GOVERNMENT COLLEGE OF ENGINEERING(**Formerly IRTT**)
ERODE-638 316

BONAFIDE CERTIFICATE

Certified that this project titled **"MACHINE LEARNING BASED PREDICTIVE ANALYTICS FOR AIR CRAFT ENGINE"**in domain of**"APPLIED DATASCIENCE"**is the bonafide work of **"BALAMURUGAN(731119106003),KIRUBAKARANS(731119106015),RAJAGANAPATHI(731119106026),SATHISH P (731119106030)**who carried out the project work under my supervision.

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CHAPTER 1:

INTRODUCTION

1.1 Project Overview:

Big data and artificial intelligence/machine learning are transforming the global business environment. Data is now the most valuable asset for enterprises in every industry. Companies are using data-driven insights for competitive advantage. With that, the adoption of machine learning-based data analytics is rapidly taking hold across various industries, producing autonomous systems that support humandecision-making.

The capacity of machinery working cannot last forever, sometimes it will be broken-down because of out-date operation. Machinery system that included sensors are just monitoring state of the machine, but cannot make a report the machine in good or bad condition. To avoid the worse event (failure) and to get information about status of a machine, maintenance strategy must apply on machinery system that scheduled. There are three best practice of maintenance strategy Corrective, Preventive, and Predictive Maintenance.

This work explored the application of machine learning to aircraft engine conceptual design. Supervised machine-learning algorithms for regression and classification were employed to study patterns in an existing, open-source database of production and research turbofan engines, and resulting in predictive analytics for use in predicting performance of new turbofan designs. The predictive analytics were trained and deployed in Keras, an open-source neural networks application program interface (API) written in Python, with Google's TensorFlow (an open source library for numerical computation) serving as the backend engine.

1.2 purpose:

This project aims to prove that Machine Learning (ML) methods are effective for Predictive Maintenance (PdM) and to obtain other developing methods that suitable applied on PdM, especially for aircraft engine, and potential method that can apply on future research .

Maintenance factors are important to prognostic the states of a machine. PdM is one of the factor strategies based on realtime data to diagnosis a failure of the machine through forecasting remaining useful life (RUL), 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. Applied ML on PdM is the huge contribution for saving cost and human life guarantee of safety. This work provides the literature survey for recent research which trends and challenges on PdM of aircraft engine using ML.

CHAPTER 2:

LITERATURE SURVEY

2.1Existing problem :

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. Any equipment can have predictive maintenance and failure detection, but we'll be dealing with engine failure for a predetermined period of days.Aircraft engines suffer failure of components very frequently. Sometimes, these failures can go overlooked resulting in catastrophic mid-air engine failures.

2.2 References:

1. Tong, M.T., “Using Machine Learning To Predict Core Sizes of High-Efficiency Turbofan Engines,” GT2019-91432, ASME Turbo-Expo 2019, June 17-21, 2019.
2. Daly, M., “Jane’s Aero-Engine,” 2017-2018.
3. Meier, N., “Civil turbojet/turbofan specifications.” http://www.jet-engine.net/civtfspec.html. Accessed August, 2018.
4. GE Aviation. https://www.geaviation.com/commercial
5. Pratt and Whitney. https://www.pw.utc.com/products-and-services/products/commercial-engines
6. Rolls Royce. https://www.rolls-royce.com/products-and-services/civil-aerospace
7. CFM International. https://www.cfmaeroengines.com/
8. International Civil Aviation Organization, “ICAO Aircraft Emissions Databank.” May, 2018
9. Guynn, M.D., Berton, J.J., Fisher, K.L., Haller, W.J., Tong, M., Thurman, D.R., “Engine Conceptual Study for an Advanced Single-Aisle Transport,” NASA/TM—2009-215784, August 2009.
10. Guynn, M.D., Berton, J.J., Fisher, K.L., Haller, W.J., Tong, M., Thurman, D.R., “Analysis of Turbofan Design Options for an Advanced Single-Aisle Transport Aircraft,” AIAA 2009-6942, September 2009.
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12. Guynn, M.D., Berton, J.J., Tong, M.T., Haller, W.J., “Advanced Single-Aisle Transport Propulsion Design Options Revisited,” AIAA 2013-4330, August 2013.
13. Nickol, C.L. and Haller W.J., “Assessment of the Performance Potential of Advanced Subsonic Transport Concepts for NASA’s Environmentally Responsible Aviation Project,” AIAA 2016-1030, January 2016.

14. Collier, F., Thomas, R., Burley, C., Nickol, C., Lee, C.M., Tong, M., "Environmentally Responsible Aviation – Real Solutions for Environmental Challenges Facing Aviation," 27th International Congress of the Aeronautical Sciences, September, 2010

2.3 Problem Statement Definition:

1.Designed an ensemble of advanced analytics solutions that could predict when sub-systems of an aircraft engine will fail and align replacements with planned maintenance schedules

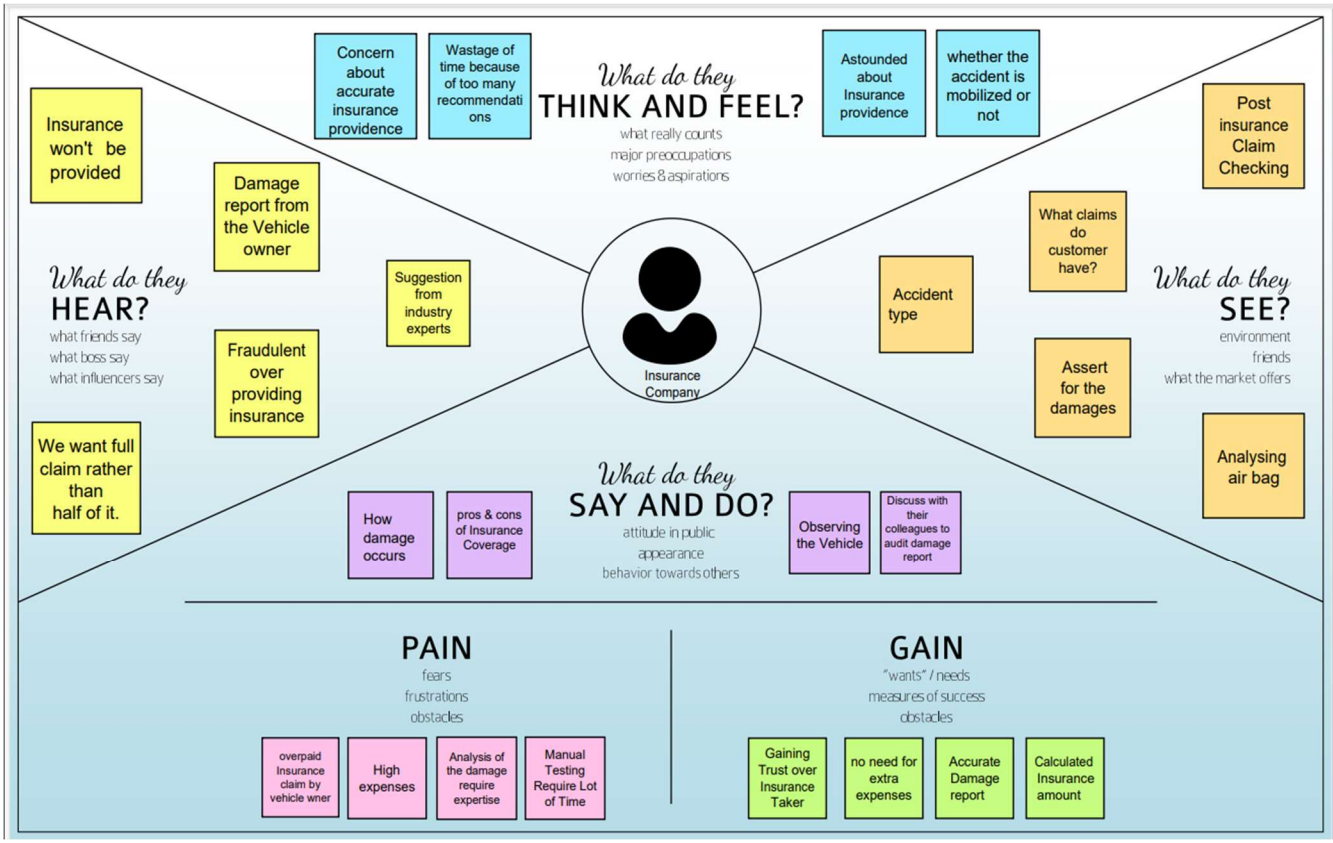
2.Used machine learning algorithms, which evaluate an engine's exception or repair history and operating or maintenance practices to predict the premature failure risk before preventive and planned maintenance

3.Created a predictive model to assess the relative performance of an engine rating—ranging from 100 (new) to 0 (failed) based upon engine risk categories—to help evaluate the estimated remaining life of the engine

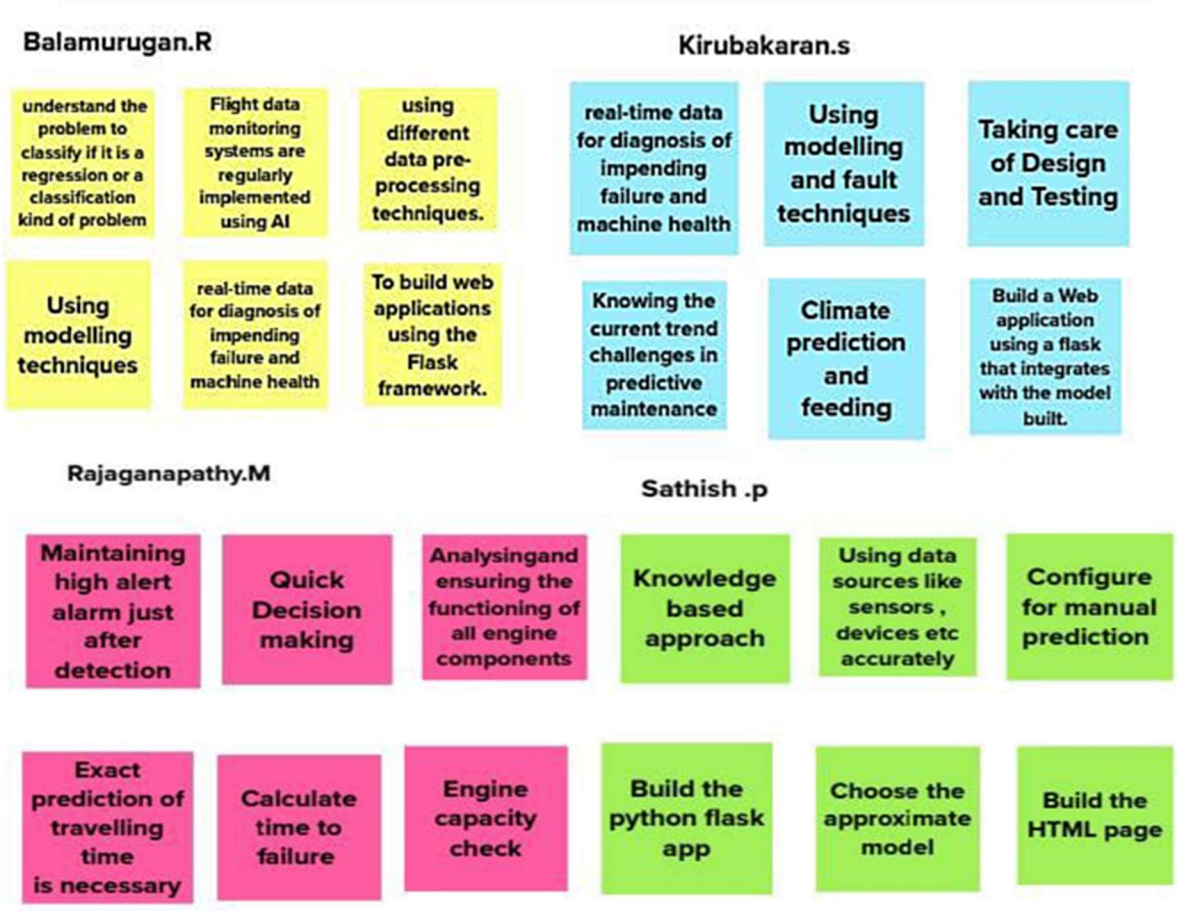
CHAPTER 3

IDEATION & PROPOSED SOLUTION

3.1 Empathy Map Canvas



3.2 Ideation & Brainstorming :



3.3 Proposed Solution

S.No	*PARAMETERS*	*DESCRIPTION*
1.	*Problem Statement*	*To predict the failure of an engine by using Machine Learning to save loss of time & money thus improving productivity.*

2.	*Idea / Solution description*	*Machine learning (ML) is a type of artificial intelligence (AI) that allows software applications to become more accurate at predicting outcomes without being explicitly programmed to do so.* *Structural failures where a broken connecting rod, crank, valve, or camshaft is present account for seventeen percent of engine failures occurs.*
3.	*Novelty / Uniqueness*	*An aircraft engine (or aero engine) is a propulsion system for an aircraft. >Aircraft engines are the key module or the heart in aviation progress.*
4.	*4 Social Impact / Customer Satisfaction*	*The advent of human flight not only boosted our power of movement and also Enhanced our vision.*
5.	*Business Model (Revenue Model)*	*The reliability analysis is also important to predict their scheduled maintenance event and the Remaining Useful Life (RUL) of engine parts.*
6.	*Scalability of the Solution*	*This app can help customers to get updates of the flight of any part of the flight.*

3.4 Problem Solution fit

1.CUSTOMER SEGMENTS *Customers are businessmen, student, tourist, traveler and all the people traveling in flight.*	*4.CUSTOMER LIMITATIONS* *Customers require accurate and early predictions of the flight engine failure. And they also look for an alternate solution.*	*5.AVAILABLE SOLUTIONS* *The reliability analysis of aircraft engines is essential for ensuring the smooth functioning of each component of an aircraft engine.*

2.PROBLEM *Engine failure occurs when a turbine engine unexpectedly stops producing power due to malfunction. This lead to a lot of customer dissatisfaction.*	*6PROBLEM ROOT / CAUSE* *The root cause of the problem is unforeseen & unpredictable engine failure that cause cancellations and arrival, departure delays.*	*7.BEHAVIOR* *The purpose of this research is to develop methods that can be used to generate reliable and timely alerts*
1. *TRIGGERS TO ACT* *To accurately predict the failure of an engine and track the flight.* 2. *EMOTIONS* *The aircraft engine failure occurs, passengers often get annoyed and frustrated. They also might lose to reach on time to some important occasions.*	*10. 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.*	*8.CHANNELS OF BEHAVIOR* *Check the engine regularly and maintained properly. And also check the fuel and oil levels regularly in the aircraft engine.*

CHAPTER 4

REQUIREMENT ANALYSIS

4.1 Functional requirement

● FR-1 User Registration ,Registration through Form Registration through Gmail Registration through LinkedIN

● FR-2 User Confirmation ,via Email Confirmation via OTP

● FR-3 Tracking Expense Helpful insights about money management

● FR-4 Alert Message Give alert mail if the amount exceeds the budget limit

● FR-5 Category This application shall allow users to add categories of their expenses

4.2 Non-Functional requirements

● NFR-1 Usability is a quality attribute that assesses how easy user interfaces are to use. The word "usability" also refers to methods for improving ease-of-use during the design process.

● NFR-2 Security consists of the platforms which protect your organization's users, endpoints and their online activity to more efficiently correlate threats. As users are increasingly logging in to networks via their personal devices, securing these is just as important as securing company owned devices.

● NFR-3 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 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 comprising performance requirements are often based on supporting end-user tasks.

● NFR-5 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.

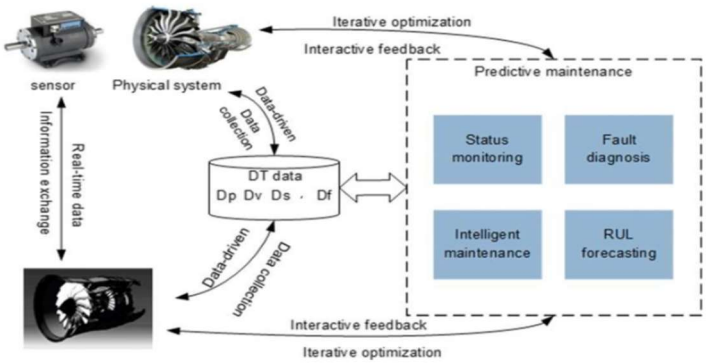
● NFR-6 Scalability Scalability requirements are, in essence, a reflection of the organization's ambition to grow and the need for a solution to support the growth with minimal changes and disruption to everyday activitie

CHAPTER 5

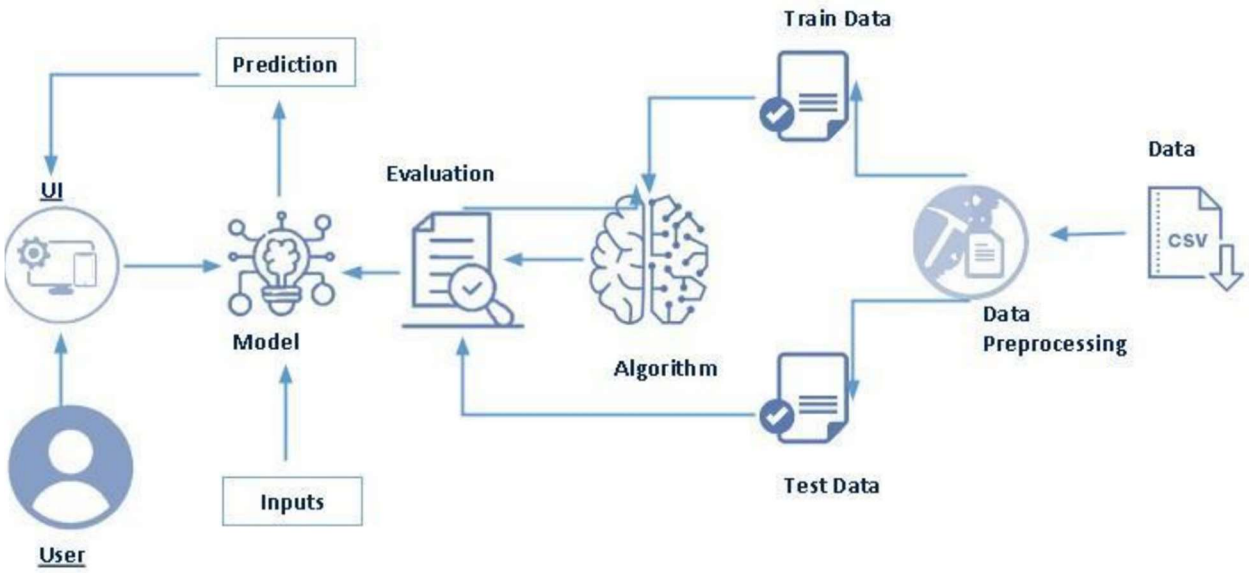
PROJECT DESIGN

5.1 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 store.



5.2 Solution & Technical Architecture



5.3 User Stories

User Type	Functional Requirement (Epic)	User StoryNumber	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	Low	Sprint-2

				dashboard with Facebook Login		
		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 StoryNumber	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	

CHAPTER 6

PROJECT PLANNING & SCHEDULING

6.1 Sprint Planning & Estimation

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Registration	USN-1	a user ,I can register for the support vector machine As algorithm tool using my email and password	7	High	Balamurugan R Sathish P
Sprint-1		USN-2	As a user, I will receive confirmation email on registering for the support vector machine algorithm tool	6	High	Kirubakaran S Rajaganapathi M
Sprint-4		USN-3	As a user, I can register for the application through my Gmail	6	Low	Balamurugan R Sathish P
Sprint-1	Login	USN-4	As a user, I can log into the application by entering my credentials	6	High	Kirubakaran S Rajaganapathi M
Sprint-3	Dashboard	USN-5	As a user, I can see my past records and activities	6	High	Balamurugan R Sathish P
Sprint-2		USN-6	As a user, I must enter my pre – engine aircraft test results	7	High	Kirubakaran S

						Rajaganapathi M

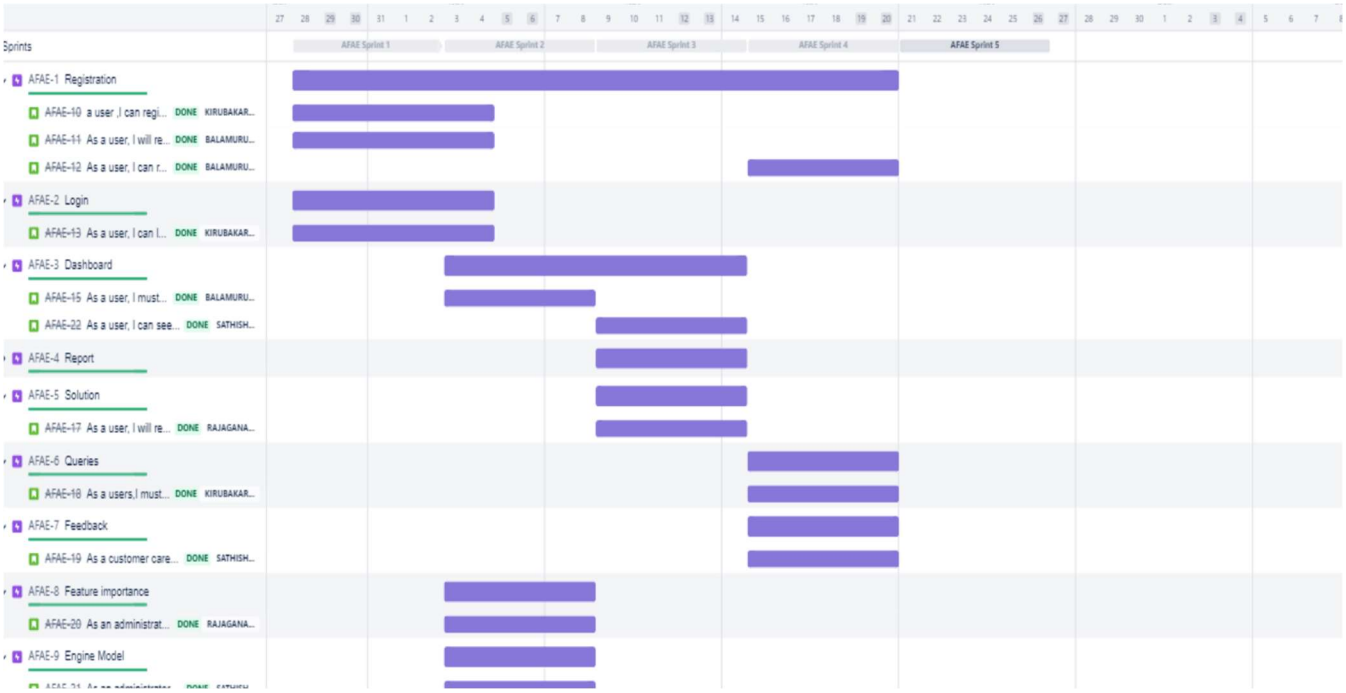
Sprint-3	Report	USN-7	As a user, I can view the report generated by the tool	7	High	Balamurugan R Sathish P
Sprint	**Functional Requirement (Epic)**	**User Story Number**	**User Story / Task**	**Story Points**	**Priority**	**Team Members**
Sprint-3	Solution	USN-8	As a user, I will receive reason to treat my engine	6	Medium	Kirubakaran S Rajaganapathi M
Sprint-4	Queries	USN-9	As a users,I must assists that face problems through Q&A	6	Low	Balamurugan R Sathish P
Sprint-4	Feedback	USN-10	As a customer care executive, I should get input for the tool's enhancement from users	7	Low	Kirubakaran S Rajaganapathi M
Sprint-2	Feature importance	USN-11	As an administrator, I should identify the most significant factors that lead to SVM based on the present trend	6	High	Balamurugan R Sathish P
Sprint-2	Engine Model	USN-12	As an administrator, I must use the most suitable ML model for detection of SVM	6	High	Kirubakaran S Rajaganapathi M

6.2 Sprint Delivery Schedule

Sprint	Total Story Points	Duration	Sprint Start Date	Sprint End Date (Planned)	Story Points	Sprint Release Date (Actual)

					Completed (as on Planned End Date)	
Sprint-1	20	6 Days	28 oct 2022	2 nov 2022	20	2 nov 2022
Sprint-2	20	6 Days	3 Nov 2022	08 Nov 2022	20	05 Nov 2022
Sprint-3	20	6 Days	09 Nov 2022	14 Nov 2022	20	12 Nov 2022
Sprint-4	20	6 Days	15Nov 2022	20 Nov 2022	20	19 Nov 2022

6.3 Reports from JIRA



CHAPTER 7

Coding and Solutioning

7.1 Feature 1

1: Trained Model Feature
2: Prediction Feature
3: Engine Feature

7.2 Feature 2

Analyze the data that gives as an input and predict it using the model trained in the IBM cloud. It let the users to know about the engine performance using the sensor values. Alerts if any performance fault is found in data.It helps to maintain the engine in a proper state.

codes:

app.py:

```
from flask import Flask, render_template, request
import numpy as np
import joblib
import random
import requests
import json
API_KEY = "lXz0XO1eh1nLZZLQ2m7wahlFW812sFxvI5d80PVEQAz9"
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}
app=Flask(_name_)
@app.route('/')
def index():
   return render_template('index.html')
@app.route('/y_predict', methods= ['POST'])
def  y_predict():
        l=[]
        l.append(float(request.form['id']))
        l.append(float(request.form['cycle']))
        l.append(float(request.form['setting1']))
        l.append(float(request.form['setting2']))
        l.append(float(request.form['setting3']))
        l.append(float(request.form['s1']))
        l.append(float(request.form['s2']))
        l.append(float(request.form['s3']))
        l.append(float(request.form['s4']))
        l.append(float(request.form['s5']))
```

```
        l.append(float(request.form['s6']))
        l.append(float(request.form['s7']))
        l.append(float(request.form['s8']))
        l.append(float(request.form['s9']))
        l.append(float(request.form['s10']))
        l.append(float(request.form['s11']))
        l.append(float(request.form['s12']))
        l.append(float(request.form['s13']))
        l.append(float(request.form['s14']))
        l.append(float(request.form['s15']))
        l.append(float(request.form['s16']))
        l.append(float(request.form['s17']))
        l.append(float(request.form['s18']))
        l.append(float(request.form['s19']))
        l.append(float(request.form['s20']))
        l.append(float(request.form['s21']))
        l.append(float(request.form['ttf']))
        print(l)
        # NOTE: manually define and pass the array(s) of values to be scored in the next
lpayload_scorin={"input_data":[{"field":['id','cycle','setting1','setting2','setting3','s1','s2','s3','s4','s5','s
6','s7','s8','s9','s10','s11','s12','s13','s14','s15','s16','s17','s18','s19','s20','s21','ttf'], "values"

response_scoring=requests.post('https://ussouth.ml.cloud.ibm.com/ml/v4/deployments/2d46
6513-0d23-4649-9345-753d51f7873d/predictions?version=2022-11-17', json=payload_scoring,
        headers={'Authorization': 'Bearer ' + mltoken})
        print("Scoring response")
        print(response_scoring.json())
        pred = response_scoring.json()
        output = pred['predictions'][0]['values'][0][0]
        print(output)
            if output >=1 and output <=2 :
           output="No Failure Expected within 30 days."
        else :
          output="Maintenance Required!! Expected a failure within 30 days."
        return render_template('index.html',ans=output)
if (_name=='main_'):
   app.run(debug=False)
```

CHAPTER 8

TESTING

8.1 Test Cases

- Prediction Page
- Result Page

8.2 User Acceptance Testing:

1. Purpose of Document

The purpose of this document is to briefly explain the test coverage and open issues of the [Product Name] project at the time of the release to User Acceptance Testing (UAT).

2. Defect Analysis

This report shows the number of resolved or closed bugs at each severity level, and how they were resolved

Resolution	Severity 1	Severity 2	Severity 3	Severity 4	Subtotal
By Design	10	4	2	8	15
Duplicate	1	0	3	0	4
External	2	3	0	1	6
Fixed	9	2	4	11	20
Not Reproduced	0	0	1	0	1
Skipped	0	0	1	1	2
Won't Fix	0	5	0	1	8
Totals	22	14	11	22	51

3. Test Case Analysis

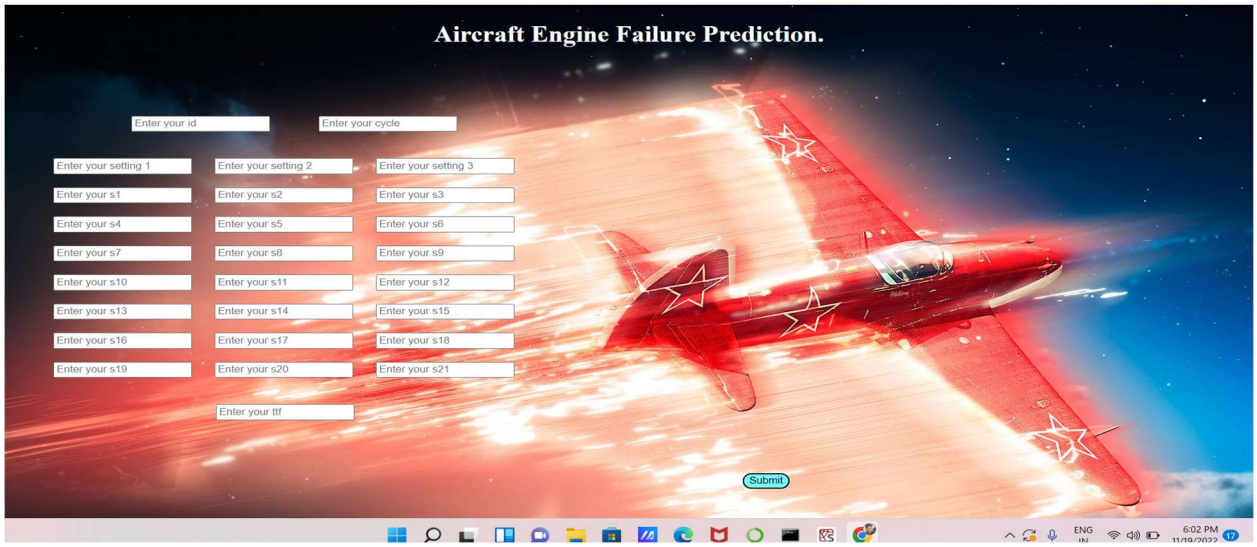
This report shows the number of test cases that have passed, failed, and untested

Section	Total Cases	Not Tested	Fail	Pass
Login	7	0	0	7
Prediction	27	0	0	27
Result	4	0	0	4

CHAPTER 9

RESULTS

9.1 PREDICTION PAGE:



9.2 PREDICTION RESULTS-1:

PREDICTION RESULTS-2:

CHAPTER 10

ADVANTAGES AND DISADVANTAGES

10.1. ADVANTAGES:

Machine learning and data science can predict future events, trends, and customer behavior to a certain extent. These predictions can enable businesses to make better decisions about where to allocate resources and how to respond to changes in the market. Machine learning algorithms use historical data as input to predict new output values. Recommendation engines are a common use case for machine learning. Other popular uses include fraud detection, spam filtering, malware threat detection, business process automation (BPA) and Predictive maintenance With the ever-growing volume of data generated every day, it is increasingly difficult for humans to process and make sense of all this information. Machine learning can help businesses handle large amounts of data more efficiently and effectively and even use decision trees to take action on the information. As humans after gaining experience improve themselves in the same way machine learning improve themselves and become more accurate and efficient in work. This led to better decisions. For example, in the weather forecast, the more data. And experience the machine gets the more advanced forecast it will provide.

10.2 DISADVANTAGES:

Although machine learning is considered to be more accurate it is highly vulnerable. For example, a set of programs provided to the machine may be biased or consist of errors. The same program is used to make another forecast or prediction then there will be a chain of errors that could be formed which may, although recognized but take some time to find out the source of the error. The more data a machine gets the more accurate and efficient it becomes thus more data is required to input to the machine for better forecasting or decision making. But it may sometimes not be possible. Also, the data must be unbiased and of good quality. Data requirements are problematic sometimes. As we have already seen that a little manipulation or biased data could lead to a long drawn error chain and therefore there are chances of the inaccuracy of interpretation also. Sometimes data without any error could also be interpreted inaccurately by the machine as the data provided previously may not fulfill all the basics of the machine.

11. CONCLUSION:

Overall, the results show that by bringing together sufficient (big) high quality data, robust machine learning algorithms, and data science, machine learning-based predictive analytics can be an effective tool for engine design-space exploration during the conceptual design phase. It would help to identify the best engine design expeditiously amongst several candidates. The promising results of the predictive analytics show that machine-learning techniques merit further exploration for application in aircraft engine conceptual design. To further improve the accuracy (and reduce the uncertainty) of TSFC prediction, the database needs to be expanded. However, the limitation of publicly available engine data is a challenge to overcome.

12. FUTURE SCOPE:

- Early predictions avoid the accident and other problems
- The process maintenance become easier..
- Predicting future also saves the money and the resources.
- Controls the machine and its performance.
- Train model in various machines can useful for the performance and maintenance.
- Machine learning algorithms can used for the models and the models monitor the performances.
- The algorithms can be update in high performance like the solution .

13. APPENDIX:

SOURCE CODE The source code has been uploaded in GitHub. To refer the final source code click SOURCE CODE

GITHUB & PROJECT DEMO LINK:

The GitHub link: https://github.com/balamuruganrs/IBM-Project-1002-1658334274

The project link: https://youtu.be/2hfgmYQNHfI