Security From Architecture (SFA)

Core Specification v1.0

Aligned with
Intelligence From Architecture (IFA) Principles

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Chapter 1: Introduction

1.1 Purpose of This Document

The **Security From Architecture (SFA) Core Specification v1.0** defines a normative architectural standard for building systems that are **secure by construction**. Unlike traditional security frameworks, which often treat security as an add-on or reactive measure, SFA embeds security as a **structural invariant**—a foundational property enforced through architecture.

This specification is designed for:

- **System architects** building secure platforms.
- **Security engineers** implementing governance and compliance.
- **Regulators and auditors** requiring proof of security.
- **Protocol designers** embedding security into autonomous systems.

SFA is **not** a tool, framework, or checklist. It is a **set of axioms, patterns, and enforcement mechanisms** that ensure systems remain secure under real-world constraints.

1.2 Core Principles of SFA

SFA is built on six core principles, directly aligned with **Intelligence From Architecture (IFA)**:

Principle	Description	Alignment with IFA
Security as Structural Invariant	Security is not an add-on; it is a property enforced by the system's architecture.	Mirrors IFA's treatment of invariants.
Allowed States Only	Systems operate within a finite set of secure states; undefined states are structurally impossible.	Aligns with IFA's deterministic core.
Centralized Authority	Security-critical decisions are made by a deterministic core, preventing authority leakage.	Reflects IFA's separation of authority and capability.
Explicit Failure Semantics	Failure is a first-class state, not an edge case. Systems fail safely and predictably.	Matches IFA's structural refusal mechanisms.
No Implicit Trust	Trust is explicit, revocable, and auditable; no implicit assumptions are allowed.	Aligns with IFA's governance and transparency.
Security as Optional-Free	Systems remain secure even if security components fail or are unavailable.	Mirrors IFA's treatment of intelligence as optional.

1.3 Why This Specification Exists

Modern systems are increasingly complex, interconnected, and targeted by adversaries. Traditional security approaches—such as firewalls, encryption, and access controls—are **reactive** and **permissive**. They assume that security can be patched onto existing architectures.

This assumption is false.

Security failures are not caused by a lack of tools or policies. They are caused by **architectural negligence**—systems that allow undefined behavior, implicit trust, and ungoverned authority.

SFA reverses this paradigm by requiring that:

- **Security is enforced by architecture, not policy.**
- **Authority is centralized and deterministic, not distributed or probabilistic.**
- **Failure is explicit and safe, not silent or catastrophic.**

1.4 Scope and Non-Goals

Scope (Normative)

This specification defines the **architectural invariants, enforcement mechanisms, and execution semantics** required for systems where:

- Decisions produce **legal, economic, or safety impact**.
- Behavior must be **auditable and explainable**.
- Security must be **enforced by construction**, not by monitoring or after-the-fact review.

Explicit Non-Goals (Normative)

This specification does **not**:

- Prescribe specific programming languages or tools.
- Mandate particular security vendors or products.
- Define user interface or product design.
- Guarantee the correctness of probabilistic security models (e.g., anomaly detection).
- Replace legal, ethical, or regulatory judgment.

SFA **constrains what systems are allowed to do**, not what they intend to do.

1.5 Normative Language

The following keywords are used as defined in **RFC 2119**:

Keyword	Meaning
MUST / SHALL	Absolute requirement.
MUST NOT / SHALL NOT	Absolute prohibition.
SHOULD / SHOULD NOT	Strong recommendation (compliance is expected but not mandatory).
MAY	Optional behavior.

Compliance Rule: A system claiming **SFA Core Compliance MUST** satisfy all **MUST** and **SHALL** requirements. Failure to meet **any** requirement constitutes **non-compliance**.

1.6 Intended Audience

This document is written for:

- **System and enterprise architects** designing secure platforms.
- **Security engineers** implementing governance, risk, and compliance.
- **Protocol and platform designers** embedding rules into autonomous systems.
- **Regulators and auditors** requiring proof of security and governability.
- **Engineers** building safety-, finance-, or mission-critical systems.

Assumed Knowledge:

- Distributed systems.
- Software architecture.
- Governance or compliance frameworks.

1.7 Compliance and Certification

Compliance with SFA is **binary**:

- A system is **either compliant or not**; there are no partial or provisional states.

Certification Boundary:

- Compliance **MUST** be verified through **audit, testing, and formal analysis**.
- Systems **MAY** use SFA as the basis for:
    - Internal enterprise standards.
    - Procurement requirements.
    - Regulatory alignment references.
    - Protocol governance baselines.
    - Certification and audit programs.

Unauthorized compliance claims are prohibited and may be misleading.

Chapter 2: Security as Structural Invariant

2.1 The Failure of Add-On Security

Most systems treat security as an **additive layer**—something bolted on after the fact.

- Firewalls block traffic.
- Encryption protects data.
- Access controls limit permissions.

This approach fails because:

- Security becomes **reactive**, not preventive.
- Attackers exploit **undefined behavior** (e.g., misconfigurations, implicit trust).
- Compliance is **performative**, not structural.

Example: A system with a firewall but no invariant enforcement can still be compromised if an attacker finds an unprotected API endpoint.

2.2 The SFA Principle: Security as Invariant

In SFA, **security is not a feature—it is a structural invariant**.

Traditional Security	SFA Security
Reactive (blocks bad actions)	Proactive (only allows secure states)
Permissive (default-allow)	Restrictive (default-deny)
Additive (layered on top)	Foundational (built into architecture)
Trust-based (implicit assumptions)	Trustless (explicit, revocable trust)

Key Idea:*A system's true security is defined by what it is **structurally incapable** of doing.*

2.3 Defining Security Invariants

Security invariants **MUST** be:

1. **Machine-checkable**: Expressed in formal logic or code.
2. **Enforced at runtime**: Validated during every state transition.
3. **Immutable**: Cannot be bypassed or overridden.

Examples of Security Invariants:

- "No user data **MAY** be accessed without explicit authorization."
- "All API inputs **MUST** conform to a formal schema."
- "No state transition **MAY** violate the principle of least privilege."

2.4 Embedding Invariants in State Transitions

In SFA, **every meaningful operation is a state transition**, and **every transition is guarded by security invariants**.

Process:

1. A component proposes an action (e.g., “Grant access to Resource X”).
2. The **Invariant Enforcement Layer (IEL)** evaluates the action against security rules.
3. If the action violates an invariant, it is **refused**, and the system enters a **failure state**.
4. If the action is permitted, it proceeds, and an **audit trace** is generated.

Example:

- **Action:** “User A requests admin privileges.”
- **Invariant:** “Admin privileges **MUST NOT** be granted without multi-factor authentication (MFA).”
- **Outcome:** If MFA is not provided, the request is **refused**, and the refusal is logged.

2.5 Preventing Security Drift

Security drift occurs when:

- Systems evolve, and security rules are **not updated**.
- Exceptions become **permanent**.
- Shadow processes (e.g., manual overrides) **bypass invariants**.

SFA Mitigations:

- **Canonical Security Graph (CSG):** Single source of truth for all security rules.
- **Immutable Audit Traces:** All decisions are recorded and tamper-proof.
- **Refusal Gates:** Terminal states for invariant violations.

2.6 Architectural Pattern: Invariant Enforcement Layer (IEL)

The **IEL** is the **gatekeeper** between components and security-critical actions.

Component	Role
Input Validator	Ensures inputs conform to formal schemas.
Rule Engine	Evaluates actions against security invariants.
Refusal Gate	Blocks actions that violate invariants; logs refusals.
Audit Logger	Records all decisions, refusals, and state transitions.

Diagram (Conceptual):

Copy

```
[Component] → [Proposed Action] → [IEL] → [Allowed/Denied] → [Audit Log]
                                    ↓
                                [Refusal State]
```

2.7 Certification Boundary

For **SFA compliance**, a system **MUST**:

1. Define security invariants as **machine-checkable rules**.
2. Enforce invariants on **every state transition**.
3. **Refuse** actions that violate invariants.
4. Generate **immutable audit traces** for all decisions.

Non-Compliant Systems:

- Rely on **monitoring or logging** without enforcement.
- Allow **bypass paths** (e.g., emergency overrides).
- Use **narrative security policies** (e.g., “be secure”) without structural enforcement.

2.8 Key Takeaways

- Security that can be violated is **not security—it’s a suggestion**.
- **Architecture enforces security**; policies and tools alone do not.
- **Invariants convert intent into enforcement**.
- **Refusal is not a bug—it’s correct behavior**.
- Systems that **cannot violate security rules** do not require trust.

Chapter 3: Allowed States Only

3.1 The Problem with Permissive Architectures

Most systems are **permissive by default**:

- They accept **arbitrary inputs** (e.g., free-form JSON).
- They allow **implicit state transitions** (e.g., fallback logic).
- They rely on **reactive security** (e.g., blocking attacks after detection).

Consequences:

- **Attack surface expands** with every new feature.
- **Undefined behavior** becomes an exploit vector.
- **Security is fragile**—dependent on constant vigilance.

3.2 The SFA Principle: Only Allowed States Exist

In SFA, **a system may only exist in explicitly defined, secure states**.

Traditional Security	SFA Security
Blocks bad actions.	Only allows predefined good actions.
Detects and responds to threats.	Prevents threats by design.
Permissive (default-allow).	Restrictive (default-deny).

Key Idea:*If a state or transition is not explicitly defined, it **cannot exist**.*

3.3 Defining the State Space

Systems **MUST**:

1. Define a **finite set of valid states** (e.g., “Authenticated,” “Authorized,” “Refused”).
2. Define a **finite set of valid transitions** (e.g., “Login → Authenticated”).
3. **Reject all undefined inputs, states, or transitions**.

Example:

- **State:** “Payment_Pending”
- **Allowed Transitions:**
  - “Payment_Pending → Payment_Approved” (if authorization succeeds).
  - “Payment_Pending → Payment_Refused” (if authorization fails).
- **Undefined Transition:** “Payment_Pending → Payment_Processed” (blocked by IEL).

3.4 Input as Grammar, Not Data

SFA treats inputs as **formal languages**, not arbitrary data.

Requirements:

- Inputs **MUST** conform to a **schema or grammar**.
- **Malformed inputs** (e.g., SQL injection attempts) **MUST** be rejected before processing.
- **No implicit parsing** (e.g., coercing strings to commands).

Example:

- **Allowed Input:** `{"user_id": "UUID", "action": "read"}`
- **Malformed Input:** `{"user_id": "DROP TABLE users", "action": "exec"}` → **Rejected** by Input Validator.

3.5 Authorization as State Transition Validity

Authorization is **not** a separate check—it is **part of the state machine**.

Process:

1. A component requests a transition (e.g., “User → Admin”).
2. The **Allowed-State Machine** checks:
    - Is the transition **defined** for the current state?
    - Are all **preconditions** (e.g., MFA, role) satisfied?
1. If **yes**, the transition proceeds.
2. If **no**, the transition is **refused**, and the system enters a **failure state**.

Example:

- **Current State:** “User_Authenticated”
- **Requested Transition:** “User_Authenticated → Admin_Granted”
- **Precondition:** “MFA_Verified = True”
- **Outcome:** If MFA is not verified, transition is **refused**.

3.6 Eliminating Implicit Behavior

Implicit behavior (e.g., default values, fallback logic) **creates security risks**.

SFA Rules:

- **No silent failures** (e.g., returning a default value on error).
- **No implicit trust** (e.g., assuming a service is secure).
- **No undefined states** (e.g., “error” as a catch-all).

Example:

- **Bad:** `if (user_not_found) { return default_admin_privileges; }`
- **Good:** `if (user_not_found) { refuse(); log_failure(); }`

3.7 Architectural Pattern: Allowed-State Machine

The **Allowed-State Machine** is the core security primitive in SFA.

Properties:

Property	Description
Closed World	Only defined states/transitions exist.
No Implicit Defaults	No fallback or “catch-all” states.
Explicit Refusal	Undefined transitions result in refusal.
Uniform Enforcement	Applied to all components (APIs, services, UIs).

Diagram (Conceptual):

Copy

```
[State A] → [Transition] → [State B]  (Allowed)

[State A] → [Undefined] → [Refusal State]  (Blocked)
```

3.8 Failure as Containment

In SFA, **failure is a security boundary**.

Failure Handling Rules:

1. On invariant violation, the system **MUST** transition to a **failure state**.
2. **No partial execution** is allowed after failure.
3. Failure **MUST** be **logged and auditable**.

Example:

- **Action:** "Delete all user data."
- **Invariant:** "Data deletion requires superadmin role."
- **Outcome:** If user lacks role, action is **refused**, and system enters `FAILURE_UNAUTHORIZED`.

3.9 Certification Boundary

For **SFA compliance**, a system **MUST**:

1. Define all valid states and transitions.
2. Reject all undefined inputs or transitions.
3. Use **formal grammars** for input validation.
4. Handle failures as **explicit, terminal states**.

Non-Compliant Systems:

- Allow **implicit transitions** (e.g., silent retries).
- Rely on **pattern matching** (e.g., regex for input validation).
- Use **narrative error handling** (e.g., "try again later").

3.10 Key Takeaways

- **Security is not about blocking bad—it's about allowing only good.**
- **Undefined = forbidden.**
- **State machines make security enforceable and visible.**
- **Implicit behavior is the enemy of security.**
- **A system that cannot misbehave does not need to be watched.**

Chapter 4: Centralized Authority

4.1 The Problem with Distributed Authority

Most systems distribute authority across components, services, and users. This creates **security risks**:

- **Authority leakage**: Components gain unintended permissions.
- **Shadow authority**: Undocumented or implicit rules bypass governance.
- **Inconsistent enforcement**: Different components apply rules differently.

Example: A microservice with direct database write access can **bypass security checks** if not properly constrained.

4.2 The SFA Principle: Authority Is Centralized and Deterministic

In SFA, **authority is not distributed—it is centralized in a Deterministic Security Core (DSC)**.

Traditional Security	SFA Security
Authority is distributed (e.g., RBAC).	Authority is centralized in the DSC.
Components make their own decisions.	Only the DSC authorizes actions.
Trust is implicit (e.g., "this service is secure").	Trust is explicit and revocable.

Key Idea:*If authority is not centralized, it **cannot be audited or enforced**.*

4.3 The Deterministic Security Core (DSC)

The **DSC** is the **only component** permitted to make security-critical decisions.

Properties of the DSC:

1. **Deterministic**: Given the same inputs and rules, it **always** produces the same output.
2. **Rule-Driven**: Decisions are based on **explicit security invariants**, not heuristics.
3. **Authority Centralization**: No other component (service, API, user) can authorize actions.
4. **Auditability**: Every decision produces an **immutable trace**.
5. **Failure Safety**: If advisory components fail, the DSC **continues to operate securely**.

Example:

- **Request:** "Grant User A admin privileges."
- **DSC Evaluation:**
    - Checks invariants (e.g., "Admin privileges require MFA + Supervisor Approval").
    - If conditions are met → **Approves** and logs the decision.
    - If conditions fail → **Refuses** and logs the refusal.

4.4 Separating Capability from Authority

In SFA, **capability** (what a component *can* do) is **separate** from **authority** (what a component is *allowed* to do).

Capability	Authority
"This service can delete data."	"This service is allowed to delete data **only if**..."
"This API can modify user roles."	"This API is allowed to modify roles **only for**..."

Example:

- A **database service** has the **capability** to delete records.
- The **DSC** holds the **authority** to decide *when* deletion is permitted.

4.5 The Advisor-Gatekeeper Pattern

SFA uses the **Advisor-Gatekeeper Pattern** to enforce separation:

Advisors (Probabilistic)	Gatekeeper (DSC) (Deterministic)
- Analyze risks.	- Enforce invariants.
- Recommend actions.	- Authorize transitions.
- Provide context.	- Generate audit traces.
- **Do not** make decisions.	- **Only** component that decides.

Example:

- **Advisor (AI Model):** "User behavior suggests a potential breach. Recommend revoking access."
- **Gatekeeper (DSC):** Evaluates the recommendation against invariants (e.g., "Revocation requires supervisor approval"). If approved, it **authorizes** the action and logs the decision.

4.6 Preventing Authority Leakage

Authority leakage occurs when:

- Components **gain direct write access** to critical systems.
- **APIs bypass the DSC** (e.g., emergency overrides).
- **Configuration changes** grant unintended permissions.

SFA Mitigations:

1. **All state mutations route through the DSC.**
2. **Capability-based access control** is enforced (e.g., "This service can *propose* deletions, but only the DSC can *authorize* them").
3. **No direct writes** to secure systems (e.g., databases, APIs) without DSC approval.
4. **Override mechanisms** are modeled as **explicit transitions** (e.g., "Emergency access requires DSC approval").

Example:

- **Non-Compliant:** A microservice directly deletes user data on request.
- **SFA-Compliant:** The microservice **requests** deletion from the DSC, which checks invariants before authorizing.

4.7 Authority in Distributed Systems

In distributed or blockchain-based systems:

- **Smart contracts** act as the DSC.
- **Transactions** are proposed by users or agents.
- **Authority** is encoded in protocol rules (e.g., "Only contract owner can modify state").

Example (Blockchain):

- **Action:** "Transfer 100 tokens to User B."
- **DSC (Smart Contract):** Checks invariants (e.g., "Sender has sufficient balance" + "Transaction is signed").
    - If valid → **Executes** and logs the transfer.
    - If invalid → **Reverts** and logs the refusal.

4.8 Certification Boundary

For **SFA compliance**, a system **MUST**:

1. Centralize all security-critical authority in a **Deterministic Security Core (DSC)**.
2. Separate **capability** (what components can do) from **authority** (what they are allowed to do).
3. Route **all state mutations** through the DSC.
4. **Log all authority decisions** in immutable traces.
5. Prevent **authority leakage** (e.g., no direct writes, no bypasses).

Non-Compliant Systems:

- Allow components to **self-authorize** actions.
- Use **implicit trust** (e.g., "this service is internal, so it’s safe").

- Rely on **human overrides** without DSC approval.

4.9 Key Takeaways

- **Distributed authority is a security risk.**
- **The DSC is the single source of truth for decisions.**
- **Advisors advise; the DSC decides.**
- **Authority leakage is an architectural violation.**
- **Auditable authority = enforceable security.**

Chapter 5: Explicit Failure Semantics

5.1 The Danger of Silent Failures

Most systems handle failures **poorly**:

- **Silent failures**: Errors are ignored or logged without action.
- **Partial failures**: Systems degrade into unsafe states.
- **Undefined failures**: No clear recovery path.

Consequences:

- **Exploitable states**: Attackers target failure modes.
- **Loss of trust**: Users and auditors cannot verify system integrity.
- **Cascading failures**: One failure triggers others.

Example: A payment system that **silently retries** failed transactions may **double-charge users** or **leak funds**.

5.2 The SFA Principle: Failure Is a First-Class State

In SFA, **failure is not an edge case—it is a designed, explicit state**.

Traditional Systems	SFA Systems
Failures are exceptions.	Failures are **explicit states**.
Silent retries or fallbacks.	**No silent recovery**; failure is terminal.
Undefined behavior on failure.	**All failure modes are predefined**.

Key Idea:*If failure is not designed, it will be **exploited**.*

5.3 Categories of Failure States

SFA defines **three classes of failure states**:

Failure Type	Description	Example
Invariant Violation	Action violates a security rule.	"User lacks permission for admin access."
System Degradation	Critical component (e.g., DSC) fails.	"DSC offline; system enters read-only mode."
External Dependency	Required service (e.g., auth provider) is unavailable.	"MFA service down; logins refused."

Each failure type MUST:

1. Be **named and documented**.
2. Have a **terminal state** (no silent recovery).
3. Generate an **audit trace**.

5.4 Failure vs. Refusal

Refusal	Failure
Action is **not permitted**.	Action **cannot be completed**.
Triggered by **invariant violation**.	Triggered by **system limitation**.
Example: "Admin access denied."	Example: "DSC offline; no new logins."

Both MUST:

- Be **explicit and terminal**.
- Produce **audit traces**.
- **Not** allow silent recovery.

5.5 No Silent Recovery

SFA **prohibits** silent recovery mechanisms, such as:

- Automatic retries without user awareness.
- Fallback to less secure states (e.g., "If MFA fails, allow password-only login").
- "Best-effort" execution (e.g., "Try to save data, but don’t alert on failure").

Example:

- **Non-Compliant:** "If the database is down, silently queue writes and retry later."
- **SFA-Compliant:** "If the database is down, enter `FAILURE_DB_OFFLINE` state and **refuse** all writes."

5.6 Failure Propagation and Containment

Failures **MUST** be contained to prevent cascading effects.

Rules:

1. **Isolate failing components** (e.g., a failed microservice does not crash the entire system).
2. **Propagate failure states** to dependent components (e.g., if the DSC fails, all services enter a **read-only mode**).
3. **Log all failure transitions** for auditability.

Example:

- **Scenario:** The DSC crashes.
- **SFA Response:**
  - System enters `FAILURE_DSC_OFFLINE`.
  - All state mutations are **refused**.
  - Users see: "System in secure mode; no changes allowed."
  - Admins are alerted with the **failure trace**.

5.7 Failure Traces as Operational Assets

Every failure **MUST** generate a **structured failure trace**, including:

- **Triggering event** (e.g., "DSC heartbeat timeout").
- **Affected components** (e.g., "Auth Service, Payment Service").
- **State transition** (e.g., `OPERATIONAL → FAILURE_DSC_OFFLINE`).
- **Recovery actions** (e.g., "Alert admin; await manual restart").

Example Trace:

```
json
```

Copy

```
{
  "failure_id": "fail_20260207_143022",
  "type": "SYSTEM_DEGRADATION",
  "trigger": "DSC heartbeat timeout after 30s",
  "affected": ["AuthService", "PaymentService"],
  "state_transition": "OPERATIONAL → FAILURE_DSC_OFFLINE",
  "actions": ["alert_admin", "disable_writes"],
```

```
  "timestamp": "2026-02-07T14:30:22Z"
}
```

5.8 Architectural Pattern: Failure State Machine

The **Failure State Machine** defines how the system behaves under failure.

Properties:

Property	Description
Finite States	All failure modes are predefined (e.g., `FAILURE_DSC_OFFLINE`, `FAILURE_AUTH_UNAVAILABLE`).
Terminal Transitions	No implicit recovery; failures require **explicit resolution**.
Audit Trails	Every transition is logged.
Containment	Failures do not propagate unpredictably.

Diagram (Conceptual):

Copy

```
[Operational] → [Failure Event] → [Failure State] → [Explicit Recovery]
                                          ↓
                                    [Audit Log]
```

5.9 Degraded Mode Is Not Failure

SFA distinguishes between:

- **Degraded mode**: Reduced functionality but **still secure** (e.g., read-only mode).
- **Failure mode**: System **cannot guarantee security** (e.g., DSC offline).

Example:

- **Degraded Mode:** "MFA service slow; require password + email code."
- **Failure Mode:** "MFA service down; **refuse all logins**."

5.10 Certification Boundary

For **SFA compliance**, a system **MUST**:

1. Model failures as **explicit, named states**.
2. **Refuse silent recovery** (no retries, fallbacks, or "best effort").
3. **Contain failures** to prevent cascading effects.
4. Generate **structured failure traces** for all incidents.
5. Distinguish **degraded mode** (secure) from **failure mode** (unsafe).

Non-Compliant Systems:

- **Silently retry** failed operations.
- **Degrade into insecure states** (e.g., disable auth on failure).
- **Lack failure traces** (e.g., "error occurred" without details).

5.11 Key Takeaways

- **Undefined failure = guaranteed exploit.**
- **Failure is a state, not an exception.**
- **Silent recovery is a security anti-pattern.**
- **Failure traces are as important as success logs.**
- **A system that fails safely can be trusted.**

Chapter 6: No Implicit Trust

6.1 The Illusion of Trust-Based Security

Many systems rely on **implicit trust**:

- "This service is internal, so it’s safe."
- "Our team follows best practices, so we don’t need strict controls."
- "We trust our cloud provider’s security."

Problem: Implicit trust creates **blind spots** that attackers exploit. For example:

- An "internal" service with excessive permissions becomes a **pivot point** for lateral movement.
- A "trusted" third-party API introduces **supply chain risks**.
- "Best practices" are **not enforced** by architecture, leading to misconfigurations.

Real-World Example: In 2021, a misconfigured internal tool at a major tech company allowed attackers to **bypass authentication** and access user data. The tool was "trusted" but not **architecturally constrained**.

6.2 The SFA Principle: Trust Is Explicit and Revocable

In SFA, **trust is never assumed—it is explicitly granted, enforced, and revocable**.

Implicit Trust	SFA Explicit Trust
"Our VPN is secure."	"VPN access requires MFA + device attestation."
"This API is internal."	"Internal APIs require mutual TLS + JWT validation."
"Our employees are trustworthy."	"All actions are logged and audited, regardless of user."

Key Idea:*If trust is not explicit, it **does not exist**.*

6.3 Zero Trust vs. SFA

While **Zero Trust** focuses on **continuous authentication and authorization**, SFA goes further by **embedding trust rules into the architecture**.

Zero Trust	SFA
"Never trust, always verify."	"Never trust, **enforce verification structurally**."
Relies on runtime checks.	Enforces trust rules at the **architectural layer**.
Trust is dynamic (e.g., short-lived tokens).	Trust is **static and auditable** (e.g., invariants in the DSC).

Example:

- **Zero Trust:** "Verify the user's identity every time they access a resource."
- **SFA:** "The **Deterministic Security Core** enforces that **only users with Role X + MFA** can access Resource Y, and this rule **cannot be bypassed**."

6.4 Trust Relationships in SFA

SFA defines trust using **three layers**:

1. **Identity Trust**:
    - **Requirements:**
        - All identities (users, services, devices) **MUST** be authenticated.
        - Authentication **MUST** use **phishing-resistant MFA** (e.g., FIDO2, hardware keys).
    - **Example:**
    - `json`
    - Copy
    - `{`
    - `  "identity": "user@MICK Ltd.ie",`
    - `  "auth_method": "FIDO2",`
    - `  "trust_level": "high"`
    - `}`
1. **Authority Trust**:
    - **Requirements:**
        - Authority is **granted by the DSC**, not assumed.
        - Authority is **contextual** (e.g., "User A can approve payments **only** in the EU region").
    - **Example:**
    - `json`
    - Copy
    - `{`
    - `  "identity": "user@MICK Ltd.ie",`
    - `  "authority": ["approve_payments_EU"],`
    - `  "conditions": ["MFA_verified", "in_EU_region"]`
    - `}`

1. **Component Trust**:
    - **Requirements:**
        - Services **MUST** prove their integrity (e.g., signed binaries, attestation).
        - **No service** can act without DSC approval.
    - **Example:**
    - `json`
    - Copy
    - `{`
    - `  "service": "PaymentProcessor",`
    - `  "trust_requirements": ["signed_binary", "DSC_approval"]`
    - `}`

6.5 Enforcing Explicit Trust with the Canonical Security Graph (CSG)

The **CSG** is the **single source of truth** for trust relationships. It defines:

- **Who** can trust **whom**.
- **Under what conditions** trust is granted.
- **How** trust is revoked.

Example CSG Entry:

`json`

Copy

```
{
  "subject": "user@MICK Ltd.ie",
  "object": "EU_Payment_API",
  "action": "approve",
  "conditions": [
    { "type": "MFA", "status": "verified" },
    { "type": "location", "value": "IE" }
  ],
  "revocation": {
    "method": "DSC_admin_override",
    "log": "audit_trail"
  }
}
```

6.6 Revoking Trust

Trust **MUST** be revocable without downtime. SFA requires:

1. **Immediate revocation** (e.g., terminate sessions on policy change).
2. **Audit trails** for all revocations.
3. **No implicit fallbacks** (e.g., "If revocation fails, allow access").

Example:

- **Action:** "Revoke User B’s access to the Payroll System."
- **SFA Process:**
    1. DSC updates the CSG to remove User B’s authority.
    2. All services **synchronize** with the CSG.
    3. User B’s active sessions are **terminated**.
    4. The revocation is **logged**.

6.7 Trust in Third-Party Systems

For external systems (e.g., SaaS, APIs), SFA enforces:

- **Contractual trust**: SLAs and security guarantees **MUST** be codified in the CSG.
- **Runtime verification**: Third-party systems **MUST** prove compliance (e.g., via attestation).
- **Failure mode**: If verification fails, the system **refuses** interaction.

Example:

- **Third-Party API:** "Stripe Payments"
- **SFA Rule:**
- `json`
- Copy
- `{`
- `  "subject": "Stripe_API",`
- `  "trust_requirements": [`
- `    { "type": "TLS_1.3" },`
- `    { "type": "SOC2_attestation", "valid_until": "2026-12-31" }`
- `  ],`
- `  "on_failure": "refuse_all_transactions"`
- `}`

6.8 Certification Boundary

For **SFA compliance**, a system **MUST**:

1. Define **all trust relationships** in the **Canonical Security Graph (CSG)**.
2. Enforce trust rules at the **architectural layer** (e.g., DSC, IEL).
3. **Log all trust grants and revocations**.
4. **Revoke trust immediately** on policy changes or breaches.
5. **Never allow implicit trust** (e.g., "internal network = safe").

Non-Compliant Systems:

- Rely on **network-based trust** (e.g., "if it’s on the VPN, it’s trusted").
- Use **long-lived credentials** (e.g., API keys without rotation).
- Lack **revocation mechanisms** (e.g., no way to terminate a compromised session).

6.9 Key Takeaways for MICK Ltd

- **Implicit trust is technical debt.**
- **The CSG is your trust ledger—keep it updated.**
- **Revocation is not optional; it’s a security invariant.**
- **Third-party trust must be verified, not assumed.**
- **At MICK Ltd, explicit trust = fewer breaches and easier audits.**

Chapter 7: Security as Optional-Free

7.1 The Fragility of Security Dependencies

Many systems **require** security components to function:

- "Our app needs the firewall to be online."
- "If the SIEM fails, we lose visibility."
- "Our auth service is a single point of failure."

Problem: When security is **not optional**, failures become **catastrophic**.

Real-World Example: In 2020, a major outage at a cloud provider took down **millions of security cameras** because they depended on a central auth service. The cameras **stopped working entirely** when the service failed.

7.2 The SFA Principle: Security Is Never a Single Point of Failure

In SFA, **core functionality remains secure even if security components fail**.

Traditional Security	SFA Security
"If the firewall fails, we're exposed."	"If the firewall fails, the **DSC enforces default-deny**."
"If the SIEM is down, we're blind."	"If the SIEM is down, **audit logs are still generated**."

Key Idea:*Security components should **enhance** security, not **enable** it.*

7.3 Designing for Optional Security

SFA systems **MUST**:

1. **Operate securely without optional components** (e.g., SIEM, threat intelligence feeds).
2. **Degrade gracefully** (e.g., switch to stricter rules if a component fails).
3. **Never fail open** (e.g., "If auth fails, refuse all access").

Example:

- **Scenario:** The **threat intelligence feed** goes offline.
- **SFA Response:**
  - The DSC **continues enforcing invariants** (e.g., "No unknown IPs allowed").
  - The system **logs the degradation** but remains secure.

7.4 Degraded Mode as a First-Class State

SFA defines **degraded modes** for security components:

Component	Normal Mode	Degraded Mode
Threat Intelligence	Blocks known malicious IPs.	**Defaults to allow-list only**.
MFA Service	Requires MFA for admin actions.	**Requires supervisor approval**.
SIEM	Real-time monitoring.	**Local audit logging + alerts**.

Example:

- **Normal Mode:** "Allow logins with MFA."
- **Degraded Mode (MFA offline):** "Allow logins **only** from whitelisted IPs + require supervisor approval."

7.5 Advisory Security Components

Security components in SFA are **advisory**, not authoritative:

- **Threat Intelligence:** "This IP is suspicious" → **DSC decides** whether to block it.
- **Anomaly Detection:** "This behavior is unusual" → **DSC evaluates** against invariants.
- **SIEM:** "This event is notable" → **DSC determines** the response.

Example:

- **Advisory Input:** "Threat feed reports IP 1.2.3.4 as malicious."
- **DSC Decision:**
  - If the IP is **not on the allow-list → Block**.
  - If the IP is **on the allow-list → Log and alert**, but **do not block**.

7.6 Preventing Silent Dependency Creep

Dependency creep happens when:

- A feature **gradually relies** on a security component (e.g., "Our API now requires the WAF").
- **Fallbacks decay** (e.g., "We removed the local auth backup").
- **Assumptions harden** (e.g., "The cloud provider's security is enough").

SFA Mitigations:

1. **Test "security-off" mode** regularly (e.g., disable the SIEM and verify the system remains secure).
2. **Document dependencies** in the CSG.
3. **Alert on silent failures** (e.g., "Threat feed offline for >1 hour").

Example:

- **Test:** "What happens if we turn off the SIEM for 24 hours?"
- **SFA Requirement:** The system **MUST** continue logging to local storage and enforcing invariants.

7.7 Security in Distributed Systems

For **microservices, edge devices, or blockchain**, SFA ensures:

- **Local enforcement**: Each component enforces **minimum security invariants** (e.g., "No unsigned transactions").
- **No central dependency**: Components **do not** require a central auth service to function.
- **Eventual consistency**: Security policies **sync when possible**, but local rules apply otherwise.

Example (Edge Device):

- **Normal Mode:** "Check with DSC for every action."
- **Degraded Mode (DSC offline):** "Enforce last-known good policy + refuse risky actions."

7.8 Certification Boundary

For **SFA compliance**, a system **MUST**:

1. **Operate securely without optional components** (e.g., SIEM, threat feeds).
2. Define **explicit degraded modes** for all security dependencies.
3. **Test "security-off" scenarios** regularly.
4. **Never fail open** (e.g., "If auth fails, refuse access").
5. **Log all degraded-mode operations**.

Non-Compliant Systems:

- **Fail open** (e.g., "If the firewall fails, allow all traffic").
- **Assume availability** (e.g., "Our auth service is always online").
- **Lack local enforcement** (e.g., edge devices with no offline security).

7.9 Key Takeaways for MICK Ltd

- **Optional security = resilient security.**
- **Degraded mode is not a backup plan—it’s a design requirement.**
- **Test failure scenarios before they happen.**
- **At MICK Ltd, optional security means fewer outages and happier customers.**
- **If a security component can take down your system, it’s not SFA-compliant.**

Chapter 8: Architectural Patterns for SFA

8.1 Overview of SFA Architectural Patterns

SFA defines **five core architectural patterns** to enforce security as a structural invariant. These patterns are designed to be **composable**, meaning they can be integrated into existing systems at **MICK Ltd** without requiring a full rewrite.

Pattern	Purpose	Alignment with IFA
Invariant Enforcement Layer	Enforces security rules at runtime.	Mirrors IFA's Invariant Enforcement Layer.
Allowed-State Machine	Restricts system operation to predefined secure states.	Aligns with IFA's deterministic core.
Deterministic Security Core	Centralizes and audits all security-critical decisions.	Directly inspired by IFA's core.
Refusal Gate	Terminates unsafe operations and logs refusals.	Implements IFA's structural refusal.
Canonical Security Graph	Acts as a single source of truth for security policies and trust rules.	Extends IFA's Canonical Knowledge Graph.

8.2 Invariant Enforcement Layer (IEL)

Purpose

The **IEL** sits between **all components** (e.g., APIs, microservices, UIs) and **security-critical actions** (e.g., data access, state changes). It ensures that **no action violates security invariants**.

Implementation at MICK Ltd

1. **Deploy as a Middleware Layer**:
    - Integrate the IEL into your **API gateway** or **service mesh** (e.g., Istio, Kong).
    - Example: Use **Envoy filters** to validate requests against the IEL before they reach backend services.
1. **Define Security Invariants**:
    - Store invariants in the **Canonical Security Graph (CSG)**.
    - Example invariant: *"No user data can be accessed without explicit consent logged in the CSG."*
1. **Enforcement Workflow**:
2. `mermaid`
3. `Copy`
4. `graph TD`
5. `  A[Component Request] --> B[IEL Validation]`
6. `  B -->|Violates Invariant| C[Refusal Gate]`
7. `  B -->|Complies| D[Deterministic Security Core]`
8. `  C --> E[Audit Log: Refusal]`
9. `  D --> F[Audit Log: Approval]`
10. **Logging and Auditing**:

- Log **all decisions** (approvals and refusals) to an immutable ledger (e.g., **AWS CloudTrail**, **Elasticsearch**).
- Example log entry:
- `json`
- Copy
- `{`
- `  "request_id": "req_20260207_154500",`
- `  "action": "access_user_data",`
- `  "invariant": "explicit_consent_required",`
- `  "status": "refused",`
- `  "reason": "No consent record in CSG",`
- `  "timestamp": "2026-02-07T15:45:00Z"`
- `}`

Tools for MICK Ltd

- **Open Policy Agent (OPA)**: Enforce invariants as code.
- **HashiCorp Vault**: Store and manage invariants securely.
- **Prometheus + Grafana**: Monitor IEL decisions in real-time.

8.3 Allowed-State Machine

Purpose

The **Allowed-State Machine** ensures the system **only operates in predefined secure states**. Undefined or unsafe states are **structurally impossible**.

Implementation at MICK Ltd

1. **Model States and Transitions**:
   - Use a **state diagram** to define allowed states (e.g., "Authenticated," "PaymentApproved") and valid transitions.
   - Example:
   - `mermaid`
   - Copy
   - `stateDiagram-v2`
   - `  [*] --> Authenticated`
   - `  Authenticated --> PaymentPending: Request Payment`
   - `  PaymentPending --> PaymentApproved: Approve`
   - `  PaymentPending --> PaymentRefused: Refuse`
   - `  PaymentApproved --> [*]`
   - `  PaymentRefused --> [*]`
1. **Enforce with a State Manager**:
   - Implement the state machine in a **centralized service** (e.g., **AWS Step Functions**, **Temporal**).
   - Example: Use **Temporal workflows** to manage payment states.

1. **Handle Undefined Transitions**:
    - If a component requests an **undefined transition** (e.g., "PaymentPending → PaymentProcessed"), the **Refusal Gate** terminates the operation.

Example for MICK Ltd's Payment System

- **State**: `PaymentPending`
- **Allowed Transitions**:
    - `PaymentPending → PaymentApproved` (if DSC approves).
    - `PaymentPending → PaymentRefused` (if DSC refuses).
- **Undefined Transition**: `PaymentPending → PaymentProcessed` → **Refused**.

8.4 Deterministic Security Core (DSC)

Purpose

The **DSC** is the **only component** authorized to make security-critical decisions. It operates **deterministically**, meaning the same inputs always produce the same outputs.

Implementation at MICK Ltd

1. **Centralize Decision Logic**:
    - Deploy the DSC as a **dedicated service** (e.g., **Kubernetes pod** with restricted access).
    - Example: Use **gRPC** for components to request DSC approvals.
1. **Define Decision Rules in CSG**:
    - Store all rules in the **Canonical Security Graph**.
    - Example rule:
    - `json`
    - Copy
    - `{`
    - `  "rule_id": "payment_approval",`
    - `  "conditions": [`
    - `    { "type": "user_role", "value": "admin" },`
    - `    { "type": "mfa_verified", "value": true }`
    - `  ],`
    - `  "action": "approve_payment",`
    - `  "on_violation": "refuse"`
    - `}`
1. **Audit Every Decision**:
    - Log all DSC decisions to a **tamper-proof ledger** (e.g., **Amazon QLDB**, **blockchain**).
    - Example audit entry:
    - `json`
    - Copy
    - `{`

```
  "decision_id": "dec_20260207_160000",
  "rule_id": "payment_approval",
  "input": { "user": "admin@MICK Ltd.ie", "mfa": true },
  "output": "approve",
  "timestamp": "2026-02-07T16:00:00Z"
}
```

Tools for MICK Ltd

- **OpenFGA**: Define and enforce fine-grained authorization rules.
- **Cerbos**: Policy decision point for the DSC.
- **AWS KMS**: Encrypt and sign DSC decisions.

8.5 Refusal Gate

Purpose

The **Refusal Gate** ensures that **any action violating security invariants is terminated immediately** and logged.

Implementation at MICK Ltd

1. **Integrate with IEL and DSC**:
   - The Refusal Gate acts as the **final checkpoint** after the IEL and DSC.
   - Example workflow:
   - `mermaid`
   - Copy
   - `graph TD`
   - `  A[Request] --> B[IEL]`
   - `  B -->|Complies| C[DSC]`
   - `  C -->|Approves| D[Execute]`
   - `  B -->|Violates| E[Refusal Gate]`
   - `  C -->|Refuses| E`
   - `  E --> F[Audit Log: Refusal]`
   - `  E --> G[Terminate Operation]`
1. **Define Refusal Conditions**:
   - Example conditions:
     - "Request lacks required MFA."
     - "User role does not match action."
     - "Input violates schema."
1. **Log Refusals**:
   - Use **structured logging** (e.g., **JSON**) to record refusals.
   - Example:
   - `json`
   - Copy
   - `{`

```
    "refusal_id": "ref_20260207_163000",
    "request": { "user": "user@MICK Ltd.ie", "action": "delete_data"
  },
    "reason": "User lacks 'admin' role",
    "timestamp": "2026-02-07T16:30:00Z"
}
```

Tools for MICK Ltd

- **Fluentd**: Aggregate and forward refusal logs.
- **Splunk**: Analyze refusal patterns for anomalies.
- **AWS Lambda**: Automate responses to refusals (e.g., alert Slack).

8.6 Canonical Security Graph (CSG)

Purpose

The **CSG** is the **single source of truth** for all security policies, trust rules, and invariants. It ensures **consistency** and **auditability** across the system.

Implementation at MICK Ltd

1. **Model the CSG as a Graph Database**:
    - Use **Neo4j** or **Amazon Neptune** to store and query the CSG.
    - Example graph:
    - Copy
    - `(User)-[:HAS_ROLE]->(Admin)`
    - `(Admin)-[:CAN_APPROVE]->(Payment)`
    - `(Payment)-[:REQUIRES]->(MFA)`
1. **Version and Audit the CSG**:
    - Use **Git** to version-control the CSG.
    - Log all changes to the CSG (e.g., "Admin added 'delete_data' permission").
1. **Synchronize with Components**:
    - Components **pull updates** from the CSG at runtime.
    - Example: Use **Redis Pub/Sub** to notify services of CSG changes.

Tools for MICK Ltd

- **Neo4j**: Store and query the CSG.
- **GitHub**: Version-control CSG changes.
- **Argo Workflows**: Automate CSG updates and deployments.

8.7 Certification Boundary

For **SFA compliance**, a system at **MICK Ltd MUST**:

1. Implement **all five architectural patterns** (IEL, Allowed-State Machine, DSC, Refusal Gate, CSG).
2. **Log all decisions and refusals** in an immutable format.
3. **Prevent bypasses** of the IEL or DSC.
4. **Synchronize all components** with the CSG.
5. **Test failure modes** (e.g., "What if the DSC crashes?").

Non-Compliant Systems:

- Allow **direct database writes** without DSC approval.
- Use **hardcoded rules** instead of the CSG.
- Lack **audit trails** for refusals.

8.8 Key Takeaways for MICK Ltd

- **IEL**: Your first line of defense—validate everything.
- **Allowed-State Machine**: Define what's possible, and **nothing else**.
- **DSC**: The brain of your security—**centralize decisions**.
- **Refusal Gate**: The kill switch—**terminate unsafe operations**.
- **CSG**: The source of truth—**keep it updated and audited**.
- **Tooling**: Use **OPA, Temporal, Neo4j, and AWS KMS** to implement SFA at MICK Ltd.

Chapter 9: Compliance and Certification with SFA

9.1 Why Compliance Matters for MICK Ltd

In **Ireland** and the **EU**, compliance with frameworks like **GDPR**, **NIS2**, and **ISO 27001** is **not optional**. SFA provides a **structural approach** to meeting these requirements **by design**, not through paperwork.

Framework	SFA Alignment
GDPR	SFA's **invariant enforcement** ensures data protection by design (Article 25).
NIS2	SFA's **failure semantics** and **audit trails** meet incident reporting requirements.
ISO 27001	SFA's **CSG** and **DSC** enforce ISO's **access control** and **risk management** clauses.
PCI DSS	SFA's **Allowed-State Machine** prevents unauthorized cardholder data access.

9.2 Mapping SFA to NIST Cybersecurity Framework

The **NIST Cybersecurity Framework (CSF)** is widely adopted in **Ireland** for critical infrastructure. SFA **directly addresses** all five CSF functions:

NIST CSF Function	SFA Implementation
Identify	**CSG** defines assets, risks, and policies.
Protect	**IEL** and **DSC** enforce access controls and invariants.
Detect	**Refusal Gate** and **audit logs** identify violations.
Respond	**Failure State Machine** contains and logs incidents.
Recover	**Degraded modes** ensure continuity; **CSG** enables policy updates post-incident.

Example for MICK Ltd:

- **Identify**: Use the **CSG** to document all data flows and risks.
- **Protect**: Deploy the **IEL** to validate API requests.
- **Detect**: Monitor **refusal logs** in **Splunk** for anomalies.
- **Respond**: Use the **Failure State Machine** to contain breaches.
- **Recover**: Update the **CSG** post-incident and redeploy policies.

9.3 SFA and ISO 27001

ISO 27001 is the **gold standard** for information security management. SFA **maps to key clauses**:

ISO 27001 Clause	SFA Implementation
A.9 Access Control	**DSC** centralizes authorization; **CSG** defines roles.
A.12 Operational Security	**Allowed-State Machine** prevents unsafe operations.
A.16 Incident Management	**Refusal Gate** and **failure logs** provide incident data.
A.18 Compliance	**Audit trails** from IEL/DSC demonstrate compliance.

Action Items for MICK Ltd:

1. **Document access controls** in the **CSG** (ISO A.9).
2. **Log all state transitions** for operational security (ISO A.12).
3. **Use refusal logs** for incident management (ISO A.16).
4. **Generate compliance reports** from audit trails (ISO A.18).

9.4 SFA for GDPR Compliance

GDPR requires **data protection by design** (Article 25) and **accountability** (Article 5). SFA **enforces both**:

GDPR Requirement	SFA Implementation
Data Minimization	**IEL** rejects requests for excessive data access.
Consent Management	**CSG** stores consent records; **DSC** enforces consent checks.
Right to Erasure	**Allowed-State Machine** ensures deletion requests comply with invariants.
Breach Notification	**Failure State Machine** logs breaches; **Refusal Gate** contains them.

Example Workflow for MICK Ltd:

1. **User requests data deletion**.
2. **IEL** checks the **CSG** for consent records.
3. **DSC** approves deletion if invariants are met.
4. **Allowed-State Machine** transitions to `DataDeleted`.
5. **Audit log** records the action for GDPR accountability.

9.5 SFA Certification Process

To certify a system at **MICK Ltd** as **SFA Core Compliant**, follow this process:

Step 1: Self-Assessment

- **Checklist**: Verify compliance with all **SFA normative requirements** (Chapters 1–8).
    - Example: "Does every component route through the IEL? [ ] Yes [ ] No"
- **Tool**: Use the **SFA Compliance Toolkit** (GitHub repo with scripts to validate IEL, DSC, etc.).

Step 2: Third-Party Audit

- **Auditor**: Engage a **certified SFA auditor** (e.g., through **ISACA** or **CREST**).
- **Scope**: The auditor will:
    1. Review **architecture diagrams** (e.g., IEL, DSC integration).
    2. Test **failure modes** (e.g., "What happens if the CSG is corrupted?").
    3. Validate **audit trails** (e.g., refusal logs, DSC decisions).

Step 3: Remediation

- Address **any gaps** identified in the audit.
- Example fixes:
    - Add **missing refusal logs**.
    - Close **bypass paths** in the IEL.

Step 4: Certification

- Once compliant, receive the **SFA Core Compliance Certificate**.
- **Display the SFA Compliance Mark** on your system (e.g., "MICK Ltd Payment System: SFA Core Compliant").

9.6 Tools for Compliance at MICK Ltd

Tool	Purpose
Open Policy Agent	Enforce SFA invariants as code.
Neo4j	Manage the **Canonical Security Graph (CSG)**.
AWS CloudTrail	Log all IEL and DSC decisions.
Splunk	Monitor refusal logs for anomalies.
GitHub Actions	Automate CSG versioning and audits.
Temporal	Implement the **Allowed-State Machine** for workflows.

9.7 Common Pitfalls and How to Avoid Them

Pitfall	SFA Solution
Bypassing the IEL	Use **service mesh policies** (e.g., Istio) to enforce IEL routing.
Hardcoding rules	Store **all rules in the CSG**; never hardcode.
Silent failures	Configure the **Refusal Gate** to log and alert on all refusals.
Inconsistent CSG updates	Use **GitOps** to manage CSG changes (e.g., Argo CD).
Poor audit trails	Integrate **AWS CloudTrail** or **Splunk** for immutable logging.

9.8 Key Takeaways for MICK Ltd

- **SFA = Compliance by Design**: Meet **GDPR, NIS2, ISO 27001** without last-minute scrambles.
- **Audit Trails Are Your Friend**: Log **everything** (IEL, DSC, refusals) for easy compliance reporting.
- **CSG is Your Compliance Ledger**: Keep it **updated and versioned**—auditors will love you.
- **Failure Modes = Compliance Tests**: Design **degraded modes** to handle auditor questions like "What if X fails?"
- **Tooling Matters**: Use **OPA, Neo4j, and Temporal** to make SFA **practical** at MICK Ltd.