FAA ADVISORY CIRCULAR AI SYSTEM: TECHNICAL IMPLEMENTATION PLAN

Solo Deployment with Optional N8N Orchestration

Scope: 1 person, iOS deployment, <500 queries/month
Vector DB: Pinecone (Starter free tier)
Framework: LangChain + MCP
Optional Enhancement: N8N multi-agent verification
Timeline: 4 weeks (Phase 1) + 2 weeks (Phase 2, optional)

I. ARCHITECTURE & TECHNOLOGY DECISIONS

1.1 Vector Database Selection

For solo deployment with <500 queries/month and 3,000 vectors (150 ACs @ ~20 vectors each):

Database	Storage	Cost	Scaling	Cold Start	Why Not
Pinecone	Cloud SaaS	$0 *(2GB, 1M reads/mo)*	To millions	<1ms	✅ Best for low usage requirements
Supabase pgvector	PostgreSQL	$5–10/mo	To 100k vectors	50–100ms	Slower cold start
Weaviate Cloud	Cloud SaaS	$0 (free tier)	Good	<50ms	Free tier, less proven
Qdrant Cloud	Cloud SaaS	$0 (free tier)	Excellent	<1ms	Free tier limited features

Rationale: Pinecone's free tier (*2GB, 1M reads/mo*) – capacity for over 200K-300K vectors. Roughly 3K vectors required (~15MB) and 500 queries/mo will use <1% of these limits. Fast retrieval (<1ms latency). Mature API with LangChain integration. Can upgrade seamlessly if volume grows.

1.2 Embedding Strategy

Component	Choice	Cost	Rationale
Embedding Model (large)	OpenAI text-embedding-3-large	$0.13/1M tokens	✅ 3,072 dimensions, but with increased cost. Updatable
Embedding Model (small)	OpenAI text-embedding-3-small	$0.02/1M tokens	1,536 dimensions *(~96% as accurate as large*); much cheaper
One-time Embedding Cost	3,000 pages × 1,000 avg tokens = 3M tokens	~$0.06	One-time corpus embedding
Monthly Refresh	New ACs detected; embedded weekly	~$0.20/mo	GitHub Actions monitors FAA website
Alternative	Local MiniLM (sentence-transformers)	$0	384 dimensions; 10% lower quality; CPU-bound

Decision: OpenAI text-embedding-3-large. Cost negligible; quality superior to local options for technical FAA language.

1.3 LLM Choice

Model	Cost/ Query	Quality	Speed	Context Window	Best For
Claude Haiku 4.5	$0.018	95% quality	Fast	200k tokens	✅ Upgraded accuracy – min cost increase
Claude Haiku 3.5	$0.015	92% quality	Fast	200k tokens	
GPT-4 Mini	$0.020	94% quality	Fast	128k tokens	Slightly better accuracy
GPT-4 Turbo	$0.30	98% quality	Slower	128k tokens	Expensive for volume
Llama 3.1 (local)	$0	80% quality	CPU-bound	8k tokens	Requires GPU

Rationale: Claude Haiku 4.5 offers the best overall value for this RAG environment. It preserves the 200 k-token context window and sub-2 second latency of Haiku 3.5 while improving reasoning accuracy and citation reliability. The cost increase is marginal (~$1.50 more per 500 queries) and easily offset by higher retrieval precision in technical FAA documents. Haiku 3.5 remains a stable fallback. The model can be swapped seamlessly in LangChain via a single configuration variable.

II. PHASE 1: RAG-ONLY IMPLEMENTATION (WEEKS 1–4)

2.1 Hallucination Rates at Each Stage

Baseline (ChatGPT, no RAG):

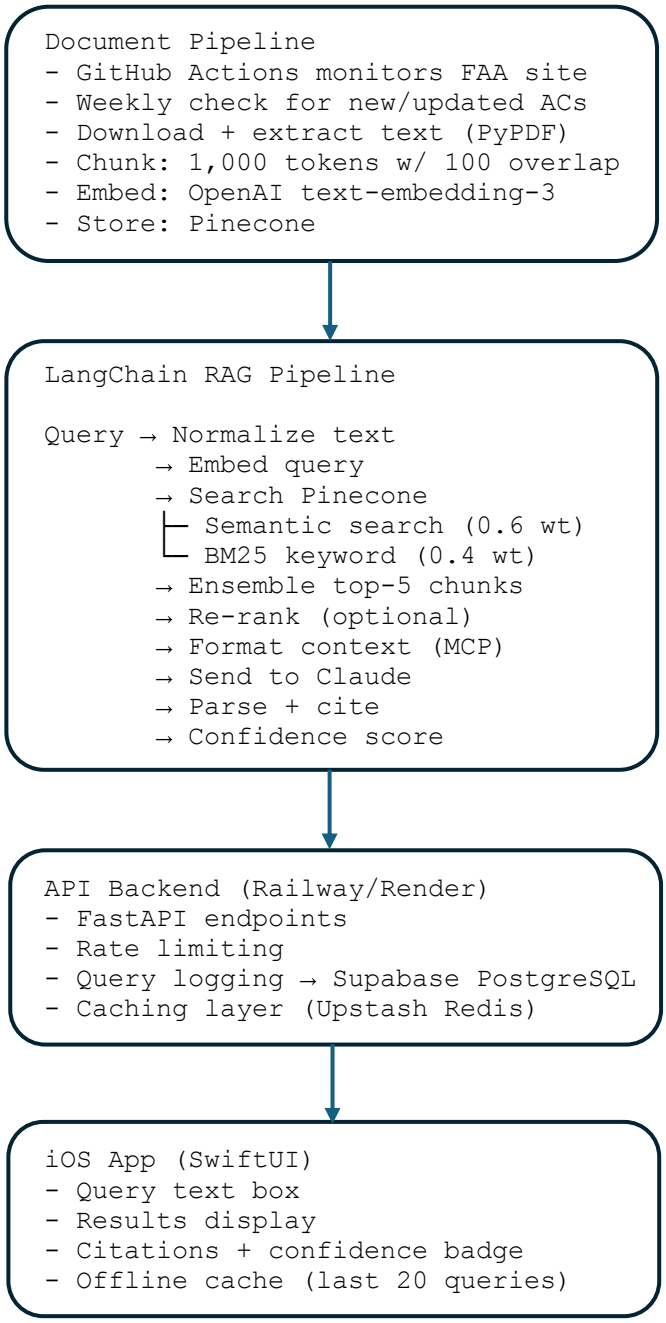
- Medium-context: 40–50% hallucination
- High-context: 50–60% hallucination
- Low-context: 70–80% hallucination

Phase 1 (RAG Only) — Expected Outcome:

Query Context	General LLM hallucination rate	RAG system hallucination rate	Notes
High	50-60%	3-8%	- 80-90% hallucination reduction - Cross-AC relationships exist in corpus - Ensemble retrieval captures all relevant sections
Medium	40-50%	3-8%	- 80-90% hallucination reduction - Full AC corpus available in retrieval - Single-AC answers well-grounded
Low	70-80%	20-30%	- 60-70% hallucination reduction - Question itself is vague; corpus cannot fix inherent ambiguity - System can clarify and re-ask

Validation: RAG achieves 3–8% on "well-known" topics. With complete FAA AC corpus, all queries are "well-known."

2.2 Technical Architecture



2.3 Implementation Steps (High Level)

Week 1: Document Preparation

1. Download 150 FAA ACs from faa.gov/airports/resources/advisory_circulars/
2. Extract text via PyPDF2 or pdfplumber
3. Chunk using LangChain RecursiveCharacterTextSplitter (1,000 tokens, 100 overlap)
4. Add metadata: AC number, section, applicability, publish date
5. **Output:** ~3,000 chunks ready for embedding

Week 2: Vector DB + Embedding

1. Create Pinecone account → Starter free tier
2. Create index: dimension=3,072 (text-embedding-3-large), metric=cosine
3. Embed all chunks via OpenAI API (~$0.60 total, ~10 minutes)
4. Upload to Pinecone (~1 minute)
5. **Output:** Searchable corpus in Pinecone

Week 3: LangChain + API

1. Build LangChain retriever:
    - **PineconeVectorStore** for semantic search
    - **BM25Retriever** for keyword search
    - **EnsembleRetriever** combining both (0.6/0.4 weights)
2. Build generation chain:
    - LLM: Claude Haiku 4.5
    - Prompt: Context + query + cite instruction
3. Add MCP server for context standardization:
    - Format retrieved chunks consistently
    - Token counting
    - Caching support
4. Wrap in FastAPI:
    - **POST /query** endpoint
    - Request validation
    - Response formatting (answer + citations + confidence)
5. Set up Databases:
    - Create Supabase account → create PostgreSQL database (free tier)
    - Create audit_logs table with schema:
        - id (uuid, primary key)
        - query_text (text)
        - confidence_score (float)
        - llm_response (text)
        - citations (jsonb)
        - timestamp (timestamptz)

    - Copy connection string for FastAPI
    - Set up Upstash Redis:
        - Create Upstash account at upstash.com
        - Create Redis database (free tier: 10K commands/day)
        - Configure FastAPI with connection URLs
    - Configure FastAPI caching:
        - Install: pip install redis supabase
        - Add Redis client with Upstash URL
        - Cache query embeddings (key: hash of query text, TTL: 24 hours)
        - Cache retrieval results (key: embedding hash, TTL: 1 hour)
        - Log all queries to Supabase PostgreSQL
    - Deploy to Railway Starter or Render (free tier for FastAPI hosting)
6. **Output:** Live API endpoint with Supabase + Upstash

Week 4: iOS App + Testing

1. SwiftUI app in Xcode:
    - TextField for question input
    - Button to submit query
    - Display area for answer + AC citations + confidence badge
    - URLSession to call API
2. Connect to your API endpoint
3. Test 50 queries manually:
    - Compare answers to actual ACs
    - Measure hallucination rate (target: 3–8% on medium, high)
    - Record latency
4. Add local caching (last 20 queries) for offline mode
5. **Output:** Working iOS app on your device

2.4 Phase 1 Costs

Component	Cost	Notes
Pinecone	$0/mo	Free tier (2GB, 1M reads/mo)
OpenAI embeddings (one-time)	$0.06 / 1X	3M tokens × $0.02 per 1M
Claude Haiku LLM (500 q/mo)	$9/mo	500 × $0.018 per query
Railway hosting	$0-5/mo	Free first month, then $0-5/mo
GitHub Actions	$0/mo	Free for public repos
Supabase PostgreSQL	$0/mo	Free Tier
Upstash Redis	$0/mo	Free Tier
iOS development	$0/mo	XCode already purchased
Phase 1 Total/Month	**$9–14**	After first month

III. PHASE 2: N8N MULTI-AGENT ORCHESTRATION (OPTIONAL, WEEKS 5–6)

3.1 When to Add Phase 2

Provides:

Capability	Description	Business Value
Proactive AC Change Detection	Monitors FAA site daily and alerts users of new or revised ACs.	Keeps compliance content current automatically.
NOTAM Integration	Links live NOTAM data to related ACs and regulations.	Adds real-time situational awareness.
Compliance Audit Reporting	Auto-generates monthly summaries on accuracy and activity.	Eliminates manual audit prep and improves oversight.
Multi-Agent Architecture	Five agents handle retrieval, summarization, explanation, verification, and review.	Improves reasoning reliability and traceability.
Cross-Model Verification	Uses Claude 4.5, GPT-4o Mini, and Sonnet 4.5 for layered validation.	Boosts accuracy through independent cross-checks.
Confidence Scoring & Flagging	Combines similarity and verifier scores into a 0–100 rating; flags low-confidence outputs.	Adds measurable reliability and prevents bad answers.
Explainability Layer	Generates short "why this is correct" citations to FAA sources.	Ensures transparency and audit-ready outputs.
Human-in-the-Loop Feedback	Sends low-confidence answers to review; user input retrains retrieval weights.	Enables continuous learning and accuracy gains.

3.2 Phase 2 Value Proposition

Phase 2 = Compliance Intelligence Automation:

Automation / Capability	Metric	Annual Value (Est.)	Notes / Cost Basis
AC Change Detection	Auto-alerts when FAA updates or releases new ACs	4–7 hrs saved per update × 12 updates ≈ **$5,000 / yr**	N8N + Claude Haiku 4.5 summarizer (< $2 / mo)
NOTAM + AC Cross-Ref	Links new NOTAMs to related ACs	15–20 hrs / yr ≈ **$1,800 / yr**	FAA RSS feed + n8n logic; no API cost
Audit Readiness Report	Auto-generates monthly compliance dashboard	24–36 hrs / yr ≈ **$2,900 / yr**	Claude Haiku 4.5 PDF summary; AWS SES email (Free Tier)
Cross-AC Validator	Flags conflicting or outdated guidance	8–12 hrs / yr ≈ **$1,000 / yr**	Pinecone query + LLM verify ($1 / mo)
Confidence Scoring & Flagging	Adds 0–100 trust score; auto-flags < 0.70 responses	~5 hrs saved per audit ≈ **$600 / yr**	N8N automation only (Free)
Explainability & Citation Layer	Generates short, cited rationale per answer	6–8 hrs / yr ≈ **$800 / yr**	Built into LLM prompt; no extra cost
Human-in-Loop Feedback	Reviewer dashboard for flagged responses	6–10 hrs / yr ≈ **$600 / yr**	Simple webform + PostgreSQL log (Free)
TOTAL ANNUAL VALUE	—	**≈ $10.7 K /solo user**	**Cost:** $31-39 / mo *All-inclusive P1+P2*

Rationale: Phase 2 introduces low-cost automation that converts the RAG system from a static reference tool into an active compliance assistant. Core functions—AC change detection, NOTAM cross-referencing, and audit reporting—run through lightweight n8n automations and the free Pinecone tier, keeping ongoing expenses under $50 per month. The multi-agent design (retrieval, summarization, verification, and review) improves accuracy while maintaining near-real-time updates and explainable outputs. Together, these upgrades deliver 18-22X ROI. Phase 2 can be deployed incrementally, scaling from a single analyst instance to multi-user environments without new infrastructure or licensing costs.

3.3 Phase 2 Architecture - *components*

Layer	Role	Tools / Models	Cost Tier
Data Ingestion & Monitoring	Detects new ACs and NOTAMs; triggers n8n workflows.	n8n HTTP Request + RSS Feed nodes	Free
Embedding & Storage	Converts PDFs to 512-dim vectors; stores in Pinecone.	OpenAI text-embedding-3-small + Pinecone Starter	≈ $0.02 / 1M tokens (FREE storage)
Retrieval Agent	Finds top-ranked FAA sections relevant to query.	LangChain Retriever + Pinecone index	Free
Reasoning Agent	Generates initial answers from retrieved chunks.	Claude Haiku 4.5 (primary)	≈ $2 / mo
Verification Agent	Cross-checks answers for accuracy and cites sources.	GPT-4o Mini (verifier) + Claude Sonnet 4.5 (esc.)	≈ $3 / mo
Confidence & Flagging	Scores 0–100 confidence; flags < 0.70 for review.	n8n logic + PostgreSQL log	Free
Explainability Layer	Produces short, cited “why this is correct” paragraphs.	LLM prompt template within LangChain	No extra cost
Audit & Feedback	Logs decisions and user feedback; updates retrieval weights.	n8n + Supabase / PostgreSQL	Free

3.3 Phase 2 Architecture – *workflows, components, and logic*

WORKFLOW 1: **Schedulers (N8N)** – *triggers and timing layer*

- AC Change Check – 06:00 UTC
- NOTAM Fetch – 08:00 UTC
- Monthly Audit – 1st of month

WORKFLOW 2: **Detect and Parse (N8N)** – *automation layer*

- Fetch FAA Site + NOTAM RSS
- Compare old vs new AC PDFs
- Parse NOTAM Keywords

NODE/COMPONENT: **Embed & Upsert** – *vectorization layer*

- Use OPENAI text-embedding-3-large (1,536 dim)
- Upsert into Pinecone (AC. + NOTAM namespaces)

AGENT COMPONENT 1: **Retriever Agent** – *RAG retrieval logic*

- Queries Pinecone for top-K related FAA Account
- Returns relevant document chunks

AGENT COMPONENT 2: **Reasoning (Claude Haiku 4.5)** – *primary LLM layer*

- Drafts answer and references sources
- Sends citations to verifier

AGENT COMPONENT 3: **Verification (GPT-4o mini/Sonnet 4.5)** – *cross-model verification layer*

- GPT-4o Mini cross checks facts
- Escalates complex cases to Sonnet 4.5
- Outputs verified answer + citation list

LOGIC LAYER: **Confidence Scoring + Flagging** – *evaluation layer*

- Combines Pinecone similarity + verifier agreement
- Generates 1-100 confidence score
- Flags results for <0.70 for review

LOGIC + REPORT LAYER: **Explain/Gate** – *explainability & governance layer*

- If >= 0.70: generate short "Why is this correct" paragraph
- If <0.70: flag for review and log feedback

WORKFLOW 3: **Outputs** – *final orchestration layer*

- Sends email/mobile update alert
- Updates PostgreSQL/Supabase audit log
- Generates monthly PDF report

3.4 Implementation (High Level)

WEEK 5: N8N Setup + AC Detection

1. **Create N8N account** (Cloud tier: $19/month, or self-host)
2. **Build Workflow 1**: FAA Change Detection
    - **HTTP Request node:** Check FAA website daily
    - **Conditional node:** New AC detected?
    - **Download + Compare:** Old vs new PDF
    - **Extract text** → run **OpenAI text-embedding-3-small**
    - **Upsert to Pinecone DB** (AC namespace)
    - **LLM node:** Claude Haiku 4.5 → summarize changes in plain English
    - **Verification call:** GPT-4o Mini → fact check and return confidence score
    - **Confidence Logic:** If < 0.70 → flag for review; else continue
    - **Email node:** Send summary + citations to user
    - **Supabase node:** Log changes and confidence score to audit table
3. **Test:** Manual FAA AC update to confirm alert and logging
4. **Output:** Daily alerts trigger automatically with FAA AC's change

WEEK 6: NOTAM + Audit Workflows

1. **Build Workflow 2**: NOTAM Processing
    - **HTTP Request:** Fetch FAA NOTAM RSS feed
    - **For each NOTAM:** Extract keywords + location codes
    - **Query Pinecone:** Find related ACs (semantic match)
    - **LLM node:** Claude Haiku 4.5 → summarize link between NOTAM and AC
    - **Verifier:** GPT-4o Mini cross-check → confidence score 0–100
    - **Condition:** If < 0.70 → flag for review via email dashboard
    - **Format alert:** Include NOTAM ID, AC reference, and score
    - **Send:** Mobile notification + email summary
2. **Build Workflow 3:** Monthly Audit Report
    - **Query PostgreSQL audit log** *(last 30 days)*
    - **Analyze:** Hallucination rate, confidence patterns, retrieval accuracy
    - **LLM node:** Claude Sonnet 4.5 → generate plain-language summary
    - **Generate PDF report:** n8n PDF node or Markdown → PDF script
    - **Email node:** Send report to user (AWS SES free tier)
3. **Output:** Automated compliance reporting + continuous audit logging

Architecture Integration Notes

- Each workflow calls the shared RAG pipeline for retrieval and verification.
- n8n handles scheduling, logging, and report delivery.
- Agents (Claude Haiku 4.5 → GPT-4o Mini → Sonnet 4.5) manage reasoning, cross-model verification, and explanations.
- Entire system runs within $31–39 / month (Phase 1 + 2 combined).

3.5 Phase 2 Costs

Component	Cost *(Monthly)*	Notes
N8N Cloud	$19	Cloud-tier; includes scheduling, email, and automation nodes. *($0 if self-hosted on Railway)*
LLM Calls (Summaries + Verification)	$3–6	Claude Haiku 4.5 (primary reasoning) + GPT-4o Mini (verifier) + Claude Sonnet 4.5 (escalation). ~500 queries / mo ≈ <$0.02 each.
OpenAI Embeddings	<$0.10	One-time cost ≈ $0.06 for 3 M tokens; negligible for weekly refresh (~$0.20 / mo).
Pinecone Vector DB	$0	Free tier (2GB, 1M reads/mo)
FAA Website Monitoring	$0	HTTP requests via n8n; no API cost.
NOTAM Feed	$0	FAA RSS feed is free and open-access.
Email Delivery	$0	AWS SES free tier (≤ 3 K emails per month).
PostgreSQL / Supabase Logging	$0	Free plan for light audit logging (< 500 MB).
PDF Reporting	$0	n8n native Markdown → PDF conversion or custom Python script.

Cost Breakdown: Phase 2 add-on: $22-$25/mo. Total cost with Phase 1: $31-$39/mo.

Rationale: All services run within free or low-tier limits. n8n orchestrates automations, while lightweight LLM calls and Pinecone storage keep costs minimal. Even at full automation scale, the system operates for <$50 per month with continuous compliance monitoring, verification, and audit reporting.

IV. FINAL HALLUCINATION RATES (PHASE 1 ONLY)

Your document: "RAG Only achieves 3–8% on well-known topics"

Your corpus: Entire FAA AC database (complete source material). **All queries**: “Well-known”

Query Type	Baseline	Phase 1	Improvement
Medium (60–70% of queries)	40–50%	**3–8%**	80–90% ↓
High (20–30% of queries)	50–60%	**3–8%**	80–90% ↓
Low (5–10% of queries)	70–80%	20–30%	60–70% ↓

Why: Complete corpus = no "unknown" info. LLM grounds every answer in actual AC text.

NOTE: Phase 2 adds verification, scoring, and audit layers that further reduce residual hallucination risk from 3–8 % to < 2 % on critical queries through multi-model cross-validation.

V. DEPLOYMENT CHECKLIST

Pre-Launch

- ☐ Pinecone free-tier account created
- ☐ 150 FAA ACs downloaded and extracted
- ☐ Chunking + metadata tagging complete
- ☐ Embeddings generated + uploaded to Pinecone
- ☐ Supabase account created + PostgreSQL database configured
- ☐ Upstash account created + Redis database configured
- ☐ Railway/Render account created *(for self-host or API)_*
- ☐ LangChain pipeline tested locally
- ☐ MCP server implemented *(manages local model calls)*
- ☐ FastAPI deployment tested *(for app → API handoff)*
- ☐ Multi-agent logic verified locally *(retriever → reasoning → verifier → confidence)*
- ☐ Confidence scoring thresholds *(>= 0.70 pass / < 0.70 flag)*
- ☐ iOS app UI built in Xcode
- ☐ API integration in iOS complete
- ☐ Supabase connection tested *(audit logs writing)*
- ☐ Upstash Redis connection tested *(caching working)*

Launch Week

- ☐ Deploy API to Railway/Render
- ☐ Deploy iOS app *(via TestFlight)*
- ☐ Run 50-query validation test *(covering High / Medium / Low contexts)*
- ☐ Measure hallucination rate *(target: 3–8% on medium/high)*
- ☐ Measure latency *(target: <2 seconds)*
- ☐ Verify confidence scoring output *(sample 10 queries >= 0.70 threshold)*
- ☐ Monitor cost tracking *(LLM + embeddings < $1/day)*

Optional (Week 5–6)

- ☐ Enable N8N orchestration *(if query volume > 1 000 / month or automation needed)*
- ☐ AC Change Detection active *(Workflow 1)*
- ☐ NOTAM integration live *(Workflow 2)*
- ☐ Audit reporting active *(Workflow 3)*
- ☐ Automated verification & flagging live
- ☐ Monthly accuracy report auto-emailed

VI. RISK MITIGATION

Risk	Mitigation
Vector search misses relevant chunks	Ensemble retrieval (semantic + keyword) + re-ranking + context expansion
LLM cost spikes	Monitor OpenAI / Anthropic dashboards weekly; set API spending alerts; throttle non-critical workflows
FAA website structure changes	Use AWS Textract (500 docs / mo free) for adaptive PDF parsing; fallback to direct HTML scrape
Pinecone free tier expires	Backup index and migrate to Qdrant or Weaviate (free community tiers); auto-sync corpus on transition
Hallucination worse than expected	Add MCP caching + cross-model verification + confidence tuning (raise threshold to ≥ 0.75)
iOS app crashes offline	Implement local SQLite cache + last 20 query history; auto-retry failed syncs

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VII. SUCCESS CRITERIA

- ✅ Phase 1: 3–8% hallucination on medium + high-context queries
- ✅ Phase 1: <2 second latency per query
- ✅ Phase 1: <$20/month ongoing cost
- ✅ Phase 2 (opt): AC changes detected within 24 hours
- ✅ Phase 2 (opt): NOTAM alerts within 2 hours
- ✅ Phase 2 (opt): Monthly audit reports generated automatically
- Phase 2 (opt): Confidence scores > 0.70 on 95% of verified answers

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Technical Plan Version: 1.0
Deployment Model: Solo, iOS, <500 q/month
Target Hallucination: 3–8% (Phase 1); < 2% after verifications (Phase 2)
Estimated Timeline: 4 weeks Phase 1, +2 weeks Phase 2 (optional)

VIII. POST-LAUNCH VALIDATION PLAN

Week 1 – System Verification

- ☐ Confirm multi-agent chain executing correctly (retriever → reasoner → verifier → confidence → explain)
- ☐ Validate confidence threshold logic (≥ 0.70 pass / < 0.70 flag)
- ☐ Cross-test 10 queries per category (High / Medium / Low context)
- ☐ Check LLM token usage and daily cost tracking (< $1 / day target)
- ☐ Verify citations and explanations display in final answers

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Week 2 – Performance & Reliability

- ☐ Measure latency (< 2 seconds avg) and identify slow nodes
- ☐ Run hallucination re-test (≥ 95 % queries above 0.70 confidence)
- ☐ Validate NOTAM → AC linkage alerts sent within 2 hours
- ☐ Monitor n8n workflow failures and error handling (log retry counts < 3 per day)
- ☐ Confirm PostgreSQL/Supabase audit logs record confidence scores and LLM versions

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Week 3 – Reporting & Governance

- ☐ Receive first auto-generated monthly PDF report
- ☐ Verify audit summaries include hallucination rate, confidence pattern, and cost trend
- ☐ Cross-check report accuracy against raw logs (± 5 % variance max)
- ☐ Archive validated report to versioned folder (GitHub / Drive)
- ☐ Document final performance baseline for Phase 3 planning

Phase 2 Completion Criteria

Metric	Target	Validated By
Confidence Accuracy	≥ 95 % responses ≥ 0.70 score	Validation log
Latency	< 2 seconds	n8n metrics
Hallucination Rate	< 2 % after verification	Audit report
Monthly Report Delivery	Auto PDF within 1 day of month-end	Email timestamp
Ongoing Cost	<$50 / month	Billing summary