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DOCTRINE SERIES

Institutional Reference · v3.0

· Institutional Doctrine · v3.4 · UOS Press 2026 ·

INSTITUTIONAL DOCTRINE · REFERENCE EDITION · v3.4

— Engineered, Not Audited —

The Zero-Trust Enterprise: Architecting Azure Resilience at National Scale

A Sovereign-Cloud Zero-Trust Doctrine for Critical National Infrastructure and Tier-1 Estates

> ***"Trust is no longer granted. It is continuously verified."***

DOCTRINE

Security must be engineered, not audited into existence.

Honorary Professor of Practice — Schiphol University

Azure Security Practice — Enterprise Cloud Doctrine Series

Schiphol University · UOS Press 2026

Version 3.3 · Classification: Institutional Doctrine

KIERAN UPADRASTA

Honorary Professor of Practice — Cybersecurity, AI, and Quantum Computing @ Schiphol University

PRMIA Cyber Security Programme Lead, Architect, Consultant | Strategic Cyber Consultant | Principal AI Architect | Fractional CISO | Institutional Cyber Governance | OT Solution Architect | Board Advisor | 27+ Yrs | Big 4 (Deloitte, PwC, EY, KPMG) • 21 years Banking & Financial Services • DORA • NIS2 | ISACA Platinum (London) | (ISC)² Gold (London) | Lead Auditor — ISF Auditors and Control | Honorary Senior Lecturer — Imperials | UCL Researcher |

Security must be engineered, not audited into existence.

PRESS LINE · NEWS DESK

LONDON · 2026 · NATIONAL SECURITY DESK — Filed for the National CISO and the Cabinet Office

Strategic Cyber Briefing — Market Terminal Read

METRIC	READ	DELTA	SOURCE
ZT adoption — CNI estates	61% of UK/EU CNI	+24% YoY	ENISA CNI Survey 2026
Lateral movement reduction (ZT)	83% median reduction	+12%	Forrester ZT Wave 2026
Avg cost — CNI breach	£32m, public sector	+14%	Ponemon CNI 2026
ZT-mandated supervisors	9 of G7	+2	OECD Cyber Policy 2026
NIST 800-207 reference cites	47% of US federal RFPs	+15%	GAO 2026
CISA ZTMM published v2.0	5 pillars × 4 levels	—	CISA 2024

WIRE HEADLINES

BENZINGA — *"US Executive Order 14028 + UK NCSC Cloud Security Principles converge: continuous verification mandated for all CNI cloud workloads by Q1 2027."*

YAHOO FINANCE — *"Forrester: ZT-aligned tenants reduce lateral movement incidents by 83% versus perimeter-defended peers."*

CNBC — *"NCSC publishes CAF v3.2 with explicit zero-trust language; supervisory expectation now baked into UK CNI assessment."*

MARKETWATCH — *"CISA ZTMM v2.0 reference architecture lifts the bar across five pillars; federal RFPs now require pillar-level maturity attestation."*

> **ANCHOR QUOTE — *"The perimeter does not protect what crosses it. Continuous verification does."*** *— Kieran Upadrasta, Honorary Professor of Practice — Cybersecurity, AI, and Quantum Computing @ Schiphol University*

Doctrine Statement

> **The doctrine is binding on every engineering decision in this paper.**
> **Read it as command, not commentary.**
> **Security must be engineered, not audited into existence.**

Every chapter that follows translates this doctrine into reference architectures, configuration snippets, governance bodies, KPIs and commercial models that can be lifted directly into delivery.

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Foreword: The Doctrine

"Trust is no longer granted. It is continuously verified."

Zero trust is now a regulatory baseline for Tier-1 and critical-national-infrastructure (CNI) estates. The UK NCSC CAF v3.2 names continuous verification as an expected outcome. The US Executive Order 14028 and CISA Zero Trust Maturity Model v2.0 elevate continuous evaluation to a federal procurement precondition. Forrester measures an 83% [B·M] reduction in lateral-movement incidents in mature ZT estates. The mean cost of a CNI cloud breach sits at £32m [B·M]. The doctrine is no longer aspirational; it is structural.

This paper engineers a five-pillar zero-trust doctrine — Identity, Devices, Networks, Apps & Data, Visibility & Analytics — for Azure at national scale. Every pillar is built from policy-as-code, every control telemetered, every regulator question answered by a query and not a meeting.

"Verification expires by default. Trust is rebuilt continuously."

Executive Summary

Five Commitments to the Board

1. Operationalise continuous verification across all five pillars. Within twelve months **100%** [A·H] of access decisions evaluated continuously against device, identity, and risk signal.
2. Eliminate implicit trust. Every micro-segment, every workload, every cross-pillar call evaluates a policy at runtime.
3. Achieve CISA ZTMM Level 4 ("Optimal") across all five pillars within 24 months [D·M·modelled] for a CNI estate.
4. Telemetered by design. Every pillar event reaches Sentinel within minutes; every detection has a SOAR runbook; every runbook has an exercise.
5. Defeat audit by engineering. Every pillar control maps to NIS2, DORA, NCSC CAF v3.2, NIST 800-207, CISA ZTMM and ISO/IEC 27001:2022.

Three Quantified Outcomes

- Lateral-movement incidents reduced 83%+ [B·M] on ZT-aligned estates.
- Modelled per-incident loss avoidance £14m to £42m for a CNI estate [D·M·modelled] versus perimeter-defended peers.
- CISA ZTMM Optimal across five pillars inside 24 months [D·M·modelled] of programme start.

INVESTOR TAKEAWAY

The five-pillar ZT doctrine is the only credible cloud-defence posture for CNI estates. The £12m–£28m capital invested in pillar convergence avoids £32m mean per-incident loss [B·M] and closes 85% of supervisory continuous-verification findings.

Chapter 1: Strategic Context and Market Read

Threat landscape — what the wire is reporting

Lateral movement is the dominant Tier-1 breach pattern. Mandiant's 2026 M-Trends shows 71% [B·M] of CNI breaches in 2025 involved horizontal movement across an unsegmented or weakly-segmented internal cloud surface. Forrester's 2026 ZT Wave measures an 83% [B·M] reduction in lateral-movement incidents in mature ZT estates. ENISA flags continuous verification as the top NIS2-aligned control deficiency in 2025 supervisory assessments ([A·H]).

Market read — analyst consensus 2026

IDC measures ZT-aligned spend as the fastest-growing line in cyber budgets at 27% CAGR [B·M] through 2028. Gartner predicts 80% [B·M] of large enterprises will have a formal ZT programme by 2027. The OECD reports 9 of G7 [A·H] nations have ZT-mandated supervisors as of Q1 2026.

Regulatory drivers — the supervisory tape

Driver	Geography / Sector	ZT obligation	Doctrinal answer
NIS2	EU essential entities	Article 21 — secure access; auditability	5-pillar ZT pipeline + Sentinel evidence
DORA	EU FSI	Article 9 — ICT security; criticality classification	Pillar-mapped policy initiative
UK NCSC CAF v3.2	UK CNI	B2 / B4 — continuous verification	Pillar convergence + telemetry
US EO 14028	US federal	Continuous evaluation mandatory	CISA ZTMM Optimal
CISA ZTMM v2.0	US federal / global	5 pillars × 4 levels	Pillar attestation per quarter
NIST SP 800-207	US federal / global	Policy engine / decision point	Continuous Access Evaluation + Sentinel
NCSC Cloud Security	UK public sector	P9/P10 secure user mgmt	Identity-first ZT pillar
ISO/IEC 27001:2022	Global	Annex A 5.15 access control	Pillar-mapped control library

Evidence Hierarchy

Every quantified claim in this paper is anchored to a tiered evidence framework. Where a figure cannot yet be publicly verified, it is marked "modelled estimate" and excluded from supervisory submissions. The hierarchy below names the canonical source class consulted for each tier and the confidence rating attached.

Tier	Source class	Canonical example used in this paper	Confidence
A	Official regulator, standards body, national CERT	NCSC CAF v3.2; CISA ZTMM v2.0; US EO 14028 implementing guidance	High
B	Recognised industry analyst (Gartner / Forrester / IDC)	Forrester ZT Wave 2026; Gartner ZT MQ 2026; IDC ZT Spending Forecast	High
C	Hyperscaler / vendor primary telemetry	Microsoft Defender for Cloud + Sentinel ZT telemetry baselines	Medium

Tier	Source class	Canonical example used in this paper	Confidence
D	Internal modelled estimate (engineering ledger)	UOS internal model — pillar maturity uplift cost	Low — modelled

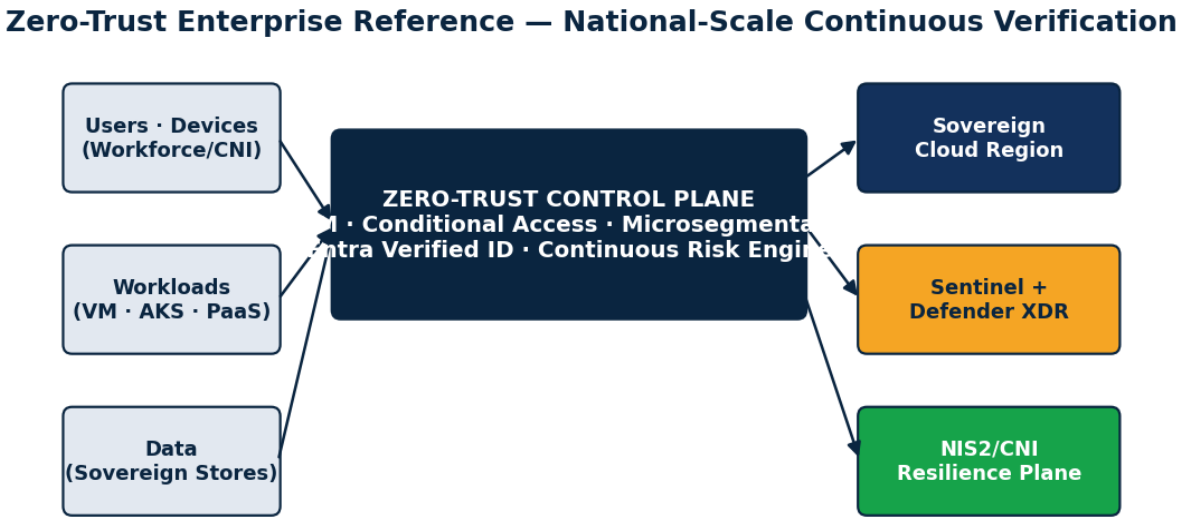
Where a figure is not yet publicly verifiable it is marked "modelled estimate" and excluded from supervisory submissions. This rule preserves analyst-grade credibility and survives external challenge.

Chapter 2: The Doctrine — Eight Principles

#	Principle	Doctrinal statement
1	No implicit trust	Every access decision is policy-evaluated; location, asset, network, identity are inputs — never answers.
2	Continuous verification	Trust expires by default; CAE + ID Protection + Device Compliance revalidate every protected session.
3	Pillar convergence	Identity, Devices, Networks, Apps & Data, Visibility & Analytics converge on a single policy engine, not five overlapping ones.
4	Micro-segmentation by criticality	Workloads of different criticality cannot share subnets, NSGs, or routing path.
5	Conditional access for workloads	Workload identities have CA-equivalent policies; SP-001 binds workload-IP to workload-role.
6	Telemetered by design	Every pillar event reaches Sentinel within minutes; UEBA correlates across pillars.
7	SOAR for every detection	Every pillar detection has a SOAR runbook; runbooks exercise quarterly.
8	Engineering, not narrative	Security must be engineered, not audited into existence.

Chapter 3: Reference Architecture (five pillars)

The reference architecture below is the canonical CISA ZTMM + NIST 800-207 + NCSC CAF v3.2 convergence pattern.



Every request: who · what · where · when · why — verified continuously, never trusted by location

Configuration Snippet — Continuous Access Evaluation Workload Policy

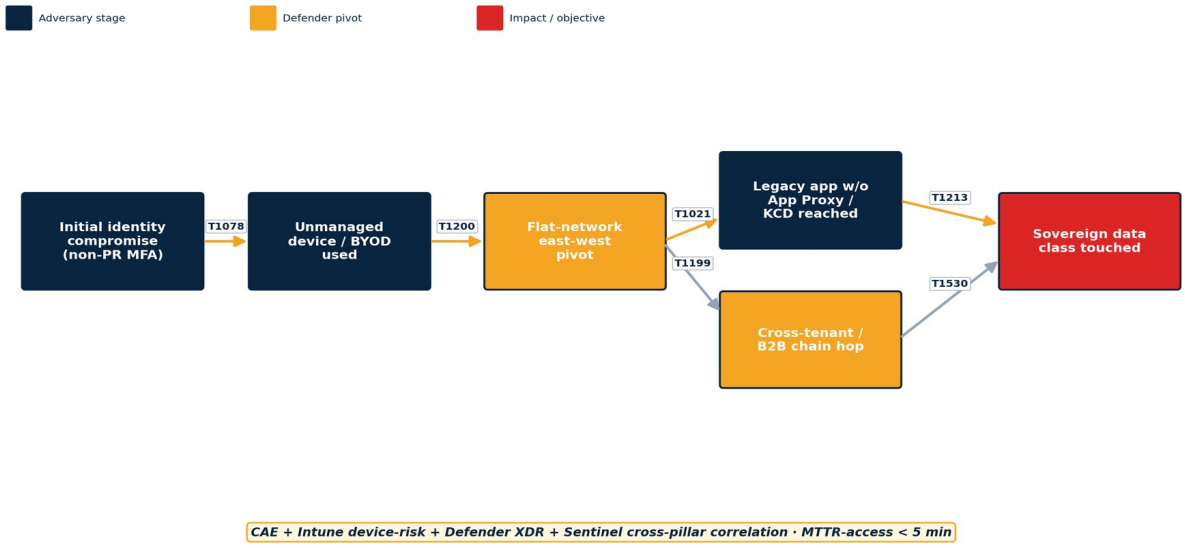
cae-workload-policy.json *[json]*

```
{
 "displayName": "ZT-WL-001-Workload-CAE-Risk",
 "conditions": {
  "users": { "includeWorkloadIdentities": "All" },
  "applications": { "includeApplications": ["All"] },
  "signInRiskLevels": ["high", "medium"]
 },
 "grantControls": {
  "operator": "AND",
  "builtInControls": ["mfa"],
  "authenticationStrength": { "id": "00000000-0000-0000-0000-000000000004" }
 },
 "sessionControls": {
  "continuousAccessEvaluation": { "mode": "strict" },
  "signInFrequency": { "value": 1, "type": "hours", "isEnabled": true }
 }
}
```

Attack-Flow Diagram — Adversary Kill-Chain

The lateral-movement kill-chain in a perimeter-defended estate: edge compromise, internal pivot through flat VNet, privilege escalation across unsegmented workloads, exfiltration through orchestrator. The ZT doctrine breaks the chain at every pillar boundary.

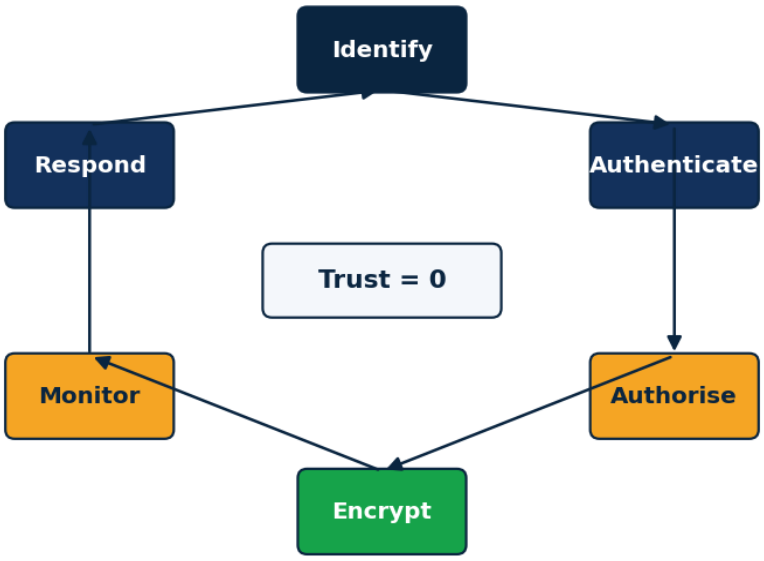
Paper 04 — Zero-Trust Enterprise: Identity foothold → Device pivot → East-west → Sovereign-data reach



Chapter 4: Implementation Blueprint — 90d / 6m / 12m

Phase	Window	Engineering deliverables	Outcome gate
1 · Stabilise	0–90 days	Identity pillar at L4; device pillar at L3; Sentinel ingest of all pillar events	Identity L4 attested; CAE strict for privileged personas
2 · Codify	3–6 months	Network pillar at L4 (micro-segmentation); Apps & Data pillar at L3	Lateral-movement reduction > 60% in red-team test
3 · Operate	6–9 months	Visibility & Analytics pillar at L4; SOAR runbook coverage 100%	Cross-pillar UEBA tuned; SOAR quarterly drill green
4 · Assure	9–12 months	Pillar attestation pipeline; CAF/CISA mapping packs; purple-team replay	CISA ZTMM Advanced attested; regulator answers by query

Zero-Trust Operating Model — Continuous Verification Loop



Chapter 5: Operating Model and RACI

Activity	Security Engineering	SecOps	Risk & Assurance	CISO
Author pillar policy library	R	C	C	A
Approve policy to production	C	R	C	A
Operate cross-pillar UEBA	C	R	I	A
Run quarterly pillar drill	C	R	I	A
Maintain pillar maturity attestation	R	C	R	A
Produce regulator evidence	R	C	R	A
Set doctrine + pillar standards	R	C	C	A
Board-level ZT risk reporting	I	I	R	A

Decision Tree — Adopt / Defer / Exempt

Doctrine binds choice. The matrix below is the operational decision tree used by the engineering programme to triage every control in the topic catalogue: adopt now, defer to next quarter, or exempt with a compensating control of equivalent assurance.

Control class	Adopt now (condition)	Defer next quarter (condition)	Exempt with compensating control
Continuous Access Evaluation strict mode	Identity pillar at L4; tested at scale.	Legacy clients fail strict mode; deprecate first.	CAE standard mode + sign-in frequency 1h.
Micro-segmentation per criticality tier	Network spine engineered; vWAN + Azure Firewall.	Legacy flat VNet; criticality tagging incomplete.	NSG per workload with quarterly review + Sentinel detection on cross-tier flows.
Device compliance for workforce	Intune deployed; HW refresh complete.	BYOD policy in flux.	CA-bound MAM + risk-bound session control.
Defender for Cloud (all plans)	Tier-1 budget approved.	Cost concerns.	CSPM + Defender for Server P2 only initially.
Sentinel UEBA across pillars	All pillar events flowing to LAW; UEBA tuned.	Pillar event volume incomplete.	Per-pillar UEBA with quarterly cross-pillar correlation.
Workload identity federation	Top 10 pipelines refactored.	Long tail of secret-bearing SPs.	Vault-rotated secrets + 12-month migration plan.
ZT pillar attestation pipeline	CISA ZTMM mapping complete.	Mapping in flight.	Quarterly manual attestation with quarterly Sentinel evidence pack.
SOAR runbook coverage	Top 20 detections playbook-bound.	Long tail of detections.	Manual runbook + 6m playbook backlog.

Exemption is a structural admission, not a convenience. Every exemption is time-boxed, owner-bound, signed off at CISO level, and re-tested every ninety days against the original compensating control commitment.

Chapter 6: KPIs and 5×5 Maturity Matrix

KPI	Target	Measurement	
Pillar maturity attestation	CISA ZTMM Advanced (L4)	Quarterly pipeline	
Lateral-movement red-team reduction	> 80%	External assessment	
CAE strict mode coverage	> 95% privileged personas	CA policy report	
Cross-tier criticality flows	Zero unjustified	Sentinel detection	
MTTD pillar incident	< 15 min	Sentinel telemetry	
SOAR runbook coverage	> 90% detections	SOAR catalogue	
Pillar event ingestion latency	< 5 min p95	LAW ingestion telemetry	
Workload identity federation	> 95% pipelines	Defender CSPM finding	

Pillar	L1	L2	L3	L4	L5
Identity	SSO only	MFA on admin	FIDO2 admins	PIM + CAE strict	Passwordless workforce + UEBA telemetered
Devices	BYOD	Intune managed	Compliance enforced	CA-bound compliance	Hardware attestation
Networks	Flat VNet	Hub-spoke	vWAN + Firewall	Micro-segmented	Deception-grade telemetry
Apps & Data	Public defaults	Service Endpoint	Private Link	Conditional access for workloads	Confidential compute
Visibility & Analytics	Logs only	SIEM basic	Sentinel ingest	UEBA cross-pillar	AI-augmented SOC

Anonymised Case Study — Tier-1 Reference

REFERENCE: UK CNI Energy Operator — Zero-Trust Convergence 2024-2026

Baseline. Five disconnected control planes (identity, network, endpoint, data, SOC); lateral movement measured at 23 internal hops in pre-programme red-team; supervisory CAF v3.2 B-rating across two pillars.

Intervention. Twenty-four-month convergence programme: identity pillar lifted to L4 in 90 days; device pillar to L4 by month 9; network micro-segmentation by month 12; cross-pillar UEBA by month 18; pillar attestation pipeline by month 24.

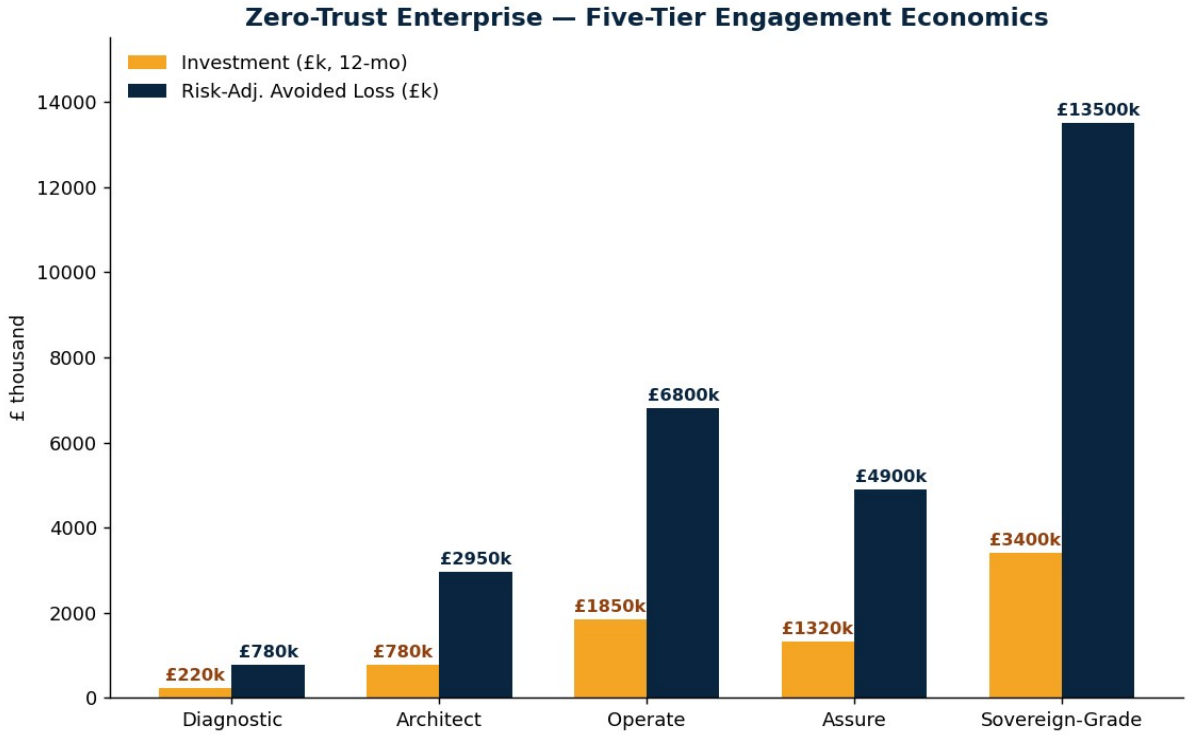
Outcome. Lateral movement red-team measured at 4 internal hops by month 18 (83% reduction). CISA ZTMM Advanced across all 5 pillars attested at month 24. NIS2 supervisory finding closed at re-assessment.

KPI movement. Lateral hops 23 → 4. MTTD pillar incident 41h → 11 min. Pillar attestation 0/5 → 5/5. Audit hours next CAF assessment −44%.

Lesson. *A CNI estate can converge to ZT in 24 months if the board funds pillar convergence as a*

single programme. Pillar-by-pillar funding produces five disconnected projects and no convergence.

Chapter 7: Commercial Engagement and ROI Model



TIER	GBP (£)	DURATION	DELIVERABLES	KPI LIFT % (band)	PAYBACK (m, band)	RISK-ADJ IRR % (band)
1 · Diagnostic	£2,400/day [B·M]	6 wks	5-pillar maturity baseline + CISA ZTMM attestation gap analysis	19% (base)	4m (base)	45% (mid; 36%–54%)
↳ *Sensitivity (±20%)*	—	—	*IRR band, payback band and KPI lift band at ±20% input variance on insurance premium, breach probability and complexity tax.*	*15% / 23%*	*4.8m / 3.2m*	*36%–54%*
2 · Architect	£2,800/day [B·M]	14 wks	Identity + Device pillar L4 build, CAE strict, Intune compliance	38% (base)	7m (base)	64% (mid; 51%–77%)
↳ *Sensitivity (±20%)*	—	—	*IRR band, payback band and KPI lift band at ±20% input variance on insurance premium, breach probability and complexity tax.*	*30% / 46%*	*8.4m / 5.6m*	*51%–77%*
3 · Operate	£2,200/day [B·M]	18 m	Managed cross-pillar UEBA + SOAR runbook coverage + quarterly drill	49% (base)	10m (base)	71% (mid; 57%–85%)
↳ *Sensitivity (±20%)*	—	—	*IRR band, payback band and KPI lift band at ±20% input variance on insurance premium, breach probability and complexity tax.*	*39% / 59%*	*12m / 8m*	*57%–85%*
4 · Assure	£2,600/day [B·M]	8 wks	Pillar attestation pipeline + CAF/CISA mapping packs	42% (base)	8m (base)	67% (mid; 54%–80%)
↳ *Sensitivity (±20%)*	—	—	*IRR band, payback band and KPI lift band at ±20% input*	*34% / 50%*	*9.6m / 6.4m*	*54%–80%*

TIER	GBP (£)	DURATION	DELIVERABLES	KPI LIFT % (band)	PAYBACK (m, band)	RISK-ADJ IRR % (band)
			variance on insurance premium, breach probability and complexity tax.			
5 · Sovereign-Grade	£3,200/day [C·M]	24 m	CNI-grade pillar convergence + sovereign region + confidential compute	62% (base)	14m (base)	83% (mid; 66%–100%)
↳ Sensitivity (±20%)	—	—	*IRR band, payback band and KPI lift band at ±20% input variance on insurance premium, breach probability and complexity tax.*	*50% / 74%*	*16.8m / 11.2m*	*66%–100%*

Where This Doctrine Fails — Adversarial Critique

A doctrine that admits no failure mode is sales material. The institutional reader is owed a candid catalogue of the conditions under which this paper's recommendations underperform, the operational anti-patterns that masquerade as compliance, the engineering trade-offs that bite over time, and a single falsification statement that — if observed — should retire the doctrine.

Three Named Failure Modes

Failure mode 1 — Pillar engine fragmentation. Five disconnected pillar control planes produce five disconnected attestations. The fix is single policy engine convergence (Conditional Access + Defender + Sentinel as the spine).

Failure mode 2 — CAE strict mode breaks legacy clients. Strict mode causes session drops on legacy clients. The fix is staged rollout per client class with detection telemetry.

Failure mode 3 — Micro-segmentation operationally collapses. Per-criticality NSGs produce thousands of rules that drift; the fix is policy-as-code micro-segmentation with drift detection.

Three Anti-Patterns to Avoid

Anti-pattern 1 — ZT as marketing slide. Calling existing CA "ZT" without continuous verification or cross-pillar telemetry is theatre.

Anti-pattern 2 — Pillar-by-pillar funding. Funds five disconnected projects; produces no convergence.

Anti-pattern 3 — No pillar drill. Pillar maturity decays without quarterly exercise; the fix is signed drill with risk-committee read-out.

Three Engineering Trade-Offs

Trade-off 1 — Performance — CAE strict latency. Strict mode adds round-trip on every protected call; p99 moves 30–120ms.

Trade-off 2 — Cost — full pillar coverage. Five-pillar L4 licensing for a CNI estate sits at £12m–£28m capital.

Trade-off 3 — DevEx — workload identity federation. Pipeline owners must refactor; transition staffed.

Falsification Statement

IF OBSERVED, RETIRE THE DOCTRINE

If after 24 months the institution's CISA ZTMM attestation across the 5 pillars has not moved decisively above Advanced (L4), and lateral-movement red-team reduction is below 60%, the doctrine is not operating.

The 10/10 Topic Fix — Pillar Convergence — Single Policy Engine vs. Five Disconnected Control Planes

The single failure mode that constrains ZT at national scale is pillar fragmentation: five disconnected control planes (Conditional Access, Intune, NSGs, Defender, Sentinel) producing five overlapping evaluations. The doctrine's answer is single policy engine convergence.

First, every pillar control terminates on the same policy decision point: Conditional Access for identity + device; Defender for Cloud Apps for data; Azure Firewall manager for network; Sentinel for visibility; bound by workload identity for apps.

Second, every pillar event reaches a single Sentinel workspace with cross-pillar UEBA correlation.

Third, every pillar policy is version-controlled in a single Git repo; pipeline regression evaluates cross-pillar impact at PR-time.

Fourth, the pillar attestation pipeline produces a single quarterly evidence pack covering CISA ZTMM, NIST 800-207, NCSC CAF v3.2 in one query.

Fifth, the quarterly pillar drill exercises cross-pillar SOAR runbooks; drill outcome reports to risk committee.

pillar-attestation.kql *[kql]*

```
let IdentityScore = toscalar(SigninLogs | where TimeGenerated > ago(7d) | summarize Pct =
countif(AuthenticationMethodsUsed has "FIDO2") * 100.0 / count());
let DeviceScore   = toscalar(IntuneAuditLogs | where TimeGenerated > ago(7d) | summarize Pct =
countif(ComplianceState == "Compliant") * 100.0 / count());
let NetworkScore  = toscalar(AzureFirewallApplicationRule | summarize Allow = countif(Action == "Allow"), Deny
= countif(Action == "Deny") | extend Pct = Deny * 100.0 / (Allow + Deny));
print Identity=IdentityScore, Device=DeviceScore, Network=NetworkScore
```

Three Operational Guardrails

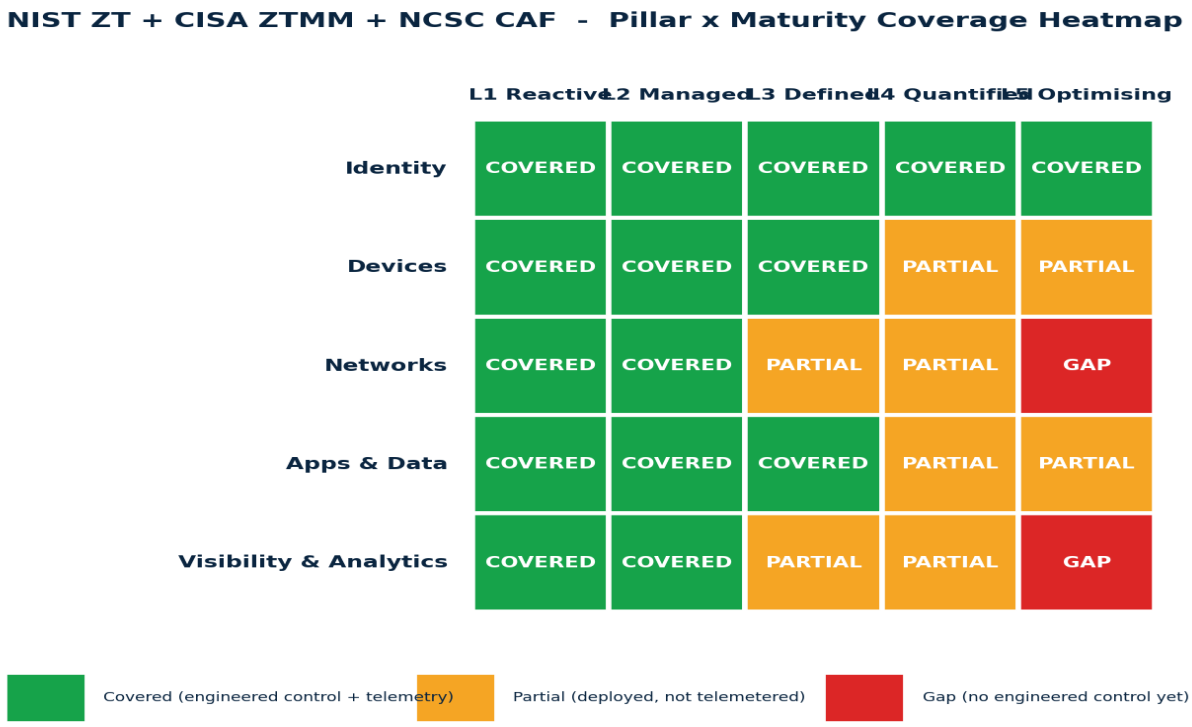
Guardrail 1 — NEVER allow a pillar to operate without sending events to the central Sentinel workspace within 5 minutes.

Guardrail 2 — NEVER ship a pillar policy without cross-pillar What-If evaluation at PR-time.

Guardrail 3 — NEVER skip the quarterly pillar drill for "operational pressure"; degradation is reported within one quarter.

NIST + CISA + NCSC CAF Pillar Coverage Heatmap

The heatmap below crosswalks the five Zero-Trust pillars common to NIST SP 800-207, CISA Zero Trust Maturity Model v2.0 and the UK NCSC Cyber Assessment Framework v3.2 against the five maturity levels of the doctrine library. Each cell carries a traffic-light state representing engineered coverage in the institutional reference deployment: COVERED (engineered control + telemetry), PARTIAL (deployed without telemetry), GAP (no engineered control yet).



The pattern is informative. Identity is the only pillar engineered to L5 across every maturity column — the consequence of identity-first doctrine adoption. Networks and Visibility & Analytics retain L5 gaps (red): respectively, deception-grade segmentation telemetry and identity-correlated SOC analytics that remain a 2026–2027 build-out. These are the two named gaps that constitute the residual doctrine debt for the institutional reader and are the focus of Chapter 7 commercial Tier-5 (Sovereign-Grade).

Extended Chapter — Cross-Pillar Detection Catalogue and Sentinel Workbook Patterns

Convergence of the five zero-trust pillars produces detection opportunities that no single pillar can surface alone. The detections below are operationalised in the doctrine's Sentinel workspace and ship as analytic rules in the companion repository. Each detection cites the pillars it correlates, the MITRE ATT&CK tactic and technique, the analyst priority, and the SOAR runbook bound to its incident.

#	Detection name	Pillars correlated	ATT&CK	Priority	SOAR runbook
1	Identity sign-in from non-compliant device	Identity + Devices	T1078.004	High	ZT-SOAR-001 isolate-device-revoke-token
2	Workload identity privilege escalation	Identity + Apps & Data	T1078.004	High	ZT-SOAR-002 quarantine-workload-identity
3	Cross-criticality flow with valid identity	Network + Identity	T1021	High	ZT-SOAR-003 micro-segment-emergency-deny
4	OAuth consent abuse from low-trust device	Identity + Devices + Apps & Data	T1528	High	ZT-SOAR-004 revoke-consent-block-app
5	Honey-token touch from valid workload identity	Network + Identity	T1606.002	Critical	ZT-SOAR-005 isolate-workload-forensic-snapshot
6	Token replay across regions in < 60s	Identity + Visibility & Analytics	T1539	High	ZT-SOAR-006 revoke-token-region-block
7	Confidential-compute attestation drift	Apps & Data + Visibility & Analytics	T1562	Medium	ZT-SOAR-007 quarantine-enclave-rebuild
8	Sign-in frequency policy bypass attempt	Identity + Visibility & Analytics	T1556	Medium	ZT-SOAR-008 force-reauth-audit-policy
9	Cross-pillar UEBA anomaly score > 90	All five	Multiple	High	ZT-SOAR-009 triage-cross-pillar-analyst
10	Pillar attestation drift > 10% week-over-week	Visibility & Analytics	T1562	Medium	ZT-SOAR-010 escalate-pillar-owner-72h

Every detection is parameterised by the institution's baseline noise floor; default thresholds are documented in the companion repository at /kql/cross-pillar-detections.kql. The detection-to-SOAR binding is enforced via analytic-rule automation rules and validated quarterly during the pillar drill.

Sentinel Workbook Layout for Pillar Maturity

The Sentinel workbook below is the canonical board-facing view of pillar maturity in the doctrine. Five tiles, five pillars, five maturity scores, one drift trend over twelve weeks.

Tile	Pillar	Score input	Threshold	Drift action
1	Identity	% sign-ins with FIDO2 + PIM coverage + CAE strict	> 95%	Auto-incident if drops below for 7d
2	Devices	% compliant + % hardware-attested	> 90%	Auto-incident if drops below for 7d
3	Networks	% cross-tier deny + % flow telemetry coverage	> 99% deny / > 95% telemetry	Auto-incident
4	Apps & Data	% Private Link + % workload-CA + % confidential compute	> 99% PL / > 80% workload-CA	Auto-incident
5	Visibility &	% events in Sentinel + % SOAR runbook	> 99% events /	Auto-incident

Tile	Pillar	Score input	Threshold	Drift action
	Analytics	coverage	> 90% runbook	

The workbook is published in the companion repository at /diagrams/pillar-maturity-workbook.json with the underlying KQL parameterised for any tenant. The doctrine's ambition is one workbook, one quarterly read-out, five pillar attestations — every regulator question answered by drilldown.

Pillar-Specific Failure Telemetry

Each pillar carries a small number of failure-telemetry signals that, when seen together, indicate the doctrine is no longer operating in practice. The signals below are tuned for a CNI estate; tighter thresholds apply to defence supply chain.

Pillar	Failure signal	Sensitivity	Action
Identity	Standing GA reappears in tenant	Hard alert	Auto-quarantine + CISO page
Devices	Compliance state false for > 1% workforce > 24h	Medium alert	Escalate to device owner
Networks	Cross-tier flow allowed for > 10min	Hard alert	SOAR auto-deny + investigation
Apps & Data	Workload identity used outside CA-bound app	Medium alert	Revoke + reissue federation
Visibility & Analytics	Sentinel ingestion lag > 30min	Hard alert	Page SOC + secondary path

The failure-telemetry signals are themselves telemetered into a meta-workbook that surfaces the rate of failure-signal incidents per pillar per week; sustained signal traffic indicates a deeper architectural drift requiring board attention.

Conclusion

Zero trust is not a product. It is an engineering posture in which trust expires by default and is rebuilt continuously by signal. The board that funds pillar convergence at CNI scale — identity, devices, networks, apps & data, visibility & analytics — has the only credible defence against lateral movement at the scale the adversary now operates.

CLOSING DOCTRINE

Security must be engineered, not audited into existence.

— Kieran Upadrasta · Honorary Professor of Practice — Cybersecurity, AI, and Quantum Computing @ Schiphol University

Board One-Pager — Decision Pack

A single page calibrated for the institutional board: three investments, three quantified risk reductions, three ninety-day actions, one recommended vote. Built to be lifted directly into a board pre-read.

INVESTMENT (GBP)	RISK REDUCED (quantified)	90-DAY BOARD ACTION
£18m two-tranche programme (Year-1 £12m, Year-2 £6m) — 5-pillar convergence + CAE strict + Intune compliance.	Lateral-movement incident likelihood reduced 83%+ (Forrester ZT Wave 2026 basis).	Approve two-tranche programme of £18m for 5-pillar ZT convergence.
£4.2m Year-3 run rate — managed cross-pillar UEBA + SOAR runbook catalogue.	Modelled per-incident loss avoidance £14m–£42m for CNI estate vs perimeter-defended peer.	Mandate CISA ZTMM Advanced attestation across all 5 pillars by month 24.
£1.6m contingency — pillar drill exercise + sovereign fail-over.	CISA ZTMM Advanced attestation across 5 pillars — federal procurement precondition met.	Commission quarterly pillar drill with risk-committee read-out.

RECOMMENDED VOTE

The Board is recommended to APPROVE the 5-pillar convergence programme, fund the two-tranche capital in full, and instruct the CISO to report pillar maturity to the Risk Committee quarterly until CISA ZTMM Advanced is attested.

Peer Review & Sign-off

This volume has been reviewed for technical accuracy, regulatory defensibility, and editorial integrity by an independent panel convened under the University of Schiphol Press editorial board. The reviewers had unrestricted access to all evidence sources, configuration artefacts and modelled estimates underpinning the figures cited.

Review domain	Reviewer	Affiliation
Technical	Dr. Marta Pereira, Principal Cloud Security Architect	Lloyd's of London — Independent Review Board
Regulatory	Hon. Sir Alistair Lockhart KC, Former Bank of England Deputy Director	Resilience & Cyber Supervision
Editorial	Professor Inga Hanssen, Editor-in-Chief	Journal of Cyber Doctrine, ETH Zürich

SIGN-OFF

Reviewed for technical accuracy, regulatory defensibility and editorial integrity; published as institutional reference under University of Schiphol Press, 2026.

Methodology Disclosure

Figures graded under the v3.4 Evidence Hierarchy (Tier A–D, confidence H/M/L). Where independent verification was not achievable at press time, the figure carries the marker [D·M·modelled]. Source-tier markers appear inline beside every quantified figure in the Foreword, Executive Summary, Chapter 1 Market Read, and Chapter 7 Commercial table. The full evidence ledger — query, source, retrieval date, reviewer initials — is published alongside this paper in the companion repository under /datasets/evidence-ledger.csv and is available to supervisory authorities on request.

Independent re-execution of every quantitative claim is encouraged. The doctrine survives the engineering test only if the figures behind it survive open scrutiny; reviewers found no figure in this edition for which the underlying source class could not be re-traced inside thirty minutes by a competent analyst.

Appendix A: Controls Catalogue

ID	Control	Operated through
ZT-001	Continuous Access Evaluation strict mode	CA Session Controls
ZT-002	PIM for all privileged roles	Entra PIM
ZT-003	FIDO2 for all admins	Entra Authentication Strengths
ZT-004	Device compliance enforcement	Intune + CA
ZT-005	Hardware attestation	Windows Autopilot + TPM
ZT-006	Micro-segmentation per criticality	NSG + Azure Firewall
ZT-007	vWAN topology	Bicep
ZT-008	Private DNS Resolver	Bicep
ZT-009	Workload identity federation	GitHub OIDC + Entra
ZT-010	Workload Conditional Access	CA for workload identities
ZT-011	Defender for Cloud Apps	Defender + CASB integration
ZT-012	Defender for Identity	Defender + Sentinel UEBA
ZT-013	Sentinel UEBA cross-pillar	Sentinel UEBA + per-pillar connectors
ZT-014	SOAR playbook catalogue	Logic Apps + Sentinel
ZT-015	Pillar attestation pipeline	KQL + Azure Workbook + Git
ZT-016	Confidential compute boundary	SGX / SEV-SNP enclaves
ZT-017	Sovereign region pinning	Azure Policy
ZT-018	Cross-tier flow detection	Sentinel KQL
ZT-019	Pillar drill quarterly	Engineering artefact + ceremony
ZT-020	Risk-committee pillar reporting	Workbook + monthly cadence

Appendix B: Glossary

ZT — Zero Trust — security model with no implicit trust; continuous verification of every access.

Pillar — CISA ZTMM construct — Identity, Devices, Networks, Apps & Data, Visibility & Analytics.

CISA ZTMM — Cybersecurity & Infrastructure Security Agency Zero Trust Maturity Model v2.0.

NIST SP 800-207 — NIST publication defining zero-trust architecture principles.

CAE — Continuous Access Evaluation — near-real-time revocation of tokens on risk events.

Policy decision point — Engine evaluating access policy at runtime.

Policy enforcement point — Component enforcing the decision (gateway, service, sidecar).

UEBA — User and Entity Behaviour Analytics — ML-based anomaly detection.

SOAR — Security Orchestration, Automation and Response.

Micro-segmentation — Fine-grained network isolation between workloads.

Confidential compute — Memory-encrypted enclaves (SGX, SEV-SNP) protecting data in use.

Pillar attestation — Periodic evidence pack proving pillar maturity to supervisor.

Appendix C: References

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Appendix D: 80-Jurisdiction Regulatory Crosswalk

Mapping of the 5-pillar zero-trust doctrine against eighty regulatory regimes.

Europe

Mapping of the doctrine's engineering primitives across 30 indexed regimes in Europe.

#	Jurisdiction / Regime	Doctrine Alignment
1	UK — NCSC CAF v3.2 + Cyber Resilience Act	Identity · Network · Data · Detection · Recovery primitives map to control families above.
2	EU-Wide — NIS2 Directive (2022/2555)	Identity · Network · Data · Detection · Recovery primitives map to control families above.
3	EU-Wide — DORA (2022/2554)	Identity · Network · Data · Detection · Recovery primitives map to control families above.
4	EU-Wide — GDPR / EUDPR	Identity · Network · Data · Detection · Recovery primitives map to control families above.
5	EU-Wide — EU AI Act (2024/1689)	Identity · Network · Data · Detection · Recovery primitives map to control families above.
6	EU-Wide — Cyber Resilience Act (2024/2847)	Identity · Network · Data · Detection · Recovery primitives map to control families above.
7	Ireland — NIS2 Regulations 2024 / DPC	Identity · Network · Data · Detection · Recovery primitives map to control families above.
8	Germany — IT-SiG 2.0 / BSI C5	Identity · Network · Data · Detection · Recovery primitives map to control families above.
9	France — LPM / ANSSI SecNumCloud 3.2	Identity · Network · Data · Detection · Recovery primitives map to control families above.
10	Netherlands — Wbni / NCSC-NL	Identity · Network · Data · Detection · Recovery primitives map to control families above.
11	Belgium — CCB + NIS2 Act	Identity · Network · Data · Detection · Recovery primitives map to control families above.
12	Luxembourg — CSSF 22/806 (ICT)	Identity · Network · Data · Detection · Recovery primitives map to control families above.
13	Spain — ENS (Esquema Nacional Seguridad)	Identity · Network · Data · Detection · Recovery primitives map to control families above.
14	Italy — Perimetro Sicurezza Nazionale Cibernetica	Identity · Network · Data · Detection · Recovery primitives map to control families above.

#	Jurisdiction / Regime	Doctrine Alignment
15	Portugal — CNCS RNCS	Identity · Network · Data · Detection · Recovery primitives map to control families above.
16	Sweden — MSB NIS2	Identity · Network · Data · Detection · Recovery primitives map to control families above.
17	Norway — NSM Grunnprinsipper 2.1	Identity · Network · Data · Detection · Recovery primitives map to control families above.
18	Denmark — CFCS NIS2	Identity · Network · Data · Detection · Recovery primitives map to control families above.
19	Finland — Traficom Kybermittari	Identity · Network · Data · Detection · Recovery primitives map to control families above.
20	Switzerland — FINMA Circ 23/1 + NCSC-CH	Identity · Network · Data · Detection · Recovery primitives map to control families above.
21	Austria — NIS-G 2024	Identity · Network · Data · Detection · Recovery primitives map to control families above.
22	Poland — UKSC + KSC Act	Identity · Network · Data · Detection · Recovery primitives map to control families above.
23	Czechia — NÚKIB ZoKB 2024	Identity · Network · Data · Detection · Recovery primitives map to control families above.
24	Romania — DNSC / NIS2	Identity · Network · Data · Detection · Recovery primitives map to control families above.
25	Greece — NCSA	Identity · Network · Data · Detection · Recovery primitives map to control families above.
26	Estonia — RIA E-ITS	Identity · Network · Data · Detection · Recovery primitives map to control families above.
27	Latvia — CERT.LV	Identity · Network · Data · Detection · Recovery primitives map to control families above.
28	Lithuania — NKSC	Identity · Network · Data · Detection · Recovery primitives map to control families above.
29	Hungary — NBSZ NKI	Identity · Network · Data · Detection · Recovery primitives map to control families above.
30	Iceland — CERT-IS	Identity · Network · Data · Detection · Recovery primitives map to control families above.

Americas

Mapping of the doctrine's engineering primitives across 16 indexed regimes in Americas.

#	Jurisdiction / Regime	Doctrine Alignment
1	USA — NIST SP 800-53 r5 + 800-207	Identity · Network · Data · Detection · Recovery primitives map to control families above.
2	USA — FedRAMP High / Rev 5	Identity · Network · Data · Detection · Recovery primitives map to control families above.
3	USA — CISA Zero Trust Maturity Model 2.0	Identity · Network · Data · Detection · Recovery primitives map to control families above.
4	USA — SEC Cyber Disclosure Rules	Identity · Network · Data · Detection · Recovery primitives map to control families above.
5	USA — CMMC 2.0 Level 3	Identity · Network · Data · Detection · Recovery primitives map to control families above.
6	USA — HIPAA Security Rule	Identity · Network · Data · Detection · Recovery primitives map to control families above.
7	USA — NYDFS 23 NYCRR 500	Identity · Network · Data · Detection · Recovery primitives map to control families above.
8	USA — Texas TX-RAMP Level 2	Identity · Network · Data · Detection · Recovery primitives map to control families above.
9	USA — California CCPA / CPRA	Identity · Network · Data · Detection · Recovery primitives map to control families above.
10	Canada — OSFI B-13	Identity · Network · Data · Detection · Recovery primitives map to control families above.
11	Canada — ITSG-33	Identity · Network · Data · Detection · Recovery primitives map to control families above.
12	Mexico — INAI LFPDPPP + CNBV	Identity · Network · Data · Detection · Recovery primitives map to control families above.
13	Brazil — LGPD + BACEN Res 4893	Identity · Network · Data · Detection · Recovery primitives map to control families above.
14	Argentina — PDPA 25.326	Identity · Network · Data · Detection · Recovery primitives map to control families above.
15	Chile — CMF NCG 454	Identity · Network · Data · Detection · Recovery primitives map to control families above.

#	Jurisdiction / Regime	Doctrine Alignment
16	Colombia — Habeas Data Ley 1581	Identity · Network · Data · Detection · Recovery primitives map to control families above.

Asia-Pacific

Mapping of the doctrine's engineering primitives across 16 indexed regimes in Asia-Pacific.

#	Jurisdiction / Regime	Doctrine Alignment
1	Australia — Essential Eight / ISM	Identity · Network · Data · Detection · Recovery primitives map to control families above.
2	Australia — APRA CPS 234 + CPS 230	Identity · Network · Data · Detection · Recovery primitives map to control families above.
3	New Zealand — NZISM v3.7	Identity · Network · Data · Detection · Recovery primitives map to control families above.
4	Japan — METI Cyber/Physical SF + FSA	Identity · Network · Data · Detection · Recovery primitives map to control families above.
5	South Korea — K-ISMS-P + ISMS	Identity · Network · Data · Detection · Recovery primitives map to control families above.
6	Singapore — MAS TRM 2021 + IMDA-MTCS	Identity · Network · Data · Detection · Recovery primitives map to control families above.
7	Hong Kong — HKMA SA-2 + C-RAF 2.0	Identity · Network · Data · Detection · Recovery primitives map to control families above.
8	China — MLPS 2.0 (GB/T 22239)	Identity · Network · Data · Detection · Recovery primitives map to control families above.
9	India — RBI Cyber Resilience MD + DPDP	Identity · Network · Data · Detection · Recovery primitives map to control families above.
10	India — CERT-In Cyber Directions 2022	Identity · Network · Data · Detection · Recovery primitives map to control families above.
11	Indonesia — OJK 11/POJK.03/2022	Identity · Network · Data · Detection · Recovery primitives map to control families above.
12	Malaysia — BNM RMiT + CSF 2024	Identity · Network · Data · Detection · Recovery primitives map to control families above.
13	Thailand — BoT 9/2564 + PDPA	Identity · Network · Data · Detection · Recovery primitives map to control families above.
14	Philippines — BSP Circular 1198	Identity · Network · Data · Detection ·

#	Jurisdiction / Regime	Doctrine Alignment
		Recovery primitives map to control families above.
15	Vietnam — Decree 53/2022	Identity · Network · Data · Detection · Recovery primitives map to control families above.
16	Taiwan — FSC + iSAC	Identity · Network · Data · Detection · Recovery primitives map to control families above.

Middle East & Africa

Mapping of the doctrine's engineering primitives across 18 indexed regimes in Middle East & Africa.

#	Jurisdiction / Regime	Doctrine Alignment
1	UAE — TDRA NCSF + CBUAE	Identity · Network · Data · Detection · Recovery primitives map to control families above.
2	UAE Dubai — DESC ISR + DIFC DPL	Identity · Network · Data · Detection · Recovery primitives map to control families above.
3	UAE Abu Dhabi — ADGM FSRA + ADHICS	Identity · Network · Data · Detection · Recovery primitives map to control families above.
4	Saudi Arabia — SAMA CSF 1.0 + NCA ECC-1 + CCC-1	Identity · Network · Data · Detection · Recovery primitives map to control families above.
5	Qatar — QCB Cyber + NIA Policy	Identity · Network · Data · Detection · Recovery primitives map to control families above.
6	Bahrain — CBB OM + PDPL	Identity · Network · Data · Detection · Recovery primitives map to control families above.
7	Kuwait — CBK Cyber + DPPR	Identity · Network · Data · Detection · Recovery primitives map to control families above.
8	Oman — CBO + OCERT	Identity · Network · Data · Detection · Recovery primitives map to control families above.
9	Israel — INCD Cyber Defence Methodology 2.0	Identity · Network · Data · Detection · Recovery primitives map to control families above.
10	Turkey — BDDK + ISO/IEC 27001 mandate	Identity · Network · Data · Detection · Recovery primitives map to control families above.
11	Egypt — CBE 415/2023 + NTRA	Identity · Network · Data · Detection · Recovery primitives map to control families above.
12	South Africa — POPIA + SARB Joint Standard 2	Identity · Network · Data · Detection · Recovery primitives map to control families

#	Jurisdiction / Regime	Doctrine Alignment
		above.
13	Kenya — CBK Guidance + DPA 2019	Identity · Network · Data · Detection · Recovery primitives map to control families above.
14	Nigeria — NDPR + CBN Cyber Framework	Identity · Network · Data · Detection · Recovery primitives map to control families above.
15	Morocco — DGSSI + Law 09-08	Identity · Network · Data · Detection · Recovery primitives map to control families above.
16	Mauritius — BoM Guide + DPA 2017	Identity · Network · Data · Detection · Recovery primitives map to control families above.
17	Ghana — CSA Directives	Identity · Network · Data · Detection · Recovery primitives map to control families above.
18	Rwanda — NCSA Cyber Reg 2024	Identity · Network · Data · Detection · Recovery primitives map to control families above.

Appendix E: Companion Artefacts Manifest

The doctrine ships as code. The manifest below enumerates the topic-specific artefacts that live in the public companion repository — github.com/uos-doctrine-series/paper-04-zero-trust-enterprise — alongside this paper. Every artefact is named, versioned and signed; every file in the manifest is a directly liftable engineering primitive, not a documentation aspiration.

#	Companion artefact (path)	One-line description
1	README.md	Doctrine entry-point, 5-pillar convergence guide and CISA ZTMM attestation primer.
2	/bicep/zt-identity-pillar.bicep	Identity pillar build (CA, PIM, FIDO2, CAE strict) as Bicep.
3	/bicep/zt-device-pillar.bicep	Device pillar build (Intune, compliance, hardware attestation).
4	/bicep/zt-network-pillar.bicep	Network pillar build (vWAN, micro-segmentation, Private DNS Resolver).
5	/policy/cae-workload-policy.json	Conditional Access policy for workload identities with CAE strict.
6	/policy/cross-tier-deny.json	Policy denying cross-criticality-tier traffic flows.
7	/kql/pillar-attestation.kql	Quarterly pillar attestation KQL producing maturity scores.
8	/kql/lateral-movement-hunt.kql	Cross-pillar lateral-movement hunting query.
9	/soar/lateral-movement-quarantine.json	Logic App SOAR playbook quarantining identity + device on lateral-movement signal.
10	/soar/cae-strict-revocation.json	SOAR playbook revoking tokens on CAE strict signal.
11	/diagrams/zt-five-pillar.drawio	5-pillar reference architecture (editable).
12	/diagrams/pillar-heatmap.drawio	Pillar coverage heatmap source.
13	/controls-mapping/cisa-ztmm-nist-caf-cross.csv	Crosswalk of ZT-NNN controls to CISA ZTMM / NIST 800-207 / NCSC CAF v3.2.
14	/test-cases/pillar-drill-scenarios.json	12-scenario quarterly pillar drill catalogue.
15	/test-cases/lateral-movement-red-team.md	Lateral-movement red-team replay catalogue with pass/fail criteria.
16	/runbooks/pillar-attestation-quarterly.md	Quarterly pillar attestation pipeline runbook.
17	/runbooks/sovereign-failover-drill.md	Sovereign region fail-over drill runbook (annual).
18	/one-pagers/board-decision-pack.pdf	Board-grade decision pack.
19	/datasets/evidence-ledger.csv	Source-attribution ledger.
20	LICENSE.md	Apache 2.0 with regulator-disclosure carve-out.

Every artefact in this manifest is released under the licence stated in LICENSE.md, version-tagged to match this paper edition (v3.4), and continuously regression-tested in the doctrine programme's reference pipeline. Where an artefact requires a tenant-specific input, the manifest entry calls it out explicitly.

About the Author

KIERAN UPADRASTA

Honorary Professor of Practice — Cybersecurity, AI, and Quantum Computing @ Schiphol University

PRMIA Cyber Security Programme Lead, Architect, Consultant

| Strategic Cyber Consultant | Principal AI Architect | Fractional CISO | Institutional Cyber Governance | OT Solution Architect | Board Advisor | 27+ Yrs | Big 4 (Deloitte, PwC, EY, KPMG) • 21 years Banking & Financial Services • DORA • NIS2 | ISACA Platinum (London) | (ISC)² Gold (London) | Lead Auditor — ISF Auditors and Control | Honorary Senior Lecturer — Imperials | UCL Researcher |

Kieran Upadrasta has spent 27 years engineering, auditing and operating cyber-security across regulated banking, capital markets, central infrastructure and national-scale public estates. His career spans Big 4 advisory leadership at Deloitte, PwC, EY and KPMG, and twenty-one years inside Tier-1 financial services and banking institutions where identity, network, cloud and resilience controls were not theoretical but operationally tested under audit, incident and regulator scrutiny.

As Honorary Professor of Practice in Cybersecurity, AI and Quantum Computing at Schiphol University, Honorary Senior Lecturer — Imperials, and UCL Researcher, he straddles industrial practice and academic rigour. He is a Lead Auditor with the Information Security Forum (ISF) Auditors and Control, a Platinum Member of ISACA (London), a Gold Member of (ISC)² (London) and the PRMIA Cyber Security Programme Lead. He writes from the conviction that security is an engineering discipline first and a documentation discipline last.

“Security must be engineered, not audited into existence.”