

How to Produce the Auditable Record Needed to Certify Autonomous Actuation

If you build systems that command physical actuators and you need to prove to a certifier why each action was permitted, you have probably discovered that runtime telemetry logs do not answer that question. This guide describes an architecture for producing a pre-action provenance record that reconstructs every actuation decision, grounded entirely in the Confidence-Governed Actuation inventive step disclosed in U.S. Provisional Application No. 64/049,409. It is a design you implement yourself, not a shipping library.

What You Are Building

You are building the record, not just the actuator. If your system commands a brake, a valve, a gate, an infusion pump, a manipulator arm, or any other physical effector, a certifier in a regulated domain will eventually ask a question your control loop cannot answer: on what evidence, under what authority, and at what confidence was this specific action permitted? A conventional log tells you what the actuator did and when. It does not reconstruct the decision that authorized the action before the actuator moved.

This guide describes an architecture that emits that reconstruction as a first-class artifact of every actuation. The goal is a governance-chain-preserving record, written before the actuator is commanded, that lets an auditor deterministically reconstruct

why the action was allowed. The approach is the confidence-governed execution primitive disclosed in U.S. Provisional Application No. 64/049,409. It targets exactly the requirement the filing names for regulated domains such as healthcare, defense, aviation safety, nuclear safety, and critical infrastructure: that every derived decision be auditable back to its source evidence.

Why the Obvious Approaches Fall Short

The usual instinct is to add logging around the actuator. You capture the command, the parameters, a timestamp, maybe the sensor snapshot that triggered it, and you write it to a telemetry stream. This is genuinely useful for debugging and post-incident forensics, and many mature control systems do it well. The structural gap is that the log is a record of execution, not a record of authorization, and the two are not the same artifact.

Three shortfalls follow from that gap. First, the log is typically written after or alongside the command, so it captures effect rather than the pre-action reasoning; if the decision inputs were transient, they are gone. Second, conventional sensor-actuator stacks, including PLC, SCADA, ECU, and cloud IoT platforms, treat incoming signals homogeneously. They evaluate readings through fixed algorithms with no notion of which authority a signal came from, so the log cannot show that the action rested on appropriately credentialed evidence. Third, most control designs are binary: they execute or they suppress. There is no recorded middle ground, so the record cannot explain a partial, staged, or advisory response, because the architecture never produced one.

Standard message-authentication approaches such as public-key infrastructure address a different problem. PKI can prove a message was signed by a valid key, which is real and valuable, but signature validity alone does not carry a semantics of governance authority, and it does not by itself produce a reconstructible chain from a physical

action back through every intermediate derivation to the originating observations. The audit requirement in a regulated domain is that chain, and it has to be intrinsic to the action rather than bolted on afterward.

The Architecture

The disclosed approach treats every physical actuation as a governed mutation that must pass a composite admissibility evaluation before an actuator driver is ever commanded, and it records the entire evaluation in a lineage field. The record is a byproduct of the decision path, not a separate logging concern.

A structured actuation chain. The filing describes actuation as a fixed sequence. The executing agent consumes credentialed observations pertinent to the actuation context. A proposed actuation is generated, specifying an actuator, a command, and parameters. That proposal is evaluated jointly against the consumed observations and the system's other decision inputs. A mode is selected from the evaluation. Critically, the selected mode, the evaluation inputs, and the evaluation determinations are recorded in the lineage field before the actuator is commanded. Only then does the driver execute. After execution the agent observes the effect, compares observed against expected, broadcasts the actuation state, and records the effect and verification outcome. The pre-execution lineage write is the load-bearing step for certification: the authorization record exists before the physical world changes.

Graduated modes instead of go or no-go. Rather than a binary permit, the disclosed mode selector produces a bounded mapping from the admissibility determination to one of many modes, including disabled, simulated, advisory, consultative, partial, constrained, stage-gated, and full. As confidence rises the selected mode moves toward more autonomous execution; as it falls the mode moves toward less autonomous execution. This matters for the record because each mode, and each

escalation or de-escalation during an action, is a distinct lineage-recorded event. The record can therefore show not merely that action was taken but the exact degree of autonomy the evidence supported at that moment.

A safe-idle default under degradation. The confidence governor modulates the unit's execution readiness against the availability and corroboration of credentialed evidence. When credentialed infrastructure is lost, readiness is reduced; in the limit the unit enters an infrastructure-denied mode operating with governance-policy-defined behavioral conservatism, and readiness is only restored as credentialed observations accumulate and corroborate perception. The design default is toward the more conservative, lower-autonomy mode when confidence is absent, and the harm-minimization path that exceeds risk thresholds resolves to the disabled mode with that decision recorded. Every transition event and every readiness change is written to the lineage field, which is precisely what an incident investigator needs to see when asking why the system did or did not act.

The lineage field as the deliverable. The filing describes the derivation-lineage record as intrinsic to every derived observation and every downstream decision, cryptographically attested for tamper-evidence, and structured as a directed acyclic graph that supports traversal back to originating sensor observations across any number of intermediate derivation agents, with every transformation and governance-policy version identified. That graph is the auditable record. It supports post-hoc analysis, regulatory compliance reporting, and incident investigation without reliance on transient telemetry, because the reasoning was captured at decision time rather than reconstructed from logs afterward.

How to Approach the Build

You are implementing an evaluation-and-recording path in front of your actuators. The following ordered steps reflect the disclosed architecture; the interface sketch below is illustrative only and faithful to the filing, not code you can drop in.

1. **Credential your evidence.** Attach an authority credential to every observation your system consumes for actuation decisions, so the evaluator can differentiate signals by governance authority rather than treating them homogeneously. This is the input your record will trace back to.
2. **Insert a proposed-actuation stage.** Do not let planning code call the actuator driver directly. Route every intended action through a proposed-actuation object carrying the actuator identifier, command, and parameters, so there is a single choke point where evaluation and recording happen.
3. **Build the composite admissibility evaluator.** Evaluate the proposal jointly against the consumed credentialed observations and your other decision inputs, producing a graded determination rather than a boolean.
4. **Map the determination to a graduated mode.** Define, per actuator class, the confidence thresholds that gate each mode. High-consequence actuators require elevated confidence for full mode; low-consequence actuators need only baseline. This mapping is your policy surface and should be configurable rather than hard-coded.
5. **Write the lineage record before you command.** This is the step that produces the certifiable artifact. Serialize the evaluation inputs, the determination, the selected mode, and the reversibility and commitment-point findings into the lineage field, then command the driver.
6. **Close the loop.** After execution, capture the observed effect, compare it against the expected-effect specification, and append the verification outcome to the record so the artifact spans decision through confirmed effect.
7. **Default to safe-idle.** Wire the governor so that loss of corroborating credentialed evidence reduces readiness and biases mode selection toward the conservative end, with each transition recorded.

An illustrative interface sketch, spec-faithful and not a package:

```
# Illustrative only. You implement each interface.
proposal = Proposal(actuator, command, params)
evidence = consume_credentialed_observations(context)
determination = admissibility.evaluate(proposal, evidence, other_inputs)
mode = mode_selector.select(determination, actuator.thresholds)
lineage.record_pre_execution(proposal, evidence, determination, mode) # BEF
result = driver.execute(proposal, mode)
observed = observe_effect()
lineage.record_post_execution(observed, verify(observed, expected))
```

What This Does Not Give You

This is an architecture, not a drop-in library. There is no package to install and nothing here "just works" on import. You implement the evaluator, the mode selector, the thresholds, the governor, and the lineage store yourself, and the quality of your record depends entirely on the fidelity of those implementations.

It is not benchmarked or production-proven. The filing discloses a method; it does not report performance numbers, and none are claimed here. The confidence thresholds, entity-class harm orderings, mode mappings, and deferral parameters are described as governance-policy-defined, which means the architecture supplies the structure and you supply the values appropriate to your domain and jurisdiction.

It does not itself certify your system. Producing a reconstructible, credentialed, pre-action record is the structural element the filing names for satisfying an auditability requirement, but a certifier applies the actual regime. The architecture gives you the artifact to bring to that process; it does not substitute for it. And it applies where actuation is genuinely governable by credentialed evidence and policy; a system with no meaningful evidence to credential or no policy to encode gains little from it.

Disclosure Scope

The approach described here, including the confidence-governed execution primitive, the graduated actuation modes, the safe-idle readiness default, and the pre-action lineage record, is disclosed in U.S. Provisional Application No. 64/049,409, cited here as the Confidence-Governed Actuation inventive step. This guide is educational. It explains an architectural approach a developer can build and is not a warranty, a certification, or an offer of software, and nothing in it should be read as a claim that a benchmarked or shipping implementation is being distributed.

Confidence-Governed Actuation (</governed-actuation>) [All 40 steps → \(/inventive-steps\)](#)

ned-actuation)

Eleven graduated modes. Preemption budget. Reversibility-aware commitment. Harm-minimization.

Provisional application

PRIMARY TECHNICAL DISCLOSURE

- [Confidence-Governed Actuation: Graduated Modes for Physical Systems \(/articles/confidence-governed-actuation-graduated-modes-for-physical-systems\)](/articles/confidence-governed-actuation-graduated-modes-for-physical-systems)

SECONDARY TECHNICAL

- [The Graduated Actuation Mode Selector \(/articles/governed-actuation/graduated-mode-set\)](/articles/governed-actuation/graduated-mode-set)
- [Preemption Budget for Rate-Limited Override \(/articles/governed-actuation/preemption-budget\)](/articles/governed-actuation/preemption-budget)
- [Reversibility Classifier \(/articles/governed-actuation/reversibility-classifier\)](/articles/governed-actuation/reversibility-classifier)
- [Stage-Gated Commitment for Irreversible Actions \(/articles/governed-actuation/staged-commitment\)](/articles/governed-actuation/staged-commitment)
- [Harm-Minimization Deviation \(/articles/governed-actuation/harm-minimization-deviation\)](/articles/governed-actuation/harm-minimization-deviation)
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- [Post-Actuation Verification \(/articles/governed-actuation/post-actuation-verification\)](/articles/governed-actuation/post-actuation-verification)

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- [Cross-Unit Coordination Through Actuation-State Broadcast \(/articles/governed-actuation/cross-unit-coordination\)](/articles/governed-actuation/cross-unit-coordination)
- [Lineage-Recorded Provenance for Every Actuation \(/articles/governed-actuation/lineage-recorded-provenance\)](/articles/governed-actuation/lineage-recorded-provenance)

APPLICATIONS · GENERAL

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- [Preemption Budget for Multi-Vehicle Fleet Operations \(/articles/governed-actuation/preemption-budget-fleet-operations\)](/articles/governed-actuation/preemption-budget-fleet-operations)
- [14 CFR Part 107 Commercial Drone Operations \(/articles/governed-actuation/cfr-part-107-drones\)](/articles/governed-actuation/cfr-part-107-drones)
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- [ISO/SAE 21434 Compliance: Binding Automotive Cybersecurity to Runtime Control \(/articles/governed-actuation/iso-21434-automotive-cyber\)](/articles/governed-actuation/iso-21434-automotive-cyber).
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