Machine Learning-Based Predictive Analysis for Aircraft Engine

PROJECT TITLE	Machine Learning-Based Predictive Analysis for Aircraft Engine
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BRANCH	Computer Science and Engineering

1. ABSTRACT:

An essential aspect of air safety is making sure the engines run properly for their entire lifespan. The number of accidents caused by a poor crew response after an engine malfunction has remained constant for many years, despite the fact that modern engines are very reliable. Engine failure is highly risky and needs a lot of time for repair. Unexpected failure leads to loss of money and time. Predicting the failure prior will save time, effort, money and sometimes even lives. The failure can be detected by installing the sensors and keeping a track of the values. The failure detection and predictive maintenance can be for any device, out of which we will be dealing with the engine failure for a threshold number of days. The project aims to predict the failure of an engine by using Machine Learning to save loss of time & money thus improving productivity. especially on aircraft machine where the safety is priority due to enormous cost and human life. ML is the technique that accurately prediction through the data. Processing of real-time sensor data is frequently used in fault diagnosis and predictive analytics of high-value engineering systems to identify obstructive or covert issues with the underlying system. To accomplish this, it is required to condition the sensor data before combining it with the system's existing design knowledge to produce insightful information. These analytics have the potential to avoid expensive breakdowns and schedule maintenance cycles efficiently. A configuration that can efficiently enable data collecting, data conditioning, secure transmission, database storage, and the execution of real-time data analytics algorithms is required to develop such a system.

2. INTRODUCTION:

2.1 Project Overview:

The ability of machinery to function cannot be guaranteed; occasionally, it will fail due to outdated operation. Sensor-equipped machinery systems can only monitor a machine's condition; they cannot determine if it is in excellent or bad shape. Maintenance strategy must be applied to scheduled machinery systems in order to prevent the worst event (failure) and obtain information about a machine's status. There are three maintenance strategies that are best practises. Maintenance that is corrective, preventive, and predictive. The fundamental maintenance method is corrective maintenance (CM), which is carried out when a machine stops functioning. Corrective maintenance (CM) can be carried out when a machine has spare components; otherwise, it has drawbacks whereas predictive maintenance (PM) is scheduled. Machine learning (ML), a branch of artificial intelligence, is a technique or algorithm that can pick up knowledge based on training, or information that is provided about something, and use that knowledge later when the algorithm is use. Due to its impact on human and economic safety, prognostic and health management (PHM) in the aviation sector will develop. Advance maintenance will be used in this sector to inform of the state of the aircraft engines. PdM is an advanced maintenance method that can be used in the aviation industry due to its high accuracy forecast, which can lower operating costs and increase safety by calculating remaining usable life.

2.2 Purpose

Making sure the engines function effectively for the duration of their lives is a crucial component of air safety. Even though modern engines are relatively reliable, the number of accidents resulting from a subpar crew response to an engine breakdown has remained steady for many years. Engine failure is quite dangerous and takes a long time to fix. Unexpected failure results in time and money losses. Saving time, effort, money, and occasionally even lives can be done by anticipating failure. By putting in the sensors and monitoring the values, the failure can be found. By putting in the sensors and monitoring the values, the fault can be found. Any device may be subject to failure detection and preventive maintenance, but we will be dealing with engine failure for a predetermined number of days. There can be various factors in which aircraft engines malfunctions, the main motive of the project is to predict the cause of the failure to improve the quality of flying experience and extricate capital loss

3. LITERATURE SURVEY

3.1 Existing Problem

The aero-engine system is complex, and the working environment is harsh. As the fundamental component of the aero-engine control system, the sensor must monitor its health status. Traditional sensor fault detection algorithms often have many parameters, complex architecture, and low detection accuracy There are earlier works on the same subject as the fundamental details of this page. A thorough analysis of PdM system architecture has been conducted somewhere, and it provides a review of the various PdM approaches currently in use, ranging from the traditional base to the use of ML and DL approaches. This work also places emphasis on DL due to its accuracy and the rise in popularity of the method among researchers over the past five years. The most often used techniques are k-means, RF, ANN, and SVM. Additionally, because the model can accurately anticipate engine activity, other researchers have provided Long Short-Term Memory (LSTM) method for prognostic methodology for aircraft fault prediction and suggested it.

3.2 References

Dubravko Miljković; He told in their research paper on “Detecting Aircraft Piston Engine Problems by Analysis of Engine Parameters” Most general aviation aircrafts use piston engines that are considerably less reliable than turbine engines. Most problems of aircraft piston engines are reflected in engine temperature parameters like cylinder head temperature (CHT) and exhaust gas temperature (EGT) that are recorded by engine monitor. Three approaches for detection of engine problems are presented. Many problems may be detected by comparison of statistical distributions of CHTs and EGTs from individual cylinders. Incipient exhaust valve failure may be detected from temporal EGT pattern containing low frequency fluctuations. The life of the exhaust valve depends on its operating temperature. Because EGT is the major contributor to the overheating of the exhaust valve and it’s cooling mostly depends on

the CHT, the remaining life of exhaust valve may be assessed from cumulative sum of EGT and CHT during the period of use.

Veer Kumar, Madhura Mokashi, "Predicting Aircraft Equipment Failure using Machine Learning Classification Algorithms "published in April 2021 proposed enormous amount of information and maintenance data exists in the aviation industry that can be utilized to draw meaningful insights in forecasting the future course of action. In this study, our prime objective is to use machine learning classification models to perform feature selection and predictive analysis to predict failures of aircraft systems. Maintenance and failure data for aircraft equipment across a period of two years were collected, and cleaned, which was followed by application feature engineering and feature election techniques before model building and evaluation. We compute a metric known as Remaining Useful Life (RUL) to predict the failure of aircraft equipment, since this is a continuous variable, we then convert it into a binary classification problem by setting a threshold RUL value to indicate an impending failure so that our classification model flags a warning well in advance to the point of breakdown, thereby giving response teams sufficient time to act upon the warning. Experimental results of our classification model demonstrate the effectiveness of our model to forecast the failure of aircraft equipment.

Xiao Du, Jiajie Chen, Haibo Zhang and Jiqiang Wang; ": Fault Detection of Aero-Engine Sensor Based on Inception-CNN" in this research paper they told the aero-engine system is complex, and the working environment is harsh. As the fundamental component of the aero-engine control system, the sensor must monitor its health status. Traditional sensor fault detection algorithms often have many parameters, complex architecture, and low detection accuracy. Aiming at this problem, a convolutional neural network (CNN) whose basic unit is an inception block composed of convolution kernels of different sizes in parallel is proposed. 3 The network fully extracts redundant analytical information between sensors through different size convolution kernels and uses it for aero-engine sensor fault detection. On the sensor failure dataset generated by the Monte Carlo simulation method, the detection accuracy of Inception-CNN is 95.41%, which improves the prediction accuracy by 17.27% and 12.69% compared with the best-performing non-neural network algorithm and simple BP neural networks tested in the paper, respectively. In addition, the method simplifies the traditional fault detection unit composed of multiple fusion algorithms into one detection algorithm, which reduces the complexity of the algorithm. Finally, the effectiveness and feasibility of the method are verified in two aspects of the typical sensor fault detection effect and fault detection and isolation process.

Arunvinthan Shan, 2015, they told in their survey that Ensuring a proper operation of the engines over their lifetime is an important air safety aspect. Even though the recent engines are highly reliable the number of accidents due to an incorrect crew response following an Engine malfunction has remained constant for many years. This prompted this study and it reveals that flight crews are not always able to identify and understand engine malfunctions precisely which leads to needless engine shutdowns, incidents, and accidents. The scope of this Book is to provide basic guidelines to identify Engine failures/malfunctions and to give operational recommendations in case

of Engine malfunction. This can be accomplished using SOM maps. Clustering the various engine parameters based on the parametric variations influenced by the faults, SOM maps are generated and they are stored as the failure template. In addition to their traditional tool based quantitative inspection of some measured variables to detect any deviation from the normal behaviour making it possible to anticipate possible faults. By proper detection of the faults suitable malfunction response for the crew will be displayed for their crew assistance. It ensures further reliability and passenger safety.

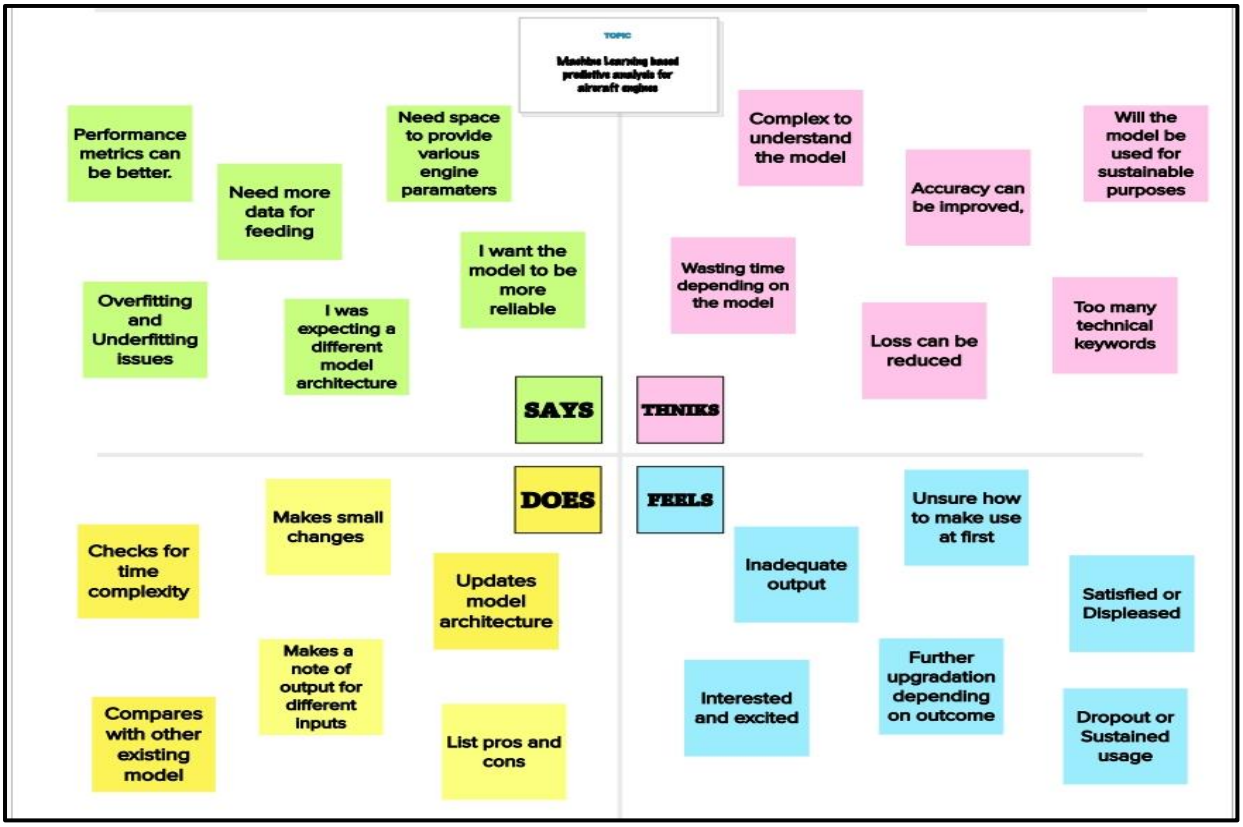
Xiaofeng Liu, Siqi An, in the year 2014 proposed the method to find the failure propagation mechanism from the complex system of aircraft engine, this paper used the topological structure to describe the coupling relations, discussing the role of topological geometry method in the failure propagation. The topological structure statistical properties of the system were analysed with small world net theory, and a failure propagation model based on the small world clustering was proposed, and the failure propagation paths and relevant key nodes with high pervasion ability were found with the Dijkstra algorithm. The results verify that this method can effectively find the weak point in the system, and provide an important basis for design improvements and failure prevention.

3.3 Problem Statement Definition

Problem Statement (PS)	I am (Customer)	I'm trying to	But	Because	Which makes me feel
PS-1	an aircraft engineer	predict aircraft engine failure	it is not certain	there are a lot of variables and factors to account for	Irritated
PS-2	a maintenance staff	predict remaining usable life of an Aircraft Engine	it has many key parameters like Temperature, Pressure, etc	it is a complex system	Confused
PS-3	an aircraft company	increase the reliability of aircraft components and systems	scheduling and maintenance has high operations cost	aircraft components and maintenance staff is high - cost	anticipated

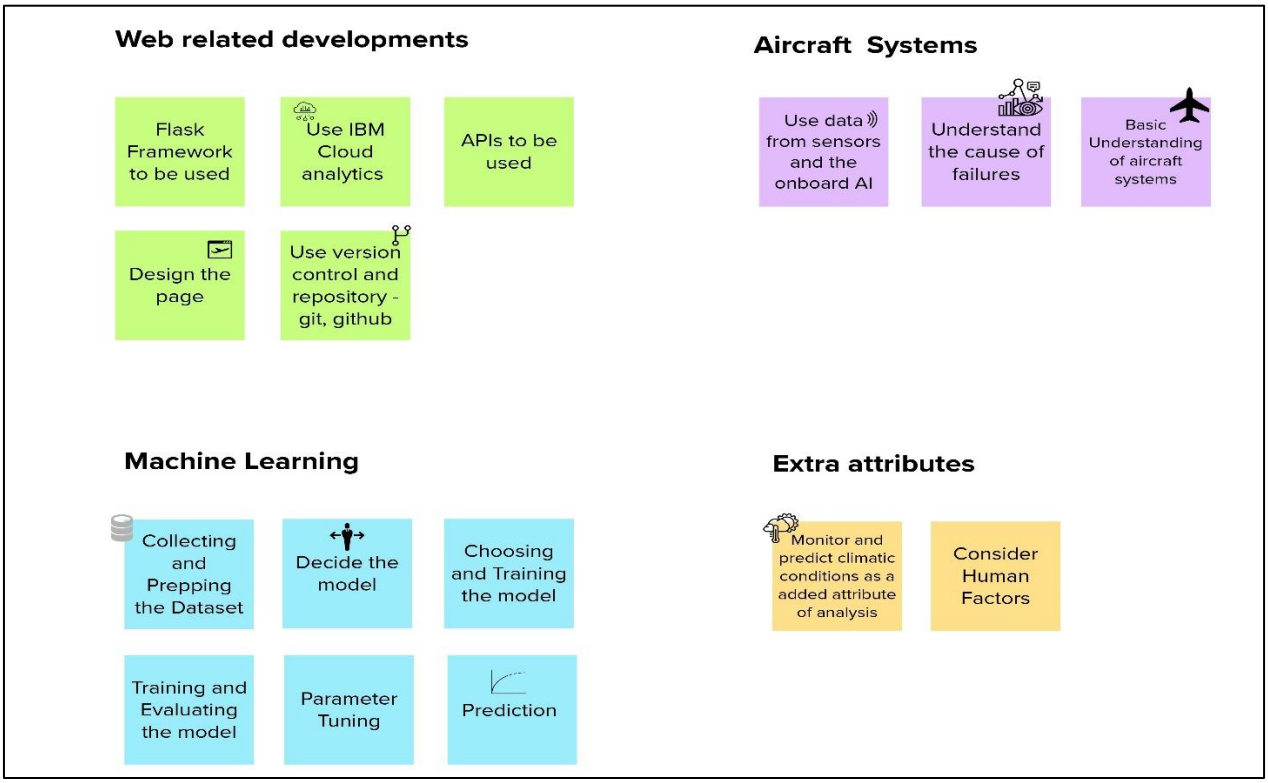
4. IDEATION & PROPOSED SOLUTION

4.1 Empathy Map Canvas



4.2 Ideation & Brainstorming

An essential aspect of air safety is making sure the engines run properly for their entire lifespan. Making sure the engines function effectively for the duration of their lives is a crucial component of air safety. The number of accidents caused by a poor crew response after an engine malfunction has remained constant for many years. Engine failure is highly risky and needs a lot of time for repair. Unexpected failure leads to loss of money and time. Predicting the failure prior will save time, effort, money and sometimes even lives. The failure can be detected by installing the sensors and keeping a track of the values. The failure detection and predictive maintenance can be for any device, out of which we will be dealing with the engine failure for a threshold number of days. The project aims to predict the failure of an engine by using Machine Learning to save loss of time & money thus improving productivity. especially on aircraft machine where the safety is priority due to enormous cost and human life. ML is the technique that accurately prediction through the data. Processing of real-time sensor data is frequently used in fault diagnosis and predictive analytics of high-value engineering systems to identify obstructive or covert issues with the underlying system. Engine failure is very dangerous and requires significant time for repair. Loss of time and money results from an unexpected failure. Time, effort, money, and occasionally even lives can be saved by predicting failure beforehand. Installing the sensors and monitoring the values will allow you to find the failure.



4.3 Proposed Solution

S. No.	Parameter	Description
1.	**Problem Statement (Problem to be solved)**	There can be various factors in which aircraft engines malfunctions, the main motive of the project is to predict the cause of the failure to improve the quality of flying experience and extricate capital loss.
2.	**Idea / Solution description**	The project aims to predict the failure of an engine by taking engine parameters, flight trajectory and other external testing parameters using Machine Learning to save loss of time & money thus improving productivity.
3.	**Scalability of the Solution**	The solution of the project "Machine learning based predictive analysis for aircraft engines" is flexible enough to meet the clients or customer requirements.
4.	**Novelty / Uniqueness**	Suggestion of remedy measures for the engine failure while comparing with the threshold values of various parameters that are involved in predicting the engine state.

5.	**Social Impact / Customer Satisfaction**	As the failure of a particular engine segment is previously predicted one could have an idea to use the affected hardware aptly and this could drastically reduce the loss of life. On encountering the plane crash, one could observe the ecosystem surrounding the crash would be seriously affected due to leakage and various chemical emission. Bird strikes occur at various wing and fuselage locations, but they usually inflict most damage to the jet engines, composed as they are of intricate high-speed rotating parts, and this is specially termed as bird ingestion engine damage.

4.4 Problem Solution

1. CUSTOMER SEGMENT(S)

- ✓ Customers are businessmen, student, tourist, traveler and all the people traveling in flight.

5. AVAILABLE SOLUTIONS

- ✓ >The reliability analysis of aircraft engines is essential for ensuring the smooth functioning of each component of an aircraft engine.

8. CHANNELS OF BEHAVIOUR

- ✓ Check the engine regularly and maintained properly. And check the fuel and oil levels regularly in the aircraft engine.

2. JOBS-TO-BE-DONE / PROBLEMS(J&P)

- ✓ Engine failure occurs when a turbine engine unexpectedly stops producing power due to malfunction. This led to a lot of customer dissatisfaction.

6. CUSTOMER CONSTRAINT(S)

- ✓ > Customers require accurate and early predictions of the flight engine failure. And they also look for an alternate solution.

9. PROBLEM ROOT CAUSE

- ✓ The root cause of the problem is unforeseen & unpredictable engine failure that cause cancellations and arrival, departure delays.

3. TRIGGERS

- ✓ To accurately predict the failure of an engine and track the flight.

4.EMOTIONS: BEFORE/ AFTER

- ✓ The aircraft engine failure occurs; passengers often get annoyed and frustrated. They also might lose to reach on time to some important occasions.

7. BEHAVIOR

- ✓ The purpose of this research is to develop methods that can be used to generate reliable and timely alerts.

10.YOUR SOLUTION

- ✓ Preventable fuel problems such as exhaustion. Structural failures where a broken connecting rod, crank, valve, or camshaft is present account for seventeen percent of engine failures Occurs.

5. REQUIREMENT ANALYSIS

5.1 Functional Requirement

Following are the functional requirements of the proposed solution.

FR No.	Functional Requirement (Epic)	Sub Requirement (Story / Sub-Task)
FR-1	User Registration	Registration through Form Registration through Gmail Registration through LinkedIN
FR-2	User Confirmation	Confirmation via Email Confirmation via OTP
FR-3	User Password	Set Password Confirm Password
FR-4	User Verification	Email Verification
FR-5	User Dataset	Add to Prediction System

FR-6	Dataset Pre-processing	Apply 80-20 rule on the dataset Transform Categorical data into Numerical values
FR-7	User Engine Data Intake	Get data input through Web Interface Communicate data to ML model
FR-8	Display Engine Failure Rate	Process input to arrive at a conclusion Display Probability of Engine Failure in Web Interface

5.2 Non-Functional Requirement

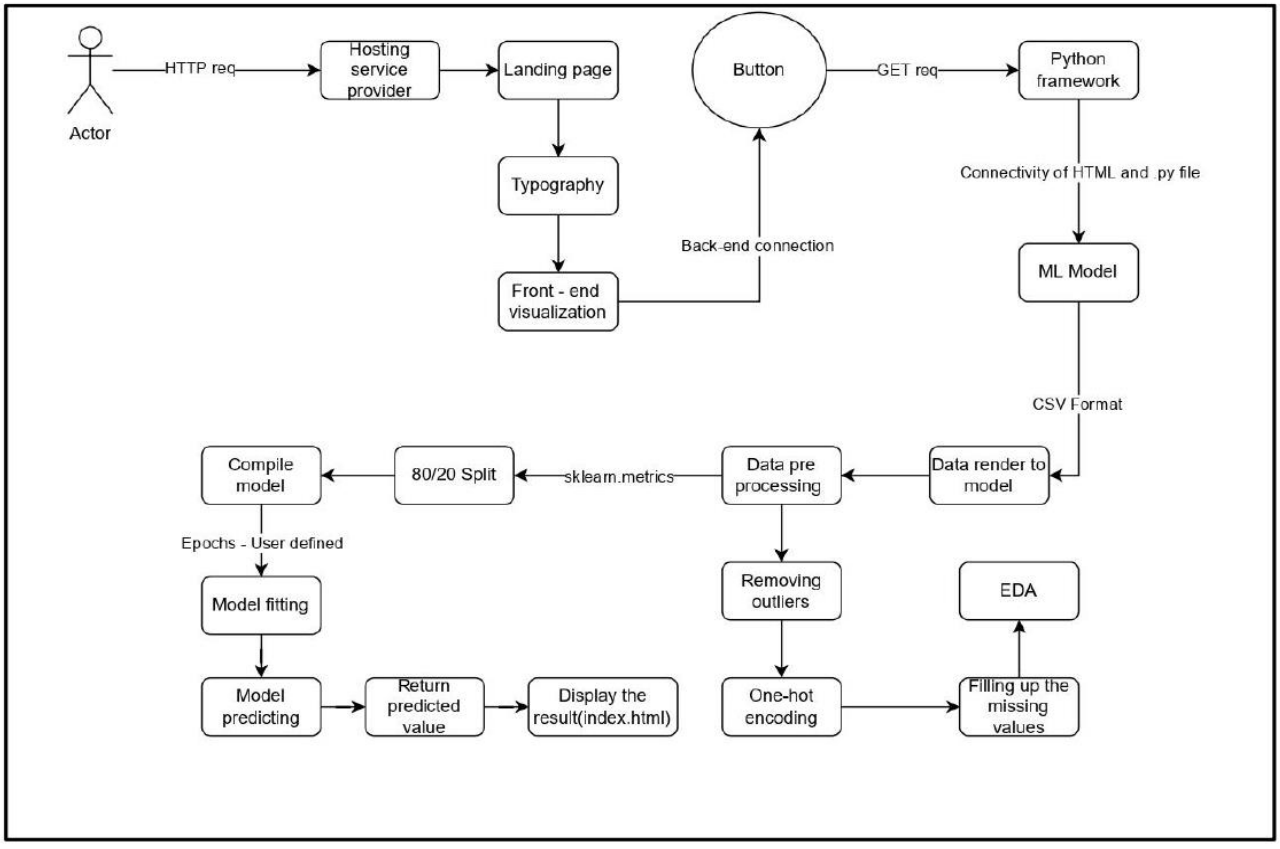
Following are the non-functional requirements of the proposed solution.

FR No.	**Non-Functional Requirement**	**Description**
NFR-1	**Usability**	Usability is a non-functional requirement, because in its essence it does not specify parts of the system functionality, only how that functionality is to be perceived by the user, for instance how easy it must be to learn and how efficient it must be for carrying out user tasks.
NFR-2	**Security**	Functional security requirements describe functional behaviour that enforces security. Functional requirements can be directly tested and observed. Requirements related to access control, data integrity, authentication and wrong password lockouts fall under functional requirements.
NFR-3	**Reliability**	Reliability requirements are typically part of a technical specifications document. They can be requirements that a company sets for its product and its own engineers or what it reports as its reliability to its customers. They can also be requirements set for suppliers or subcontractors.
NFR-4	**Performance**	Performance requirements define how well the software system accomplishes certain functions under specific conditions. Examples include the software's speed of response, throughput, execution time and storage capacity. The service levels compromising performance requirements are often based on supporting end-user Tasks.

NFR-5	**Availability**	Availability describes how likely the system is accessible to a user at a given point in time. While it can be expressed as an expected percentage of successful requests, you may also define it as a percentage of time the system is accessible for operation during some time period.
NFR-6	**Scalability**	Non-functional Requirements capture conditions that do not directly relate to the behaviour or functionality of the solution, but rather describe environmental conditions under which the solution must remain effective or qualities that the systems must have. They are also known as quality or supplementary requirements.

6. PROJECT DESIGN

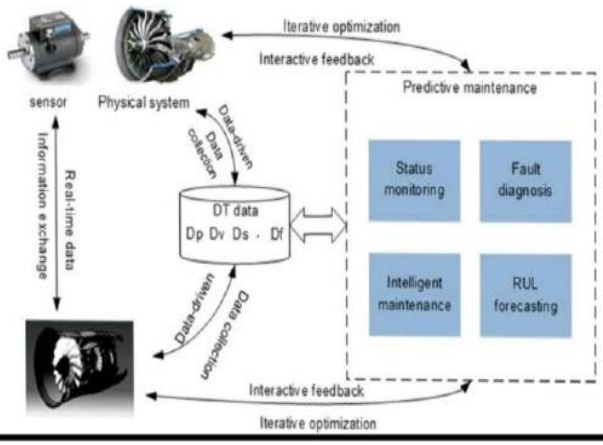
6.1 Data Flow Diagram



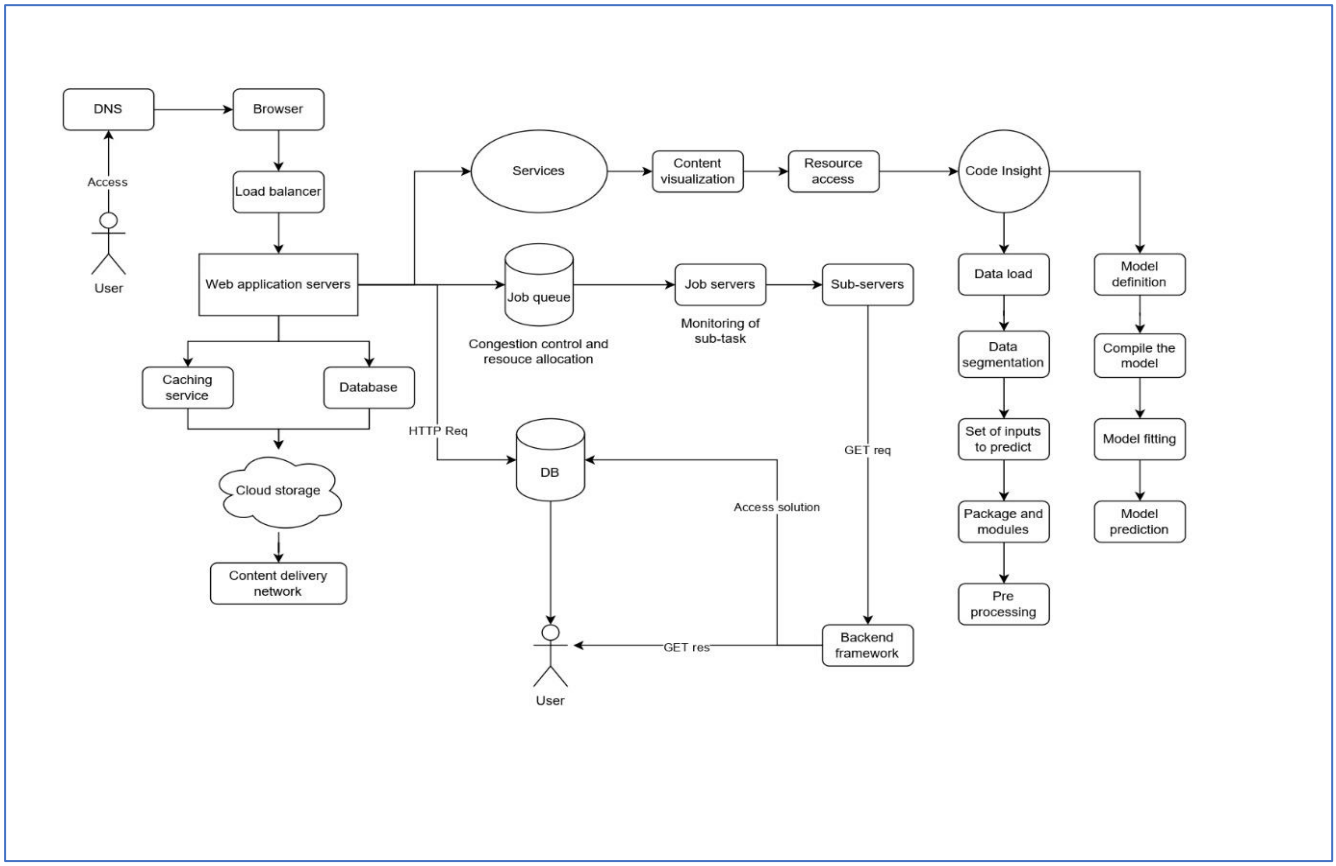
Data Flow Diagrams:

A Data Flow Diagram (DFD) is a traditional visual representation of the information flows within a system. A neat and clear DFD can depict the right amount of the system requirement graphically. It shows how data enters and leaves the system, what changes the information, and where data is stored.

EXAMPLE: **Data flow diagram for** Machine Learning-Based Predictive Analytics for Aircraft Engine



6.2 Solution & Technical Architecture



6.3 User Stories

DT-Data technology

DP-Data Processing

DV-Data visualization

DS-Data Server

User Stories

Use the below template to list all the user stories for the product.

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	Release
Customer (Mobile user)	Registration	USN-1	As a user, I can register for the application by entering my email, password, and confirming my password.	I can access my account / dashboard	High	Sprint-1
		USN-2	As a user, I will receive confirmation email once I have registered for the application	I can receive confirmation email & click confirm	High	Sprint-1
		USN-3	As a user, I can register for the application through Facebook	I can register & access the dashboard with Facebook Login	Low	Sprint-2
		USN-4	As a user, I can register for the application through Gmail	I can access the application through gmail	Medium	Sprint-1
	Login	USN-5	As a user, I can log into the application by entering email & password		High	Sprint-1
	Dashboard	USN-1	As a user ,I can search my requirements			
Customer (Web user)	Registration	USN-1	As a user, I can register for the application by entering my email, password, and confirming my password	I can access my account / dashboard	High	Sprint-1
		USN-2	As a user, I will receive confirmation email once I have registered for the application	I can receive confirmation email & click confirm	High	Sprint-1

User Type	Functional Requirement (Epic)	User Story Number	User Story / Task	Acceptance criteria	Priority	Release
		USN-3	As a user, I can register for the application through Facebook	I can register & access the dashboard with Facebook Login	Low	Sprint-2
		USN-4	As a user, I can register for the application through Facebook	I can access the application through gmail	Medium	Sprint-1
customer web verification	Captcha	USN-1	As a user ,By clicking the correct pictures of the given puzzles	By clicking the puzzles i can log in page	low	Sprint-2
Customer Care Executive	User issue	USN-1	If the users facing any issue ,user can contact customer care executive	Customer care executive will solve the users requirements.	Medium	
Administrator	Checking user security and requirements	USN-1	when user facing any security issue	Administrator will solve the users requirements	High	
	Monitoring the users verifications	USN-2	when users verify through email,captcha	Administrator will monitor the verification stage issue	High	

7. PROJECT PLANNING & SCHEDULING

7.1 Sprint Planning & Estimation

- SPRINT PLAN
- ANALYZE THE PROBLEM
- PREPARE AN ABSTRACT, PROBLEM STATEMENT
- LIST A REQUIRED OBJECT NEEDED
- CREATE A PROGRAM CODE AND RUN IT
- MAKE A PROTOTYPE TO IMPLEMENT

- TEST WITH THE CREATED CODE AND CHECK THE DESIGNED PROTOTYPE

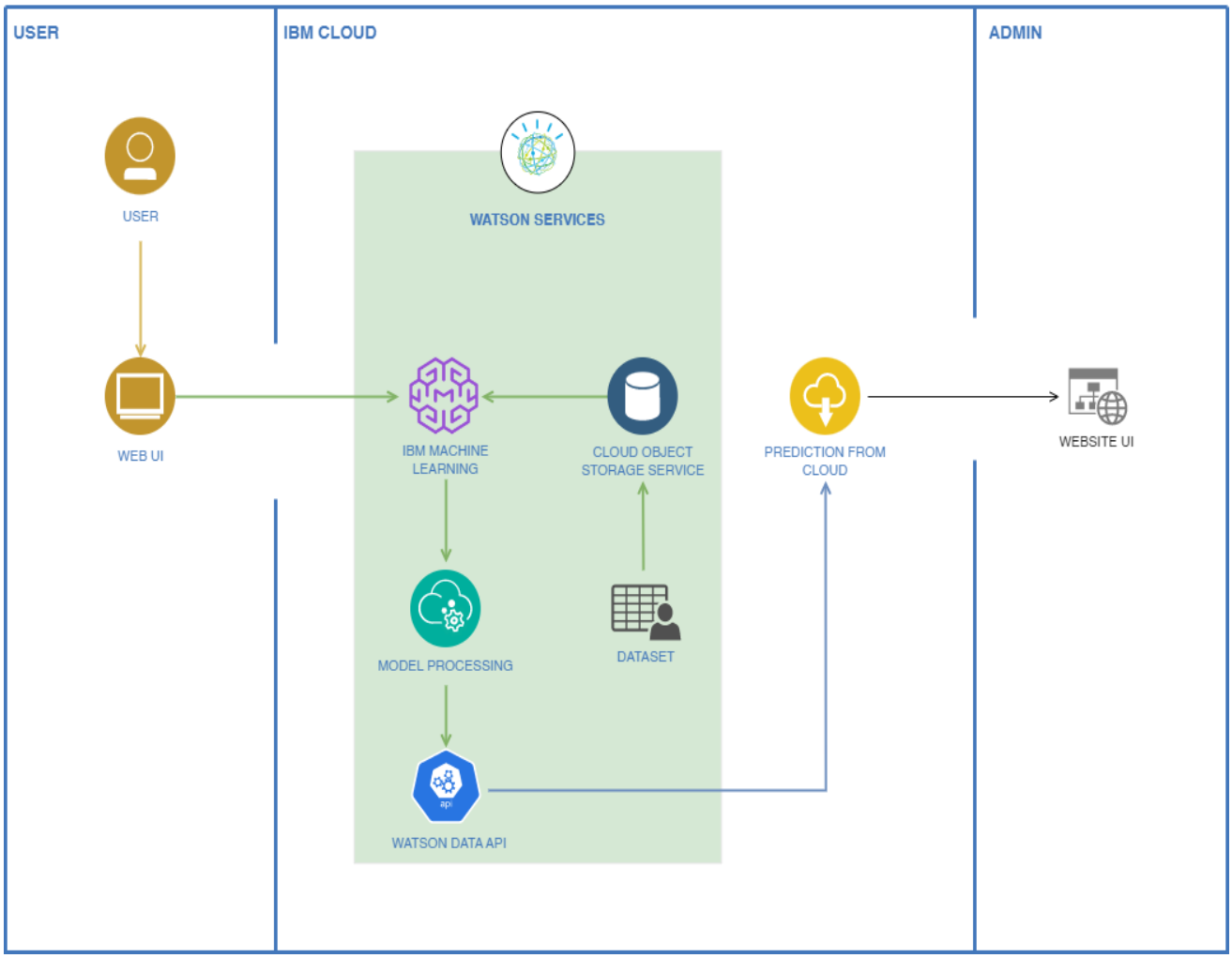
7.2 Sprint Delivery Schedule

- Sprint 1
- Sprint 2
- Sprint 3
- Sprint 4

We are Developing the code in this Schedule

8. SCHEMATIC DIAGRAM OF PROJECT & COMPONENTS:

8.1 Technical Architecture



8.2 Components Used

S. No	Component	Description	Technology
1.	User Interface	The User interacts via a web UI	HTML, CSS, JavaScript
2.	Application Logic-1	Running the web server and UI forwebsite	Flask, Python
3.	Application Logic-2	Running the Machine Learning Model	IBM Watson Studio, Machine Learning
4.	Application Logic-3	Logic for a process in the application	IBM Watson Assistant
5.	Cloud Database	Database Service on Cloud	IBM DB2, IBM Cloudantetc.
6.	File Storage	Storage for storing Dataset	Cloud object storage service
7.	Internal API	API Used for getting the predicted datafrom machine learning model in watson	Watson Data API
8.	Machine Learning Model	Machine Learning Model for predicting Aircraft Engine Failure	Object Recognition Model, etc.
9.	Infrastructure (Server / Cloud)	Application Deployment on CloudCloud Server Configuration: Intel Xeon E3-1270 v64 Cores, 3.80 GHz 16 GB RAM 1 x 1 TB HDD CentOS 20 TB bandwidth*	Web hosting on IBM Cloud

Application Characteristics

S.NO	Characteristics	Description	Technology
1.	Open-Source Frameworks	List the open-source frameworks used	Python, GIt, Github, Keras,Tensorflow, Jupyter Notebooks
2.	Security Implementations	In the web server created by the teamwill be secure and when deployed on cloud the cloud security will cover the web app	HTTPS, IBM Cloud WebHosting
3.	Scalable Architecture	This is a 3 Tier Architecture	IBM Watson Studio, Python,Flask
4.	Availability	Taken care by the cloud provider, availability required is high	IBM Cloud Load Balancers, Multiple Data Servers
5.	Performance	High performance rate is required toprovide accurate predictions	Watson Machine Learningon Cloud Pak

9. CONCLUSION

Engine failure is highly risky and needs a lot of time for repair. Unexpected failure leads to loss of money and time. Predicting the failure prior will save time, effort, money and sometimes even lives. The failure can be detected by installing the sensors and keeping a track of the values. The main objective of predictive maintenance is to predict when equipment failures can occur. Then prevent that failure by taking relevant actions.

10. FUTURE SCOPE

By reducing the likelihood of a serious engine failure and the need for the pilot to shut down an engine during flight with all the potential emergency ramifications that can result, the ability to detect an impending failure in an aircraft engine mechanical power system at an early stage, where expensive and potentially catastrophic system failures can be prevented, will improve aircraft safety. Various other algorithms can be used to predict the aircraft engine failure more accurately and prevent this failure before it happens.

11. APPENDIX

Source Code:

```
import pandas as pd
import numpy as np
from sklearn.preprocessing import MinMaxScaler
from sklearn.metrics import confusion_matrix,accuracy_score
import matplotlib.pyplot as plt
plt.style.use("ggplot")
%matplotlib inline
import os, types
import pandas as pd
from botocore.client import Config
import ibm_boto3

def __iter__(self): return 0

# @hidden_cell
# The following code accesses a file in your IBM Cloud Object Storage. It includes your credentials.
# You might want to remove those credentials before you share the notebook.
cos_client = ibm_boto3.client(service_name='s3',
    ibm_api_key_id='H95mJxwqMx9yvfdsQ7cPTV8-CxJWwLTNvO0gxBASZLid',
```

```
    ibm_auth_endpoint="https://iam.cloud.ibm.com/oidc/token",
    config=Config(signature_version='oauth'),
    endpoint_url='https://s3.private.us.cloud-object-storage.appdomain.cloud')

bucket = 'ibmpredictiveanalyticsforaircraft-donotdelete-pr-rmnlchqvrumk01'
object_key = 'PM_train.xlsx'

body = cos_client.get_object(Bucket=bucket,Key=object_key)['Body']

df_train = pd.read_excel(body.read())
df_train.head()
df_train.shape
df_train.isnull().any()
import os, types
import pandas as pd
from botocore.client import Config
import ibm_boto3

def __iter__(self): return 0

# @hidden_cell
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    ibm_auth_endpoint="https://iam.cloud.ibm.com/oidc/token",
    config=Config(signature_version='oauth'),
    endpoint_url='https://s3.private.us.cloud-object-storage.appdomain.cloud')

bucket = 'ibmpredictiveanalyticsforaircraft-donotdelete-pr-rmnlchqvrumk01'
object_key = 'PM_test.xlsx'

body = cos_client.get_object(Bucket=bucket,Key=object_key)['Body']

df_test = pd.read_excel(body.read())
df_test.head()
df_test.isnull().sum()
import os, types
import pandas as pd
from botocore.client import Config
import ibm_boto3

def __iter__(self): return 0

# @hidden_cell
# The following code accesses a file in your IBM Cloud Object Storage. It includes your credentials.
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cos_client = ibm_boto3.client(service_name='s3',
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    ibm_api_key_id='H95mJxwqMx9yvfdsQ7cPTV8-CxJWwLTNvO0gxBASZLid',
    ibm_auth_endpoint="https://iam.cloud.ibm.com/oidc/token",
    config=Config(signature_version='oauth'),
    endpoint_url='https://s3.private.us.cloud-object-storage.appdomain.cloud')

bucket = 'ibmpredictiveanalyticsforaircraft-donotdelete-pr-rmnlchqvrumk01'
object_key = 'PM_truth.xlsx'

body = cos_client.get_object(Bucket=bucket,Key=object_key)['Body']

df_truth = pd.read_excel(body.read())
df_truth.head()
df_truth.isnull().any()
dp=pd.DataFrame(df_test.groupby('id')['cycle'].max()).reset_index()
dp.columns=['id','max']
dp
df_truth['rtf']=df_truth['more']+dp['max']
df_truth
df_truth.drop("more",axis="columns",inplace=True)
df_truth
df_test=df_test.merge(df_truth,on=['id'],how='left')
df_test["ttf"]=df_test['rtf']-df_test['cycle']
df_test.drop("rtf",axis="columns",inplace=True)
df_test
df_train['ttf']=df_train.groupby(['id'])['cycle'].transform(max)-df_train['cycle']
df_train
period=30
df_train['label_bc']=df_train['ttf'].apply(lambda x: 1 if x <= period else 0)
df_test['label_bc']=df_test['ttf'].apply(lambda x: 1 if x <= period else 0)
df_train
df_test
x_train=df_train.iloc[:,:-1].values
y_train=df_train.iloc[:,-1:].values
from sklearn.model_selection import train_test_split as tts
x_train,x_test,y_train,y_test=tts(x_train,y_train,test_size=0.2,random_state=0)
from sklearn.linear_model import LogisticRegression
model_lr=LogisticRegression()
model_lr.fit(x_train,y_train)
y_predlog=model_lr.predict(x_test)
from sklearn.metrics import accuracy_score as acs
acs(y_test,y_predlog)
from sklearn.metrics import confusion_matrix as cm
cm(y_test,y_predlog)
from sklearn.ensemble import RandomForestClassifier
model_rf=RandomForestClassifier(n_estimators=5000, criterion='gini', max_depth=None,
min_samples_split=3,
                        min_samples_leaf=1, min_weight_fraction_leaf=0.0, max_features='sqrt',
```

```
                    max_leaf_nodes=None, min_impurity_decrease=0.0, bootstrap=True,
oob_score=False,
                    n_jobs=None, random_state=None, verbose=0, warm_start=False,
class_weight=None,
                    ccp_alpha=0.0, max_samples=None)
model_rf.fit(x_train,y_train)
RandomForestClassifier(max_features='sqrt', min_samples_split=3,
                       n_estimators=5000)
y1_predlog=model2.predict(x_test)
acs(y_test,y1_predlog)
from ibm_watson_machine_learning import APIClient
wml_credentials={
   "url":"https://us-south.ml.cloud.ibm.com",
   "apikey" :"gDD09sX6I55MvqO0c92YsKLieC7VDgMLCKK1MbCuTii0"
}
client=APIClient(wml_credentials)
def guid_from_space_name(client, space_name):
   space = client.spaces.get_details()
   return(next(item for item in space['resources'] if item ['entity']['name'] ==
space_name)['metadata']['id'])
space_uid = guid_from_space_name (client, 'cloud_model_space')
print("Space UID ="+ space_uid)
client.set.default_space(space_uid)
client.software_specifications.list()
software_spec_uid = client.software_specifications.get_uid_by_name("runtime-22.1-py3.9")
software_spec_uid
model_details = client.repository.store_model(model=model_lr,meta_props ={
   client.repository.ModelMetaNames.NAME:"engine_model",
   client.repository.ModelMetaNames.TYPE:"scikit-learn_1.0",
   client.repository.ModelMetaNames.SOFTWARE_SPEC_UID:software_spec_uid

})
model_id=client.repository.get_model_id(model_details)
model_id
x_train[0]
model_lr.predict([[ 2.70000e+01,  1.08000e+02, -4.80000e-03,  0.00000e+00,
       1.00000e+02,  5.18670e+02,  6.42500e+02,  1.58658e+03,
       1.41020e+03,  1.46200e+01,  2.16100e+01,  5.53290e+02,
       2.38810e+03,  9.07818e+03,  1.30000e+00,  4.74700e+01,
       5.21280e+02,  2.38810e+03,  8.15268e+03,  8.44090e+00,
       3.00000e-02,  3.94000e+02,  2.38800e+03,  1.00000e+02,
       3.87300e+01,  2.33405e+01,  4.80000e+01]])
```

App.py:

```
from flask import Flask, render_template, request
from model_cloud import cloud_model
```

```
app = Flask(__name__)

@app.route('/')
def load():
    return render_template('Manual_predict.html')

@app.route('/result',methods=['POST'])
def result():
    pred_vals = [float(x) for x in request.form.values()]
    print(pred_vals)
    pred = cloud_model(pred_vals)
    if(pred==0):
        pred_text = "No failure expected within 30 days"
        return render_template('Prediction_no_failure.html',prediction_text_no_failure =
pred_text)
    else:
        pred_text = "Maintenance Required! Expected a failure within 30 days"
        return render_template('Prediction_failure.html',prediction_text_failure = pred_text)

if __name__== '__main__':
    app.run(debug=True,port=3000)
```

model_cloud.py

```
import requests

def cloud_model(data):
    # NOTE: you must manually set API_KEY below using information retrieved from your
IBM Cloud account.
    API_KEY = "gDD09sX6I55MvqO0c92YsKLieC7VDgMLCKK1MbCuTii0"
    token_response = requests.post('https://iam.cloud.ibm.com/identity/token', data={"apikey":
    API_KEY, "grant_type": 'urn:ibm:params:oauth:grant-type:apikey'})
    mltoken = token_response.json()["access_token"]

    header = {'Content-Type': 'application/json', 'Authorization': 'Bearer ' + mltoken}

    # NOTE: manually define and pass the array(s) of values to be scored in the next line
    payload_scoring = {"input_data": [{"field":
['id','cycle','setting1','setting2','setting3','s1','s2','s3','s4','s5',
                                        's6','s7','s8','s9','s10','s11','s12','s13','s14','s15','s16','s17','s18',
                                        's19','s20','s21','ttf'], "values": [data]}]}

    response_scoring = requests.post('https://us-
south.ml.cloud.ibm.com/ml/v4/deployments/ibmclouddep/predictions?version=2022-11-19',
json=payload_scoring,
    headers={'Authorization': 'Bearer ' + mltoken})
    prediction_val = response_scoring.json()
    return prediction_val['predictions'][0]['values'][0][0]
```

```
predict_val = [ 2.70000e+01,  1.08000e+02, -4.80000e-03,  0.00000e+00,
       1.00000e+02,  5.18670e+02,  6.42500e+02,  1.58658e+03,
       1.41020e+03,  1.46200e+01,  2.16100e+01,  5.53290e+02,
       2.38810e+03,  9.07818e+03,  1.30000e+00,  4.74700e+01,
       5.21280e+02,  2.38810e+03,  8.15268e+03,  8.44090e+00,
       3.00000e-02,  3.94000e+02,  2.38800e+03,  1.00000e+02,
       3.87300e+01,  2.33405e+01,  4.80000e+01]
```

Templates:

Manual_predict.html

```
<!DOCTYPE html>
<html lang="en">

<head>
  <meta charset="UTF-8">
  <meta http-equiv="X-UA-Compatible" content="IE=edge">
  <meta name="viewport" content="width=device-width, initial-scale=1.0">
  <title>Engine Failure Prediction</title>
  <link href="https://cdn.jsdelivr.net/npm/bootstrap@5.2.0/dist/css/bootstrap.min.css"
rel="stylesheet" integrity="sha384-
gH2yIJqKdNHPEq0n4Mqa/HGKIhSkIHeL5AyhkYV8i59U5AR6csBvApHHNl/vI1Bx"
crossorigin="anonymous">
  <link rel="stylesheet" type="text/css" href="{{ url_for('static',filename='style.css')}}">
  <link rel="shortcut icon" href="{{ url_for('static', filename='favicon32.png') }}">
  <link rel="preconnect" href="https://fonts.googleapis.com">
  <link rel="preconnect" href="https://fonts.gstatic.com" crossorigin>
  <link
href="https://fonts.googleapis.com/css2?family=Open+Sans:wght@500&display=swap"
rel="stylesheet">
  <link href="https://fonts.googleapis.com/css2?family=IBM+Plex+Sans&display=swap"
rel="stylesheet">
</head>

<body>

  <div id="hero">
    <div class="top">
      <h2 class="h">Machine Learning-Based Predictive Analytics for Aircraft Engine</h2>
    </div>
  </div>
  <div class="td">
    <div class="row r1">
      <div class="col-sm-6 r1c1">
        <p class="tdh">Team Details :</p>
        <p>Team ID : PNT2022TMID21701</p>
```

```
        <p>Team Leader : S.Sakthivel</p>
        <p>Team Members : Ayaan Gouse</p>
        <p class="ms">M.Sasitharan</p>
        <p class="mb">M.Bhupesh</p>
        <p class="con">Context :</p>
        <p class="context">Engine failure is highly risky and needs a lot of time for repair. Unexpected failure leads to loss of money and time. Predicting the failure prior will save time, effort, money and sometimes even lives. The failure can be
          detected by installing the sensors and keeping a track of the values. The failure detection and predictive maintenance can be for any device, out of which we will be dealing with the engine failure for a threshold number of days.
          The project aims to predict the failure of an engine by using Machine Learning to save loss of time & money thus improving productivity.</p>
      </div>
      <div class="col-sm-6 r1c2">
        <p class="ta">Technical Architecture :</p>
        <img src="{{url_for('static',filename='img1.jpg')}}" class="img1">
      </div>
    </div>
  </div>
  <div class="formd row">
    <div class="col-md-3"></div>
    <div class="col-md-6" style="text-align: center;">
      <form action="result" method="post">
        <h5 class="eep">Enter Engine Parameters</h5>
        <div class="row text-center">
          <div class="col-md-4">
            <div class="mb-3" style="color: white;">
              <input name="id" step="any" type="number" class="form-control" id="id" placeholder="Engine ID">
            </div>
            <div class="mb-3" style="color: white;">
              <input name="cycle" step="any" type="number" class="form-control" id="cycle" placeholder="Cycle">
            </div>
            <div class="mb-3" style="color: white;">
              <input name="set1" step="any" type="number" class="form-control" id="set1" placeholder="Setting 1">
            </div>
            <div class="mb-3" style="color: white;">
              <input name="set2" step="any" type="number" class="form-control" id="set2" placeholder="Setting 2">
            </div>
            <div class="mb-3" style="color: white;">
              <input name="set3" step="any" type="number" class="form-control" id="set3" placeholder="Setting 3">
            </div>
            <div class="mb-3" style="color: white;">
              <input name="s1" step="any" type="number" class="form-control" id="s1" placeholder="S1">
```

```
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s2" step="any" type="number" class="form-control" id="s2"
placeholder="S2">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s3" step="any" type="number" class="form-control" id="s3"
placeholder="S3">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s4" step="any" type="number" class="form-control" id="s4"
placeholder="S4">
          </div>
        </div>
        <div class="col-md-4">
          <div class="mb-3" style="color: white;">
            <input name="s5" step="any" type="number" class="form-control" id="s5"
placeholder="S5">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s6" step="any" type="number" class="form-control" id="s6"
placeholder="S6">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s7" step="any" type="number" class="form-control" id="s7"
placeholder="S7">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s8" step="any" type="number" class="form-control" id="s8"
placeholder="S8">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s9" step="any" type="number" class="form-control" id="s9"
placeholder="S9">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s10" step="any" type="number" class="form-control" id="s10"
placeholder="S10">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s11" step="any" type="number" class="form-control" id="s11"
placeholder="S11">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s12" step="any" type="number" class="form-control" id="s12"
placeholder="S12">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s13" step="any" type="number" class="form-control" id="s13"
placeholder="S13">
```

```
          </div>
        </div>
        <div class="col-md-4">
          <div class="mb-3" style="color: white;">
            <input name="s14" step="any" type="number" class="form-control" id="s14"
placeholder="S14">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s15" step="any" type="number" class="form-control" id="s15"
placeholder="S15">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s16" step="any" type="number" class="form-control" id="s16"
placeholder="S16">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s17" step="any" type="number" class="form-control" id="s17"
placeholder="S17">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s18" step="any" type="number" class="form-control" id="s18"
placeholder="S18">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s19" step="any" type="number" class="form-control" id="s19"
placeholder="S19">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s20" step="any" type="number" class="form-control" id="s20"
placeholder="S20">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s21" step="any" type="number" class="form-control" id="s21"
placeholder="S21">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="ttf" step="any" type="number" class="form-control" id="ttf"
placeholder="ttf">
          </div>
        </div>
      </div>
      <center> <input type="submit" class="btn btn-dark" value="Evaluate" /></center>
    </form>
  </div>
  <div class="col-md-3"></div>
 </div>
 <div class="footer">
  <a href="https://github.com/IBM-EPBL/IBM-Project-11180-1659275121"
target="_blank"><img src="{{url_for('static',filename='fimg1.png')}}" class="fimg1"></a>
```

```
    <a href="mailto:sakthii6@outlook.com"  target="_blank"><img
src="{{url_for('static',filename='fimg2.png')}}" class="fimg2"></a>
  </div>
</body>
</html>
```

Prediction_failure:

```
<!DOCTYPE html>
<html lang="en">

<head>
  <meta charset="UTF-8">
  <meta http-equiv="X-UA-Compatible" content="IE=edge">
  <meta name="viewport" content="width=device-width, initial-scale=1.0">
  <title>Engine Failure Prediction</title>
  <link href="https://cdn.jsdelivr.net/npm/bootstrap@5.2.0/dist/css/bootstrap.min.css"
rel="stylesheet" integrity="sha384-
gH2yIJqKdNHPEq0n4Mqa/HGKIhSkIHeL5AyhkYV8i59U5AR6csBvApHHNl/vI1Bx"
crossorigin="anonymous">
  <link rel="stylesheet" type="text/css" href="{{ url_for('static',filename='style.css')}}">
  <link rel="shortcut icon" href="{{ url_for('static', filename='favicon32.png') }}">
  <link rel="preconnect" href="https://fonts.googleapis.com">
  <link rel="preconnect" href="https://fonts.gstatic.com" crossorigin>
  <link
href="https://fonts.googleapis.com/css2?family=Open+Sans:wght@500&display=swap"
rel="stylesheet">
  <link href="https://fonts.googleapis.com/css2?family=IBM+Plex+Sans&display=swap"
rel="stylesheet">
</head>

<body>

  <div id="hero">
    <div class="top">
      <h2 class="h">Machine Learning-Based Predictive Analytics for Aircraft Engine</h2>
    </div>
  </div>
  <div class="pred-text-failure">{{prediction_text_failure}}</div>
  <div class="formd row">
    <div class="col-md-3"></div>
    <div class="col-md-6" style="text-align: center;">
      <form action="result" method="post">
        <h5 class="eep">Enter Engine Parameters</h5>
        <div class="row text-center">
          <div class="col-md-4">
            <div class="mb-3" style="color: white;">
              <input name="id" step="any" type="number" class="form-control" id="id"
placeholder="Engine ID">
            </div>
```

```
          <div class="mb-3" style="color: white;">
            <input name="cycle" step="any" type="number" class="form-control" id="cycle"
placeholder="Cycle">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="set1" step="any" type="number" class="form-control" id="set1"
placeholder="Setting 1">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="set2" step="any" type="number" class="form-control" id="set2"
placeholder="Setting 2">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="set3" step="any" type="number" class="form-control" id="set3"
placeholder="Setting 3">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s1" step="any" type="number" class="form-control" id="s1"
placeholder="S1">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s2" step="any" type="number" class="form-control" id="s2"
placeholder="S2">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s3" step="any" type="number" class="form-control" id="s3"
placeholder="S3">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s4" step="any" type="number" class="form-control" id="s4"
placeholder="S4">
          </div>
        </div>
        <div class="col-md-4">
          <div class="mb-3" style="color: white;">
            <input name="s5" step="any" type="number" class="form-control" id="s5"
placeholder="S5">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s6" step="any" type="number" class="form-control" id="s6"
placeholder="S6">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s7" step="any" type="number" class="form-control" id="s7"
placeholder="S7">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s8" step="any" type="number" class="form-control" id="s8"
placeholder="S8">
          </div>
```

```
          <div class="mb-3" style="color: white;">
            <input name="s9" step="any" type="number" class="form-control" id="s9"
placeholder="S9">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s10" step="any" type="number" class="form-control" id="s10"
placeholder="S10">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s11" step="any" type="number" class="form-control" id="s11"
placeholder="S11">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s12" step="any" type="number" class="form-control" id="s12"
placeholder="S12">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s13" step="any" type="number" class="form-control" id="s13"
placeholder="S13">
          </div>
        </div>
        <div class="col-md-4">
          <div class="mb-3" style="color: white;">
            <input name="s14" step="any" type="number" class="form-control" id="s14"
placeholder="S14">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s15" step="any" type="number" class="form-control" id="s15"
placeholder="S15">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s16" step="any" type="number" class="form-control" id="s16"
placeholder="S16">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s17" step="any" type="number" class="form-control" id="s17"
placeholder="S17">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s18" step="any" type="number" class="form-control" id="s18"
placeholder="S18">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s19" step="any" type="number" class="form-control" id="s19"
placeholder="S19">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s20" step="any" type="number" class="form-control" id="s20"
placeholder="S20">
          </div>
```

```
          <div class="mb-3" style="color: white;">
            <input name="s21" step="any" type="number" class="form-control" id="s21"
placeholder="S21">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="ttf" step="any" type="number" class="form-control" id="ttf"
placeholder="ttf">
          </div>
        </div>
      </div>
      <center> <input type="submit" class="btn btn-dark" value="Evaluate" /></center>
    </form>
   </div>
   <div class="col-md-3"></div>
  </div>
  <div class="footer">
   <a href="https://github.com/IBM-EPBL/IBM-Project-11180-1659275121"
target="_blank"><img src="{{url_for('static',filename='fimg1.png')}}" class="fimg1"></a>
   <a href="mailto:sakthii6@outlook.com"  target="_blank"><img
src="{{url_for('static',filename='fimg2.png')}}" class="fimg2"></a>
  </div>
</body>
</html>
```

Prediction_no_failure.html

```
<!DOCTYPE html>
<html lang="en">

<head>
  <meta charset="UTF-8">
  <meta http-equiv="X-UA-Compatible" content="IE=edge">
  <meta name="viewport" content="width=device-width, initial-scale=1.0">
  <title>Engine Failure Prediction</title>
  <link href="https://cdn.jsdelivr.net/npm/bootstrap@5.2.0/dist/css/bootstrap.min.css"
rel="stylesheet" integrity="sha384-
gH2yIJqKdNHPEq0n4Mqa/HGKIhSkIHeL5AyhkYV8i59U5AR6csBvApHHNl/vI1Bx"
crossorigin="anonymous">
  <link rel="stylesheet" type="text/css" href="{{ url_for('static',filename='style.css')}}">
  <link rel="shortcut icon" href="{{ url_for('static', filename='favicon32.png') }}">
  <link rel="preconnect" href="https://fonts.googleapis.com">
  <link rel="preconnect" href="https://fonts.gstatic.com" crossorigin>
  <link
href="https://fonts.googleapis.com/css2?family=Open+Sans:wght@500&display=swap"
rel="stylesheet">
  <link href="https://fonts.googleapis.com/css2?family=IBM+Plex+Sans&display=swap"
rel="stylesheet">
</head>

<body>
```

```
  <div id="hero">
    <div class="top">
      <h2 class="h">Machine Learning-Based Predictive Analytics for Aircraft Engine</h2>
    </div>
  </div>
  <div class="pred-text-no-failure">{{prediction_text_no_failure}}</div>
  <div class="formd row">
    <div class="col-md-3"></div>
    <div class="col-md-6" style="text-align: center;">
      <form action="result" method="post">
        <h5 class="eep">Enter Engine Parameters</h5>
        <div class="row text-center">
          <div class="col-md-4">
            <div class="mb-3" style="color: white;">
              <input name="id" step="any" type="number" class="form-control" id="id"
placeholder="Engine ID">
            </div>
            <div class="mb-3" style="color: white;">
              <input name="cycle" step="any" type="number" class="form-control" id="cycle"
placeholder="Cycle">
            </div>
            <div class="mb-3" style="color: white;">
              <input name="set1" step="any" type="number" class="form-control" id="set1"
placeholder="Setting 1">
            </div>
            <div class="mb-3" style="color: white;">
              <input name="set2" step="any" type="number" class="form-control" id="set2"
placeholder="Setting 2">
            </div>
            <div class="mb-3" style="color: white;">
              <input name="set3" step="any" type="number" class="form-control" id="set3"
placeholder="Setting 3">
            </div>
            <div class="mb-3" style="color: white;">
              <input name="s1" step="any" type="number" class="form-control" id="s1"
placeholder="S1">
            </div>
            <div class="mb-3" style="color: white;">
              <input name="s2" step="any" type="number" class="form-control" id="s2"
placeholder="S2">
            </div>
            <div class="mb-3" style="color: white;">
              <input name="s3" step="any" type="number" class="form-control" id="s3"
placeholder="S3">
            </div>
            <div class="mb-3" style="color: white;">
              <input name="s4" step="any" type="number" class="form-control" id="s4"
placeholder="S4">
            </div>
```

```
        </div>
        <div class="col-md-4">
          <div class="mb-3" style="color: white;">
            <input name="s5" step="any" type="number" class="form-control" id="s5"
placeholder="S5">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s6" step="any" type="number" class="form-control" id="s6"
placeholder="S6">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s7" step="any" type="number" class="form-control" id="s7"
placeholder="S7">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s8" step="any" type="number" class="form-control" id="s8"
placeholder="S8">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s9" step="any" type="number" class="form-control" id="s9"
placeholder="S9">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s10" step="any" type="number" class="form-control" id="s10"
placeholder="S10">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s11" step="any" type="number" class="form-control" id="s11"
placeholder="S11">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s12" step="any" type="number" class="form-control" id="s12"
placeholder="S12">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s13" step="any" type="number" class="form-control" id="s13"
placeholder="S13">
          </div>
        </div>
        <div class="col-md-4">
          <div class="mb-3" style="color: white;">
            <input name="s14" step="any" type="number" class="form-control" id="s14"
placeholder="S14">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s15" step="any" type="number" class="form-control" id="s15"
placeholder="S15">
          </div>
          <div class="mb-3" style="color: white;">
```

```
            <input name="s16" step="any" type="number" class="form-control" id="s16"
placeholder="S16">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s17" step="any" type="number" class="form-control" id="s17"
placeholder="S17">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s18" step="any" type="number" class="form-control" id="s18"
placeholder="S18">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s19" step="any" type="number" class="form-control" id="s19"
placeholder="S19">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s20" step="any" type="number" class="form-control" id="s20"
placeholder="S20">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="s21" step="any" type="number" class="form-control" id="s21"
placeholder="S21">
          </div>
          <div class="mb-3" style="color: white;">
            <input name="ttf" step="any" type="number" class="form-control" id="ttf"
placeholder="ttf">
          </div>
        </div>
      </div>
      <center> <input type="submit" class="btn btn-dark" value="Evaluate" /></center>
    </form>
  </div>
  <div class="col-md-3"></div>
 </div>
 <div class="footer">
  <a href="https://github.com/IBM-EPBL/IBM-Project-11180-1659275121"
target="_blank"><img src="{{url_for('static',filename='fimg1.png')}}" class="fimg1"></a>
  <a href="mailto:sakthii6@outlook.com"  target="_blank"><img
src="{{url_for('static',filename='fimg2.png')}}" class="fimg2"></a>
 </div>
</body>
</html>
```

GitHub Repo Link:

https://github.com/IBM-EPBL/IBM-Project-11180-1659275121