Modulign: Architecture, Implementation, and Applications of a Dimensional Address Grammar for Observable Reality

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Abstract

This paper presents Modulign (DAG-OR) as a unified research program comprising a formal address grammar for observable phenomena, three interoperable registries, a reproducible classification protocol, and a growing empirical corpus now exceeding 3.79 million classified observations across 32 active language editions of Wikipedia. We synthesize twenty prior publications—spanning formal logic, analytic epistemology, philosophy of reference, legal epistemology, evidence law, synthetic content governance, AI certification, privacy governance, empirical validation, observer certification, federated registry governance, error correction, and constitutional compliance for automated evidence—into a single coherent account. We argue that the classification deficit identified across scientific, legal, and journalistic domains is not a tooling problem but a grammatical one: existing systems lack the expressive structure to encode observation, causation, jurisdiction, epistemic status, and provenance within a single address. Modulign resolves this deficit. We report on the formal properties of the system (10 invariants, decidable classification, bounded error rate), its empirical performance (inter-rater reliability across trained classifiers, throughput benchmarks, multilingual coverage), and its demonstrated applications to evidence authentication, Gettier-case dissolution, synthetic content governance, and journalistic epistemology. The paper concludes with an honest accounting of open problems and the conditions under which the system would be falsified.

Keywords: classification, address grammar, epistemology, evidence law, formal ontology, rigid designation, observational ledger, synthetic content, Gettier problem, dimensional address

1. Introduction

Every empirical discipline depends on classification. A biologist names a specimen. A forensic analyst tags an evidence sample. A journalist attributes a claim. A physicist records a measurement. In each case, the act of classification does the same thing: it takes a raw observation and renders it addressable—findable, comparable, contestable, and reusable.

And yet the systems that perform this work are, for the most part, mutually unintelligible. A GenBank accession number cannot speak to a chain-of-custody tag. An ISO 27037 digital evidence identifier shares no grammar with a Wikidata Q-number. A journalist's attribution practice—"according to a senior official"—has no formal relationship to the epistemologist's analysis of testimonial justification. Each domain has built its own classification apparatus in isolation, and the result is not pluralism but fragmentation.

This fragmentation has consequences worth naming directly. In courtrooms, digitally generated evidence is admitted without formal means to distinguish it from observational evidence [11]. In international law, the Rome Statute's Article 50 multilingual parity requirement is honored procedurally but violated epistemically [9]. In philosophy, the Gettier problem persists in part because existing epistemological frameworks lack the structural resources to encode the dimensional context in which justified true belief fails [3]. In journalism, the norms of attribution, verification, and accountability are practiced but never formalized to the point of intersubjective reproducibility [15].

Modulign does not solve these problems by building a better database. It solves them by specifying a grammar—a dimensional address system in which any observable phenomenon, at any scale, in any jurisdiction, can receive a permanent, unique, structured identifier that encodes what was observed, where, when, by whom, at what scale, under what epistemic conditions, and with what causal and relational context. The system is called DAG-OR: Dimensional Address Grammar for Observable Reality. This synthesis paper serves as the front door to the program. It is written for the reader encountering Modulign for the first time, and it is intended to be useful, not merely descriptive.

2. The Canonical Corpus

The Modulign research program is documented across twenty publications, each addressing a distinct aspect of the system. Rather than treat these as independent contributions, we present them here as components of a single argument.

Foundational specification: The Modulign Standard v3.0 [1] and the v3.1 Amendment [14], which added the ENV and BIO domains and established NAT/ENV and NAT/BIO boundary rules.

Formal foundations: The Formal Logic paper [2], proving 10 invariants, the ATNA principle, and Daubert-grade error rate bounds. The Reference Theory paper [6], establishing DAG-OR addresses as rigid designators in the Kripke sense.

Epistemological contributions: The Gettier Dissolution paper [3], demonstrating that the ATK formulation structurally blocks Gettier cases. The Inter-Rater Reliability Study [13], reporting 44.4% overall agreement, 100% on TRN, and the NAT/ENV ambiguity that motivated v3.1.

Legal applications: The Legal Epistemology Treatise [4], the Chain of Custody Formalisation [10], the Classification Deficit [9], and the AI-Generated Evidence paper [11].

Governance and ethics: The %AUT Certification Framework [7], the Synthetic Content White Paper [5], and the Privacy Commitment & Governance Roadmap [8].

Observer certification and compliance: The Epistemology of Observation [17], providing the full academic treatment of the %AUT framework. The Human Attestation Protocol [20], specifying the Crawford-compliant testimony procedure for automated classifications in criminal proceedings.

Registry infrastructure and error resolution: The Correction Protocol [19], specifying the formal mechanism for append-only error resolution. The Federated Infrastructure paper [18], specifying node compliance requirements, amendment governance, and the three-phase governance transition.

Empirical validation and domain applications: The Empirical Validation Paper [12] and the Inter-Rater Reliability Study [13]. "On the Record" [15], formalizing journalistic attribution, verifiability, and accountability as Modulign addresses.

These twenty documents are not sequential chapters of a single book. They are independently valid arguments sharing a common formal substrate. The synthesis offered here is the argument that this substrate constitutes a research program—a progressive one in the Lakatosian sense, generating novel predictions and absorbing anomalies without ad hoc modification.

3. The Grammar: What a Modulign Address Is

3.1 The Core Claim

Modulign's central claim is architectural: a coordinate system for observable phenomena must encode not merely what was observed, but the full dimensional context that makes the observation meaningful, contestable, and reusable. An MGN address is not a tag. A tag labels. An address locates. Location within a structured space entails relationships—to neighboring addresses, to scale boundaries, to jurisdictional constraints, to temporal ordering—that a flat label cannot express.

3.2 The 19-Segment Address

The Standard [1] defines the MGN code as a 19-segment structured address: §DOM (domain, 11 in v3.1), §RLM (realm), §SCL (scale tier), §LOC (spatial coordinates), §TMP (temporal encoding), §CAU (causal encoding), §JUR (jurisdictional encoding), §OBS (observer encoding), §AUT (automation/AI certification), §RES (resolution/precision), §VR (verification status), §PROV (provenance chain), §EVID (evidentiary embedding), §REL (relational pointers), §EID (entity identifier), §CONF (confidence encoding), §FLAG (status flags), §META (metadata segment), and §SIG (signature chain). Mandatory segments are §DOM, §TMP, §OBS, §PROV, and §SIG. The grammar is complete: every expressible dimension of an observation has a defined address segment.

3.3 Rigid Designation

The Reference Theory paper [6] establishes that MGN addresses function as rigid designators in the technical Kripkean sense: they refer to the same observation in every possible world in which that observation exists. The proof proceeds by showing that DAG-OR addresses satisfy the criteria for rigid designation—introduced by an initial baptism (the CDP classification act), tracking their referent across modal contexts (via the EID mechanism), and not reducing to definite descriptions. The MGN code is neither a Millian name nor a Russellian description. It is a dimensional address that rigidly designates an observation by encoding the full context of its epistemic origin.

4. Formal Properties

4.1 The Ten Invariants

The Formal Logic paper [2] proves ten invariants for any well-formed Modulign classification within the specification as defined: (1) Uniqueness; (2) Permanence; (3) Completeness; (4) Decidability—the CDP terminates in finite steps for any input; (5) Reproducibility; (6) Scale-sensitivity; (7) Temporal ordering; (8) Jurisdictional constitutivity; (9) Provenance integrity; (10) Signature binding. These are theorems of the system—formal consequences of the specification as axiom set. The demonstration that a running implementation satisfies these invariants under all operating conditions is a distinct empirical question, addressed in §10.

4.2 The ATNA Principle

The most philosophically significant result in the Formal Logic paper is ATNA: Addressability Tracks Noetic Access. The principle states that the dimensional address of an observation is isomorphic to the epistemic access conditions under which that observation is known. ATNA holds as a consequence of the grammar's design: because every dimension of epistemic access has a dedicated address segment, the address is the access specification. This is a design virtue, not an independent discovery about the world—and a grammar built to encode epistemic access fully is a better grammar than one that does not.

4.3 Error Rate

The Formal Logic paper computes a Daubert-compatible error rate for the system. The Inter-Rater Reliability Study [13] provides the empirical basis: at 44.4% overall agreement—with domain-specific rates substantially higher (TRN = 100%)—the system's error characteristics are known, measurable, and improvable. The v3.1 amendment [14] was a direct response to the NAT/ENV boundary disagreement identified in [13], demonstrating that the system responds to measured disagreement with formal specification refinement. Domain-by-domain reliability data post-v3.1 constitutes a priority item for the next empirical study.

5. The Classification Decision Protocol

The CDP is the epistemic engine of Modulign: an eight-step procedure transforming a raw input into a classified GSI-ID with a full MGN address. (1) Input acceptance; (2) Domain assignment; (3) Realm assignment; (4) Scale determination; (5) Dimensional encoding; (6) Entity resolution; (7) Relation linking; (8) Signature and commit—irreversible.

The criterion for admission into the class of observable phenomena is structural: an observation is any event or state of affairs for which the mandatory segments can be populated without contradiction. The grammar defines the system's scope—you can classify what you can address. That is a coherent boundary, and it means the system's jurisdiction is explicit rather than assumed.

The CDP is designed to be intersubjective: any trained classifier following the protocol should arrive at a compatible classification for the same input. The 44.4% overall agreement rate in [13] must be read in context—it was measured across all domains including those with known boundary ambiguities subsequently resolved. The epistemological significance of the CDP is treated at length in [3], which argues that the protocol structurally blocks Gettier cases by ensuring dimensional completeness.

6. The Three Registries

6.1 The Observation Registry (GSI-IDs)

Every classified observation receives a globally unique GSI-ID. The registry is append-only: entries are never modified or deleted after commit. As of April 2026, the registry contains over 3.79 million entries generated from 32 active Wikipedia language editions.

The append-only constraint is a legal and epistemic commitment [10]: an evidence registry that permits deletion or modification is, by definition, not a chain of custody. The Correction Protocol [19] specifies the formal mechanism for addressing erroneous classifications without violating this constraint: corrections are committed as new GSI-IDs referencing the original, carrying a §FLAG value of SUPERSEDED on the original, with a full audit trail permanently attached. The original entry is never modified—history happened—but the correction is inescapably linked, such that any downstream retrieval of the original encounters it.

6.2 The Entity Registry (EIDs)

Persistent entities—objects, organisms, institutions, locations, phenomena that endure across multiple observations—receive Entity Identifiers. The EID mechanism allows Modulign to distinguish between observing the same entity twice and observing two similar entities once each. The Reference Theory paper [6] establishes the EID as the formal anchor for rigid designation: it is the EID, not the MGN code, that tracks entity identity across modal contexts.

6.3 The Relation Registry (RIDs)

Causal, temporal, and structural relationships between observations are recorded as Relation Identifiers. RIDs connect GSI-IDs to form directed graphs of causation, temporal succession, spatial containment, and structural composition. The Relation Registry is what makes Modulign more than a collection of classified points—it is what makes it a map.

7. Epistemological Contributions

7.1 The Gettier Dissolution

The Gettier problem (Gettier, 1963) has resisted solution for over sixty years. The Gettier Dissolution paper [3] argues that DAG-OR structurally blocks the Gettier cases rather than solving them on their own terms. The ATK formulation (Addressability-Tracking Knowledge) holds that S knows that p if and only if S's belief that p is supported by a dimensionally complete Modulign address for the observation grounding p. Dimensional completeness entails the absence of Gettier-generating conditions: for fake barn cases, the §SCL and §RES segments encode the scale and resolution at which the observation was made, honestly representing its epistemic limitations; for Zagzebski-recipe cases, dimensional completeness is a structural property of the address rather than a single additional condition—you cannot Gettierize a coordinate system.

7.2 ATNA and Epistemic Access

If addressability tracks noetic access, then the Modulign registry is not merely a record of what has been observed but a map of the epistemic landscape—a formal representation of what is known, at what resolution, by whom, and under what conditions. This is the sense in which Modulign is an epistemological contribution and not merely a technical one.

8. Legal Applications

8.1 Evidence Authentication

The Legal Epistemology Treatise [4] demonstrates that a GSI-ID, with its embedded §EVID, §PROV, and §SIG segments, satisfies FRE 901(b)(9) authentication requirements for evidence "described by a process or system." The authentication argument proceeds in three steps: the system (DAG-OR) is described in a published, peer-reviewable specification [1]; the process (CDP) produces a result shown to be accurate by the formal properties in [2] and empirical results in [12, 13]; and the signature chain provides tamper-evidence while the append-only ledger provides custody continuity.

8.2 Chain of Custody and the Confrontation Clause

The Chain of Custody Formalisation [10] establishes that ^EVID is not metadata about an observation but an embedded property of its identity. A Crawford v. Washington analysis (541 U.S. 36, 2004) is required before Modulign classifications are offered in criminal proceedings. If a GSI-ID is offered to prove that an observation occurred as classified, the classifier is a declarant and the classification is a testimonial statement. For human classifiers, this is straightforward. For automated classifiers at the :A (Autonomous) level, Crawford presents a structural constraint: an algorithm cannot be cross-examined.

The Human Attestation Protocol [20] specifies the formal procedure for satisfying Crawford when automated classifications are offered in criminal proceedings. It identifies three mandatory roles—the Certifier (who evaluated and certified the automated system), the Operator (who was responsible for the system at the time of the specific classification), and the Interpreter (who reviewed the specific classification's protocol traceability record and can attest to its correctness)—and maps each to the constitutional and evidentiary requirements of Crawford, Melendez-Diaz v. Massachusetts (557 U.S. 305, 2009), and Bullcoming v. New Mexico (564 U.S. 647, 2011). Automated classifications in criminal proceedings are admissible under this protocol. They are constrained, not excluded.

8.3 The Classification Deficit in International Law

The Classification Deficit [9] identifies a specific, demonstrable gap in international legal infrastructure. Article 50 of the Rome Statute requires that the Statute's six authentic language versions be "equally authentic." There is no shared classification grammar across these versions. The paper performs a clause-by-clause gap analysis and proposes FRE 901(b)(11) and 901(c) as domestic pathways, along with a 4-step framework oriented toward ICC adoption. ICC adoption would require amendment of the Rules of Procedure and Evidence by the Assembly of States Parties (Article 51)—a process involving 124 member states operating by consensus. The proposed framework maps the substantive case; the institutional pathway through the ASP is a next step.

8.4 Synthetic Content and AI-Generated Evidence

The Synthetic Content White Paper [5] and the AI-Generated Evidence paper [11] address the most consequential evidentiary question of this decade: how to handle AI-generated content in court. The VR/·:SYN biconditional establishes a formal equivalence between an observation being synthetic and its Modulign address carrying the ·:SYN marker—proven, not stipulated. The AI-Generated Evidence paper [11] distinguishes Category A evidence (wholly AI-generated) from

Category B (human-originated but AI-enhanced), arguing that existing rules are structurally incapable of handling Category A and proposing Rule 707 as a partial remedy.

9. Governance and Ethics

9.1 Observer Certification

The %AUT Certification Framework [7] and its full academic treatment [17] specify three levels of automated observer competence: :T (Trained)—restricted domain classification with no measured error rate; :E (Evaluated)—known and documented error characteristics with published confusion matrices; :A (Autonomous)—certified for unsupervised classification with mandatory out-of-distribution detection and explainability requirements. The Epistemology of Observation [17] argues that observer competence is constitutive of the classification itself—not an annotation on the observation but a dimension of it, grounded in the ATNA principle. As noted in §8.2, deployment of :A-level classifiers in criminal proceedings is subject to Crawford constraints independent of this certification framework.

9.2 Privacy

The Privacy Commitment [8] establishes that Modulign's classification power creates privacy obligations. The §RES segment must encode consent status when the observation involves identifiable persons. For EU deployments, processing rests on Article 6(1)(e) (public interest) in conjunction with the Article 17(3)(d) derogation from the right to erasure for archiving in the public interest. No directly identifiable personal data enters the registry—observations involving identifiable persons must be pseudonymized before minting. Each EU-based deployment must conduct a Data Protection Impact Assessment under Article 35 prior to operation.

9.3 Governance Transition and Federated Infrastructure

The Governance Roadmap [8] and the Federated Infrastructure paper [18] specify a 3-phase transition: Phase 1 (current)—sole authorship; Phase 2—advisory board with 5–7 domain experts, author as Founder Emeritus with one vote; Phase 3—federated stewardship with multiple independent nodes, consensus-based amendment by two-thirds supermajority, anti-concentration protections, and a succession protocol. The Modulign™ and MGN™ trademarks are to be assigned to the Phase 2 governance entity via an escrow instrument executed during Phase 1. A trademark usage policy must be established before Phase 3 can function as genuine stewardship rather than licensed tenancy. The recommended Phase 2 legal form is a U.S. 501(c)(3) formed in Florida, appropriate to the author's jurisdiction and the system's current operational base.

10. Empirical Validation

10.1 The Corpus

The Empirical Validation Paper [12] reported on an initial corpus of 155,000 GSI-IDs. As of April 2026, the Observation Registry contains over 3.79 million entries, generated by an automated pipeline ingesting content from 32 active Wikipedia language editions on a Supabase-hosted PostgreSQL instance. The throughput benchmarks below document operational performance at scale:

Metric	Value	Timestamp
Fastest to 1M GSI-IDs	12h 30m 16s	From pipeline start
Fastest to 2M GSI-IDs	24h 54m 51s	From pipeline start
Most GSI-IDs in one minute	87,003	2026-04-18 08:53 UTC
Most GSI-IDs in one second	5,200	2026-04-18 08:53:06 UTC
Most GSI-IDs in one calendar day	1,426,650	Easter Sunday, April 20, 2026
Most GSI-IDs in one hour	118,456	2026-04-20 12:00 UTC

A system that classifies nearly four million observations without structural failure, continuously, across dozens of languages simultaneously, is operational infrastructure. The specification proofs of §4 establish what the system is designed to guarantee; these throughput results establish that the design survives contact with production load. The gap between specification proof and implementation audit—verifying the ten invariants against the running system under race conditions and at scale—is the priority item for the next independent validation study.

10.2 Multilingual Coverage

The pipeline operates across all six UN languages (Arabic, Chinese, English, French, Russian, Spanish) plus 26 additional Wikipedia editions. This multilingual coverage tests the system's claim to language-independence: the grammar should encode the structure of the observation, not the structure of the language describing it. Processing 32 language editions is a necessary but not sufficient test of this claim. The Babel argument (Gonzalez, forthcoming) will provide the controlled study: taking the same observable phenomenon, examining its descriptions across multiple independently authored language editions, classifying each under the CDP, and measuring address compatibility. Until that study is complete, language-independence is a well-motivated hypothesis with large-scale operational support.

10.3 Comparison with Existing Systems

Semantic Web (RDF/OWL)—expressive but without first-class epistemic status, provenance integrity, or jurisdictional encoding. Wikidata (Q-numbers)—scalable but flat, identifying entities rather than observations, with no dimensional encoding or scale sensitivity. ISO 27037—designed for digital evidence chain of custody but without causal structure, epistemic status, or cross-domain classification. Modulign is not a replacement for these systems. It is the grammar that makes them interoperable.

11. Applications

11.1 Forensic Science

A forensic laboratory adopting Modulign gains: FRE 901(b)(9)-compliant evidence authentication, chain of custody as an embedded property of every evidence identifier, Daubert-compatible error rate documentation, and tamper-evident signature chains. The 8-step adoption pathway in [10] is designed for a single laboratory pilot. Criminal-case deployment of automated classifiers is subject to the Crawford compliance procedure specified in the Human Attestation Protocol [20].

11.2 Journalism

"On the Record" [15] demonstrates that Modulign formalizes, rather than replaces, existing journalistic norms. Attribution becomes %OBS. Verifiability becomes GSI-ID plus append-only ledger. Accountability becomes the CDP audit trail. A newsroom that classifies its sourcing using Modulign addresses makes its editorial practice formally reproducible and externally verifiable.

11.3 AI Governance

The EU AI Act (Regulation 2024/1689) requires, in Article 50, that AI-generated content be marked as such. The VR/·:SYN biconditional [5] provides a formally proven mechanism. The %AUT Certification Framework [7, 17] provides the competence-level infrastructure Article 50 requires but does not specify. EU deployment is subject to the GDPR basis specified in §9.2.

11.4 Biodiversity and Earth Science

The v3.1 addition of BIO and ENV domains [14] creates address space for biodiversity observations and environmental monitoring data. Integration with GBIF (Global Biodiversity Information Facility) occurrence data is a planned near-term expansion that the registry architecture is already built to support.

12. Open Problems and Falsification Conditions

An honest research program states the conditions under which it would be wrong. Modulign would be falsified or require fundamental revision under the following conditions:

The CDP is shown to be undecidable for a class of real-world inputs. If a phenomenon class is identified for which the 8-step protocol does not terminate, the grammar requires extension.

Inter-rater reliability fails to improve with specification refinement. If post-amendment agreement rates fail to reach 70% across two successive studies with $N \geq 200$, the system's claim to intersubjectivity is weakened, and formal human certification tiers analogous to the automated tiers must be introduced.

The rigid designation claim is defeated by a modal counterexample. If a scenario is constructed in which the same GSI-ID refers to different observations in different possible worlds, the Reference Theory argument fails.

The VR/·:SYN biconditional admits false negatives at scale. If synthetic observations systematically evade the ·:SYN marker under correct CDP application, the legal applications collapse.

The append-only constraint becomes practically unenforceable at scale. The hosting requirements necessary to guarantee append-only operation must be specified in host-agnostic terms. The Federated Infrastructure paper [18] provides the architecture; the first independent node is the proof.

No institution other than the author's operates a federation node within three years of Phase 2 readiness. If the value proposition is insufficient to attract independent operators, the federation does not exist, and the system's claims to permanence and independence are undermined.

These are the actual research frontier—the places where the system could genuinely break, and where the most interesting work remains to be done.

13. Conclusion

Modulign is a grammar. It is a grammar for the same reason that latitude and longitude are a grammar: because observable reality has structure, and structure can be addressed. The contribution of this research program is not a new database, a new ontology, or a new tagging system. It is the demonstration that a single address grammar—with explicit encoding for domain, realm, scale, location, time, causation, jurisdiction, observer, automation status, resolution, verification, provenance, evidence, relation, entity, confidence, status, metadata, and signature—can serve as a universal coordinate system for classified observation.

The system is specified [1, 14]. Its formal properties are proven within the grammar as defined [2, 6]. Its epistemic consequences are demonstrated [3]. Its legal applications are argued, with deployment scoping conditions stated [4, 5, 9, 10, 11, 20]. Its governance framework is published [7, 8, 17, 18]. Its error resolution mechanism is formal [19]. Its empirical performance is measured [12, 13]. Its domain applications are explored [15]. Its pipeline is running, its corpus is growing, and its specification is open under CC BY 4.0.

The classification deficit is real. The grammar that resolves it exists. The work now is implementation, validation, and adoption—and there is genuine reason to think that work is worth doing.

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Competing interests. The author holds trademark rights to Modulign™ and MGN™. The specification is licensed CC BY 4.0. No financial conflicts exist.

Data availability. The Observation Registry is maintained at the Supabase project identified in the system documentation. Snapshot datasets for empirical validation are deposited on Zenodo with the cited DOIs.