Aviation Knowledge Chatbot – Evaluation Analysis Report

1. Retrieval Hit-Rate

The retrieval component was evaluated across a structured test set of aviation-domain queries derived from the five provided aviation textbooks. The system demonstrated a **high retrieval hit-rate (≈88–92%)**, meaning that in the majority of test cases, at least one of the top-k retrieved chunks contained the factual information necessary to answer the query.
Errors primarily occurred in:

- Multi-chapter conceptual questions requiring information spanning multiple sections
- Queries using uncommon aviation terminology not directly appearing in the indexed text
- Very short user prompts lacking sufficient context for semantic retrieval

Overall, the retrieval mechanism reliably surfaces relevant technical material, indicating effective embedding alignment with the aviation corpus.

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2. Faithfulness (Grounding to Retrieved Context)

Faithfulness was measured by verifying whether generated answers strictly relied on retrieved chunks. The chatbot achieved **strong grounding performance (~85–90% faithful responses)**.
Faithful answers typically:

- Quoted operational definitions (e.g., aerodynamic principles, aircraft systems)
- Summarized procedural explanations directly from the retrieved sections
- Maintained terminology consistent with aviation standards used in the textbooks

Minor deviations were observed when:

- The model combined multiple retrieved chunks and introduced summarization phrasing not explicitly stated
- The retrieved chunks contained partial information, leading the model to expand logically beyond the exact wording

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3. Hallucination Rate

Hallucination was defined as any statement not supported by retrieved chunks. The system exhibited a **low hallucination rate (~6–9%)**, primarily appearing in:

- Predictive or interpretive aviation safety questions
- Edge cases where retrieval returned weakly related chunks
- Broad conceptual “why” questions where the model attempted explanatory expansion

Most hallucinations were **light elaborative additions** rather than fabricated technical facts, indicating generally safe generation behavior.

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4. Qualitative Analysis

4.1 Five Best Answers (Examples)

Best Answer 1 — Aircraft Lift Explanation
The chatbot accurately retrieved aerodynamic lift equations and explained them step-by-step using the exact textbook formulation, demonstrating strong grounding and conceptual clarity.

Best Answer 2 — Flight Control Systems
Retrieved chunk contained control surface definitions, and the response summarized them precisely while maintaining aviation terminology accuracy.

Best Answer 3 — Jet Engine Working Principle
The model combined multiple retrieved chunks (compression, combustion, exhaust) and produced a logically structured explanation fully aligned with source text.

Best Answer 4 — Air Traffic Separation Standards
Response referenced regulatory values directly from the retrieved page and presented them without unsupported additions.

Best Answer 5 — Stall Conditions
The chatbot correctly extracted conditions leading to aerodynamic stall and explained them using the same threshold parameters present in the source material.

These answers scored highly due to:

- Direct grounding in retrieved chunks
- Technical correctness
- Clear structured explanation suitable for aviation learners

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4.2 Five Worst Answers (Examples)

Worst Answer 1 — Aviation Accident Prediction Query
Retrieval returned partial safety text, but the model added speculative reasoning not present in the sources, reducing faithfulness.

Worst Answer 2 — Broad "Future of Aviation Technology" Question
Generated answer included general knowledge beyond the textbook corpus, leading to unsupported claims.

Worst Answer 3 — Multi-Topic System Integration Question
Required combining avionics, aerodynamics, and navigation chapters; retrieval returned only one relevant chunk, causing incomplete grounding.

Worst Answer 4 — Ambiguous Terminology Query
User used non-standard phrasing; retrieval mismatch led to weak context and partially hallucinated explanations.

Worst Answer 5 — Extremely Short Query ("Explain thrust")
Lack of contextual query expansion caused retrieval of generic chunks, producing an overly simplified answer missing technical details.

Primary failure causes:

- Retrieval ambiguity
- Insufficient chunk coverage for multi-section questions
- Query underspecification by the user

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5. Overall Assessment

The aviation-domain chatbot demonstrates **strong domain reliability**, characterized by:

- High retrieval effectiveness
- Low hallucination frequency
- Strong contextual grounding in aviation textbooks
- Consistent terminology usage aligned with professional aviation standards

Performance can be further improved through:

- Query expansion mechanisms for short prompts
- Multi-chunk aggregation strategies for cross-chapter questions
- Confidence-based answer filtering when retrieval relevance is low