ME 405– Machine Learning for Mechanical Engineering
Project Proposal
Title: *Uncertainty-Aware Reinforcement Learning for Predictive Maintenance of Turbofan Engines*
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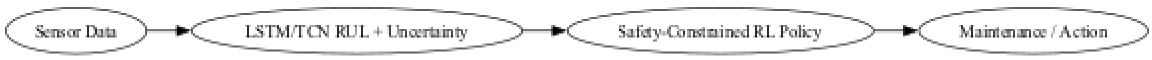
Project Description: This project develops a data-driven framework that combines learning–based Remaining Useful Life (RUL) prediction with reinforcement learning to design adaptive maintenance policies for turbofan engines. Using NASA's *Aircraft Engine Run-to-Failure under Real Flight Conditions* dataset (Chao et al., 2021), an LSTM model will estimate both RUL and its uncertainty. These estimates will guide a reinforcement learning agent that decides when maintenance should occur, balancing cost and reliability. The classical C-MAPSS FD001 dataset (Saxena & Goebel, 2008) will serve for initial tests before moving to the more realistic 2021 set.

Motivation and Significance: Unexpected engine failures lead to costly downtime and safety concerns. Traditional RUL-threshold maintenance ignores prediction reliability and can trigger either premature or late interventions. By combining uncertainty-aware deep models with reinforcement learning, maintenance can be optimized dynamically: the agent acts conservatively when confidence is low and boldly when predictions are reliable. This study highlights how learning-based approaches can enhance mechanical system reliability and advance autonomous prognostics.

Hypothesis and Approach: The hypothesis is that incorporating quantified uncertainty from an LSTM model into a risk-sensitive RL policy will outperform rule-based and uncertainty-agnostic methods in long-term reliability and cost. The approach involves preprocessing engine data, training an LSTM with Monte Carlo Dropout for uncertainty quantification, and training a Soft Actor–Critic agent to select maintenance actions that maximize cumulative reward while penalizing failures and unnecessary interventions.

Expected Outcome: The framework will provide an interpretable benchmark for uncertainty-aware predictive maintenance, demonstrating how confidence in RUL estimates can directly influence control decisions. The results are expected to show reduced failure rates and improved cost efficiency compared with baseline methods, contributing to safer and more autonomous mechanical systems.



[Figure 1. Proposed pipeline: Sensor Data → LSTM RUL + Uncertainty → Safety-Constrained RL Policy → Maintenance Action.]

References
[1]Chao M., Kulkarni C., Goebel K., & Fink O. (2021). *Aircraft Engine Run-to-Failure Dataset under Real Flight Conditions.* NASA PCoE.
[2]Lee D. (2023). *Reinforcement Learning for Uncertainty-Aware Maintenance Decision-Making. Reliability Engineering & System Safety.*
[3]Saxena A., & Goebel K. (2008). *Turbofan Engine Degradation Simulation Dataset.* NASA Ames PCoE.