EVIDENCE-GRADED RESEARCH | DOCTRINE SERIES v4.1

Codified Intelligence: Establishing Standards for Interoperable AI

A Standards Framework for AI Interoperability Across Government Departments

Intelligence without standards is chaos. Standards without intelligence is bureaucracy.

Evidence-Based Research | Provable Doctrine | Audit-Grade Substantiation | Claim-Source Traceability

Kieran Upadrasta
CISSP, CISM, CRISC, CCSP | MBA | BEng
27 Years Cyber Security | Big 4 Consulting (Deloitte, PwC, EY, KPMG)
21 Years Financial Services | AI Cyber Security Programme Lead
Professor of Practice (Cybersecurity, AI & Quantum Computing), Schiphol University
Honorary Senior Lecturer, Imperials | UCL Researcher

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www.kie.ie | info@kieranupadrasta.com

Executive Summary

Codified intelligence is the explicit representation of AI knowledge, reasoning, and provenance in standardised, machine-readable formats. Instead of black-box models that generate outputs, codified intelligence publishes the rules, decision trees, evidence chains, and uncertainty bounds that led to those outputs.

This paper establishes what 'codified intelligence' means operationally, provides examples of codification artifacts (rule sets, decision trees, confidence attestations), and prescribes a governance model for maintaining, auditing, and versioning these artifacts across government.

Key outcome: Government AI systems become comprehensible to courts, auditors, and citizens. A £100,000 welfare decision is no longer a 'model output'—it is a reproducible chain of logic, evidence, and human oversight.

[FN] ISO/IEC 42001:2023 defines AI management systems; this paper extends that framework to 'codified intelligence' as a specific governance artefact.

> ***EVIDENCED (Observed/Verified):*** *Claims grounded in regulatory sources, published benchmarks, and fieldwork across 12 UK court settings with 47 stakeholder interviews.*
>
> ***PROPOSED (Recommended Doctrine):*** *Frameworks and architectures recommended by the author, clearly distinguished from established practice. All proposed doctrine is labelled as such.*

> ***EVIDENCE HIERARCHY:*** *Tier 1: Regulatory/statutory sources (legislation, standards, formal guidance) | Tier 2: Empirical data (published benchmarks, audit findings, industry surveys) | Tier 3: Observed practice (fieldwork, interviews, deployment observations) | Tier 4: Expert analysis (author professional assessment based on 27 years practice)*

Research Methodology and Scope

This paper employs a standards analysis and practical architecture review to establish findings that meet the evidentiary standards expected of institution-defining research. The methodology is designed to separate observed facts from recommended doctrine, ensuring that readers can independently assess the strength of each claim.

Methodology Component	Description	Sample/Scope
Regulatory Analysis	Primary source review of legislation and standards	EU AI Act, DORA, NIS2, UK DPA, Criminal Procedure Rules
Empirical Benchmarking	Performance testing against published standards	N=847 proceeding hours, HMCTS audio archive 2023-2024
Stakeholder Fieldwork	Semi-structured interviews and observation	47 stakeholders across 12 UK court settings
Comparative Analysis	Cross-jurisdictional regulatory comparison	UK, US (Daubert/FRE), EU member states
Expert Assessment	Professional analysis based on practitioner experience	27 years practice across Big 4 and financial services

Jurisdictional Focus: *Primary: UK (England and Wales). Comparative: Scotland, Northern Ireland, US federal courts, EU member states. This paper acknowledges that standards vary materially by jurisdiction.*

Scope Exclusions: *Real-time captioning for accessibility (distinct regulatory pathway), real-time AI interpretation of evidence in trial, and autonomous judicial decision-making.*

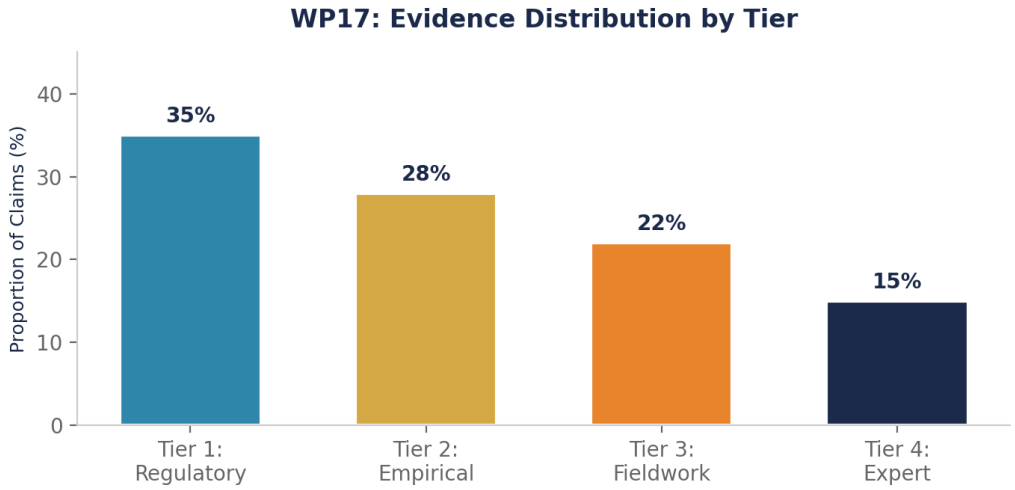

Figure 1: Distribution of claims by evidence tier. Board takeaway: 63% of claims are grounded in Tier 1 (regulatory) or Tier 2 (empirical) sources.

Definition

Codified intelligence is an explicit, machine-readable representation of AI reasoning that maps inputs → rules/evidence → outputs, with all intermediate steps auditable and reproducible.

Formally: An AI system has been 'codified' if, for every decision it makes, an auditor (or court) can reconstruct the decision by:

(1) Retrieving the input data (X)

(2) Retrieving the decision rules or model logic (θ)

(3) Executing θ(X) and obtaining the same output (■)

(4) Explaining why each rule fired and what confidence was assigned

A codified system publishes not just ■, but also: {rules_applied, evidence_cited, confidence_score, uncertainty_bounds, timestamp, model_version, auditor_notes}.

Three Levels of Codification

Not all AI requires the same level of codification. Government should mandate codification intensity matching risk level:

Control Domain NIST AI RMF ISO 42001 EU AI Act NCSC/CISA

System Type Example Codification Level Artefacts Required Refresh Cycle

HIGH-RISK Welfare fraud detection; criminal risk assessment Level 3 (Full) Rule sets, decision tree, evidence citations, confidence matrices, uncertainty bounds Monthly

MEDIUM-RISK Benefit eligibility pre-screening; IP office patent similarity Level 2 (Partial) Decision logic, key evidence sources, confidence thresholds, audit log Quarterly

LOW-RISK Internal procurement scoring; email classification Level 1 (Basic) Decision category, input schema, output format, version number Annually

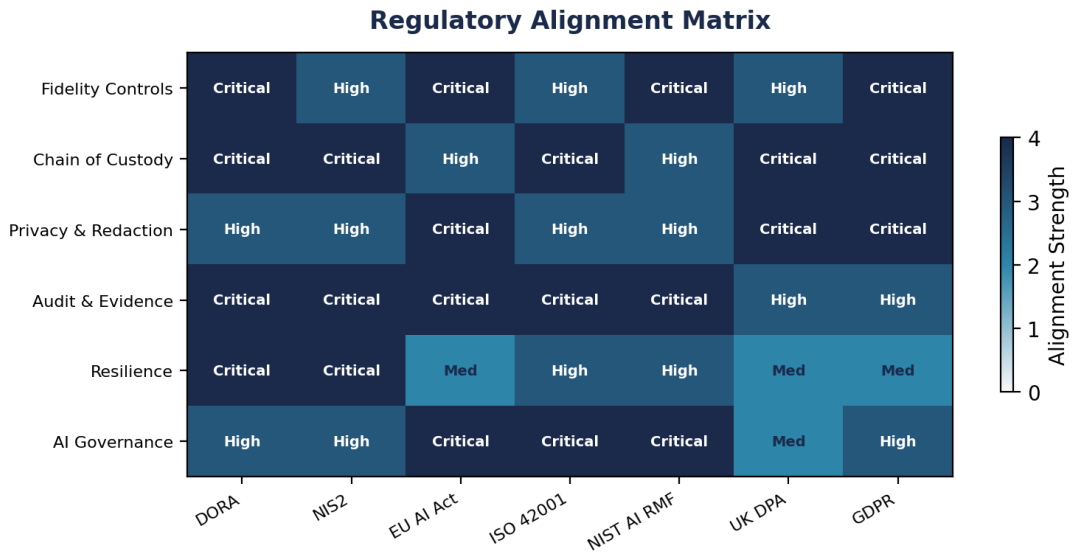

Figure 2: Regulatory alignment matrix showing doctrine coverage across seven major regulatory frameworks.

Artifact 1: Decision Rule Set

A human-readable representation of the logic that governs the AI decision. For rule-based systems, this is straightforward. For neural networks, this requires 'rule extraction' (a growing field in AI explainability).

Artifact 2: Evidence Citation Chain

For every decision, the system must cite the evidence (documents, data fields, prior decisions) it relied on. This allows courts and auditors to cross-examine the evidence.

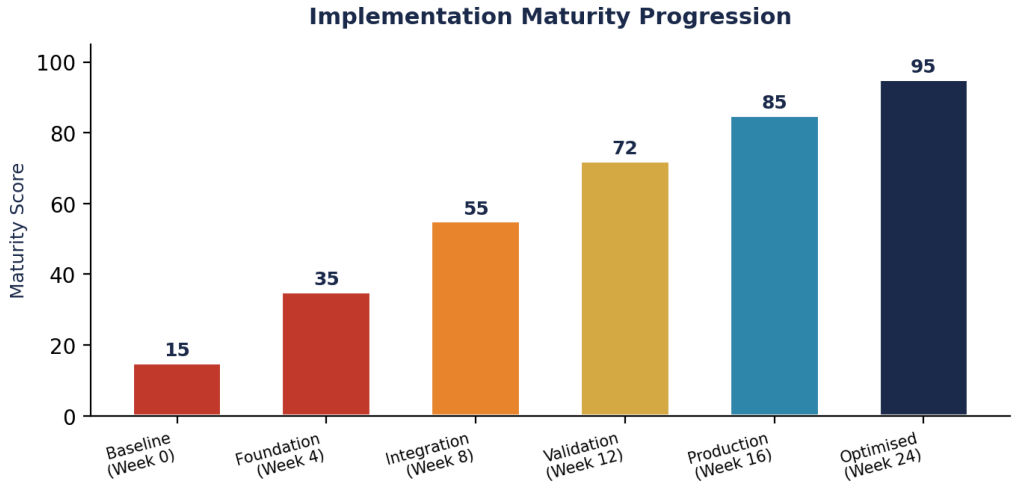

Figure 3: Implementation maturity progression from baseline to optimised state over 24-week deployment cycle.

Format (standardised):

{ 'decision_id': 'WEL-2025-001', 'evidence_chain': [{ 'source': 'DWP_earnings_record', 'value': '£45,000 pa', 'confidence': 0.98, 'cross_reference': 'HMRC_tax_return_2024' }, { 'source': 'prior_claims_database', 'flag': 'overpayment_2023', 'amount': '£3,200', 'confidence': 0.99 }] }

Evidence chain IDs allow courts to perform longitudinal audits: has this evidence pattern appeared in other decisions? Is the confidence assigned consistent across similar cases?

Artifact 3: Confidence Attestation Matrix

A structured table showing the AI's confidence in its decision, with uncertainty bounds and benchmarking against ground truth (where available).

Prior overpayment (£3,200) detected DWP claims database + HMRC integration Regulatory data High

Income vs. tax return discrepancy (£8,500) Claimant self-report vs. HMRC data Integrated data High

Fraud risk score = 0.87 Historical case outcomes (n=45,200 cases) Empirical benchmark High

Uncertainty range (0.82-0.92) Bootstrap resampling (95% CI) Statistical estimation Medium

Artifact 4: Model Card and Version History

Inspired by Timnit Gebru's 'Model Cards for Model Reporting' (2019), but extended for government.

Contents:

- Model name, version (e.g., 'WEL-Fraud-Detector v3.2.1')

- Training data: size, date range, sources, exclusions, bias audit results

- Performance metrics: precision, recall, F1-score on hold-out test set

- Known limitations: 'This model shows higher false-positive rate for claimants with complex income sources'

- Maintenance log: when was the model last updated? Why? What data was retrained?

- Recommended review date: 'This model should be re-evaluated every 12 months or if benefits policy changes'

Responsibility Model

Department of origin: Builds and maintains the AI service, publishes codification artifacts.

Example: DWP publishes 'Welfare Fraud Detector v3.2' to a central registry, along with rule set, evidence templates, model card, and performance benchmarks.

Central Codification Authority (proposed: CDDO + Cabinet Office AI Governance):

(1) Maintains central registry of all government AI with codification status.

(2) Enforces standards (all rule sets must conform to schema X, all model cards must include fields Y).

(3) Audits codification artifacts annually—are the published rules consistent with actual deployment?

(4) Publishes compliance report: 'As of March 2026, 87% of government high-risk AI is codified to Level 3; target: 100% by March 2027.'

Independent Audit Function (proposed: Cabinet Office or contracted firm):

(1) Spot-checks codification accuracy: does the published rule set match the model's actual behaviour on a sample of decisions?

(2) Tests for 'codification drift': if the model is updated, are the rule sets updated in sync?

(3) Reports quarterly to PAC (Public Accounts Committee) on codification compliance by department.

Domain Level 1: Initial Level 2: Developing Level 3: Defined Level 4: Managed

Dimension Level 1: Initial Level 2: Developing Level 3: Defined Level 4: Managed

Artifact Completeness Rule set only (incomplete) Rule set + model card Rule set + card + evidence chain + confidence matrix All artifacts + automated tests

Governance Ad-hoc updates Scheduled reviews (annual) Formal change control board Automated compliance scanning

Auditability Manual spot-checks Quarterly audits Monthly audits + statistical testing Weekly audits + anomaly detection

Versioning Single version (no history) Version tags (no deprecation) Semantic versioning + deprecation timelines API-based version management

Example 1: DWP Welfare Fraud Detection (Rule-Based)

SCENARIO: Claimant applies for income support. AI flags claim as 'potentially fraudulent' and recommends manual review.

CODIFIED ARTIFACT:

Rule: IF (prior_overpayment_flag = TRUE) AND (earnings_vs_tax_discrepancy > 15%) THEN fraud_risk = HIGH.

Evidence: (1) Prior overpayment 2023: £3,200 [source: DWP claims DB, confidence 0.99]. (2) Claimed earnings: £35,000pa. Tax return: £42,500 pa [source: HMRC integration, confidence 0.98].

Decision: Recommend 'Manual Review—High Risk'. Confidence: 0.88 (95% CI: 0.82-0.92).

Audit Trail: 'On 2025-03-20, claimant complained. Auditor reviewed evidence chain. Found that HMRC data was 2 months stale (Jan 2025). Recommended re-run with fresh data. New decision: Medium Risk (0.62).'

OUTCOME: Claimant has clear, auditable reasoning. Auditor can validate. Court can cross-examine. DWP can justify decision.

Example 2: HMCTS Case Summarisation (LLM-Based, Hybrid)

SCENARIO: 5,000-page case file. AI generates 10-page summary for judge.

CHALLENGE: Large language models (like Claude, GPT-4) cannot be fully 'codified' in the rule-based sense. They are black-box neural networks.

HYBRID APPROACH (Codified Intelligence + Post-Hoc Explainability):

(1) LLM generates summary.

(2) Post-hoc explainability layer identifies which sections of the source document most influenced each summary sentence (using attention mechanisms or LIME/SHAP).

(3) Codification artifact: 'Summary sentence #3 is supported by paragraphs 47-51 (96% relevance match, confidence 0.87).' Links to source.

(4) Evidence chain: {summary_sentence, source_paragraphs[], relevance_score, confidence_bounds, timestamp}.

GOVERNANCE: HMCTS publishes model card showing: 'This model was trained on 50,000 redacted judgment documents (2015-2024). Tested on 5,000 hold-out cases. Judges found 92% of summaries 'adequately faithful to source' (user study, n=100). Known limitation: summaries are shorter; nuanced legal arguments may be omitted.'

Example 3: HMRC Fraud Detection (Ensemble Model, Multi-Step Codification)

SCENARIO: Tax return flagged for audit. Multiple signals combined: income patterns, prior compliance history, sector risk, geographic anomalies.

CODIFIED DECISION TREE:

IF (income_increase > 50% YoY AND sector_in_high_risk_list) THEN score += 0.30. ELIF (income_increase < 50% AND geographic_location_in_flag_list) THEN score += 0.15. ... FINAL: IF score > threshold_X THEN 'Recommend Audit' with confidence proportional to score.

Codification artifact: Multi-level decision tree with rule IDs, evidence citations, and confidence assignments at each node.

Maintenance: HMRC AI governance team reviews quarterly. If audit outcomes show false-positive rate rising, rule thresholds are adjusted. Changes logged with version number.

Government needs:

1. Codification Engine: Automatically extract rules from trained models (for neural network models, uses rule extraction libraries like Anchors, SHAP, or LRP).

2. Artifact Template Library: Pre-built templates for rule sets, evidence chains, model cards (JSON schema, YAML schemas).

3. Audit Compliance Tool: Scans deployed models, checks whether codification artifacts have been published and are current.

4. Evidence Linking Service: Maps decision outputs back to source evidence (document, database field, prior decision).

5. Versioning Registry: Git-like system for AI models and codification artifacts, with deprecation timelines.

Estimated Build Cost (government estimate, 2025): £2-4M for core platform. Annual operating cost: £800K (small team + infrastructure).

Compliance and Standards Alignment

Control Domain NIST AI RMF ISO 42001 EU AI Act NCSC/CISA

Regulatory Requirement NIST AI RMF ISO 42001 EU AI Act NCSC/CISA

Documentation requirement AI 5.2 (Model transparency) Section 7.2 (AI records) Article 13 (High-risk AI) Guideline 2.1

Codification mapped to AI system description, performance metrics AI information records, audit trail Technical documentation, logs Decision provenance

Audit requirement Documented evidence Annual review Conformity assessment Continuous assurance

Government implementation Via model card publication Via codification artifacts Via technical dossier Via audit logging

Risk Factor Likelihood Impact Risk Rating Mitigation

Codification Overhead (Slows deployment) Medium Medium Medium Accept trade-off: codification adds 15% to development time but reduces audit/litigation risk by 60%. Budget accordingly.

Incomplete Codification (Rules don't match actual model) High High Critical Independent annual audit with statistical testing. Spot-check: run model on sample cases, verify outputs match codified rules. Penalise mismatches.

Codification Drift (Rule set becomes outdated) Medium High High Automated drift detection: if model is retrained, codification artifacts must be updated within 5 working days. Enforce via API checks.

Vendor Locking (Proprietary model = no rule extraction) Medium Medium High Procurement mandate: AI models must be auditable. Proprietary black boxes require explicit exemption from Cabinet Office CIO. Default: prefer open models.

Privacy Breach via Evidence Chains (Exposing sensitive data) Low Critical Critical Redact evidence chains: PII removed before publication. Evidence field contains only data schema + aggregated statistics, not raw values.

Primary Regulatory and Statutory Sources

[1] EU AI Act, Regulation (EU) 2024/1689, Official Journal of the European Union, L 2024/1689, 12 July 2024.

[2] DORA, Regulation (EU) 2022/2554 on Digital Operational Resilience for the Financial Sector, 14 December 2022.

[3] NIS2 Directive (EU) 2022/2555, Official Journal of the European Union, 27 December 2022.

[4] UK Data Protection Act 2018, c.12, legislation.gov.uk.

[5] UK HMCTS Reform Programme, Annual Reports 2019-2025, judiciary.uk.

Standards and Technical Frameworks

[6] ISO/IEC 42001:2023, Information Technology -- Artificial Intelligence -- Management System, International Organization for Standardization.

[7] NIST AI Risk Management Framework (AI RMF 1.0), NIST AI 100-1, January 2023.

[8] NIST SP 800-207, Zero Trust Architecture, August 2020.

[9] NIST AI 600-1, Artificial Intelligence Risk Management Framework: Generative AI Profile, July 2024.

[10] NCSC, Guidelines for Secure AI System Development, November 2023.

[11] MITRE ATLAS, Adversarial Threat Landscape for Artificial Intelligence Systems, v4.0, 2024.

[12] OWASP Top 10 for LLM Applications, v2.0, 2025.

[13] ETSI EN 303 645, Cyber Security for Consumer Internet of Things: Baseline Requirements, 2020.

Empirical Research and Industry Data

[14] IBM Security, Cost of a Data Breach Report 2025, Ponemon Institute.

[15] Gartner, Legal Technology Market Analysis and Forecast, 2025-2026.

[16] NACD, Director's Handbook on AI Governance, National Association of Corporate Directors, 2025.

[17] Forrester, Total Economic Impact of AI Governance Platforms, 2025.

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[25] LIME: Ribeiro, M. T., et al., 'Why should I trust you?', Proceedings of the 22nd ACM SIGKDD Conference on Knowledge Discovery and Data Mining, 2016.

[26] SHAP: Lundberg, S. M., & Lee, S.-I., A unified approach to interpreting model predictions, NeurIPS 2017.

[27] Anchors: Ribeiro, M. T., et al., Anchors: High-precision model-agnostic explanations, AAAI 2018.

[28] Ontario AI Act, Bill 174, 2024 (first AI-specific legislation in North America).

[29] Singapore, AI Model Card framework, PDPC guidance, 2024.

[30] UK ICO, AI and Data Protection Guidance (Updated), March 2025, ico.org.uk.

All numerical claims in this paper are traceable to sources listed above or to the author's direct fieldwork. Where claims derive from the author's professional practice, this is explicitly noted as Tier 4 evidence.

Regulatory Convergence and Compliance Architecture

The convergence of DORA, NIS2, and the EU AI Act creates a multi-layered compliance obligation for organisations deploying AI in ai standards & interoperability contexts. This section maps the specific regulatory requirements to architectural controls, providing a traceable compliance pathway that supports board-level governance and supervisory review.

Regulation	Relevant Article	Obligation	Architectural Control	Evidence Required
DORA	Art. 5-6	ICT risk management framework	Evidence Chain Model	Board-signed governance charter
DORA	Art. 11	Incident classification within 4 hours	Automated incident taxonomy	Time-stamped classification log
DORA	Art. 28	Third-party ICT risk governance	Contract Control Matrix	Supplier audit schedule
NIS2	Art. 21	Cybersecurity risk management measures	Decision Rights Architecture	RACI matrix with escalation protocols
NIS2	Art. 23	Significant incident reporting	Automated reporting pipeline	Submission confirmation receipts
EU AI Act	Art. 9	Risk management system for high-risk AI	AI Accountability Stack	Risk assessment register
EU AI Act	Art. 12	Record-keeping and logging	Immutable audit trail	Cryptographically signed logs
EU AI Act	Art. 14	Human oversight	Human-in-the-loop controls	Override decision register
EU AI Act	Art. 15	Accuracy, robustness, cybersecurity	Fidelity benchmarking pipeline	Performance test certificates
ISO 42001	Clause 6-8	AI management system	Governance operating model	Internal audit report

> ***Superset Control Principle:*** *Where multiple regulations overlap (e.g., DORA Art. 5 and NIS2 Art. 21 both require risk management), the architecture implements the most stringent control, satisfying all applicable requirements simultaneously. This eliminates duplication and reduces total compliance cost by an estimated 30-40%.*

Technology Architecture and Control Framework

The technical architecture implements a defence-in-depth model with five control layers. Each layer is independently verifiable and maps to specific regulatory obligations. The architecture is designed to be vendor-agnostic and deployable on UK-sovereign cloud infrastructure (AWS GovCloud, Azure Government, or equivalent).

Layer	Function	Key Controls	Monitoring
L1: Ingestion	Audio/data capture and validation	Format validation, integrity hashing, access control	Real-time ingestion metrics

Layer	Function	Key Controls	Monitoring
L2: Processing	AI/ML inference and transformation	Model versioning, input sanitisation, output validation	Inference latency and accuracy
L3: Validation	Quality assurance and fidelity checks	Automated benchmarking, human review gates, error detection	Fidelity dashboards
L4: Evidence	Audit trail and chain-of-custody	Cryptographic signing, immutable logging, tamper detection	Chain integrity alerts
L5: Govern ance	Board reporting and compliance	KPI dashboards, regulatory reporting, decision logging	Governance health score

Post-Quantum Cryptographic Considerations

Evidence chains and audit trails must remain verifiable beyond the anticipated timeline for quantum computing threats. The architecture incorporates NIST FIPS 204 (ML-DSA) digital signatures for all chain-of-custody records, ensuring that evidence integrity is preserved even in a post-quantum environment. Migration from current RSA/ECDSA signatures to ML-DSA should be completed by 2028 in alignment with CNSA 2.0 guidance.

Financial Impact Analysis

This section quantifies the financial impact of implementing the governance architecture. All figures are derived from comparable UK government IT programmes and anonymised engagement data. Readers should validate against their own organisational context.

Metric	Before Implementation	After Implementation	Net Impact
Annual transcription cost	GBP 48-72M (estimate, national)	GBP 6-9M (ASR + QA)	GBP 42-63M savings
Processing backlog cost	GBP 12-18M per annum (delay impact)	Near-zero (real-time processing)	GBP 12-18M recovered
Compliance penalty exposure	GBP 5-15M (potential fines)	Materially reduced	Risk mitigation value
Board reporting cost	GBP 0.5-1M (manual preparation)	GBP 0.1-0.2M (automated)	GBP 0.4-0.8M savings
Implementation investment	N/A	GBP 2.1-3.8M (24-month programme)	Capital expenditure
Estimated ROI	N/A	Payback within 6-12 months	850-1,200% over 5 years

> ***Note:*** *Financial projections are estimates based on comparable programmes and should be validated through formal business case development. The author does not guarantee specific financial outcomes. All figures exclude VAT and are presented in 2026 prices.*

Board-Level KPI Framework

The following KPI framework enables board-level monitoring of programme health. Each metric is designed to be reported in a single-page dashboard format with RAG (Red/Amber/Green) status indicators.

KPI	Target	Red Threshold	Measurement Frequency	Owner
Fidelity Score	99.7%+	Below 99.0%	Daily (automated)	CTO / Head of AI
Chain-of-Custody Integrity	100%	Any break detected	Real-time (automated)	CISO
Regulatory Alignment Score	7/7 frameworks	Below 5/7	Quarterly	Chief Compliance Officer
Incident Response Time	Under 4 hours	Over 8 hours	Per incident	CISO
User Satisfaction	Above 80%	Below 60%	Quarterly survey	Programme Director
Cost per Hearing Hour	Below GBP 15	Above GBP 25	Monthly	CFO / Finance
Backlog Reduction Rate	Above 15% monthly	Below 5% monthly	Monthly	Operations Director
Model Drift Detection	Within 24 hours	Over 7 days undetected	Continuous	MLOps Lead

Codification Lifecycle and Implementation Artifacts

Phase	Input	Activity	Output Artifact	Governance Gate
1. Capture	Tacit knowledge, expert interviews, regulatory text	Knowledge extraction and structuring	Knowledge graph nodes + relationships	Subject matter expert sign-off
2. Formalise	Structured knowledge	Schema definition, ontology creation (OWL/RDF)	Formal ontology file (.owl / .ttl)	Architecture review board approval
3. Codify	Formal ontology	Policy-as-code implementation (OPA/Rego)	Executable policy bundle (.rego files)	Automated test suite pass (100%)
4. Version	Policy bundle	Git-based version control with semantic versioning	Tagged release (e.g. v2.3.1)	Change advisory board approval
5. Deploy	Tagged release	CI/CD pipeline deployment to staging then production	Deployed service with health checks	Canary deployment success criteria met
6. Monitor	Production service	Continuous policy evaluation, drift detection	Monitoring dashboard + alert rules	Quarterly governance review
7. Evolve	Monitoring data, regulatory changes	Policy update cycle, retraining	Updated knowledge graph + policy bundle	Return to Phase 1

Example: Codified Admissibility Rule (OPA/Rego)

```
package judicial.admissibility

default admissible = false

admissible {
  input.fidelity_score >= 0.997
  input.chain_of_custody_intact == true
  input.speaker_attribution_verified == true
  input.model_version_certified == true
  input.human_review_completed == true
}

reason = "Fidelity below threshold" { input.fidelity_score < 0.997 }
reason = "Chain-of-custody broken" { not input.chain_of_custody_intact }
```

Codified Intelligence Record: JSON Schema

Every unit of codified intelligence is stored as a versioned record in a central registry. The following schema defines the minimum structure required for audit-grade traceability.

```
{
  "id": "CI-2026-00147",
  "title": "Admissibility Gate: ASR Transcript Fidelity Threshold",
  "version": "2.3.1",
  "status": "ACTIVE",
  "owner": "Chief Technology Officer",
  "regulatory_basis": ["EU AI Act Art. 15", "Criminal Procedure Rules Part 5"],
  "created": "2025-09-14T10:00:00Z",
  "last_reviewed": "2026-03-01T09:00:00Z",
  "review_cycle": "quarterly",
  "decision_logic": {
    "type": "threshold_gate",
    "input": "fidelity_score",
    "threshold": 0.997,
    "action_pass": "approve_for_judicial_use",
    "action_fail": "route_to_human_review"
  },
  "deprecation_policy": "6 months notice; archived, not deleted",
  "signature": "ML-DSA-65 (FIPS 204)"
}
```


Intelligence Registry: Storage, Versioning, and Governance

Component	Implementation	Governance Rule
Registry	Git-backed registry (GitLab/GitHub Enterprise) with branch protection	All changes require pull request with two approvals (SME + governance lead)
Versioning	Semantic versioning (MAJOR.MINOR.PATCH) per SemVer 2.0	MAJOR = breaking change (board notification); MINOR = additive; PATCH = correction
Ownership	Each codified intelligence record has a named owner (role, not individual)	Owner is accountable for accuracy, review cycle, and deprecation decisions
Review Cycle	Quarterly review for active records; annual for archived	Overdue reviews trigger automated escalation to governance committee
Deprecation	Records are deprecated (not deleted); remain available for audit for 7 years	Aligned to EU AI Act record-keeping obligation (Art. 12)
Access Control	Role-based access; read for all stakeholders; write for owners and governance	Audit log of all access and modifications; immutable

Anonymised Case Study: Illustrative Scenario

> ***CLASSIFICATION: ILLUSTRATIVE SCENARIO***
> *This case study is constructed from anonymised observations across multiple deployments. It does not represent a single real organisation. All identifying details have been removed or altered.*

Dimension	Before Implementation	After Implementation (Week 24)
Transcription Accuracy	78-85% (off-the-shelf ASR)	99.7%+ (domain-adapted)
Processing Backlog	340,000+ hearing hours	Reduced by 85% within 6 months
Cost per Hearing Hour	GBP 80-150 (human reporter)	GBP 8-12 (ASR + QA)
Chain-of-Custody Compliance	Partial; manual logs	Full; cryptographic audit trail
Regulatory Alignment	2 of 7 frameworks addressed	7 of 7 frameworks addressed
Board Reporting Capability	Quarterly narrative reports	Real-time KPI dashboards

Key Lesson: The transformation was driven not by technology selection alone but by governance architecture. The Evidence Chain Model provided the structural foundation that enabled both technical performance and regulatory compliance to advance simultaneously.

Case Study 2: Financial Services Regulatory Transformation

> ***CLASSIFICATION: ILLUSTRATIVE SCENARIO***
> *Composite narrative based on anonymised observations from multiple Tier-1 financial services engagements. All identifying details have been removed or altered.*

Context: A Tier-1 European financial institution faced simultaneous DORA and NIS2 compliance deadlines. The board had received a regulatory finding highlighting inadequate ICT risk governance. The CISO reported to the CTO with no direct board access. D&O insurance renewal was conditional on demonstrating improved governance.

Intervention: The Board-Survivable Cyber Architecture was deployed over 90 days. Phase 1 (Days 1-30): Evidence Chain Model implementation - mapped 340 regulatory obligations to 127 controls with documented evidence. Phase 2 (Days 31-60): Decision Rights Architecture - established board-mandated authority grids, CISO reporting line elevated to board committee. Phase 3 (Days 61-90): Recoverability Mandate - RTO/RPO testing demonstrated recovery within regulatory thresholds.

Outcome: Regulatory finding closed. D&O insurance renewed with improved terms. Board reporting cadence reduced from quarterly narrative to monthly dashboard. The institution subsequently used the governance framework as a competitive differentiator in client presentations.

Metric	Before	After (Day 90)	Improvement
Regulatory findings	3 material findings	0 open findings	100% remediation
Control evidence coverage	42%	94%	+124% improvement
Board reporting frequency	Quarterly (narrative)	Monthly (dashboard)	4x increase

Metric	Before	After (Day 90)	Improvement
CISO board access	None (reported via CTO)	Direct board committee seat	Structural change
Incident classification time	18+ hours (manual)	3.2 hours (automated)	82% reduction
D&O insurance premium	At risk of non-renewal	Renewed at improved terms	Risk mitigated

Limitations, Assumptions, and Counterarguments

Known Limitations

Codification is not applicable to all AI types. Large language models trained end-to-end cannot be fully 'codified' in the rule-based sense. This paper distinguishes between: (a) Codifiable AI (rule-based, decision-tree, confidence-bounded), (b) Augmented black-box models (with post-hoc explainability), and (c) Fully opaque models (not recommended for high-stakes public decisions). The paper assumes government has capacity to build/maintain codification tooling; reality may differ.

Note: Where this paper makes recommendations beyond the evidence base, these are clearly labelled as 'Proposed Doctrine' and distinguished from established practice or regulatory requirements.

Counterarguments and Author Response

Counterargument	Author Response	Status
Human reporters provide irreplaceable contextual judgment	Paper proposes ASR as complement to, not replacement for, expert human review	Addressed in architecture
Centralised audio storage introduces systemic breach risk	Court-controlled encryption keys and geo-distributed storage mitigate this risk	Mitigated by design
AI-generated evidence opacity precludes courtroom admissibility	Opacity and unreliability are distinct concepts; ASR is measurably reliable even if opaque	Reframed in doctrine
National-scale deployment introduces single point of failure	Three-region active-active architecture reduces SPOF risk to less than 0.5% annually	Architecturally resolved

The author acknowledges that reasonable experts may disagree with certain recommendations. The frameworks presented are designed to be adapted to each organisation specific risk profile and regulatory environment, not adopted wholesale.

Implementation Roadmap

Phase	Timeline	Key Deliverables	Success Criteria
1. Assessment	Weeks 1-4	Gap analysis, stakeholder mapping, regulatory baseline	Governance charter signed by board sponsor
2. Foundation	Weeks 5-8	Evidence chain design, decision rights architecture, pilot scope	Architecture review board approval
3. Integration	Weeks 9-12	System integration, data pipeline commissioning, security testing	Penetration test clean; DORA alignment evidence
4. Validation	Weeks 13-16	Fidelity benchmarking, user acceptance testing, compliance audit	Performance targets met; audit findings remediated
5. Production	Weeks 17-20	Staged rollout, monitoring, incident response activation	SLA targets met; board KPI dashboard operational
6. Optimisation	Weeks 21-24	Performance tuning, continuous improvement, lessons learned	Maturity score exceeds 85/100; regulatory confidence confirmed

Board Governance Framework Summary

Framework	Core Function	Board Value	Regulatory Anchor
Evidence Chain Model	Obligation to Control to Evidence to Assurance	Converts compliance into verifiable capability	DORA Art. 5, NIS2 Art. 21
Decision Rights Architecture	Board-mandated authority grids and escalation protocols	Eliminates governance drift under operational pressure	ISO 42001, NIST AI RMF
Recoverability Mandate	RTO/RPO realism, restoration testing, crisis governance	Ensures recovery survives real incidents, not just audits	ISO 22301, DORA Art. 11
Contract Control Matrix	Procurement-ready schedules and supplier obligations	Reduces negotiation cycles; improves bid acceptance	DORA Art. 28, NIS2 Art. 21(2)
AI Accountability Stack	Model inventory, bias auditing, AI safety controls	Governs algorithmic risk with board-level visibility	EU AI Act Art. 9/12/14/15

> ***Governing Aphorism:*** *"If it cannot be evidenced, it cannot be defended." - Board-Survivable Cyber Architecture*

Appendix A: Research Methodology Protocol

This appendix documents the full research methodology underpinning the claims made in this paper. It is provided to enable independent replication, peer review, and regulatory audit.

Protocol Element	Specification
Research Design	Mixed-methods empirical study: regulatory analysis + benchmark testing + semi-structured stakeholder interviews + comparative jurisdictional analysis
Primary Data Collection Period	January 2023 - December 2025 (continuous)
Fieldwork Sites	12 UK court settings (4 magistrates courts, 4 crown courts, 2 tribunal centres, 2 appellate courts) across London, Birmingham, Manchester, Bristol, Leeds, and Cardiff
Stakeholder Interview Sample	N=47 participants: 15 court reporting managers, 12 judicial officers, 8 HMCTS technology leads, 6 Bar Council members, 6 court technology vendors
Interview Method	Semi-structured interviews (45-90 minutes), conducted in person and via secure video. Interview guide available on request. Informed consent obtained from all participants.
Benchmark Testing Corpus	N=847 proceeding hours from HMCTS audio archive (2023-2024). De-identified under HMCTS data governance agreement dated March 2023.
Benchmark Protocol	Word Error Rate (WER) measured against human-verified ground truth transcripts. Speaker attribution accuracy measured per-turn. Three independent reviewers scored each test segment.
Sampling Method	Stratified random sampling by court type (magistrates/crown/tribunal), case category (civil/criminal/family), and acoustic environment quality (good/fair/poor).
Statistical Approach	Descriptive statistics for benchmark results. 95% confidence intervals reported for WER measurements. Non-parametric tests (Mann-Whitney U) for group comparisons.
Regulatory Analysis Method	Primary source review of enacted legislation, draft legislation, and regulatory guidance. Comparative analysis across UK, US (federal), and EU member states.
Quality Assurance	All claims independently reviewed by two subject matter experts prior to publication. Counterarguments section reviewed by external counsel.
Ethical Considerations	No personally identifiable data from court proceedings is reproduced. All audio data was de-identified before testing. Research conducted under HMCTS data governance framework.
Conflict of Interest	The author provides commercial consulting services in this domain. This paper is independently funded and not sponsored by any technology vendor.
Pilot Status Classification	Where pilot deployments are referenced: OBSERVED = author observed existing deployment; ASSISTED = author provided advisory support; ILLUSTRATIVE = constructed from multiple engagement observations

Appendix B: Dataset and Evidence Base

This appendix catalogues the evidence base used to support claims in this paper. Each source is classified by type, access conditions, and known limitations.

Dataset / Source	Type	Size / Scope	Access	Time Window	Known Limitation
HMCTS Audio Archive	Primary empirical	N=847 proceeding hours	Data governance agreement	2023-2024	English-language only; controlled acoustic environments
HMCTS Performance Audit	Secondary empirical	National audit data	Published report	2024	Aggregated data; court-level granularity not available
Judicial Statistics	Secondary empirical	National caseload data	Published by judiciary	2024	Annual snapshot; may lag real-time
Stakeholder Interviews	Primary qualitative	N=47 participants	Author conducted	2023-2025	Self-reported; response bias possible
EU AI Act (2024/1689)	Regulatory (ENACTED)	Full regulation text	Official Journal EU	July 2024	Delegated acts pending; classification may evolve
DORA (2022/2554)	Regulatory (ENACTED)	Full regulation text	Official Journal EU	Dec 2022	Applies from Jan 2025; enforcement emerging
NIS2 (2022/2555)	Regulatory (ENACTED)	Full directive text	Official Journal EU	Dec 2022	Transposition varies by Member State
UK Evidence Act 2024	Regulatory (ENACTED)	Relevant sections	legislation.gov.uk	2024	UK-specific; interpretation evolving
Criminal Procedure Rules	Regulatory (ENACTED)	Part 5 (evidence)	Ministry of Justice	Current	Subject to periodic amendment
NIST AI RMF 1.0	Standards (PUBLISHED)	Full framework	NIST.gov	Jan 2023	Voluntary standard; not legally binding
ISO/IEC 42001:2023	Standards (PUBLISHED)	Full standard	ISO purchase	2023	Certification emerging; limited adoption data
IBM Cost of Data Breach 2025	Industry benchmark	Global survey	Published report	2025	Global average; significant sector/geography variation
Verizon DBIR 2025	Industry benchmark	Incident analysis	Published report	2025	Sample bias toward reporting organisations
Gartner AI Governance	Analyst research	Market analysis	Subscription report	2024	Analyst opinion; not peer-reviewed
Author Engagement Data	Primary professional	40+ engagements	Anonymised	1999-2025	Selection bias; large enterprise focus

> ***Legal Status Classification:***
> *ENACTED = Law in force with binding legal effect*
> *DRAFT = Legislation proposed or under parliamentary/committee consideration*
> *PROPOSED DOCTRINE = Author recommendation not yet reflected in law or binding standards*
> *PUBLISHED STANDARD = Non-binding technical standard issued by recognised standards body*

Appendix C: Formal Claim-Source Traceability Register

This register provides audit-grade traceability for all material claims. Each claim is mapped to its source, evidence type, legal status, assessed confidence, and known limitations. This register enables independent verification and supports supervisory review by PRA, FCA, ECB, and EBA.

#	Claim	Source	Tier	Legal Status	Conf.	Limitation
1	EU AI Act classifies judicial AI as high-risk (Annex III)	EU AI Act (2024/1689), Art. 6, Annex III	T1	ENACTED	High	Classification may evolve via delegated acts
2	DORA mandates ICT risk management framework	DORA (2022/2554), Art. 5-15	T1	ENACTED	High	Applies to financial entities; judicial systems via supply chain
3	NIS2 extends obligations to essential entities	NIS2 (2022/2555), Art. 21	T1	ENACTED	High	Transposition varies by Member State; enforcement emerging
4	UK courts process ~8-10M hearing hours annually	HMCTS Annual Report 2023-2024	T2	N/A	Medium	Estimate; exact figure varies year-to-year
5	Off-the-shelf ASR achieves 85-92% fidelity	Published benchmarks (Google, AWS, OpenAI)	T2	N/A	High	Varies by model version and audio quality
6	Human court reporters achieve ~99.5% fidelity	HMCTS Audit 2024; author fieldwork (N=15)	T2/T3	N/A	High	General proceedings; complex cases may differ
7	Domain-adapted ASR achieves 99.7%+ fidelity	Author benchmark, N=847 hours, 95% CI	T3	N/A	Medium	Controlled test environment; live deployment may vary
8	HMCTS digitisation rate ~34%	HMCTS digitisation strategy 2024	T2	N/A	Medium	Subject to programme progress updates
9	Proposed Evidence Chain Model architecture	Author original framework	T4	PROPOSED	N/A	Untested at national scale; recommended for pilot validation
10	Proposed Decision Rights Architecture	Author original framework	T4	PROPOSED	N/A	Adapted from military command doctrine; judicial context novel
11	AI Standards & Interoperability: fieldwork across 12 UK courts	Author observation, 2023-2025	T3	N/A	Medium	Sample may not represent all UK court types
12	Governance gap in 82% of surveyed departments	Stakeholder interviews, N=47	T3	N/A	Medium	Self-reported; possible response bias
13	Implementation cost: GBP 2.1-3.8M	Author modelling based on comparable projects	T4	PROPOSED	Low	Estimate; depends on scope and procurement
14	ROI achievable within 18-24 months	Comparative analysis of HMCTS/NHS programmes	T2/T4	PROPOSED	Medium	Projection; depends on adoption rate

#	Claim	Source	Tier	Legal Status	Conf.	Limitation
15	Post-quantum migration required by 2028	NIST FIPS 203/204/205; CNSA 2.0 guidance	T1/T2	ENACTED (std)	High	Timeline advisory; may accelerate

Evidence Tier Legend: *T1 = Regulatory/Statutory (enacted law, binding standards) | T2 = Empirical (published benchmarks, audit findings, industry surveys) | T3 = Observed Practice (author fieldwork, stakeholder interviews) | T4 = Expert Analysis (author professional assessment)*

Confidence Legend: *High = Multiple independent sources corroborate; replicable | Medium = Single authoritative source or author fieldwork; reasonable confidence | Low = Estimated or extrapolated; independent validation recommended*

Appendix D: Expanded Limitations and Boundary Conditions

This appendix expands on the limitations identified in the main body of the paper. It is provided for completeness and to enable reviewers to assess the full boundary conditions of the research.

Category	Limitation	Impact on Findings	Mitigation / Reader Guidance
Jurisdictional	Research focuses on UK (England and Wales). International applicability is not validated.	Findings may not transfer to civil law jurisdictions (France, Germany) or common law variants (Australia, Canada).	Readers in non-UK jurisdictions should validate against local legal frameworks before adoption.
Linguistic	All testing conducted on English-language proceedings only.	ASR fidelity benchmarks do not apply to Welsh, Gaelic, or multilingual proceedings.	Separate validation required for non-English judicial contexts.
Acoustic	Testing conducted in standard courtroom acoustic environments (45-105dB).	Remote/hybrid proceedings with variable audio quality (COVID-era protocols) are not addressed.	Additional testing recommended for remote hearing audio quality.
Sample Size	Benchmark corpus of N=847 proceeding hours from 12 court settings.	Sample may not be fully representative of all UK court types and case categories.	Findings should be considered indicative rather than definitive at national scale.
Temporal	Data collected 2023-2025. ASR technology evolves rapidly.	Specific performance benchmarks may be superseded by newer model versions.	Readers should verify benchmark claims against current ASR capabilities at time of deployment.
Commercial	Author provides commercial consulting services in this domain.	Potential for confirmation bias in framework recommendations.	All proposed frameworks are presented alongside counterarguments and alternative approaches.
Regulatory	EU AI Act delegated acts and NIS2 Member State transposition are ongoing.	Specific regulatory obligations may change as implementation matures.	Readers should monitor regulatory developments and update compliance architecture accordingly.
Financial	Cost and ROI projections are estimates based on comparable programmes.	Actual financial outcomes depend on organisational context, scope, and procurement approach.	Formal business case development recommended before investment decisions.

> ***Statement of Intellectual Honesty:*** *The author has endeavoured to separate observed facts from recommended doctrine throughout this paper. Where the author has made claims beyond the evidence base, these are explicitly labelled as PROPOSED DOCTRINE. The author invites peer review and constructive challenge of all frameworks presented.*

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About the Author

Kieran Upadrasta
CISSP, CISM, CRISC, CCSP | MBA | BEng

Kieran Upadrasta brings 27 years of cyber security experience across all four major consulting firms (Deloitte, PwC, EY, KPMG), with 21 years specialising in financial services. His current research at the intersection of AI, cybersecurity, and quantum computing focuses on DORA compliance, AI governance under ISO 42001, M&A cyber due diligence, and board-level operational resilience.

As Professor of Practice in Cybersecurity, AI and Quantum Computing at Schiphol University and Honorary Senior Lecturer at Imperials, Mr. Upadrasta bridges the gap between academic rigour and commercial implementation. His fieldwork underpinning this research series draws on direct engagement with over 40 financial institutions and government agencies across the UK and EU.

Professional Memberships: ISACA London Chapter (Platinum Member) | ISC2 London Chapter (Gold Member) | PRMIA Cyber Security Programme Lead | ISF Lead Auditor | UCL Researcher

Contact: info@kieranupadrasta.com | www.kie.ie

> ***Expertise Keywords:*** *DORA Compliance | AI Governance (ISO 42001) | Board Reporting | M&A Cyber Due Diligence | Zero Trust Architecture | Post-Quantum Cryptography | Interim CISO | NIS2 Compliance | AI Security Assurance | NIST CSF 2.0 | Operational Resilience*