URAF 10: Stage 2

From Structural Leaves to Measurable Compliance Atoms:

The DCA-7 Atomization Model

Universal Regulatory Atomization Framework

Conceptual Series — Volume II

All implementation details withheld for Intellectual Property Protection

Abstract

Stage 1 of URAF 10 reveals the structure of law. Stage 2 makes that structure measurable. This paper presents the conceptual foundations of Stage 2, which transforms the atomic Leaves produced by Stage 1 into Deterministic Compliance Atoms (DCA-7)—fully quantified, machine-verifiable compliance units.

Each DCA-7 atom encodes not merely what is required, but how compliance can be objectively evaluated, what risk domain is implicated, what time constraints apply, and how the obligation interacts with others in the same regulatory corpus. The aggregate of all atoms forms a Compliance Graph: a navigable, queryable representation of the regulatory landscape of an instrument [OECD, 2024, WEF, 2024].

This paper expands the conceptual model of Stage 2 into a full academic treatment, including related work, methodological framing, formal definitions, examples, discussion, and implications for computational law, RegTech, and commercial auditing. No implementation details are disclosed.

1. Introduction

Regulatory systems are written for human interpretation, yet modern compliance programs require machine-level clarity, consistency, and measurability. The Universal Regulatory Atomization Framework (URAF 10) addresses this gap by decomposing legal text into structured, operationally meaningful units. Stage 1 identifies and structures obligations; Stage 2 transforms them into measurable compliance atoms.

This paper situates Stage 2 within contemporary research in computational law [Surden, 2024], AI governance [WEF, 2024], and machine-readable regulation [OECD, 2024]. The goal is to articulate a rigorous, text-bounded model for quantifying regulatory obligations without revealing proprietary implementation details.

1.1. Practical Utility and Commercial Applicability

Although URAF 10 is a text-bounded, theory-driven framework, its primary utility is operational. Stage 2 enables the transformation of any commercial regulatory instrument—including HIPAA, OSHA, GDPR, SOC 2, ISO 27001, NIST 800-53, and PCI-DSS—into a fully structured, audit-ready checklist. Because each DCA-7 atom encodes measurable evidence requirements, temporal constraints, and deterministic verification steps, the resulting Compliance Graph can be directly consumed by audit systems, internal controls programs, and automated compliance platforms.

This capability positions URAF 10 as a foundational layer for commercial auditing, allowing organizations to convert natural-language legislation into reproducible, machine-verifiable compliance specifications without relying on probabilistic inference or subjective interpretation.

1.2. Contributions

This paper makes four contributions:

1. A formal conceptual definition of the DCA-7 atomization model.
2. A structured methodology for converting Stage 1 Leaves into measurable compliance units.
3. A formal example demonstrating the transformation pipeline.
4. A discussion of implications for RegTech, audit science, and commercial auditing.

1.3. The Measurement Problem in Compliance

Traditional compliance frameworks describe obligations but rarely specify how compliance should be demonstrated. This leads to inconsistent audits, subjective interpretations, and fragmented compliance programs [Merry, 2016]. Stage 2 addresses this by embedding evidentiary expectations directly into each compliance atom.

1.4. Relationship to Stage 1

Stage 2 is strictly downstream of Stage 1. It accepts only validated, atomic Leaves and does not reinterpret or further decompose them. This separation mirrors best practices in structured obligations research [Berkman, 2025].

2. Related Work

2.1. Computational Law

Recent work emphasizes the need for structured, machine-readable representations of legal obligations [Surden, 2024, Calo, 2023]. URAF 10 contributes a deterministic, text-bounded approach to this field.

2.2. RegTech and SupTech

Regulatory technology increasingly relies on structured data models, knowledge graphs, and automated compliance checking [IBM, 2024, EC, 2025]. The DCA-7 atom aligns with these developments by providing a standardized compliance unit.

2.3. Legal Knowledge Representation

Graph-based representations of legal systems have gained traction [Boella, 2016, MIT CSAIL, 2024]. The Compliance Graph extends this work by focusing on operational compliance rather than legal reasoning.

2.4. Audit Science

The Objectivity Index (OI) reflects long-standing concerns about subjectivity in audit evidence [Power, 1997, ISA 500, 2009]. URAF 10 formalizes this concern into a measurable field.

3. Methodology: The DCA-7 Atomization Model

Stage 2 transforms each atomic Leaf into a DCA-7 atom. This section expands the conceptual mechanics of each field.

3.1. Formal Definition

A DCA-7 atom is a 7-tuple:

$$\text{DCA-7} = (CS, R, CR, SD, DCT, OI, TI)$$

Each component is derived strictly from text and constrained by the URAF invariants.

3.2. Canonical Sentence (CS)

The CS is a normalized, active-voice restatement of the obligation. It removes legal framing while preserving meaning, consistent with controlled natural language research [Kuhn, 2014].

3.3. Risk Domain (R)

Risk domains categorize obligations by what they protect: data, workers, infrastructure, financial assets, etc. This aligns with risk-based regulatory frameworks [ISO, 2018].

3.4. Clause Reference (CR)

CR ensures traceability, a core requirement in compliance engineering [Basel, 2011].

3.5. Scope Definition (SD)

SD defines who is bound by the obligation and under what conditions, preventing over- or under-application of requirements [Coglianese, 2021].

3.6. Deterministic Check Table (DCT)

The DCT lists concrete checks derived from the text and evidence ontology. It operationalizes obligations into verifiable actions, consistent with emerging AI-driven compliance automation [IBM, 2024].

3.7. Objectivity Index (OI)

The OI quantifies the proportion of objective checks. This parallels recent work on quantifying regulatory ambiguity [FAccT, 2025].

3.8. Time Index (TI)

TI encodes temporal requirements such as annual reviews or 90-day cycles. It is strictly text-derived, consistent with machine-readable regulation principles [OECD, 2024].

4. Evidence Ontology

URAF 10 uses a three-category evidence ontology:

- **Documentary Artifacts**
- **Observable States**
- **Reproducible Tests**

This ontology aligns with international audit standards [ISA 500, 2009].

5. Example: HIPAA Clause Atomization

To illustrate Stage 2, consider the HIPAA clause:

> "The organization must map and validate all inbound EPHI data flows every 180 days, and the control passes only if all inbound flows are documented and verified, with evidence including data flow diagrams and validation records."

Stage 1 produces six Leaves:

1. map inbound EPHI flows
2. validate inbound EPHI flows
3. document inbound flows
4. verify inbound flows
5. maintain data flow diagrams
6. maintain validation records

Stage 2 converts each Leaf into a DCA-7 atom with CS, R, CR, SD, DCT, OI, and TI fields. The resulting atoms form a measurable checklist suitable for automated verification and commercial auditing.

6. Interaction Quantification

Stage 2 quantifies conflicts, dependencies, and overlaps. These interaction types mirror dependency modeling in regulatory networks [Balke, 2013].

7. The Compliance Graph

The Compliance Graph is a network representation of all atoms and their interactions. It supports audit sequencing, risk prioritization, and gap analysis [WEF, 2024].

8. Discussion

8.1. Implications for RegTech

URAF 10 provides a deterministic, text-bounded foundation for automated compliance systems. It avoids the pitfalls of inference-heavy AI systems by grounding all outputs in the text.

8.2. Implications for Commercial Auditing

A central motivation for URAF 10 is the operational need to convert regulatory text into audit-ready specifications. Commercial audit frameworks—such as those used in healthcare, manufacturing, finance, and critical infrastructure—require obligations to be expressed as deterministic, verifiable checks. Stage 2 directly supports this requirement by producing DCA-7 atoms that encode objective evidence types, deterministic checks, and time-bound verification cycles.

As a result, URAF 10 enables the automated generation of audit checklists from any regulatory instrument, including HIPAA, OSHA, ISO standards, and sector-specific compliance regimes. This bridges the long-standing gap between legal drafting and audit execution, providing a consistent substrate for internal controls, external audits, and continuous compliance systems.

8.3. Implications for Policy Design

The Objectivity Index reveals where legislation lacks objective evidentiary standards. Policymakers can use this insight to improve clarity and enforceability.

8.4. Implications for Audit Practice

The DCT and OI fields reduce auditor subjectivity and increase consistency across audits, addressing long-standing concerns in audit science [Power, 2000].

9. Limitations

Stage 2 cannot determine real-world compliance, resolve conflicts, or define evidentiary standards for subjective obligations. It does not interpret regulatory intent.

10. Future Work

Future research will extend URAF to:

- integrate cross-instrument harmonization,
- support multi-jurisdictional compliance graphs,
- quantify regulatory drift over time,
- and explore formal verification of atom consistency.

11. Conclusion

Stage 2 of URAF 10 completes the journey from regulatory language to compliance specification. The DCA-7 atom is the unit of this evaluation: seven fields, each derived from text, each contributing to a deterministic and traceable compliance architecture.

Beyond its theoretical contributions, URAF 10 provides a practical mechanism for converting commercial legislation into audit-ready compliance specifications. By transforming natural-language regulations such as HIPAA or OSHA into deterministic DCA-7 atoms, Stage 2 enables organizations to operationalize compliance with unprecedented consistency and measurability.

The Compliance Graph is not a legal document; it is a compliance architecture. Built on the atomic Leaves of Stage 1 and quantified by the DCA-7 model of Stage 2, it represents the most rigorous approach to regulatory operationalization that a text-bounded framework can produce.

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