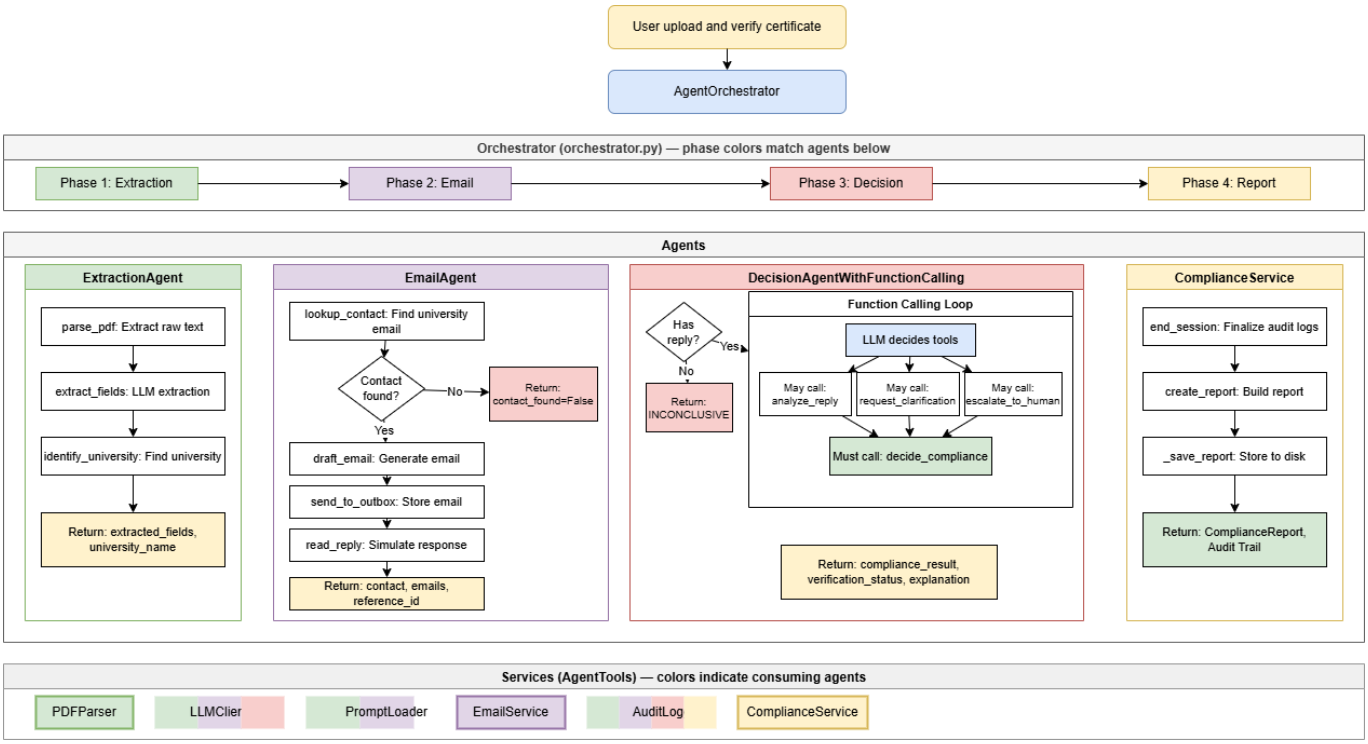
Research & Engineering Insight

1. Research Insight

Architecture Overview

The workflow follows a fixed sequential order: **Extraction → Email → Decision → Report**. Compliance processes require predictable, auditable execution paths—the Orchestrator enforces this strictly.



Three specialized agents handle each domain:

Agent	LLM Usage	Behavior
ExtractionAgent	Content generation (field extraction)	Deterministic tool sequence
EmailAgent	Content generation (email drafting)	Deterministic tool sequence
DecisionAgent	Tool selection via Function Calling	Adaptive—handles ambiguous replies

This separation enables clear audit trails—each agent's actions are logged independently with timestamps and inputs/outputs.

Why Handcrafted Orchestration + Function Calling?

The alternative was full LangChain/LangGraph—letting the framework handle both orchestration and tool execution. Given the prototype scope and timeline, the **handcrafted approach** was chosen: zero additional dependencies, and the LLM decides only where needed instead of every step.

LangChain excels at dynamic agent behavior—and with more time, it could be configured to enforce sequential phases. However, for a fixed compliance workflow, handcrafted orchestration achieves the same result with less complexity. **Function Calling in DecisionAgent** provides the balance: the workflow stays

deterministic, but the LLM retains intelligent tool selection where ambiguity exists (interpreting email replies). This avoids both extremes—fully autonomous agents and fully hardcoded logic. If requirements evolve (e.g., dynamic phase ordering), LangGraph would be reconsidered.

Trade-offs Accepted

What I Gave Up	Why It's Acceptable
Dynamic workflow changes—cannot reorder phases at runtime	Compliance workflows are inherently fixed; dynamic ordering would break audit requirements
Framework ecosystem—no LangChain integrations (memory, callbacks, tracing)	Prototype scope doesn't require these; can add later if needed
Less "agent-like"—most steps are deterministic, not LLM-driven	Deliberate choice: predictability over autonomy for regulated processes

Function Calling in DecisionAgent compensates for the third point—the system retains intelligent decision-making where it matters most.

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2. Engineering Solution Thinking

Tools, Prompts, and Models Structure

Tools are organized using a **mixin pattern** (`DocumentToolsMixin`, `CommunicationToolsMixin`, `AnalysisToolsMixin`). Each mixin groups related tools by domain, making the codebase easier to navigate and test independently. **Prompts** are externalized to **Jinja2 templates** (`config/prompts/*.j2`). This separates logic from content—prompts can be modified without code changes, and version-controlled independently. **University Mappings** are config-driven (`config/universities.json`). Adding a new university requires no deployment—just a JSON update.

Failure Cases

Failure	Handling
PDF unreadable	LLM Vision API extracts text from rendered images; handles scanned documents
University not found	Return `INCONCLUSIVE`; flag for manual review
Ambiguous/fraud reply	Lower confidence score triggers human review queue
LLM hallucination	Schema validation on all outputs; reject malformed responses

The decision to use **LLM Vision for all PDFs** (instead of traditional Python PDF readers like PyMuPDF) was deliberate: it avoids arbitrary fallback thresholds and provides consistent handling regardless of PDF type—digital or scanned.

Auditability

Every tool call creates an `AuditLogEntry` with: timestamp, agent name, tool name, sanitized inputs/outputs, and success status. Credentials are redacted and long values truncated in logs. PII sanitization is extensible via

config. The audit trail enables **timeline reconstruction** (sequential step numbering), **accountability** (which agent made which decision), and **reproducibility** (Session ID links all related logs).

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3. Real-World Applicability

Production Extensions

Current (Prototype)	Production Path
Simulated outbox/inbox	SendGrid/AWS SES for sending; IMAP/Gmail API for receiving
LLM Vision for PDFs	Already production-ready; handles scanned certificates
JSON university config	Database + external APIs (My eQuals, National Clearinghouse, etc.)

Scaling to 1,000+ Checks/Day

Architecture: `FastAPI → Redis Queue → Celery Workers`. Features include horizontal scaling via worker pool, per-university rate limiting (avoid spam triggers), and dead letter queue for failed verifications.

Monitoring & Reliability: Target 30s processing time (SLA); alert if queue exceeds threshold. Retries use exponential backoff (10s → 30s → 60s) for transient failures. Observability via Prometheus metrics on processing time, result distribution, and error rates.

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4. Security & Compliance Thoughts

Data Privacy

Audit logs automatically redact sensitive credentials to prevent leakage. For production, the system will enforce encryption at rest (AES-256) and in transit (TLS 1.3), alongside strict retention policies for GDPR/CCPA compliance.

Model Hallucination Risks

Mitigation	Implementation
Schema Validation	Pydantic models validate all LLM outputs to ensure structural integrity
Structured Outputs	Function Calling restricts responses to valid enum values, preventing open-ended fabrications
Confidence Thresholds	Scores below 0.7 immediately trigger fallback to human review

Traceability

The detailed audit trail allows for complete timeline reconstruction. A unique **Session ID** links every log entry for a specific verification request, ensuring that every automated decision can be traced back to its inputs and timestamp.

Human-in-the-Loop

This architecture prioritizes safety by treating the AI as an **accelerator, not a replacement**. Full automation is strictly reserved for clear-cut success paths. **Automatic Breaks** are triggered for any result marked `INCONCLUSIVE` / `NOT_COMPLIANT`, or any `COMPLIANT` result with low confidence (< 0.7). These edge cases are routed to a **human review queue**, ensuring ambiguity is resolved by human judgment rather than probabilistic guessing. Only high-confidence `COMPLIANT` results are permitted to bypass this safety layer.