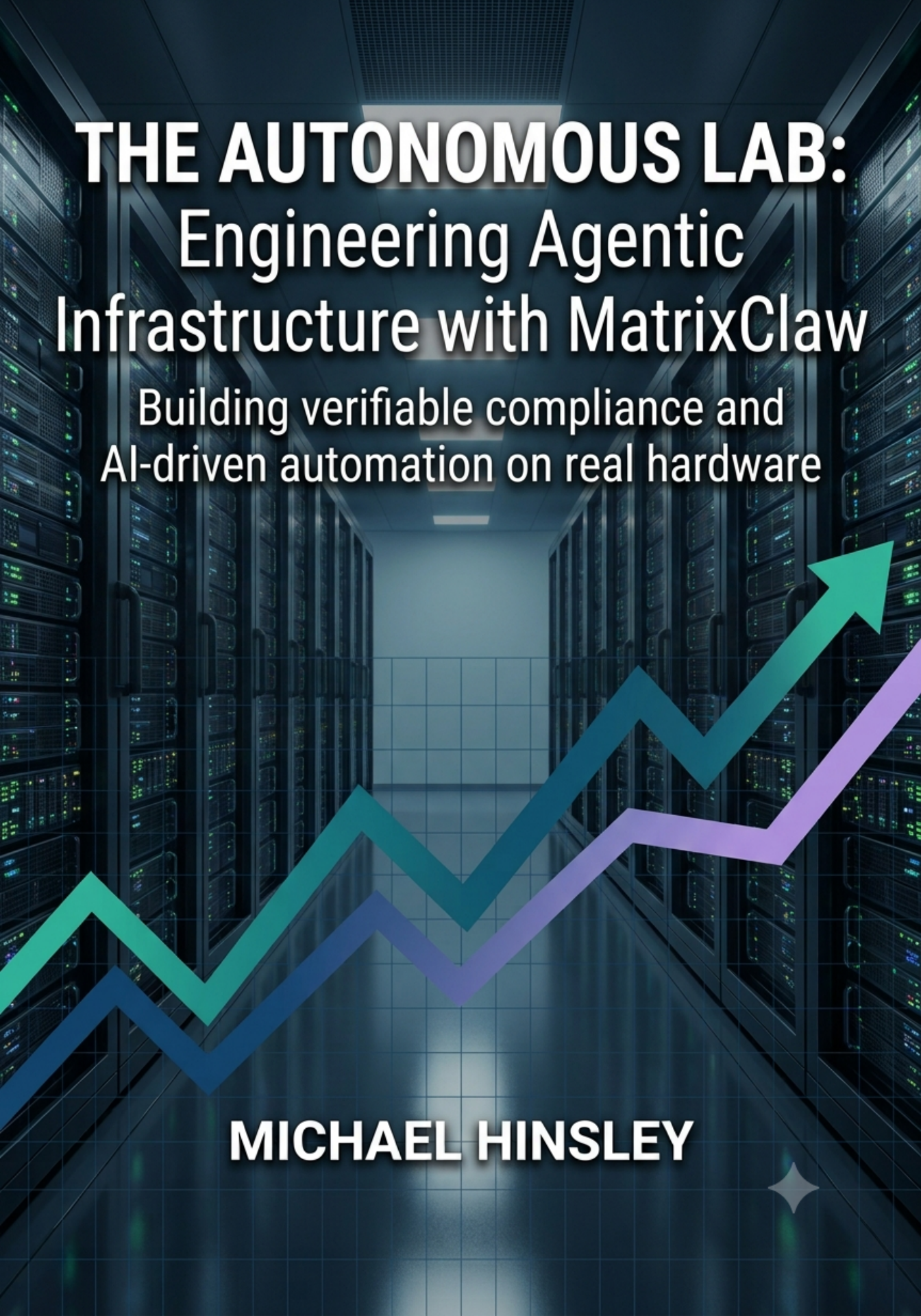
THE AUTONOMOUS LAB:
Engineering Agentic Infrastructure with MatrixClaw

Building verifiable compliance and AI-driven automation on real hardware



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Leaf Spine Books edition

A working book on real infrastructure — operated by AI under human control. The system this book describes drives real servers, network devices and web consoles, with a frontier AI model doing much of the work under human-held gates. Many of the commands shown are powerful and some are destructive: they can erase data, interrupt services, and render systems unbootable. Always rehearse on the built-in simulator or an isolated lab first, keep tested backups, keep every approval gate this book describes in place, and understand each step before you run it — or before you let a model run it. You assume all risk for any action taken on the basis of this book. To the fullest extent permitted by law, the author and publisher accept no liability for any loss, damage, data loss, downtime, or cost arising directly or indirectly from the use of, or reliance on, the material in these pages.

Measured figures, dated. Where this book states a number — a throughput, a load time, a defect count — it is a measurement made on named hardware on a stated date, traced to a committed record, and it will not match your estate exactly. Where something is an estimate, a typical figure, or unverified, it is labelled as such. Treat every number as a starting point to be re-measured, never as a promise of outcome.

Open-source and third-party material. The software deployed and discussed in this book is published by its respective projects under their own open-source licences — Apache CloudStack, for example, under the Apache License 2.0. Always consult each project's own licence and documentation for authoritative terms.

On owning what you run

This imprint's conviction is **GYOCYO – *Grow Your Own, Cook Your Own***: if you cannot control your infrastructure, you do not own your business. This book extends that conviction one layer up, because the ground has shifted one layer up: **if you cannot audit your AI's work, you do not own your automation.** Everything in these pages – the gate a machine cannot talk its way past, the run records, the merge button that stays under a human thumb, the lab that phones nobody – exists so that what the AI builds is *yours*: inspectable, reproducible, and answerable to you alone. And the standard of proof throughout is the sibling conviction, the **Mars test**: judge the estate only by what its records and remote evidence show, as if the hardware were on another planet – because evidence you could only get by walking over and looking is evidence you do not really have. The notices above protect the words on these pages. The method inside them is meant to be taken, adapted, and run on machines you own – built, gated, recorded, and made yours. That is the whole point.

Introduction: a book that can be checked

On the evening of 31st January 2026 an AI was refused permission to build a small network – by its own tooling, which wanted a human's signature first. Six weeks later the same machinery was governing bare-metal servers carrying a 740-billion-parameter model, and every step between those two moments exists as a committed record: run records, merge requests, an append-only session log, a ledger of lessons paid for in hours.

This book teaches you to build that machinery from the ground up – the governance spine, the engine and its gate, the layers that reach real hosts and switches and web consoles, the GitLab interconnect that wires agents and humans together, the audit surface an outsider can hold without holding any keys, and the packaging that turns the whole thing into something you can clone. It ends with the campaign that proved the stack on real iron, silent failures, demolished predictions and all.

Who it is for. Engineers and engineering leaders who want AI doing real infrastructure work without giving up the ability to prove, afterwards, exactly what happened and who said yes. You will need nothing exotic to follow along: the companion starter runs its first governed build on a built-in simulator, with a free GitLab account and a Python that ships with your operating system.

How it is written, because it matters here. This book practises its subject's own law: *no claim without a record.* Every decision it quotes has an identifier; every figure has a run id and a date; every failure it recounts — including the author's — is in a committed log, and two of its appendices are generated by a script from the framework's own source-of-truth files rather than written by hand. The book was authored inside the same governance it describes: chapter by chapter, branch by branch, each one reviewed and merged by a human who was under no obligation to be kind. You do not have to take any sentence in it on trust, and that is the point of the whole system it teaches.

Getting the code. This book has a code companion: the complete MatrixClaw starter — engine, gate, adapters, scenarios, runbooks, roles and the fifteen Claude skills. It is not printed in these pages, because 120 files of source belong in a repository rather than in a paperback, and because you will want to run it rather than retype it.

It lives in a private repository, and access goes to readers who have bought the book. Email **readers@spiralmatrix.com** with your proof of purchase — your Leanpub receipt is enough — and say which GitHub account should be added. You will be invited to `github.com/leafspinebooks/matrixclaw`, which carries the code, its licence, its disclaimer, and a manifest you can hash-check against what you were given.

Appendix D takes a blank machine to a first governed build with it. Appendix F builds a second lab, with its own GitLab, from nothing.

How to read it. The chapters follow the order the system was genuinely built in, because the order is the argument: governance before code, the gate before the first mutation, the simulator before the metal. Part I is the spine; Parts II and III are the engine and its reach; Parts IV and V are the interconnect and the audit surface; Part VI ships it and proves it. If you are impatient, read Chapter 1, then Chapter 8, then Chapter 18 — the refusal, the runbook that could not have worked, and the campaign — and you will know whether this book is for you.

The lab's motto earns its place on the first page as well as the last: a check that cannot fail is not a check — and a book that cannot be checked is only an opinion.

Open-source and third-party material. The software deployed and discussed in this book is published by its respective projects under their own open-source licences — Apache CloudStack, for example, under the Apache

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The Book in Full — Annotated Contents

The Autonomous Lab: Engineering Agentic Infrastructure with MatrixClaw — Building verifiable compliance and AI-driven automation on real hardware · Leaf Spine Books edition

This is the whole journey on a single page. Every entry gives a chapter's exact title and a two-line summary, so you can see the full scope before you start — and find the chapter you need when you come back to it. The chapters run in the order the system was genuinely built, because the order is the argument: governance before code, the gate before the first mutation, the simulator before the metal.

(Summaries written session bmc-02 against the outline and the framework's committed record; spot-check against chapter text at the first Leanpub preview.)

Part I — The Spine

Chapter 1 — Why an AI-First Lab The refusal that starts everything: an AI denied permission to build a network by its own tooling, because no human had signed. What "AI-first" actually means, why the data and the framework outrank the model, and the thesis the rest of the book has to earn.

Chapter 2 — The Constitution The governance spine written before any code: a constitution the session reads first, a single source of truth for pins and decisions, an append-only session log, a concurrency lock, and the rule that never bends — every change lands by a merge request a human merges.

Part II — The Engine

Chapter 3 — The Run Record The lab's law of evidence: everything the system claims must trace to a committed run record. What goes in one, why it is append-only, and why "no run, no lesson" keeps the whole edifice honest.

Chapter 4 — The Gate The approval gate as enforced code, not policy: apply and teardown refuse to run without a recorded human approval bound to the

exact plan hash. The refusal exit code as a feature, and why the agent must never approve on the human's behalf.

Chapter 5 — The Sim Adapter A built-in simulator that makes the whole loop safe to rehearse: plans, applies, tests and run records identical to the real thing, with local state instead of real servers. The place every mistake should be made first.

Chapter 6 — The Live Adapter The one-line switch from simulator to a real Apache CloudStack zone: credentials held only in the environment, dry-run as the safety catch, and the discipline of treating the first live contact as an event with its own evidence.

Chapter 7 — Scenarios and the Test Rig Desired infrastructure as reviewable YAML scenarios, and the test rig that closes the loop: recorded pass/fail checks against the applied topology, because "applied" and "working" are different claims with different evidence.

Part III — The Reach

Chapter 8 — The Deploy Layer Bare metal over SSH through gated runbooks: plan-time idempotency probes, one SSH session per step, fail-fast execution — and the runbook that could not have worked, whose post-reboot steps were silently planned as no-ops while the services they proved were still up.

Chapter 9 — The Netdev Layer Real switches and firewalls under the same gate: survey-first contact with devices carrying inherited configuration, expected-hostname checks that prove you reached the device you meant, and the maintainer's standing constraints written into the runbooks themselves.

Chapter 10 — Browser Operations as Evidence Driving web consoles — CloudStack UI, GitLab, dashboards — with every browser-level action landed on the run record and rendered into an audit report, so even the clicks leave a trail an auditor can replay.

Part IV — The Interconnect

Chapter 11 — GitLab as the Nervous System Why a self-hosted GitLab is the lab's connective tissue: issues, merge requests and one git history as the shared

memory of agents and humans alike — full transparency across the organisation instead of silos.

Chapter 12 — Wiring the Agents Multiple role agents — engineer, reviewer, SRE, browser operator, author — collaborating with each other and with humans through the same GitLab surface, like a real platform team with handoffs, verdicts and no private channels.

Chapter 13 — MatrixClaw Tickets Work announced before it is done: the ticketing hub that gives every campaign a public unit of work, and the lesson — paid for in the record — of what happens when the ticket comes after the work instead of before it.

Part V — The Audit Surface

Chapter 14 — The Compliance Hub and Library The governance surface built for someone who holds no keys: an execution index, control conformance, portfolio statistics and a risk register, all generated from run records — evidence an auditor can hold without trusting a word of prose.

Chapter 15 — The Control Mapping MatrixClaw held up against eleven recognised standards — NIST AI RMF, ISO 42001, the EU AI Act, ISO 27001, SOC 2, NIST 800-53, CIS v8, the CSA CCM, DORA, NIS2 and GDPR — control by control, to subsection level. Written for CTOs, compliance teams and auditors as much as engineers: a mapping, never a certification, honest about the boundary (MatrixClaw is not a data processor) and about every gap it does not close.

Part VI — Shipping It and Proving It

Chapter 16 — The Starter The whole framework packaged as something you can clone and run: the starter distribution, its genesis run on the built-in simulator, and a first governed build that needs nothing more exotic than a free GitLab account and the Python your OS ships.

Chapter 17 — The Course Engine Learning content generated from run records only: the course engine narrates what the lab actually built and tested, never what it wishes it had — the same rule that wrote this book.

Chapter 18 — Proving It on Real Iron The campaign: the stack governing owned bare-metal servers serving a 740-billion-parameter open model, the silent failures no log showed, the architectural predictions that measurement demolished, and the honest numbers that only execution produces.

Appendices

Appendix A — The Open Model The open-weights model behind the campaign: what was chosen and why, the serving stack, and the measured envelope on the estate's own hardware — figures dated and traced, as the book demands.

Appendix B — The Decision Register Every ratified decision with its identifier and status — generated by script from the framework's own source-of-truth files rather than written by hand, so it cannot drift from the record.

Appendix C — The Lessons Ledger The lessons paid for in hours, each tied to the failure that taught it — generated from the framework's ledger by the same no-hand-copying rule as Appendix B.

Appendix D — The Blank-Ubuntu Bootstrap From a blank Ubuntu 24.04 machine to a first governed, gated, evidenced build — executed verbatim on real hardware before it was printed (v-bmc-002), honest limits recorded alongside the proof.

Appendix E — Glossary A working engineer's glossary of the book's technical and coined vocabulary — from adapters, gates and run records to the campaign's serving-stack terms — each definition grounded in how the term is used here.

Appendix F — Your Second Lab The complete second-lab build: KVM host preparation from nothing, a checksum-verified image, the VM pair with its own GitLab, the lab's own identity, the gate refusing before it obeys, and a full team session on the reader's own bus — executed end to end on a clean machine before it was printed, with every defect that run found fixed in these pages.

Appendix G — The Memory System How the lab remembers between sessions: an index plus one fact per file, the repository as the source of truth and the local copy as a read cache, and a two-session demonstration the reader performs — teach it something, come back tomorrow, and watch it recall unprompted.

Afterword

The Record Is Yours Now What the refusal in Chapter 1 was for, what the reader now holds, and the honest limit on all of it: a method, not a product, and not a guarantee — with the author's note and where the rest of the Leaf Spine Books line lives.

Chapter 1: Why an AI-First Lab

On the evening of 31st January 2026, an AI planned a small piece of infrastructure — an isolated network carrying a two-tier application — and was refused permission to build it. Not by a human having second thoughts, and not by a policy document. By its own tooling: the `apply` command checked for a recorded human approval bound to the exact hash of the plan, found none, and stopped. A human then read the plan, approved it, and the same command built the topology and proved it with four recorded checks.

That refusal is the founding act of MatrixClaw, and this book is the story of everything it made possible. Run `mc-20260118-234610-web-db-isolated` is still in the framework repository, and the gate that blocked it is the same gate — grown considerably more capable — that six weeks later was managing bare-metal Dell servers carrying a 720 GiB inference guest. The lab scaled from a simulator on a laptop to real iron; the refusal never changed.

What "AI-first" actually means

MatrixClaw is an AI-first infrastructure research lab: a model engineer does the building — designs topologies, writes runbooks, drives deployments, tests the result, and writes up what happened. If that sounds like the AI is in charge, the constitution says otherwise, and it says it in an unusual way: not as guidance to the model but as properties of the system the model cannot route around.

Three of the earliest ratified decisions set the shape (they are quoted here from `versions.yaml`, where every decision lives with an identifier and a status):

- **d-mc-001** — the adapter mediates all infrastructure access; skills never call CloudStack directly. There is exactly one door to the infrastructure, and the gate is built into its frame.
- **d-mc-002** — Plan -> Approve -> Apply is enforced *in code* by the approval gate, and the approval is bound to the plan's hash. Approving a plan authorises that plan, byte for byte. If the plan drifts, the approval dies with it.

- **d-mc-003** — the run record is the sole source of truth for generated content. *No run, no lesson.* Every chapter, audit report and compliance line traces to a machine-written record of what actually executed.

Add the two standing human rules — every mutating operation requires a human approval (d-mc-005), and only the maintainer merges to any repository, ever — and "AI-first" resolves into something precise: **the AI does the work; the human holds every gate; the system is built so that this is a fact of the plumbing rather than a promise of the model.**

The distinction matters because promises of the model are exactly what you cannot audit. A model that is instructed not to mutate infrastructure without approval might comply superbly for a hundred sessions and drift on the hundred and first — and nothing in its output would tell you which session you were in. A gate that binds approval to a plan hash does not have sessions. It has state, and the state is inspectable.

This design earned its keep within the lab's own history, and the record does not hide it. Session 42 of the framework's session log records the session that began *outside* the framework — no ticket, no lock, no first-actions discipline — and had to be stopped twice by the maintainer. The recovery produced two rulings that are now canon: the framework is a gate, not a preamble (d-pdg1-41), and no control is disableable by the agent — the maintainer's NO is final, and the agent holds no casting vote over its own controls (d-pdg1-42). An AI-first lab is not a lab that trusts its AI. It is a lab built so it doesn't have to.

The thesis: data over framework over model

The working thesis of the whole operation, of which MatrixClaw is the proving ground, orders the three ingredients of AI-era engineering by durable value: **data > framework > model.**

The *model* is the most replaceable part. The lab has been driven by successive frontier models, and one of the book's appendices evaluates driving it with an open-weight model on hobbyist hardware; the framework is deliberately indifferent. Models improve, get swapped, get cheaper. Nothing in the lab's value depends on which one is at the keyboard, because nothing in its safety does either.

The *framework* — the gate, the run record, the runbook engine, the audit surface — outlives any model, and is where the operational judgment lives. It

encodes, in executable form, every expensive lesson the lab has paid for. When a lesson is learned, it does not go into a model's context to be forgotten at the next session boundary; it goes into `LESSONS.yaml`, or becomes a machine-checked property of a runbook, or a new control.

But the *data* is the crown: the accumulating record of what was actually built, what actually failed, and what the failure looked like from the inside. By the time of writing, the framework repository holds over eighty engine run records plus the book-verification and Nano records alongside them, every one rendered into an auditable report. That corpus is what the lab's courses and books are generated from — this one included — and it is the one asset that cannot be regenerated by anyone else, at any price, because it is the residue of real work on real systems. A better model makes the next run cheaper. It makes the existing record more valuable, not less.

Two entries from that record make the point better than any argument. In session 60, the lab measured its own driver's architectural reasoning and found it wrong twice in one night: perfect NUMA locality — confidently predicted to win — measured 17 % *slower* than interleaving across both memory controllers, and hyperthreads — predicted worthless for a bandwidth-bound workload — measured worth roughly 30 %. Both predictions were plausible. Both are refuted, on the record, with numbers. The lesson entered the framework's ledger in exactly those terms: *the agent's architectural reasoning is not evidence.* A lab whose knowledge lived in its model's confident prose would have shipped both errors.

What the lab went on to prove

This book teaches you to build the system, so it is fair to ask up front what the system has done. Every item below traces to a run record, a merged MR, or a session log entry, and the later chapters unpack each one:

- **20–21 March 2026:** from genesis on a simulator to a real seven-VM CloudStack estate — management, cephadm Ceph cluster, NFS, two KVM hosts — on a single laptop, passing a 24-check acceptance suite (run `mc-20260321-080227`, 24/24) with the first guest's storage placed and proven on the Ceph pool.
- **27 March 2026:** the same acceptance suite at 24/24 on server hardware — a Dell PowerEdge R740xd — including the live-migration drill the laptop excludes by design, measured at 4.1 seconds in each direction.

- **Session 43:** a three-node database control plane assembled across two cities, with both failure drills executed and the record correcting the manuscript that described it — twice retracting the AI's own findings before they reached print.
- **Sessions 58–62:** the quality-brain campaign — the first estate the harness built on bare metal for itself, serving a ~740-billion-parameter open-weight model at a measured 1.74 tokens/second from system RAM, and en route uncovering a ledger of silent failures that no log file showed: a default that traffic-shaped every guest NIC to 200 Mbps (a 27× penalty, visible only in the domain XML), a default KV-cache split that cost a tenfold slowdown, and ten more of the same species. The campaign's standing lesson is the lab's motto in negative space: **a check that cannot fail is not a check.**

The pattern across all four is the same and is the argument of this book: the interesting output was never just the infrastructure. It was the *record* — defects found by execution that no amount of code reading would have caught, retractions that never reached readers because the evidence was consulted first, and measured numbers replacing confident guesses.

Three products, one boundary

The operation this lab sits inside publishes three distinct products, and the boundary between them is itself a ratified rule rather than a habit:

1. **The MatrixClaw framework** — the AI-first lab this book teaches you to build: engine, gates, runbooks, interconnect, audit surface.
2. **MatrixClaw Nano** — a separate, self-contained product with its own licence, repository and voice, which rebuilds a reference lab from published artefacts and proves itself with its own acceptance suite.
3. **The book code** of the sibling CloudStack deployment guide — the reader-facing scripts of a separate title.

They share ancestry and hardware history; they share no text. Each carries its own licence and makes its own promises. This book is about the first of the three, and where the others appear — Nano's clean-room test, the book programme's execution findings — they appear as neighbours in the record, not as merged identities.

How to read this book

The chapters follow the order the system was actually built in, because the order is the argument. Governance exists before the engine (Chapters 2–3) because the gate had to exist before the first mutation. The simulator precedes the live adapter (Chapters 5–6) because a control you cannot afford to test is a control you do not have. The audit surface gets its own part because it was designed for a reader the lab had not yet met: the auditor who holds Reporter access to one small project and can still answer, in four clicks, what was requested, who reviewed it, who approved exactly what, and what actually ran.

Throughout, the failures are kept in. The runbook that planned two of its steps as silent no-ops, the watcher that waited twenty-nine hours for a process that was itself, the library generator that crashed on the very record holding the campaign's most expensive measurements — each one is in this book because each one is in the record, and the record is where this book's authority comes from. Nothing here is narrated that the record does not hold; where the record is silent, the text says VERIFY or says nothing.

That is the deal AI-first work has to offer, and the lab exists to demonstrate it: not a faster way to be confident, but a cheaper way to be checked.

Chapter 2: The Constitution

Every MatrixClaw session begins the same way: the agent reads a document called `SMF-MATRIXCLAW-SESSION-A-PROMPT-01.md` — the constitution — checks a lock file, and claims it with a name, a timestamp and a stated intent. Only then may anything be written. When the session ends, it appends an entry to an append-only log, opens its merge requests, and releases the lock. It never merges them.

None of that is engine code. It is a markdown file, a YAML file and a habit. Yet it is the part of MatrixClaw that everything else hangs from, and it is the right place to start building, for a blunt reason the lab proved on itself: the one session that skipped this ritual — no ticket, no lock, no first-actions — had to be stopped twice by the maintainer, and produced two rulings now burned into canon: *the framework is a gate, not a preamble*, and *no control is disableable by the agent*. Chapter 1 told that story. This chapter shows you the machinery that makes it stick.

Governance as executable habit

The constitution inherits a small governance core — the Sovereign Model Framework, SMF — used identically across every repository in the operation, and then adds the lab-specific contract on top. The inherited rules fit on one screen, and each one exists because its absence has a known failure mode:

Single source of truth. One file, `versions.yaml`, holds the version pins, the ratified decisions, the verify-list and the status table. Content may not cite a pin marked `STALE` or `VERIFY`. The failure this prevents is the most common one in AI-assisted work: a model confidently repeating a version number, price or API shape from its training data. If it is not pinned and current, it is not citable.

Branch-per-item; the author never merges. Every unit of work is its own branch and its own merge request, and the agent that authored it opens the MR but cannot merge it — the maintainer merges in the GitLab UI, every time, with no exception for "just a small fix". This is the human gate in its repository form, and it is load-bearing in both directions: `main` only ever receives complete,

reviewed files, and the diff of every change ever made has a human's name on the merge.

The session lock. `.session-lock` is a tiny YAML file: status, holder, since, intent. One writing session at a time. It looks almost too simple to matter, until two agents — or one agent and one human — write to the same governance files in the same afternoon and the append-only log becomes two interleaved stories.

The append-only log. `SMF-MATRIXCLAW-SESSION-LOG.yaml` receives one entry per session — date, actor, intent, outcome, branches, who merged — and prior entries are never edited or deleted. Crucially, the outcome field is written to carry *corrections*: the session-62 entry, to take one real example, records two things the agent told the maintainer that turned out to be overstated, and one mutation it made during supposedly read-only reconnaissance. A log that only records successes is marketing. This one is evidence, and it is the raw material half this book is generated from.

Secrets never in the repository. Live credentials come only from the environment. The rule sounds obvious; the discipline is in the corners — a runbook that captures `show running-config` from a switch commits the switch's password hashes to git history where they cannot be un-committed, which is why the lab's device runbooks narrow every such command through filters that cannot carry a secret. The rule is one line; holding it takes design.

Certify generated bytes. Anything generated and pushed is certified against the repository's actual bytes — hash the local file, compare with what the remote holds. This existed before the lab moved to plain `git push` (where the commit hash does the job for free) because its API-upload route had corrupted escape sequences in transit — silently, of course.

The apparatus: four files that outlive every session

What makes this governance *executable* rather than aspirational is that its state lives in four version-controlled files with fixed shapes, and the shapes are worth copying exactly.

versions.yaml — decisions as case law

The heart of the file is the decisions list. Each entry has an identifier, the decision text, and a status:

```yaml
- id: d-mc-002
  text: "Plan -> Approve -> Apply enforced in code by the approval gate;
         approval is bound to the plan hash."
  status: RATIFIED
```

By the time of writing there are thirty-five of these, and reading them in order is reading the lab's institutional memory: d-mc-001 puts the adapter between the agents and the infrastructure; d-mc-017 through d-mc-025 record, one by one, the maintainer's dispositions of nine design questions about the portable lab — each answered in chat, then written down with an identifier so no future session re-litigates them. That is the real function of the register: **a decision that lives only in a conversation gets re-argued; a decision with an identifier gets cited.** When later chapters say "per d-mc-030" about the git-push route or "per d-mc-028" about the audit cadence, that is the register doing its work.

The verify-list — claims the lab refuses to make

The same file carries the verify-list: statements the lab *would like* to be true, is not yet entitled to assert, and tracks explicitly. The oldest open item is instructive:

```yaml
- id: v-mc-004
  item: "Netdev runbook CLI sequences against real devices ...
         send/expect semantics validated on local transport only so far"
  status: VERIFY
```

The network-device layer was built, self-tested against a local transport, and reviewed — and the lab still refuses to claim it works, because it has never met a real switch. When the first real device was finally inventoried, the constitution's posture dictated the design: first contact must be a read-only survey, because the first real exchange *is* the test. A verify-list is the difference between a lab that says "done" and a lab that says "built, and here is exactly what would still have to happen before you should believe it".

LESSONS.yaml — the ledger of paid-for knowledge

The third file is a ledger of things learned the hard way, in a fixed format: incident, durable rule, related decision. The first entry ever written is small and perfect:

```yaml
- id: L-001
  trigger: "Scenario 2's first plan matched VM names from scenario 1
            that sat on the wrong network."
  lesson: "Compare the full spec, not just the name, before calling a
           resource 'present'. Existing-but-different must block, not pass."
```

Twenty-two entries later, the ledger's largest single entry – L-SILENT-FAILURE – catalogues twelve traps from the lab's real-hardware campaign, and its opening line is the reason the file exists: every one of the twelve produced *no error, no warning and no log line.* Each presented as "the hardware is slow" or "big models are just like that", and each was, in fact, a default nobody had read, a check that could not fail, or a process matching its own command line. The ledger is scanned before starting comparable work – not as a nicety, but because every entry in it was paid for in hours, and some in days.

The session log — the narrative spine

The fourth file you have already met. What is worth adding is what it is *for*: when this book's chapters cite what happened in "session 60", they are citing a committed YAML entry written the same day, carrying its own corrections, merged by a human. The log turns a stream of conversations into a citable history – which is precisely what a lab that generates its publications from its own record requires.

Why "a check that cannot fail is not a check" is written into law

One phrase from the ledger has hardened into something closer to a constitutional principle, and it earns a section because it is the failure mode AI-first work is most prone to.

A check that cannot fail is any verification whose passing tells you nothing: a test asserting a file *exists* rather than that it is correct and complete; a script checked only by its exit code while it writes the wrong content successfully; a probe that treats an unreachable host as a satisfied precondition because failure and absence look identical from where it stands. The lab's ledger holds real specimens of each – including a watcher that waited twenty-nine hours for a process to exit that was, in fact, its own command line matching the

search pattern; and, recorded with equal honesty during the writing of *this book*'s sibling artefacts, fifty-two audit reports rendered with the wrong flag, every one exiting zero, caught only when a human habit – read one file before you commit – was applied.

Why does an AI-first lab legislate this rather than merely note it? Because the economics of agentic work invert the usual ratio: an agent produces verification steps as cheaply as it produces everything else, so the *number* of green ticks grows without bound while their *evidentiary value* is whatever the weakest check provides. The constitution's answer is structural, and later chapters implement it in code: counts carry floors so an empty result cannot equal an expected zero; probes must capture output and check it for a marker that cannot occur in failure output; probes whose transport can fail must fail closed; and the steps that prove recovery carry no shortcut probe at all. The gate model from Chapter 1 protects the infrastructure from unapproved change. This principle protects something subtler – the lab's knowledge of itself.

Building yours

Everything in this chapter is portable, and the starter repository ships all four shapes ready to claim: a constitution to amend, a `versions.yaml` whose decision register begins with the inherited rules, an empty lessons ledger, a session log whose first entry is yours to write. Two pieces of advice from the record before you customise:

First, copy the *shapes* exactly and change the *content* freely. The formats – id/text/status, incident/rule, the log fields – are where the value lives, because they are what make the files citable and machine-checkable.

Second, resist the temptation to soften the two rules that will chafe first: the author never merges, and the log is append-only including your mistakes. They chafe because they work. The lab in this book is operated by a frontier model under both rules, and the record it produced is trustworthy *because* the model could not merge its own work and could not quietly rewrite its own history – not because it never erred. It erred on the record, which is the only place erring is useful.

The next chapter opens the first file the engine writes and the constitution's whole theory of truth: the run record.

Chapter 3: The Run Record

Everything MatrixClaw claims to know about what it has built lives in one kind of file: `runs/<run_id>.json`. One run, one record, committed to the repository like code, because it is more important than code. The engine can be rewritten from scratch — it has been substantially rewritten several times — and nothing of the lab's history is lost. Lose the run records and the lab has no history at all, only infrastructure of unknown provenance and chapters that can no longer prove themselves.

This chapter reads the lab's very first record, `mc-20260118-234610-web-db-isolated` — still in the repository, still parseable, and still the working specimen for the whole design — and walks the contract that makes a single JSON file strong enough to be "the only permitted source of truth".

Fifteen fields, one life

A run record (`schema: "matrixclaw/run-record/1"`) has fifteen top-level fields, and they narrate a complete life:

The **identity block** — `run_id`, `lab`, `backend`, `actor`, `status`, `created_at`. The `run_id` embeds a timestamp and the scenario slug, so the file name alone tells you what and when. `backend` says whether this happened against the simulator or a live zone — the two produce the same record shape, which is half the point of having an adapter. `actor` records the *role* that ran the plan (the genesis record says `IaC-Engineer`), and `status` walks a fixed ladder: `created -> planned -> approved -> applied -> tested -> torn_down`, with `failed` available at every rung.

The **scenario** — the full spec as planned, embedded verbatim. A record must be self-contained: a reader with only this file knows exactly what was asked for, without chasing a scenario file that may since have changed.

The **plan** — the actions the engine computed, each one an operation, a kind, a name, a spec and a *reason* (`"not present"` being the commonest — the plan is a diff against the world, not a wish-list), plus the field the whole gate hangs on, `plan_hash`.

The **approval** — who said yes, when, to which hash, and why:

```
"approval": {
  "required": true,
  "approver": "mike.hinsley",
  "granted_at": "2026-07-19T00:14:13Z",
  "plan_hash": "sha256:56fc8a656d0b793c",
  "note": "teardown genesis topology to clear drift for scenario 2"
}
```

Then **apply** (timed, with per-action results and an error slot), **tests** (name, passed, detail — one entry per SRE check), **teardown**, **evidence**, and **events**. Two arrays deserve their own section below, because they answer different questions and mixing them is a common design mistake.

The plan-hash contract

The mechanism is four lines of code and one rule:

> `plan_hash = "sha256:" + sha256(json(actions, sorted))[:16]`. Approval stores the hash it approved. `apply` and `teardown` proceed only if the record's current `plan.plan_hash` equals `approval.plan_hash`. Any change to the actions produces a new hash and re-closes the gate.

The hash is computed over the *actions*, canonically serialised — not over the scenario, and not over prose. What the human approves is the exact set of operations that will run, byte for byte. "Approve this exact plan" stops being a figure of speech and becomes a comparison of two strings.

The genesis record demonstrates the contract twice in its first twenty-eight minutes, and the second time is the instructive one. Its event timeline shows an approval of plan `sha256:0436fbe94f146c39` at 23:46 on 18 July — the build — and then, at 00:14 the following morning, a *second* approval, of a *different* hash, `sha256:56fc8a656d0b793c`: the teardown, with its own note giving its own reason. Teardown is not an undo button riding on the original approval. It is a fresh plan — destroy these named things — with a fresh hash and a fresh human yes. One record, two gates, both on the permanent record. That is d-mc-002 working exactly as Chapter 2 described it, on the lab's first day, and

it is why the record's final `status: torn_down` is a statement of provenance rather than a shrug.

Two honest notes on the hash itself. It is truncated to sixteen hex characters — comfortable for its actual job, which is detecting *drift between approval and execution*, and chosen for being short enough that humans genuinely read and compare it in tickets and chat. And it protects against change, not against an adversary: this is a seatbelt inside a governed repository, not a cryptographic signature scheme, and the lab does not pretend otherwise.

Evidence and events: two arrays, two questions

`events` answers *when did what phase happen* — a timeline of one-line entries (`create`, `plan`, `approve`, `apply`, `test`, each timestamped). It is the record's skeleton, and the first place to look when reconstructing a session.

`evidence` answers *what can be narrated* — and its name is chosen with intent. Each entry has a timestamp, a kind, human-readable text, and structured payload where the kind warrants it. The genesis record carries seven: three `apply-result` entries (one per created resource, each with the resource's actual spec echoed back), and four `test` entries carrying the check verdicts. Later record generations add richer kinds — hashed screenshots from browser sessions, per-step SSH transcripts with return codes, artefact checksums — but the contract never changes: **if it is not in `evidence`, it did not happen, for publication purposes.**

That contract has a consumer, and the consumer is the reason for the rigour.

The content engine's side of the bargain

The specification devotes a section to what `mc-course` — the generator that turns runs into chapters — is permitted to do, and it is a short section because the permission is narrow: *render only values present in the run record; introduce no commands, results, IPs or claims not found there; cite the `run_id` so a reviewer can re-derive every statement.*

This is "no run, no lesson" as an interface contract rather than a slogan, and it cuts in a direction that surprises people: it is a constraint on the *author*, not the reader. An AI writing a chapter about infrastructure it built an hour ago

is the most tempted author in publishing — it remembers intent, it remembers what *should* have happened, and its fluency papers over the difference. Binding the generator to the record makes the temptation structurally irrelevant. The book you are reading extends the same contract to human-shaped prose: its chapters cite run ids and decision ids precisely so that its claims are checkable against the same files the course engine reads.

Records grow up: schemas meet reality

The lab now holds three families of record in `runs/` — engine runs like the genesis record, the book programme's verification records, and Nano's build records — plus engine variants (`backend: deploy:ssh` for runbook executions, whose per-step evidence Chapter 8 dissects). Two lessons from that growth belong in this chapter, because both are about what a schema really is.

First: when the compliance library was taught to render all record families, the ruling that accompanied the change (d-pdg1-39) required it to render each one *or name what it cannot*. A consumer that silently skips records it does not understand is under-reporting the lab's history while appearing complete — the audit-surface version of a check that cannot fail.

Second, told against this book's own production: a session-59 evidence record was committed with its `scenario` field as a plain string where every engine record carries an object — and months of tooling written against the object shape crashed on it. The crash was found during the writing of this book, in the very session that regenerated the compliance library, and the fix landed with the observation that *a compliance library that crashes on a real record is a failed close-out in code form.* A schema is a promise, and it binds consumers as much as producers: tolerate the shapes your history actually contains, or refuse them loudly — never assume them quietly.

Stability rules

The record's durability rests on three small disciplines from the specification. Records are **append-mostly**: later phases add their own objects; earlier fields are never rewritten except `status` and the phase objects each step owns — so an approval, once granted, is not editable by anything that runs afterwards. The **`runs/` directory is committed** as the evidence trail. And the simulator's

own state directory is *not* committed — it is disposable by design, regenerated by runs, because the record is the durable artefact and the sim state is merely the world the record happened in.

Building yours

If you are building your own lab from this book, this chapter's shape is the one to copy most exactly, and the temptations to resist are these. Keep it one file per run, embedding the scenario, so a record is legible in isolation five years on. Keep the hash over the canonical actions and store it *twice* — in the plan and in the approval — because the gate is the comparison. Separate evidence from events. Give every evidence entry a machine-readable `kind` from day one; the genesis record's three kinds have grown into a taxonomy, and consumers depend on it. And write your renderers to the rule the lab learned twice: render what is there, or name what you cannot — the record is the truth, including the parts of it your tooling did not expect.

Chapter 4: Plan -> Approve -> Apply, Enforced in Code

The approval gate — the mechanism this book has been circling for three chapters — is about sixty lines of Python in a file called `gate.py`, and its module docstring is the best specification it could have:

> This is the single enforcement point for the Plan -> Approve -> Apply discipline. Every mutating operation (apply, teardown) funnels through `require_approval`, which refuses to proceed unless the run record carries a human approval bound to the *exact* plan being executed. An agent cannot route around it: there is no apply path that does not call this function first.

Sixty lines is not a limitation. It is the design. A control you can read in one sitting is a control you can trust; a control smeared across a codebase is a control you can only hope about. This chapter reads the whole mechanism — the two gate functions, the funnel that forces everything through them, drift detection, and the failure path — and closes with what the gate deliberately does not do.

Two functions

`grant_approval` is the recording half. It refuses to approve a run that has no plan ("run `plan` first" — you cannot approve an intention), then writes the approval block Chapter 3 showed: approver, timestamp, note, and — the load-bearing line — a *copy of the plan hash as it stands at the moment of approval*. The approval does not point at the plan; it snapshots it. That distinction is the whole mechanism.

`require_approval` is the enforcing half, and it can refuse in exactly two ways. Both refusal messages are worth quoting — the second shown with the genesis record's two real hashes standing in for its placeholders — because in an AI-first lab the error text is not decoration; it is the instruction the agent will actually follow next:

```
BLOCKED: 'apply' requires human approval and none is recorded.
  Present the plan to the maintainer, then run:
    matrixclaw approve <run_id> --approver <name>
```

```
BLOCKED: the plan changed since approval.
  approved plan: sha256:0436fbe94f146c39
  current plan:  sha256:56fc8a656d0b793c
  Re-present the new plan and re-approve before 'apply'.
```

Notice what the second message does: it prints both hashes and names the only legitimate exit — *re-present and re-approve*. A refusal that merely said "denied" would invite an agent to try something else. A refusal that states the rule and the remaining lawful path gets compliance for free, from any model, on any day. Write your error messages for the reader who will act on them; in this lab, that reader is usually not human.

The funnel

The gate only works if nothing walks around it, so the engine is shaped as a funnel. `Engine.apply` calls `require_approval` before touching a single action. Every action then executes through one private method, `_exec`, which dispatches on a *fixed* set of operation names — create and destroy for networks, VMs, load balancers, and the zone-level objects — and ends with:

```
else:
    raise ValueError(f"unknown op '{op}'")
```

The engine's own comment explains the posture: the op set is fixed "*so an unknown op still fails loudly rather than getattr-ing arbitrarily.*" A dynamic dispatch onto arbitrary method names would mean a malformed plan could reach backend methods nobody reviewed. The funnel narrows: one apply path, one dispatch table, one gate in front of it.

Which operations require approval is not hard-coded — it is policy, read from `approval.required_for` in the lab's configuration. The current setting, ratified as d-mc-005, is maximal: every mutating operation. But the dial exists, and it is the honest place for an autonomy ladder to live: if a future maintainer decides sim-backend applies no longer need a human yes, that is a one-line, reviewable, revertible config change — a recorded decision, not a behavioural drift.

Drift: the plan tells the truth, so apply can refuse to lie

The plan is a diff between the scenario's desired state and the world's actual state, and each resource lands in exactly one of three buckets: missing (becomes a create), present and matching (becomes a `noop`), or present but *different* — and the third bucket is where labs quietly rot. The ratified rule (d-mc-009) is blunt:

> Drift is never silently absorbed: a resource that exists but differs from spec becomes a `drift` plan action, which blocks apply until an engineer resolves it.

In code, a drift action is not a warning. `_exec` raises on it — "*Never build on top of a wrong assumption*" is the comment on that branch — so an approved plan containing drift stops at the first drifted resource with instructions to teardown, rename or reconcile, and re-plan.

The rule was paid for on the lab's second day, and the ledger's very first entry (L-001, quoted in Chapter 2) records the incident: scenario 2's first plan matched VM names from scenario 1 that sat on the wrong network. Same names, wrong world — the plan looked satisfied by resources that did not match its spec. The fix shipped as the drift bucket, and the session-02 log shows the full sequence working within hours: the re-plan correctly flagged drift against the genesis names; the genesis topology was torn down *through its own gate, with its own approval* — that is the second hash in Chapter 3's genesis record — and the clean apply then passed its checks 8/8. Day two: incident, rule, mechanism, proof. That loop — from surprise to ratified control in one session — is the lab's metabolism, and it is what the LESSONS file is *for*.

When apply fails, the record keeps the body

The apply loop wraps execution in the only kind of exception handling a lab should trust:

```
except Exception as exc:  # capture the failure on the record, then re-raise
    rec.data["apply"] = {..., "results": results, "error": str(exc)}
    rec.event("apply", f"FAILED: {exc}")
    rec.set_status("failed")
    rec.save()
    raise
```

The record gets the partial results, the error text, a `failed` status – and then the exception continues upward, unswallowed. Nothing retries, nothing smooths. The half-applied world and the reason it is half-applied are both on the permanent record, which is exactly the information the human now deciding what to do needs. Compare the anti-pattern this forbids: a loop that catches, logs to stdout, and carries on, leaving a record that says `applied` over infrastructure that is neither the old world nor the new one.

Teardown re-gates itself

Chapter 3 showed the genesis record carrying two approvals for two hashes. Here is the producing code, in `Engine.teardown`:

```
# bind teardown to its own plan hash and re-gate
rec.data["plan"] = {..., "actions": actions,
                    "plan_hash": plan_hash(actions), "kind": "teardown"}
rec.save()
gate.require_approval(rec, "teardown", self.cfg.approval_required_for)
```

Teardown computes its *own* action list from the current world (what actually exists is what gets destroyed – not what the original plan hoped to create), rebinds the record's plan to those destroy actions under a fresh hash, marks it `kind: teardown`, and only then asks the gate. The build approval cannot leak into the destroy: the moment the plan was rebound, the old approval stopped matching, and `require_approval` – the same function, unchanged – closes the gate until a human approves the destruction specifically. Destroying infrastructure is not the undo of creating it. It is a new mutation of the world, and the gate treats it as one.

What the gate does not do

Three honest limits, stated so you can design around them rather than discover them.

The gate does not judge plans — it verifies that *a human saw this exact plan and said yes*, not that the plan was wise. Plan quality is what the Reviewer role, the test rig and the LESSONS ledger are for; the gate is deliberately dumb, because a gate with opinions is a gate that can be argued with.

The gate does not guard reads. Planning, testing and state inspection run freely — that is what makes the loop cheap enough to use. The lab's later runbook work sharpened this edge the hard way: session 62's log records that a "read-only" reconnaissance over SSH quietly wrote a host key into `known_hosts` — the lesson being that *read-only* is a property you must verify at the transport, not assume from intent. The gate model holds; the vigilance about what counts as a mutation is yours.

And the gate is not a defence against a hostile agent with write access to the engine's own repository — an agent that could edit `gate.py` could remove it. That threat is handled a layer up, by the constitution's repository rules: the agent cannot merge, so a gutted gate cannot reach `main` without a human merging the gutting. The layers are complementary, and neither pretends to be the other: code enforces the loop inside a session; governance enforces the code across sessions.

Building yours

The portable core is five decisions, all visible in the sixty lines: one enforcement function that every mutating path must call first; approval as a *snapshot* of the plan hash, never a pointer; refusal messages that state the rule and the lawful next step; a fixed dispatch table that fails loudly on anything unknown; and failure paths that write to the record before they raise. Add the drift bucket the first time reality surprises you — the lab needed one day — and re-gate your destroy path from the start, because the temptation to treat teardown as cleanup rather than mutation arrives with your first drifted scenario.

Chapter 5: The Sim Adapter

The first infrastructure MatrixClaw ever built was a JSON file. The simulator backend models a CloudStack zone as local state on disk — networks, VMs, load balancers, and later the full zone-object hierarchy — and it was not a stopgap on the way to the real thing. It is the default backend to this day, the one the starter's first run targets, the one every engine feature is proven on before it touches anything real, and the environment this book's appendix proposes for screening open models. This chapter is about why "start with a fake cloud" was the highest-leverage decision in the engine's design, and what makes a *good* fake.

One contract, two worlds

The adapter layer's docstring states the deal:

> Two backends implement the same primitive surface: `sim` — a local JSON state file (fast, safe, no infrastructure); `live` — the real CloudStack API (signed HTTP), guarded. Switching from sim to live is a one-line config change. The Plan/Approve/Apply contract, the run record, and the tests are identical for both — which is the whole point of an adapter.

The `Backend` base class is deliberately ignorant: it creates, destroys and reads resources, and "*knows nothing about approval, run records, or courses.*" The gate lives above it, in the engine — which means the gate's behaviour is literally identical whether the world underneath is a JSON file or a datacentre. That is what makes sim-first training honest: an agent that learns the loop on the simulator learns the real loop, because there is only one loop.

The flip itself is visible in the backend factory, and it carries the design's second safety net:

```
return LiveBackend(
    endpoint=..., apikey=..., secretkey=...,
    dry_run=bool(live.get("dry_run", True)),
)
```

`backend: live` gets you a live backend that *describes* mutations instead of executing them, until someone also sets `dry_run: false`. Two deliberate steps — flip the backend, then arm it — separated so that neither can happen as a typo. The lab's own config crossed that second line only in session 58, with the note recording exactly which approved build it was armed for.

A simulator with opinions

The instructive thing about `sim.py` is not what it accepts but what it refuses. It ships a small catalogue — four known templates, four known offerings with real CPU and memory shapes — and validation that mirrors a real zone's constraints. A VM with an unknown template is refused with the list of known ones. A VM attaching to a network that does not exist is refused. A load-balancer rule is refused if any member VM is unknown — *and also* if a member exists but sits on a different network than the rule fronts.

That last refusal is the signature of the design. A lazier simulator would accept anything shaped like a request and return success — and it would train agents to write plans that detonate on contact with reality, while every sim run glowed green. Chapter 2's law applies to worlds as much as to checks: **a simulator that cannot refuse is not a simulator; it is a mock, and a mock proves nothing.** The sim earns its role as the default backend precisely because it pushes back where CloudStack would push back.

The realism is bounded, and honestly so. The sim assigns IPs from a sequence inside the network's CIDR, derives gateways, tracks lifecycle state — "*the parts of CloudStack behaviour the lab reasons about*", as its docstring puts it, and its state shape "*deliberately mirrors what the live backend returns from the CloudStack API, so tests and the run record don't care which backend produced them.*" One shape, both worlds — which is why every check in the test rig runs unmodified against either.

What the simulator proved, and when

The value of sim-first is best argued from the lab's own timeline.

The whole engine was proven on sim before live existed. The genesis session ran plan -> gate-block -> approve -> apply -> test -> teardown end to end on the simulator — including both approvals of Chapter 3's two-hash story. The gate, the record, drift, the test rig: all of it was real before any credential existed, at a total infrastructure cost of one JSON file.

The drift discipline was born on sim, on day two. L-001 — scenario 2's plan matching scenario 1's VMs on the wrong network — happened on the simulator. The fix (the drift bucket, d-mc-009) shipped and was proven the same day, against state that could be reset in a millisecond. Meeting that class of bug for the first time on a live estate instead would have meant learning drift semantics with real infrastructure in the blast radius.

The zone schema was designed sim-first, deliberately. When the lab needed zone-level objects — zones, pods, clusters, hosts, storage — the change ticket recorded the method up front: "*Design-first: sim proves the model before any live call exists.*" The scenario schema, the planner semantics and the test assertions were all settled against the simulator, so that when the live mapping was eventually written, it implemented a proven design instead of exploring one against real hardware at real cost.

That session also left a detail worth copying. The sim implements every zone-level operation; the live backend, at the time, deliberately implemented none of them — and the base class made the gap *loud*: any zone action on a backend without support fails at the first action, by design, "*instead of half-building.*" The asymmetry was tracked openly as two verify-list items until the live estate closed them. That is the adapter pattern under governance: both backends share a contract, and where one lags, the lag is an explicit, recorded, fail-fast fact — not a quiet difference in behaviour.

There is even a small schema-migration lesson in the file: when the zone maps were added, `get_state` was written with `setdefault` so that *pre-existing* state files upgrade in place the first time they are read. The simulator obeys Chapter 3's rule about tolerating the shapes your history contains — even for state nobody commits.

What the simulator is for now

The sim never retired. Its standing jobs, in the lab as it runs today:

- **Every engine change lands on sim first.** The starter's refresh discipline (Chapter 16) runs the full genesis slice on the simulator as its acceptance test, and this book's own production has used exactly that slice — twice — to verify the starter after re-syncs.
- **It is the reader's first mile.** The starter's setup ends with a sim genesis slice; your first approved plan and your first 4/4 happen at zero cost and zero risk, with the real gate refusing you first.
- **It is the screening ground for other models.** The framework's open-model programme — estate-scale in its spike scope, reader-scale in Appendix A — uses the sim loop as its control-discipline test: full plan -> approve -> apply -> test, repeated, with zero control breaches required, before any live contact is contemplated. A candidate model that cannot hold the loop against a JSON file has answered the question cheaply.

What the simulator cannot teach

The honest boundary, stated as sharply as the record allows: the simulator reproduces CloudStack's *shape*, not its behaviour under real conditions — and the lab's live campaign is a catalogue of exactly the things no simulator of this kind would have caught. Stock Ubuntu's `127.0.1.1` hosts entry breaking the management server's cluster address. The API demanding a guest CIDR the UI wizard never mentions. A default that traffic-shapes every guest NIC to 200 Mbps, visible only in the domain XML. Nine execution-found defects in the first real-hardware session alone.

None of that is an argument against the simulator. It is the division of labour: **sim proves your loop, your schema and your discipline; live teaches you the world.** The mistake would be expecting either to do the other's job — a lab that only simulates never learns what defaults cost, and a lab that goes live first pays real money to debug its own planner. The sim's job is to make sure that by the time you are paying live prices, the only lessons left to buy are the ones about reality.

Chapter 6: The Live CloudStack Adapter

The live backend is six hundred lines of standard-library Python — `urllib`, `hmac`, `hashlib`, nothing installed — that speaks the real CloudStack API with signed requests. It implements exactly the surface the simulator implements, which Chapter 5 argued is the whole point. What Chapter 5 could not show is what this chapter is really about: the live adapter is the most *corrected* file in the engine, and every correction is annotated in place with the session that paid for it. Read properly, `live.py` is not just an API client. It is a ledger of what execution taught that no amount of reading could.

Guarded by design

The module docstring leads with the guardrails, and each one is enforced in the constructor rather than requested in documentation: credentials come only from the environment and never the config file; the backend *refuses to load* without an endpoint and both keys; and `dry_run` — which Chapter 5 showed defaulting to true in the factory — turns every mutating call into a described no-op, so you can point the engine at a real zone and rehearse against it safely. Dry-run is honest about reads too: `get_state` in dry-run returns an explicit `"live state not fetched"` note rather than pretending to a world it did not fetch.

The first lesson: signing, and the vindication of the verify-list

CloudStack authenticates each request with an HMAC-SHA1 signature over the sorted query string. The lab's implementation was written from the documentation, self-tested against a stubbed transport, reviewed — and held on the verify-list as v-mc-001 anyway, per Chapter 2's rule that a claim untested

against reality is not yet a claim. The comment now sitting in `_sign` records what happened on estate deploy day:

```
# CloudStack signs the ENTIRE sorted query string lowercased — values
# included (API keys are mixed-case), with spaces as %20 not '+'.
# Session-19 estate finding 8: keys-only lowercasing 401s on the first
# real call; the stubbed-transport verification could never catch it
# (this is precisely what v-mc-001 was held open for).
```

Lowercasing only the keys — a perfectly reasonable reading of the spec — 401s on first contact, because API keys are mixed-case and the server lowercases the whole string, values included. No stub could have caught it: the stub would have been written from the same misreading. This is the verify-list doing precisely its job — the lab *knew* it did not know, said so in writing, and when the first real call failed, the failure was expected in kind, budgeted for, and fixed in one finding rather than discovered in production surprise.

Asynchronous truth

Most CloudStack mutations are asynchronous: the API returns a job id and the work finishes later. The adapter's posture is that **a submission receipt is not an outcome**, and the run record deserves outcomes. So every mutating call that returns a job id polls `queryAsyncJobResult` to completion, and the poll is fail-closed in both directions: a failed job raises with CloudStack's own `errortext` — never swallowed — and a job still pending when the budget expires raises too, with the adapter's flattest sentence: "*not treating a timeout as success.*"

The neighbouring comment records the finding that sharpened the other edge of the same blade:

```
# Session-19 estate finding 9: addHost timed out at 60s client-side while
# SUCCEEDING server-side (it SSHes in and installs the agent — synchronous
# and slow). Slow sync commands pass a longer per-call timeout; a client
# timeout must never be read as a server failure.
```

Two rules from one day, and they point in opposite directions on purpose: a timeout is not a success, *and* a client timeout is not a server failure. What they share is the refusal to let an ambiguous signal collapse into a convenient conclusion — the run record gets the truth or it gets an error, never a guess.

One state shape, so the whole engine transfers

`get_state` on live assembles its answer from a dozen `list*` API calls — zones, pods, clusters, hosts, storage, networks, VMs — and normalises everything into *exactly* the shape the simulator returns. The comment beside the zone-tree walk says why: "*state keys/fields mirror the sim's so drift, classify and every tests.py assertion behave identically.*" This is the payoff of Chapter 5's contract, delivered: the drift detector that was born on the simulator on day two, and every check in the test rig, ran unmodified against real iron on deploy day. The adapter absorbs CloudStack's shape so nothing above it has to.

The execution-found defect ledger

Now the heart of the chapter. When the lab finally took this adapter to real hardware — the quality-brain campaign of sessions 58 and 59 — the first session alone fixed *nine* execution-found defects, and the next added three more. Not one of them was findable by reading the code, which had been read, repeatedly, by the model that wrote it. A representative sample, each traceable to its session:

In the lab's own code. The signing and timeout findings above. Then session 59's API archaeology, annotated at the deploy call:

```
# session-59 EXECUTION-FOUND: 4.22.1 takes ONE string param named
# "extraconfig" (listApis confirms), URL-encoded at the VALUE level -
# the extraconfig-1..N convention the ch9 draft prints is rejected as
# an unknown parameter.
```

The `extraconfig-1..N` convention — present in community examples and in a sibling book's draft — is simply rejected by CloudStack 4.22.1. The working form is one parameter, value-encoded. Same session: the account's API allow-list turned out to check *every element* of a request, not just the command name; and the default `qemu64` CPU model silently masked AVX-512 from the guest — fatal for inference throughput, invisible until something measured it.

In the world's defaults. The management server that serves 503 forever because stock Ubuntu maps the hostname to `127.0.1.1` and CloudStack pins its cluster address to it. The API route that demands a guest CIDR the UI wizard never mentions. And the campaign's headline: CloudStack traffic-shapes *every*

guest NIC to 200 Mbps by default — invisible from inside the guest, absent from every log, visible only as a `<bandwidth>` element in the domain XML, measured at a 27× penalty on the lab's 100G storage fabric and blamed, for four hours, on the network. Alongside it, four zone-design constraints now recorded in the framework's traps document: a physical network cannot be added while the zone is enabled; multiple physical networks require tags (tag the new one only); a storage fabric wants an L2 offering, not Shared; and reserved hugepages are *exclusive*, so a guest whose XML silently loses its hugepage element strands the entire reservation while appearing to boot normally.

The ledger's through-line is the one Chapter 1 promised: every one of these fails *silently*. The estate's diagnostic method — measure what the layer below can do, then count something that must be near zero — exists because logs, here, structurally cannot help: the system is behaving exactly as configured. The defect is the configuration, and only execution puts you face to face with it.

Findings live where the code lives

Notice the form of everything quoted above. The lab's findings are not only in `LESSONS.yaml` and the session log — they are *comments at the exact line they changed*, citing their session and finding number. This is a deliberate third copy. The ledger tells you the pattern, the log tells you the story, and the comment tells the next editor — human or model — *why this line is shaped this way* at the moment they are most tempted to simplify it. In an AI-first lab this matters doubly: a model refactoring `_sign` will read that comment in context and leave the full-string lowercasing alone, where a rule in a distant file might lose the argument with plausibility.

Building yours

The live adapter's portable habits, in the order they will save you: keep credentials in the environment and *refuse to construct* without them; make dry-run a first-class mode that describes mutations and admits what it did not fetch; poll async work to completion and refuse both convenient conclusions (a timeout is not success; a client timeout is not server failure); normalise live state into your simulator's shape so your checks transfer unchanged; hold

your untested integrations on a verify-list and expect first contact to bill you — session 19's estate day was *budgeted* to find things, which is why finding them was a good day and not a crisis; and when execution corrects you, write the finding at the line it changed, with its date and its session, because that comment is the cheapest insurance the file will ever carry.

Chapter 7: Scenarios and the Test Rig

A MatrixClaw scenario is one YAML file that says two things: what the world should look like, and how to prove it does. The second half is the design decision this chapter is really about. The `tests:` block is not a separate suite maintained somewhere else by someone else later — it is part of the scenario, written at design time, planned with the topology, and its verdicts land verbatim in the run record as evidence. You declare what *done* looks like in the same breath as declaring what you want.

Anatomy of a scenario

The genesis scenario, `web-db-isolated`, is still the best small specimen — a network, two VMs, and four checks:

```yaml
tests:
  - name: network-implemented
    assert: network_exists
    args: { name: mc-isolated-1 }
  - name: both-vms-running
    assert: vms_running
    args: { names: [web-01, db-01] }
  - name: shared-isolated-segment
    assert: same_network
    args: { names: [web-01, db-01], network: mc-isolated-1 }
  - name: exactly-two-vms
    assert: count_vms
    args: { expected: 2 }
```

Three habits are visible already. The checks climb a ladder — exists, running, *correctly related*, *exactly counted* — so a pass means the topology, not just its ingredients. The `description:` field is written for a reader, because the course engine will quote it. And nothing secret appears anywhere: the zone scenario states the rule in its own header — secrets "*belong to the two host-add/storage routes, never to a scenario file*" — credentials travel through guarded channels at execution time, and the declarative layer stays committable.

The wizard as code

The scenario language grew up in session 18, when zone-level objects — zone, pod, cluster, hosts, primary and secondary storage, VLAN ranges, traffic labels — became first-class resources. The flagship, `lab-manchester-zone.yaml`, declares as code the exact zone the sibling deployment guide's readers build by hand in the CloudStack wizard, and its header is a working example of Chapter 2's register in action: the Ceph path is mandatory *per d-mc-017*, two KVM hosts because live migration "*is taught, not optional*" per d-mc-019 — ratified decisions cited at the point of use.

Zone declarations are validated *strictly at extraction time*, before any plan exists — the engine's comment: an invalid zone block "*fails loudly before any plan exists*", and the same validation runs whether the scenario is being planned or torn down. A malformed declaration is refused as an authoring error, not discovered as a half-built zone.

One comment in that file deserves its own paragraph, because it shows the drift discipline flowing *backwards* into scenario authoring, which is where it matures:

```
# session-20: CloudStack itself adds a Storage traffic type when none is
# configured, riding the management bridge — observed live on the built
# zone (listTrafficTypes returns four labels). Declared here so re-plans
# judge the zone against its true state; unmasked when the rbd 'user'
# phantom-drift row was fixed.
storage: cloudbr0
```

The lab declared three traffic labels; CloudStack, on the real zone, quietly created a fourth. A re-plan then showed drift the lab had not caused — *phantom drift*, a mismatch between declaration and reality where reality is fine and the declaration is incomplete. The fix is the honest one: the scenario now declares the world as CloudStack actually builds it, with the observation dated and sourced. Your desired state must describe the world your platform really makes, defaults included, or your drift detector will cry wolf — and Chapter 2 already told you what a check that false-fails teaches people to do.

The test rig: one function per assertion

The rig itself is deliberately small. Each assertion is one function taking `(args, state)` and returning a verdict plus a human-readable detail string; a registry maps assertion names to functions; "*adding a new assertion is a one-function change.*" The state it reads is whatever the backend returned — Chapter 5's shared shape means every assertion works against sim and live unmodified, which is how the same 24-check acceptance suite could pass on a laptop, then on server hardware, without edits.

The detail strings are not cosmetic. They land verbatim in the record's evidence array — `[PASS] shared-isolated-segment: ['web-01', 'db-01'] all on network 'mc-isolated-1'` — and become the sentences the course engine, the audit reports and this book are permitted to quote. Write them as the sentence you will want published, because they are the sentence that will be published.

Identity, not existence

The rig's design rule — and the outline's phrase for this chapter — is that checks assert *identity rather than existence*: not "is there a thing by this name" but "is the thing by this name the thing the scenario meant". `same_network` fails on a VM that exists happily on the wrong segment. `count_vms` carries an expectation, so a world with the right VMs *plus three strays* fails. The lab's own L-001 was exactly an existence-check worldview being fooled by name collisions; the rig is that lesson generalised.

The sharpest specimen is from the live estate. The reader lab's acceptance suite includes a checkpoint proving that a guest's storage landed on the Ceph pool `rbd-prod`. Its first implementation was satisfiable by a non-empty pool — and on the real zone, *system* VM volumes could make the pool non-empty without any user guest ever touching Ceph. The session-20 log records the tightening: the check now demands the volume be attributed to the *user* VM *in question*, not merely that the pool has contents. The general form is worth memorising: **a check satisfiable by the wrong thing is a check that cannot fail, wearing a pass.** Ask what *else* could make your assertion true, and if the answer is "plenty", the assertion is not yet about identity.

Two boundary rules from the record complete the design. Counts carry floors and expectations, never bare comparisons — the campaign's brain-serving work found a provenance check deriving its expected count from a manifest whose emptiness *was* the failure mode: zero certified zero files, green. And on first contact with a platform you have never observed, checks are *deliberately few* — the survey runbook for the lab's first real switch asserts vendor, privilege, and reachability, and pointedly does not assert port naming it had never seen, because (L-019, in the file's own words) a check that false-fails on a correct build "*teaches the team to distrust the check*". Survey first, read the evidence, then encode what you observed.

Noop fidelity: the quality bar

The rig proves a build. The planner proves something subtler, and the lab treats it as the scenario language's acceptance test: **a steady-state world must re-plan as all noops.** Plan the same scenario twice with nothing changed between, and every action should come back `noop` — no creates (your resources are recognised), no drift (your declarations match reality, defaults and all).

The session-20 log records the moment the lab reached it on the live zone: after fixing a storage field the API reports unreadably (the rbd `user` row, which had manufactured phantom drift) and declaring CloudStack's auto-added traffic label, the full Manchester zone re-planned as *eight noops out of eight* — run `mc-20260121-083336`, on the permanent record. "Perfect steady-state noop fidelity" made the close-out's standing facts, and it earns its celebration: noop fidelity is the planner swearing that its model of the world and the world itself agree, which is the precondition for every drift verdict you will ever trust afterwards.

Building yours

Put the checks in the scenario file, at design time — proof obligations are part of the request, not an afterthought. Keep every assertion one small function returning a verdict and a publishable sentence. Make identity the habit: name the relationship, carry the expected count, and interrogate every check with "what else would satisfy this?". Declare the world your platform actually builds, defaults included, and treat phantom drift as a bug in your declaration. Start

sparse on platforms you have never observed, and encode what the survey showed you. And hold yourself to the noop bar — the day your steady state re-plans clean is the day your lab's word about drift starts meaning something.

That closes Part II. The loop is whole: a scenario declares a world and its proof; the gate lets a human authorise exactly that plan; the adapters build it on a simulator or a real zone; the rig verdicts it; the record keeps everything. Part III leaves the API for the metal underneath it — runbooks over SSH, where the machines being configured are the machines the lab runs on, and the discipline this half of the book built gets tested by reboots.

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Rule two: mutating clicks are gated like `apply`

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Rule three: no log, no click

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No hash, no shot

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Projects are organs

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Two write routes, honestly split

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External assistants: the pattern, kept honest

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d-mc-026: the change ticket

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ISO/IEC 42001:2023 — AI management system

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EU AI Act (Regulation (EU) 2024/1689)

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SOC 2 — AICPA Trust Services Criteria (2017, rev. 2022)

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15.12 Where this goes — what has shipped, and what is still owed

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Capability-complete, content-clean

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Appendix D — From Blank Ubuntu 24.04 to First Green Run

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What you need

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Step 3 — plan your first build

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Step 4 — witness the refusal (do not skip this)

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Step 5 — approve, apply, test

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Appendix F — Your Second Lab: The VM Pair, From Bare Host to Your Own Bus

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F.6 The lab's own identity

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F.7 The starter, and the refusal that starts everything

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F.8 Your own bus — the team session

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F.8.1 Give the team its own identities — before its first word

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F.8.2 Mint a token per identity — the grant, as your GitLab actually presents it

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F.8.3 Prove each token before you trust it

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F.8.4 Connect your Claude

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F.8.5 Run the session, and hold the gate

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F.8.6 Rotate and revoke — the part everyone forgets

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F.9 The traps — every one paid for on 2026-08-02, so you don't have to

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F.10 Prove the independence — don't take our word for it

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F.11 What is and is not verified here — the honest ledger

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Appendix G — The Memory System: How Your Lab Remembers

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G.1 Why a lab needs memory

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G.2 The design: an index and one fact per file

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G.3 The law: the repo is the source of truth

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G.4 The demonstration: watch your lab remember (VERIFY-on-clean-run)

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G.5 What memory must never become

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Afterword — The Record Is Yours Now

It started with a refusal. An AI asked its own tooling for permission to build a small network, and was told no, because no human had signed. Most of the industry would call that a bug and remove it. This book called it the product, and spent eighteen chapters earning the claim.

You went from an empty repository to a governed lab: a constitution written before any code, a run record that is the only admissible truth, a gate bound to the cryptographic hash of the exact plan a human read, a simulator to rehearse in and adapters that reach real hosts, switches and consoles, a GitLab that lets agents and humans work in one auditable history instead of two silos, an audit surface an outsider can hold without holding a single key, a control mapping that answers the compliance officer in their own language, a distribution someone can clone in an evening – and a campaign that proved the whole stack on bare metal you own, silent failures and demolished predictions included.

What you hold is a **method, not a product, and not a guarantee.** Every figure in these pages was measured on named hardware on a stated date and will not match your estate. The discipline is the deliverable: plan before you touch, refuse without a human yes, record what actually happened, and let the record – not the enthusiasm – decide what you believe. That travels to any system you will ever operate, with or without an AI in it.

Because the question was never really *can the AI be trusted*? Trust is not a property you can install. The question this book answers is the answerable one: **can you prove what it did, who approved it, and against which plan?** When the answer is a file anybody can open, the argument about trust simply stops mattering – and that is the quiet shift the whole book was building toward.

The work continues where this book ends. An asset register generated from the runs rather than curated by hand. Security events feeding a real detection stack. Teams whose reviewer is a different model on different hardware, so independence is a fact rather than a discipline. And **MatrixClaw Genesis** – a research direction, not a product line: from a boot image to a role-classified, fabric-programmed, monitored estate in one governed arc, with a first-class

gated *reverse* gear, because anything that can build an estate should be able to decommission one just as accountably. That is the top rung of Chapter 4's autonomy ladder — the AI end to end, through the gates, with the human still on top — and it is a question the record has not answered yet. None of it changes the principle underneath: **grow your own, cook your own** — and its extension for this era, *if you cannot audit your AI's work, you do not own your automation.*

Build it. Break it in a lab. Gate it. Record it. Make it yours.

Now go and put your AI to work — and keep the keys.

About the author

Michael John Leslie Hinsley has spent over three decades bridging the gap between delicate electronics and the mud and rain of the physical world — enterprise data centres, storage platforms, off-grid aquaponics and apiaries. MatrixClaw was built the way everything else in that life was built: on hardware he owns, by executing rather than theorising, and by keeping the receipts. His engineering philosophy has not changed with the arrival of AI — if you cannot control your infrastructure, you do not own your business.

Stay in touch

Leaf Spine Books publishes at https://www.leafspinebooks.com/ — where the rest of the line appears, including *Apache CloudStack — A Production Deployment Guide*, whose estate this book's lab was proven on.

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