Milestone 4 Report

1. Introduction

Milestone 4 focused on finalizing the predictive maintenance system by improving explainability, generating automated reports, enhancing dashboard functionality, validating model reliability, and preparing the system for final submission. This milestone completed the transition of the project from a prototype to a polished, usable, and interpretable predictive maintenance solution based on RUL estimation.

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2. Work Completed in Milestone 4

2.1 Full PDF Report Automation

A complete PDF report generation module was developed to allow users to download analysis for any uploaded engine data.

The PDF includes:

- Predicted RUL
- Engine health classification
- Summary of operating cycles
- Sensor trend plots
- Degradation curve
- Correlation heatmap
- Model pipeline summary

This enables end-users (engineers, operators, managers) to quickly assess engine condition offline.

2.2 Dashboard Enhancement and Finalization

Multiple improvements were made to the interactive dashboard built in Milestone 3:

Key upgrades:

- Clean and structured UI formatting
- Clear separation of prediction, sensor trends, and heatmap sections
- Optimized plot rendering
- Improved handling of large uploads
- Error messages for missing or corrupted columns
- Enhanced color schemes for readability

Additionally, responsiveness and performance of the dashboard were improved to handle multiple engine evaluations.

2.3 Explainability Integration

To improve transparency and trust in the model, an explainability layer was added.

Explainability features implemented:

- Feature contribution summaries
- Identification of influential sensors for given predictions
- Sensor-level degradation indicators
- Contextual interpretation of RUL scoring

While advanced SHAP integration is possible, this milestone focused on practical, understandable explanations accessible to non-ML users.

2.4 Performance Validation and Reliability Testing

Extensive testing was done to ensure the system behaves consistently under multiple real-world scenarios.

Validation steps:

- Uploading FD001–FD004 engines
- Testing various CSV formats
- Verifying predictions across long and short sequences
- Checking model performance stability
- Ensuring visual consistency across different engines
- Measuring inference time and ensuring responsiveness

All tests confirmed that the model and dashboard meet the specified functional requirements.

2.5 Model Optimization and Final Tuning

Minor optimizations were made to the predictive model:

- Adjusted batch size and sequence length to improve inference stability
- Ensured consistent scaling across all engine types
- Confirmed alignment between training and inference feature ordering
- Refined early stopping to maintain optimal generalization

The system now reliably predicts RUL and performs well across all datasets.

2.6 Final Project Documentation and Presentation Materials

Comprehensive project documentation was completed, including:

- Complete technical report

- Milestone summaries (M1–M4)
- Final presentation slides
- User instructions for dashboard operation
- Explanation of model architecture

These materials prepare the project for academic evaluation, client demonstration, or deployment handover.

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3. Summary of Milestone 4 Outcomes

Milestone 4 completed the functional lifecycle of the project. The main outcomes include:

- Fully automated PDF reporting
- Robust, polished, and user-friendly dashboard
- Clear model interpretability features
- Verified prediction stability across datasets
- Finalized documentation and presentation content
- System ready for real-world demonstration or deployment

This milestone represents the final refinement stage of the predictive maintenance system.

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4. Future Work and Recommendations

Even though the project is completed for this phase, the following enhancements are recommended for future development:

4.1 Advanced Explainability (SHAP/LIME Integration)

Use SHAP values to generate:

- Per-cycle explanations
- Sensor-wise importance heatmaps
- Local vs global model interpretability

4.2 Real-Time Streaming Integration

Integrate with an IoT pipeline to process:

- Live engine telemetry
- Real-time RUL predictions
- Continuous monitoring dashboards

4.3 Degradation Trend Forecasting

Extend the model to forecast:

- Future sensor readings
- Future degradation curves
- Probabilistic RUL under uncertainty

4.4 Ensemble or Hybrid Models

Explore advanced architectures:

- CNN-LSTM
- Transformer models
- Attention-based RUL predictors
- Ensemble averaging with GRU/LSTM

4.5 Deployment as Cloud Service

Containerize the system using Docker and deploy via:

- AWS (EC2/S3/Lambda)
- Azure ML
- Google Cloud Run

This would enable scalability and remote accessibility.

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5. Conclusion

Milestone 4 successfully finalized the predictive maintenance solution by completing reporting, explainability, testing, and interface refinement. The RUL prediction system now operates end-to-end, from data ingestion to visualization and reporting, delivering a reliable and intuitive tool for engine health assessment. This milestone marks the conclusion of the development lifecycle and prepares the project for practical deployment or final academic evaluation.