple Independence Countertheorem	THM
T2-CTHM-12.16	Four Prohibited Implications	THM
T2-CTHM-13.12	False External Implications Without Additional Hypotheses	THM
T2-CTHM-15.13	Invalid Analytic Implications Without Additional Hypotheses	THM
T2-CTHM-15.5	Nilpotency Does Not Imply Ellipticity	THM
T2-CTHM-15.7	Formal Symmetry Does Not Imply Self-Adjointness	THM
T2-CTHM-16.8	Coarse Moduli Cannot Recover a Stack Germ Without Stabiliser Data	UNMARKED
T2-CTHM-17.2	Equal Dimensions Do Not Define Wall Crossing	UNMARKED

All eight countertheorems are retained. The English master also preserves explicit ABSTAIN and FAIL branches, no-go implications, local-to-global counterexamples, and the separation of mathematical structure from physical event claims.

PHYSICAL BOUNDARY. Independent EXT-RUN is absent and EMP-OBS is absent. Numerical reproducibility, source hashes, virtual counts, probabilities, or model certificates do not supply an empirical bridge by themselves.

T2-F.7. Terminology and Cross-Volume Consistency

Ledger rows	PASS in T1/T2 corpus	Reserved without collision	Conflicts
125	125	0	0

The audit uses the frozen cross-volume T1-T3 terminology ledger. Direct T3 recompilation is outside this checkpoint; consistency with Volume III is checked through that ledger rather than by creating a new T3 translation.

Term	Audited rule	Verdict
Reper	Never replaced by “reference point” or an ordinary coordinate frame.	PASS
Time@Space	The @ ordering is retained; it is not silently collapsed into spacetime.	PASS
D / Dom	Sufficient foundation and admissible domain remain distinct.	PASS
kernel / nucleus	Kernel is reserved for maps/operators; nucleus for algebraic associativity.	PASS
probability firewall	Canonical noun-compound form; adjectival “probabilistic” remains permitted.	PASS
R⋆R / ⊙ / ⋆_Hdg / Ass_⊙	The symbols remain distinct and are not normalised by visual similarity.	PASS

T2-F.8. Controlled Corrections

ID	Location	Correction	Class
T2-EN-AUD-001	Front release passport	Predecessor: T2-EN-MODULI-v0.4 -> Predecessor: T2-EN-ASSEMBLY-v0.7	EDITORIAL-METADATA
T2-EN-AUD-002	Front release passport	Scope: formulas T2-F001-T2-F381 -> Scope: formulas T2-F001-T2-F404 and Appendices T2-A-T2-E	EDITORIAL-METADATA
T2-EN-AUD-003	Front release passport	Next checkpoint points to T2-EN-ASSEMBLY-v0.7 -> Next checkpoint: T2-EN-FC-v0.9	EDITORIAL-METADATA
T2-EN-AUD-004	Title and running headers	T2-EN-ASSEMBLY-v0.7 -> T2-EN-AUDIT-v0.8	VERSION-CONTROL
T2-EN-AUD-005	Formula parity rule	Literal equality statement without a lexical qualifier -> Mathematical-token parity plus controlled translation of connective prose and decimal punctuation	AUDIT-PRECISION
T2-EN-AUD-006	T1-T3 terminology ledger	probabilistic firewall -> probability firewall (canonical noun compound); adjectival variant allowed	TERMINOLOGY

These corrections concern version control, metadata, audit precision, or terminology. They do not alter Chapter 1-24, Appendices T2-A-T2-E, formula content, theorem hypotheses, proof status, counterexamples, or evidence obligations.

T2-F.9. Residual Blockers and Decision

ID	Blocker	Status	Effect
EXT-AUDIT-SIGN	External signed bilingual audit	OPEN NON-VETO	Does not veto authorial freeze-candidate preparation; remains required for an external trust claim.
EXT-RUN	Independent external computational/empirical run	ABSENT	No claim of independent validation is permitted.
EMP-OBS	Independent empirical observations	ABSENT	Physical hypotheses remain PHY-HYP / EMP-PLAN.
RU-CHANGESET	Any proposed change to the frozen Russian source	NOT OPENED	Must be handled in a separate Russian change-set, not inside the translation.

FREEZE-CANDIDATE GATE. The internal bilingual audit passes. Proceed to T2-EN-FC-v0.9 with a controlled v0.7->v0.8 diff, source-card hashes, immutable candidate artifacts, and a detached release receipt.

Final Record T2-EN-AUDIT-v0.8

The internal bilingual mathematical audit is complete. The audited English master preserves the frozen Russian authority, the complete identifier system, formula signatures, negative results, evidence-status boundaries, and cross-volume terminology. This checkpoint is not yet the immutable v1.0 release.

NEXT CHECKPOINT. T2-EN-FC-v0.9 - Freeze Candidate, controlled diff, source-card audit, immutable candidate hashes, and detached authorial receipt.

Derivative Appendix T2-G. Freeze-Candidate Record and Release Receipt

This derivative appendix records checkpoint T2-EN-FC-v0.9. It is a release-control layer of the English derivative and is not a new canonical appendix of the frozen Russian Volume II. It preserves the audited mathematical corpus and creates the evidence required for an explicit authorial freeze decision.

T2-G.1. Freeze-Candidate Passport

Field	Fixed value
Author	Ivan Borisovich Kurpishev
Project	KURPISHEV LOGIC 2 · Basic KLT-RBD Project
Volume	II · Strict Nonassociative Packet Reper Geometry NAPG 3.0
Checkpoint	T2-EN-FC-v0.9
Canonical authority	T2-RU T2-FREEZE-v1.0
Upstream English authority	T1-EN-FREEZE-v1.0
Predecessor	T2-EN-AUDIT-v0.8
Scope	24 chapters; T2-A-T2-E; derivative T2-F-T2-G; T2-F001-T2-F404; T2-PO-001-T2-PO-500
Status	FREEZE CANDIDATE - NOT YET FROZEN
Next gate	Explicit authorial decision for T2-EN-FREEZE-v1.0

T2-G.2. Controlled No-Scientific-Change Diff

The release candidate is accepted only if the audited corpus remains unchanged. The comparison is made at three independent layers: normalized scientific text, derivative audit text, and embedded media bytes.

Layer	Acceptance test	Gate
Chapters 1-24 and Appendices T2-A-T2-E	Exact normalized element hash equality with v0.8	PASS required
Derivative Appendix T2-F	Exact normalized element hash equality with v0.8	PASS required
Formula and identifier systems	T2-F001-T2-F404; T2-PO-001-T2-PO-500; 339 formal objects	PASS required
Embedded media	Path-by-path SHA-256 map equality	PASS required
Permitted changes	Version metadata, freeze-candidate front matter, Appendix T2-G, detached receipt and sidecars	Editorial only

NO-SCIENTIFIC-CHANGE RULE. Any difference in a formula, hypothesis, theorem status, negative result, domain, evidential boundary, or scientific figure returns the candidate to controlled correction. Editorial readiness cannot override a failed scientific diff.

T2-G.3. Immutable Source and Predecessor Hash Contract

The following classes of hash are fixed in the sidecar source-hash ledger: the frozen Russian DOCX/PDF, the frozen English Volume I DOCX/PDF, the audited predecessor DOCX/PDF, the normalized scientific corpus, the normalized audit appendix, and the embedded-media map. Hash equality proves byte identity or equality under the declared normalization. It does not prove mathematical or physical truth.

- Canonical Russian authority: tom2_v1_0(1).docx and tom2_v1_0(1).pdf, T2-FREEZE-v1.0.
- Upstream English authority: tom1_en_v1_0.docx and tom1_en_v1_0.pdf, T1-EN-FREEZE-v1.0.
- Immediate predecessor: tom2_en_v0_8.docx and tom2_en_v0_8.pdf, T2-EN-AUDIT-v0.8.
- Candidate release objects: tom2_en_v0_9.docx and tom2_en_v0_9.pdf.

T2-G.4. Release Object Inventory

Class	Artifact	Function
Primary master	tom2_en_v0_9.docx	Controlled editable freeze candidate
Reference rendering	tom2_en_v0_9.pdf	Searchable A4 release candidate
Manifest	T2_EN_FC_v0_9_manifest.json / .txt	Machine-readable and human-readable release identity
Controlled diff	T2_EN_FC_v0_9_controlled_diff.csv	No-scientific-change evidence
Hash ledger	T2_EN_FC_v0_9_source_hash_ledger.csv	Canonical, predecessor, logical and candidate digests
Media ledger	T2_EN_FC_v0_9_media_hashes.csv	Path-by-path embedded-media hashes
Detached receipt	T2_EN_FC_v0_9_authorial_release_receipt.docx / .pdf / .json	Unsigned decision instrument
QA record	T2_EN_FC_v0_9_QA.txt / .json	Render, structure, navigation and accessibility checks
Complete package	T2_EN_FC_v0_9_COMPLETE_PACKAGE.zip	Deterministic release package

T2-G.5. Detached Authorial Release Receipt Contract

The detached receipt is unsigned at this checkpoint. It binds an eventual authorial decision to the exact candidate hashes. Signing or explicitly accepting the receipt may authorize the construction of T2-EN-FREEZE-v1.0. It does not validate an open theorem, a physical hypothesis, an empirical claim, or an independent EXT-RUN.

Receipt field	Controlled value
Receipt ID	T2-EN-RELEASE-RECEIPT-v0.9
Candidate	T2-EN-FC-v0.9
Decision options	ACCEPTED FOR FREEZE / RETURNED FOR CONTROLLED CORRECTION
Binding objects	Candidate DOCX SHA-256; candidate PDF SHA-256; scientific corpus hash; source-hash ledger
Current state	UNSIGNED / NO AUTHORIAL DECISION RECORDED
Effect of acceptance	Prepare immutable tom2_en_v1_0.docx and tom2_en_v1_0.pdf with freeze manifest and final authorial card
Effect of return	Open a new controlled change-set; do not silently modify the candidate

T2-G.6. Freeze Gate and Boundary of Inference

FREEZE GATE. T2-EN-FC-v0.9 is ready for an explicit authorial decision only after all sidecar checks return PASS. Until that decision, the candidate is not the immutable English Volume II release.

STATUS FIREWALL. truth_layer_promotion=0. OPEN, COND, MODEL, PHY-HYP, ABSTAIN, the absence of independent EXT-RUN, and the absence of EMP-OBS are preserved. The external signed bilingual audit remains OPEN NON-VETO.

Final Record T2-EN-FC-v0.9

The freeze candidate records the audited English Volume II without scientific change, binds it to its canonical sources and predecessor hashes, and supplies an unsigned detached authorial release receipt. The release state is FREEZE CANDIDATE - NOT YET FROZEN. The only planned next checkpoint is T2-EN-FREEZE-v1.0 after explicit authorial acceptance; otherwise a new controlled correction cycle is required.