Cortex XAI Engine Monitoring System

Project Technical Report

1. Executive Summary

The Cortex XAI Engine Monitoring System is a state-of-the-art predictive maintenance solution designed for aircraft turbofan engines. By leveraging the NASA CMAPSS dataset and advanced Machine Learning (XGBoost, Random Forest), the system accurately predicts the Remaining Useful Life (RUL) and Flight Worthiness of engines. Crucially, it incorporates eXplainable AI (XAI) techniques (LIME, SHAP) to provide transparent, actionable insights for maintenance technicians, solving the 'black box' problem in AI adoption. The system features a decoupling architecture with a fast Python backend and a modern React 'AeroGlass' frontend.

2. System Architecture

The system follows a modern Client-Server architecture:

A. Backend (FastAPI):
- Serves as the computational core.
- Handles data ingestion (CMAPSS FD001-FD004).
- Executes ML inference pipeline.
- performs real-time 'What-If' simulations.
- Exposes RESTful API endpoints (e.g., /predict_explain, /predict_simulated).

B. Frontend (React + Vite):
- Provides an interactive 'AeroGlass' dashboard.
- Visualizes live telemetry with Recharts.
- Features a Fleet Health Monitoring Sidebar.
- Includes a Simulation Panel for variable parameter adjustment.

3. Technical Implementation

Data Pipeline:
Raw sensor data (Temperature, Pressure, Fan Speeds) is preprocessed to remove noise and filtered based on operating conditions. Constant sensors (e.g., Setting 3) are dropped to improve model stability.

Machine Learning Models:

1. RUL Regressor: An XGBoost model trained to predict the precise number of remaining flight cycles.

2. State Classifier: A Random Forest classifier that categorizes engine health into 'Normal', 'Warning', or 'Critical' states.

Explainable AI (XAI):

The system uses LIME (Local Interpretable Model-agnostic Explanations) to perturb input features and identify which specific sensors contributed most to a prediction. This allows the efficient generation of text-based Maintenance Recommendations (e.g., 'Inspect HPT Coolant Bleed due to high variance').

4. Key Features

- Predictive Maintenance: Forewarns of failures cycle-by-cycle.
- Diagnostics Forensics: Pinpoints root causes (e.g., 'Sensor 11 High').
- What-If Simulation: Allows engineers to simulate stressors (e.g., +5% Heat) and see immediate RUL impact.
- Fleet Monitoring: Single-pane-of-glass view for managing multiple assets.
- AeroGlass UI: Dark-themed, high-contrast aesthetics optimized for control room environments.

5. Conclusion

The Cortex XAI System successfully demonstrates how advanced AI can be bridged with human-centric design. By moving beyond simple predictions to providing 'Simulations' and 'Explanations', it empowers operators to make data-driven safety decisions with high confidence.