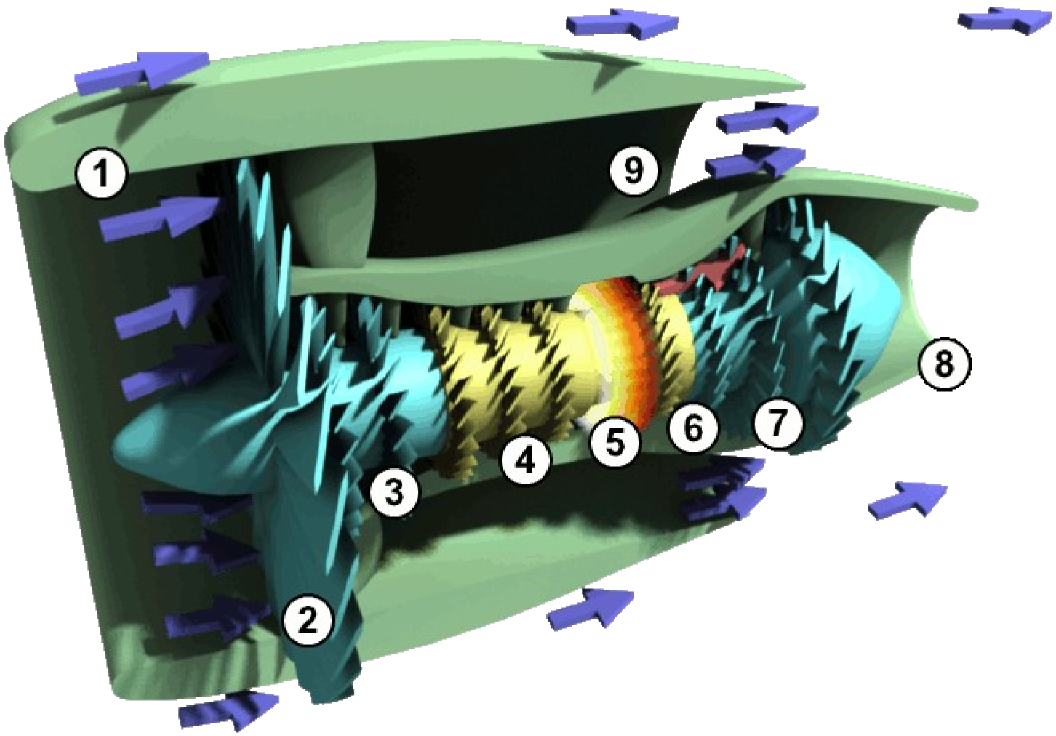
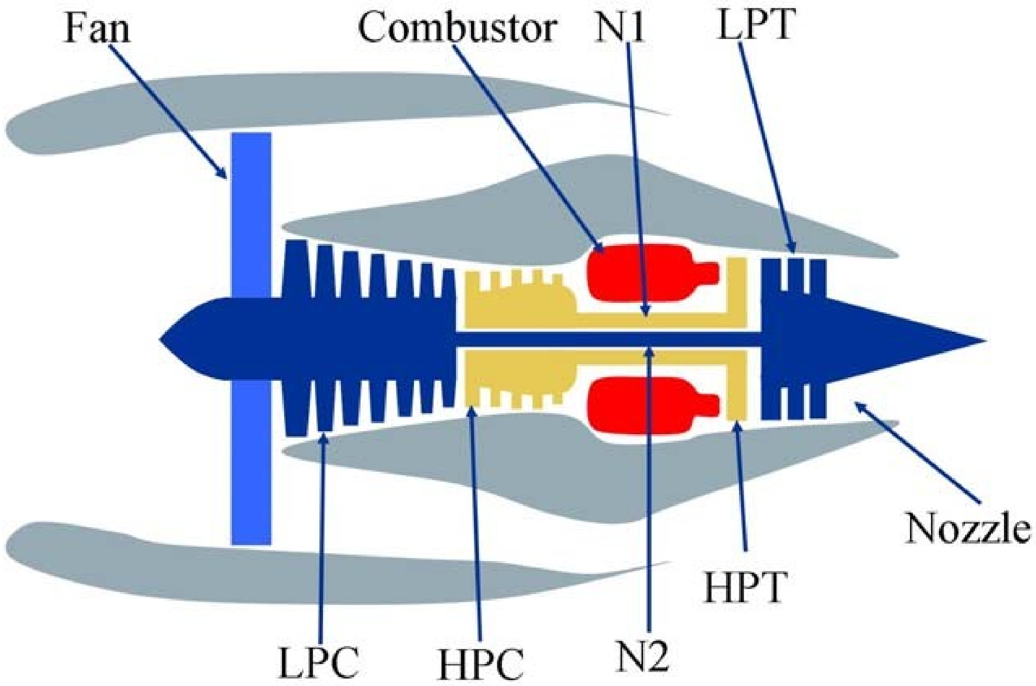


A Study on Predictive Maintenance for Turbofan Aircraft Engines

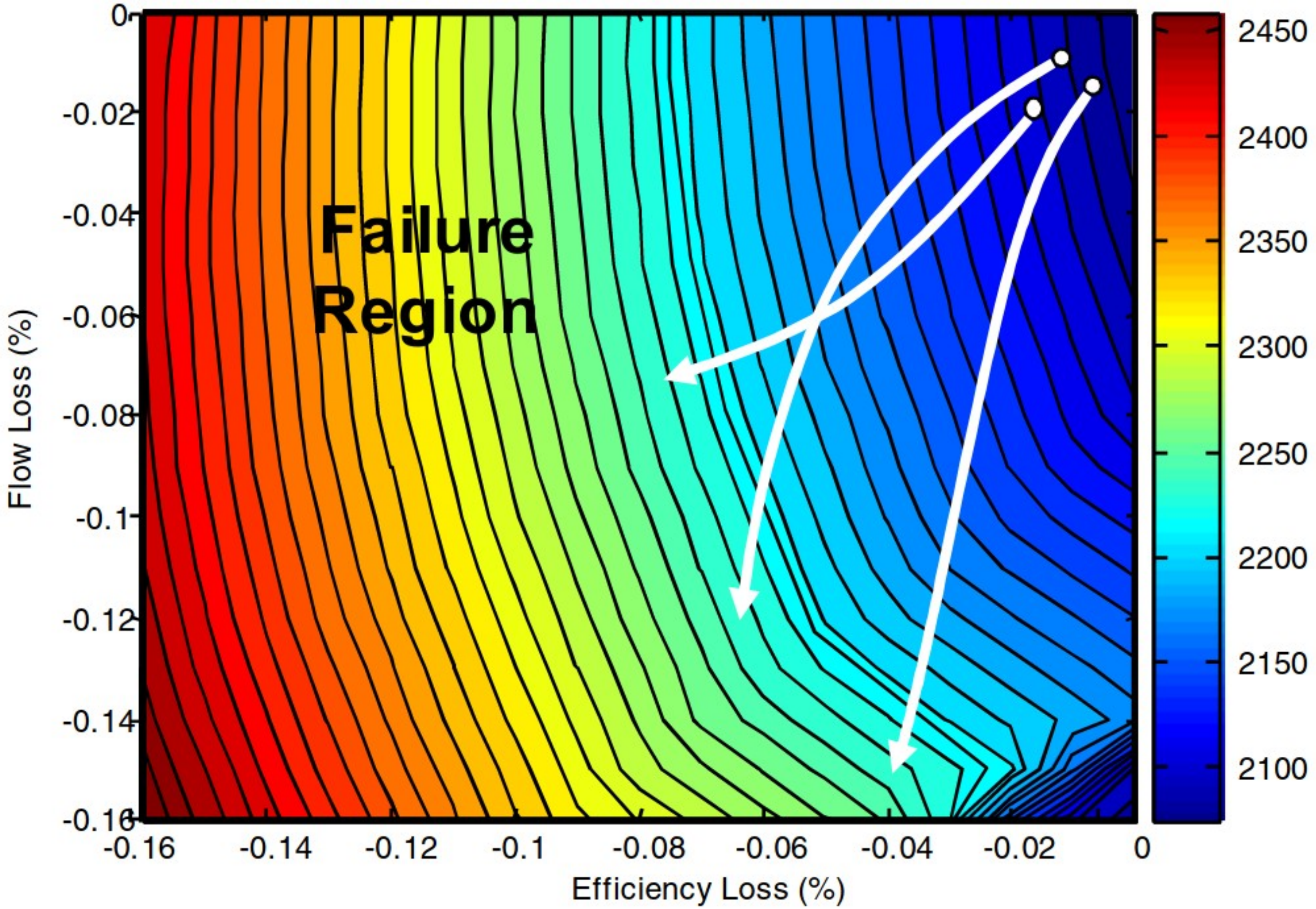
Basic Structure of a Turbofan Engine



The Problem

- Normal, progressive degradation of engine operations over time
- Failure = Reduced margins
  - Failure under study is NOT anomaly or catastrophe prediction

Failure Model



The Dataset

- Source: NASA
  - Integrated Vehicle Health Management (IVHM) program
  - Ames Research Center
- (Simulated) 90,000 lb thrust class high-bypass turbofan engine
- Training set: 100 simulated engines run to failure
- 24 features: 3 operational settings, 21 sensors

Outcomes to Predict

Based on current and historical operations and sensor data…

- Classification:

  Binary - predict failure within ***x*** cycles

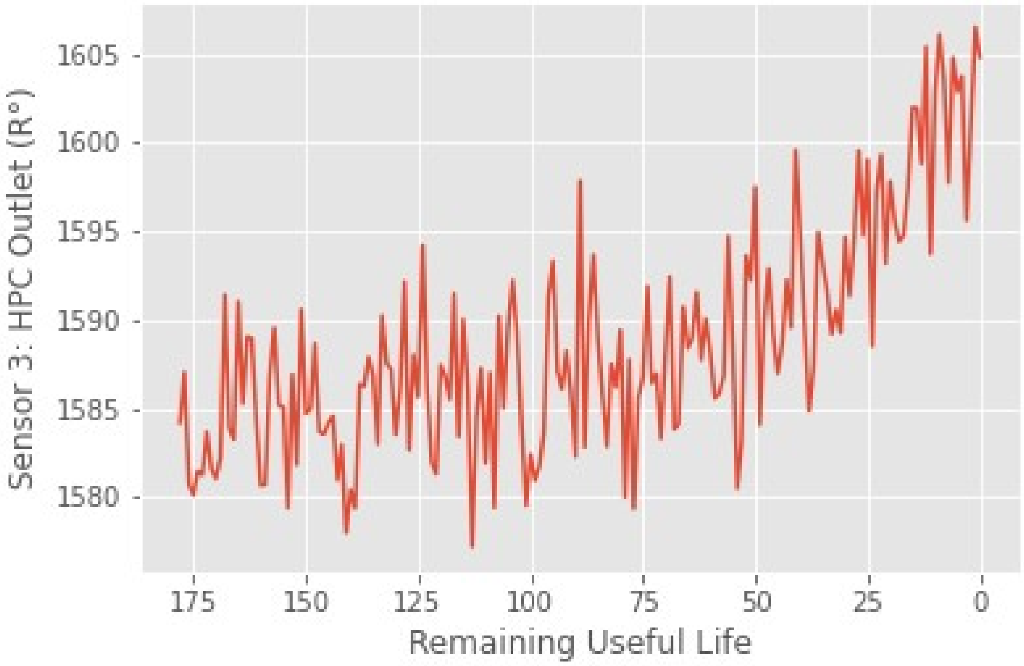
  Multiclass – predict failure within ***x*** cycles, then within ***y***<*x* cycles

- Regression: predict *remaining useful life*, or ***RUL***
  - *Initial RUL in dataset ranged from 128 to 362 cycles*

"Early is Better than Late"

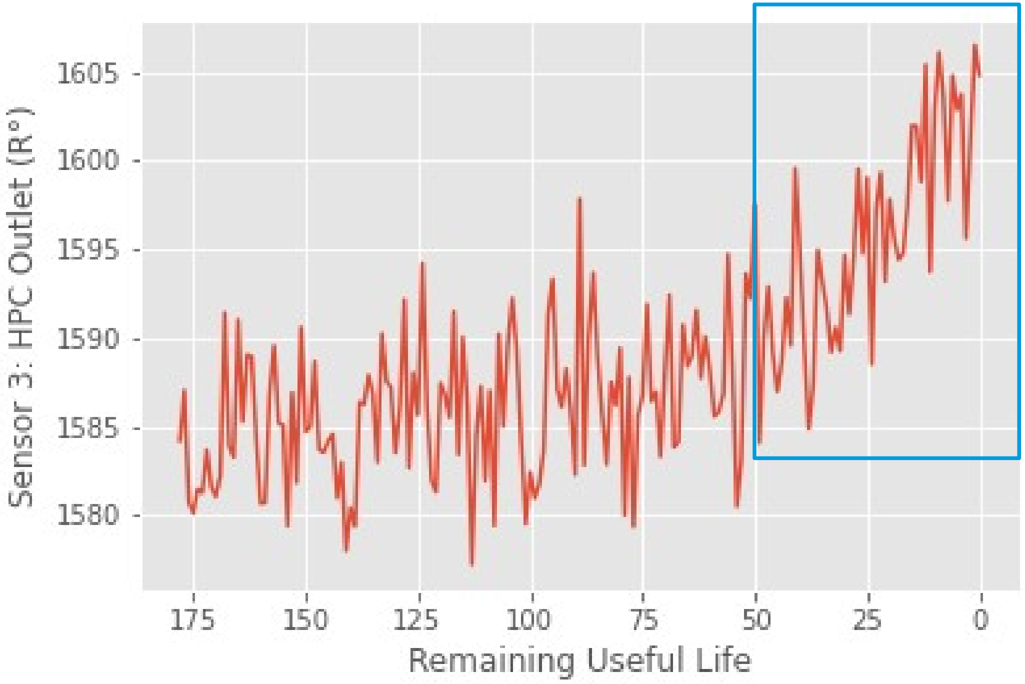
Sensor Data Trending

Engine 3 High Pressure Compressor Outlet Temperature (Rankine)



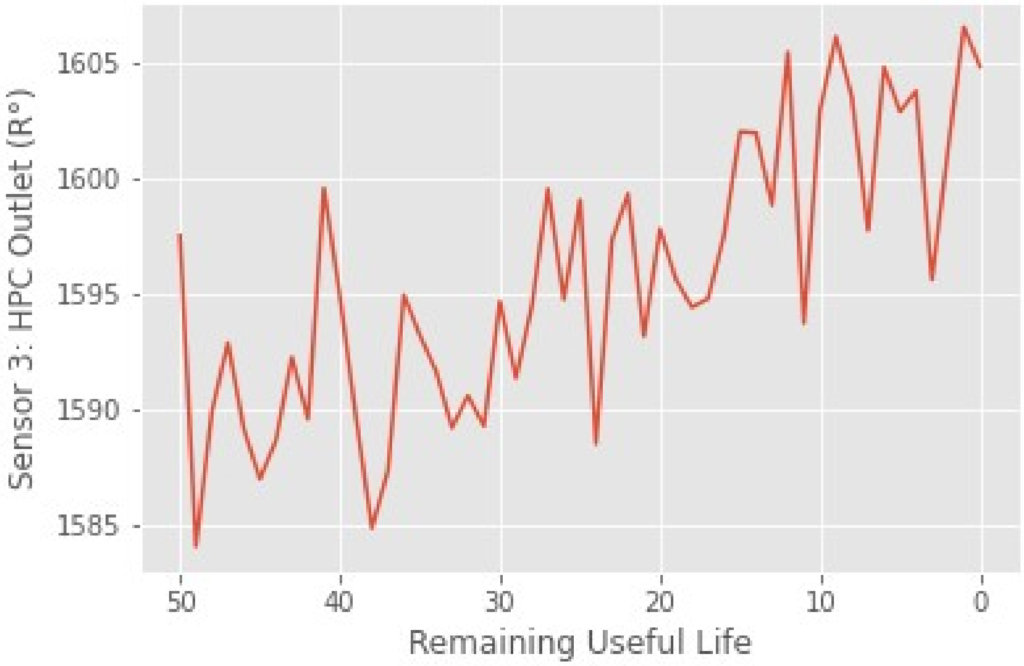
Sensor Data Trending

Engine 3 High Pressure Compressor Outlet Temperature (Rankine)



Sensor Data Trending

Engine 3 High Pressure Compressor Outlet Temperature (Rankine)



Sensor Data Trending

Engine 3 High Pressure Compressor Outlet Temperature (Rankine)

Models

- Logistics Regression
- Linear Regression
- Random Forest
  - Classifier
  - Regressor
- Neural Network
  - LSTM

Models

- Logistics Regression
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- Regression:

  RMSE = 35 cycles

- Classification:

  recall = 80%

- Neural Networks:

  single response for all inputs

Way Forward

- Score Weights
  - Create different penalties for ‘Late’ predictions
- Smooth data and amplify the signal in the noise

Image Credits

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Slide 2:

- Left image: Hideyuki KAMON, CC BY-SA 2.0 , http://www.flickr.com/photos/hyougushi/66755262/
- Right image: Saxena, A., Goebel, K., Simon, D., & Eklund, N. (2008). Damage propagation modeling for aircraft engine run-to-failure simulation. 2008 International Conference on Prognostics and Health Management, 1–9. https://doi.org/10.1109/PHM.2008.4711414
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Slide 4:

- Saxena, A., Goebel, K., Simon, D., & Eklund, N. (2008). Damage propagation modeling for aircraft engine run-to-failure simulation. 2008 International Conference on Prognostics and Health Management, 1–9. https://doi.org/10.1109/PHM.2008.4711414

Questions