Executive Summary

This capstone project offers an AI-Based Predictive Maintenance System to predict breakdowns of equipment in an industrial setting. Mechanical breakdowns are among the most expensive and disruptive problems in the manufacturing, aviation, and heavy equipment sectors. Maintenance systems in place are of 3 types: reactive, scheduled, or inefficient, either responding too late, or wasting resources to remove and replace parts that are functionally working. This project offers an updated, and efficient, data-driven modern solution using machine learning (ML) and deep learning (DL) to predict breakdowns before they happen.

The system utilizes the turbofan engines of the NASA CMAPSS dataset, containing multi-sensor time-series data streams of engines degrading over time in various regimes. For this system, the dataset undergoes extensive data preprocessing in the form of irreverent sensors removal, RUL (Remaining Useful Lifetime) calculation, feature engineering, sequence generation, and scaling. This is done to optimize the data for prediction and to accurately model the patterns of degradation over time.

The architecture comprises of two models, a Random Forest classifier to predict failures on a short-term horizon (30 cycles) and an LSTM neural network to predict the Remaining Useful Life (RUL) over long horizons. Each model has a unique role – the classifier issues alarms for early warning, while the regressor outputs the low/high ranges of the continuous degradation levels over time. The combination of both of units results in producing a reliability insight system since both models are interpretable and provide a higher range of accuracy across different activities.

The system was designed to be user friendly in practical contexts, which includes a Streamlit interface. In the interactive dashboard, users have the ability to input sensor data, view the predicted RUL, and observe failure probabilities over time, including the ability to use SHAP explainability to interpret the model predictions. The system was designed to be transparent to the end users, including engineers and technicians, to improve the decision making during maintenance activities.

Overall, this capstone project serves as a final demonstration of the incorporation of the most essential principles of Machine Learning, Deep Learning, Data Engineering, Computer Vision-type Pipelines, and Deployment. It focuses on the technical detail while also meeting the practical requirements guaranteeing an AI system that reduces downtime, enhances maintenance cost efficiency, and improves safety within the operational environment.