Our data includes data of 100 engines, each doing their respective number of cycles as per their functional lifecycle., During each cycle the sensors installed collects the data in each respective cycle., Based on this collected data we need to build a model which would predict the remaining useful life, (RUL, time before which engine goes for maintenance to avoid unexpected breakdown) of a already/newly installed engine based on its current cycle data

Lets understand basic layout and working mechanism of a TURBOFAN JET ENGINE

In [1]:
```
from PIL import Image
from IPython.display import display
img = Image.open('final.png')
display(img)
```

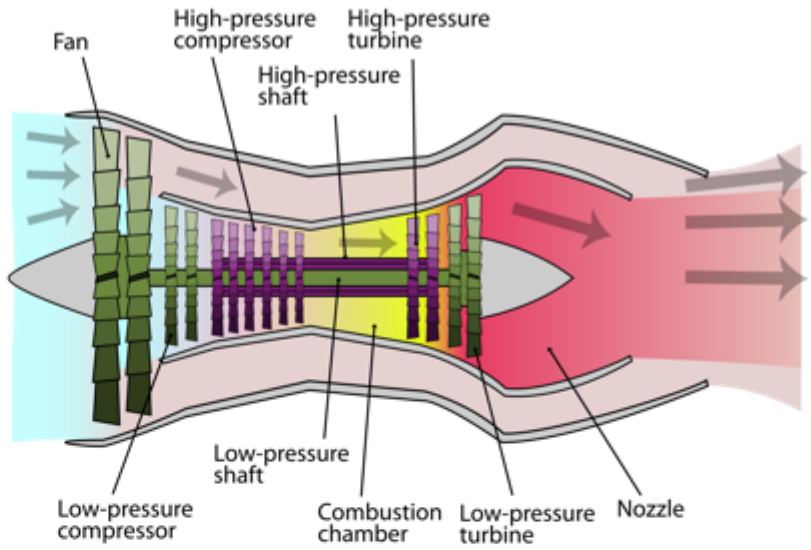


Figure 1. A simplified layout of engine components and working mechanism

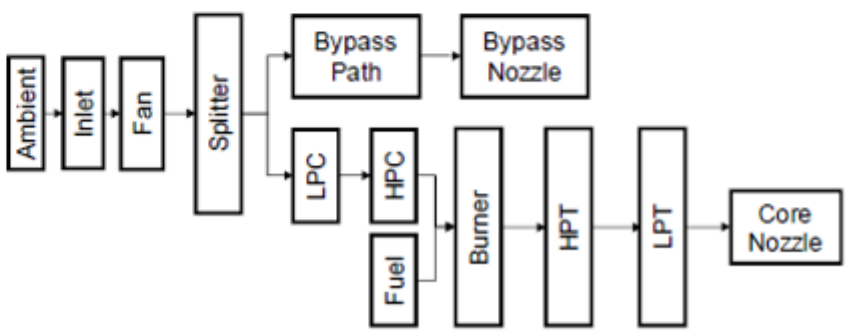


Figure 2. A layout showing various modules and their connections as modeled in the simulation [11].

In [2]:
```
#import libararies
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import warnings
warnings.filterwarnings('ignore')
```

In [3]:
```
#Reading and importing data"
jet_data = pd.read_csv('train_FD001.txt', sep=" ", header=None)
```

In [4]:
```
jet_data.head()
```

Out[4]:

	0	1	2	3	4	5	6	7	8	9	...	18	19	20	21	22	23	24	25	26	27
0	1	1	-0.0007	-0.0004	100.0	518.67	641.82	1589.70	1400.60	14.62	...	8138.62	8.4195	0.03	392	2388	100.0	39.06	23.4190	NaN	NaN
1	1	2	0.0019	-0.0003	100.0	518.67	642.15	1591.82	1403.14	14.62	...	8131.49	8.4318	0.03	392	2388	100.0	39.00	23.4236	NaN	NaN
2	1	3	-0.0043	0.0003	100.0	518.67	642.35	1587.99	1404.20	14.62	...	8133.23	8.4178	0.03	390	2388	100.0	38.95	23.3442	NaN	NaN
3	1	4	0.0007	0.0000	100.0	518.67	642.35	1582.79	1401.87	14.62	...	8133.83	8.3682	0.03	392	2388	100.0	38.88	23.3739	NaN	NaN
4	1	5	-0.0019	-0.0002	100.0	518.67	642.37	1582.85	1406.22	14.62	...	8133.80	8.4294	0.03	393	2388	100.0	38.90	23.4044	NaN	NaN

5 rows × 28 columns

In [5]:
```
#find the sensor names as available in C-MAPSS setup
sensor = Image.open('sensor.png')
display(sensor)
```

Symbol	*Description*	*Units*
Parameters available to participants as sensor data		
T2	Total temperature at fan inlet	°R
T24	Total temperature at LPC outlet	°R
T30	Total temperature at HPC outlet	°R
T50	Total temperature at LPT outlet	°R
P2	Pressure at fan inlet	psia
P15	Total pressure in bypass-duct	psia
P30	Total pressure at HPC outlet	psia
Nf	Physical fan speed	rpm
Nc	Physical core speed	rpm
epr	Engine pressure ratio (P50/P2)	--
Ps30	Static pressure at HPC outlet	psia
phi	Ratio of fuel flow to Ps30	pps/psi
NRf	Corrected fan speed	rpm
NRc	Corrected core speed	rpm
BPR	Bypass Ratio	--
farB	Burner fuel-air ratio	--
htBleed	Bleed Enthalpy	--
Nf_dmd	Demanded fan speed	rpm
PCNfR_dmd	Demanded corrected fan speed	rpm
W31	HPT coolant bleed	lbm/s
W32	LPT coolant bleed	lbm/s

In [6]:
```
#setting column names accordingly
jet_data.columns = ["Engine","cycle","setting1","setting2","setting3","Fan Inlet Temperature (◦R)",
"(LPC Outlet Temperature) (◦R)",
"(HPC Outlet Temperature) (◦R)",
"(LPT Outlet Temperature) (◦R)",
"(Fan Inlet Pressure) (psia)",
"(Bypass-Duct Pressure) (psia)",
"(HPC Outlet Pressure) (psia)",
"(Physical Fan Speed) (rpm)",
"(Physical Core Speed) (rpm)",
"(Engine Pressure Ratio(P50/P2)",
"(HPC Outlet Static Pressure) (psia)",
"(Ratio of Fuel Flow to Ps30) (pps/psia)",
"(Corrected Fan Speed) (rpm)",
"(Corrected Core Speed) (rpm)",
"(Bypass Ratio) ",
"(Burner Fuel-Air Ratio)",
"(Bleed Enthalpy)",
"(Required Fan Speed)",
"(Required Fan Conversion Speed)",
"(High-Pressure Turbines Cool Air Flow)",
"(Low-Pressure Turbines Cool Air Flow)",
"Sensor1",
"Sensor2"]
```

In [7]:
```
# Creating a new dataframe for maximum cycles of each engine
jet_id_and_rul = jet_data.groupby('Engine')['cycle'].max().reset_index()
```

In [8]:
```
#to make hidden rows and column visible
pd.set_option('display.max_rows', 500)
pd.set_option('display.max_columns', 500),
pd.set_option('display.width', 1000)
```

In [9]:
```
jet_data.head(500)
```

Out[9]:

	Engine	cycle	setting1	setting2	setting3	Fan Inlet Temperature (◦R)	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(Fan Inlet Pressure) (psia)	(Bypass-Duct Pressure) (psia)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(Phy Sp (
0	1	1	-0.0007	-0.0004	100.0	518.67	641.82	1589.70	1400.60	14.62	21.61	554.36	2388.06	90
1	1	2	0.0019	-0.0003	100.0	518.67	642.15	1591.82	1403.14	14.62	21.61	553.75	2388.04	90
2	1	3	-0.0043	0.0003	100.0	518.67	642.35	1587.99	1404.20	14.62	21.61	554.26	2388.08	90
3	1	4	0.0007	0.0000	100.0	518.67	642.35	1582.79	1401.87	14.62	21.61	554.45	2388.11	90
4	1	5	-0.0019	-0.0002	100.0	518.67	642.37	1582.85	1406.22	14.62	21.61	554.00	2388.06	90
5	1	6	-0.0043	-0.0001	100.0	518.67	642.10	1584.47	1398.37	14.62	21.61	554.67	2388.02	90
6	1	7	0.0010	0.0001	100.0	518.67	642.48	1592.32	1397.77	14.62	21.61	554.34	2388.02	90
7	1	8	-0.0034	0.0003	100.0	518.67	642.56	1582.96	1400.97	14.62	21.61	553.85	2388.00	90
8	1	9	0.0008	0.0001	100.0	518.67	642.12	1590.98	1394.80	14.62	21.61	553.69	2388.05	90
9	1	10	-0.0033	0.0001	100.0	518.67	641.71	1591.24	1400.46	14.62	21.61	553.59	2388.05	90
10	1	11	0.0018	-0.0003	100.0	518.67	642.28	1581.75	1400.64	14.62	21.61	554.54	2388.05	90
11	1	12	0.0016	0.0002	100.0	518.67	642.06	1583.41	1400.15	14.62	21.61	554.52	2388.09	90
12	1	13	-0.0019	0.0004	100.0	518.67	643.07	1582.19	1400.83	14.62	21.61	553.44	2388.12	90
13	1	14	0.0009	-0.0000	100.0	518.67	642.35	1592.95	1399.16	14.62	21.61	554.48	2388.09	90
14	1	15	-0.0018	-0.0003	100.0	518.67	642.43	1583.82	1402.13	14.62	21.61	553.64	2388.11	90
15	1	16	0.0006	0.0005	100.0	518.67	642.13	1587.98	1404.50	14.62	21.61	553.94	2388.05	90
16	1	17	0.0002	0.0002	100.0	518.67	642.58	1584.96	1399.95	14.62	21.61	553.80	2388.06	90
17	1	18	-0.0031	-0.0001	100.0	518.67	642.62	1591.04	1396.12	14.62	21.61	554.20	2388.05	90
18	1	19	0.0032	-0.0003	100.0	518.67	641.79	1587.56	1400.35	14.62	21.61	554.18	2388.04	90
19	1	20	-0.0037	0.0001	100.0	518.67	643.04	1581.11	1405.23	14.62	21.61	554.81	2388.05	90
20	1	21	-0.0012	0.0001	100.0	518.67	642.37	1586.07	1398.13	14.62	21.61	554.08	2388.11	90
21	1	22	0.0002	0.0000	100.0	518.67	642.77	1592.93	1400.57	14.62	21.61	553.63	2388.04	90
22	1	23	0.0034	-0.0003	100.0	518.67	642.14	1588.19	1394.75	14.62	21.61	553.98	2388.05	90
23	1	24	-0.0010	0.0003	100.0	518.67	642.38	1590.83	1398.81	14.62	21.61	553.49	2388.12	90
24	1	25	0.0023	-0.0004	100.0	518.67	642.77	1594.10	1399.39	14.62	21.61	554.00	2388.02	90
25	1	26	0.0000	0.0002	100.0	518.67	642.16	1589.08	1396.07	14.62	21.61	554.11	2388.07	90
26	1	27	-0.0012	-0.0004	100.0	518.67	642.44	1590.47	1401.84	14.62	21.61	554.07	2388.02	90
27	1	28	-0.0024	0.0005	100.0	518.67	642.35	1582.84	1399.13	14.62	21.61	554.68	2388.12	90
28	1	29	0.0012	-0.0001	100.0	518.67	641.91	1584.83	1400.99	14.62	21.61	554.25	2388.05	90
29	1	30	-0.0022	0.0000	100.0	518.67	642.20	1593.52	1396.08	14.62	21.61	554.37	2388.07	90
30	1	31	0.0014	0.0005	100.0	518.67	642.02	1584.18	1396.90	14.62	21.61	554.13	2388.08	90
31	1	32	0.0005	-0.0003	100.0	518.67	642.33	1591.38	1400.36	14.62	21.61	554.96	2388.04	90
32	1	33	-0.0042	-0.0004	100.0	518.67	642.71	1588.40	1402.43	14.62	21.61	554.61	2388.04	90
33	1	34	0.0015	-0.0001	100.0	518.67	642.54	1581.47	1400.48	14.62	21.61	554.30	2388.03	90
34	1	35	0.0003	0.0002	100.0	518.67	642.44	1590.00	1403.00	14.62	21.61	554.30	2388.04	90
35	1	36	-0.0004	-0.0002	100.0	518.67	642.54	1581.72	1405.54	14.62	21.61	554.53	2388.01	90
36	1	37	-0.0004	-0.0000	100.0	518.67	641.99	1579.11	1398.90	14.62	21.61	554.63	2388.07	90
37	1	38	-0.0018	-0.0002	100.0	518.67	641.93	1589.60	1399.50	14.62	21.61	554.70	2388.08	90
38	1	39	-0.0030	-0.0001	100.0	518.67	642.01	1583.21	1400.69	14.62	21.61	553.97	2388.02	90
39	1	40	-0.0000	-0.0004	100.0	518.67	642.24	1582.08	1401.77	14.62	21.61	554.57	2388.06	90
40	1	41	0.0033	0.0004	100.0	518.67	642.40	1591.31	1403.21	14.62	21.61	553.72	2388.06	90
41	1	42	0.0005	-0.0004	100.0	518.67	642.12	1584.66	1401.38	14.62	21.61	553.94	2388.08	90
42	1	43	-0.0027	0.0005	100.0	518.67	642.24	1591.52	1406.05	14.62	21.61	553.68	2388.03	90
43	1	44	-0.0001	0.0002	100.0	518.67	641.93	1586.94	1401.20	14.62	21.61	554.15	2388.04	90
44	1	45	-0.0013	-0.0000	100.0	518.67	642.53	1582.42	1399.16	14.62	21.61	553.83	2388.08	90
45	1	46	0.0003	0.0001	100.0	518.67	642.43	1588.29	1401.27	14.62	21.61	553.76	2388.06	90
46	1	47	0.0000	0.0005	100.0	518.67	642.21	1580.32	1402.89	14.62	21.61	554.38	2388.06	90
47	1	48	0.0019	0.0001	100.0	518.67	641.89	1588.51	1399.16	14.62	21.61	554.02	2388.08	90
48	1	49	-0.0014	0.0005	100.0	518.67	642.23	1584.35	1397.76	14.62	21.61	554.23	2388.07	90
49	1	50	-0.0032	-0.0001	100.0	518.67	642.77	1588.49	1403.62	14.62	21.61	553.92	2388.06	90

	Engine	cycle	setting1	setting2	setting3	Fan Inlet Temperature (◦R)	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(Fan Inlet Pressure) (psia)	(Bypass-Duct Pressure) (psia)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(Phy Sp (
50	1	51	-0.0010	0.0003	100.0	518.67	642.81	1585.54	1400.42	14.62	21.61	553.73	2388.02	90
51	1	52	0.0018	-0.0001	100.0	518.67	642.76	1583.77	1395.57	14.62	21.61	553.04	2388.04	90
52	1	53	0.0021	-0.0001	100.0	518.67	642.61	1579.82	1402.26	14.62	21.61	554.16	2388.05	90
53	1	54	-0.0002	0.0005	100.0	518.67	642.42	1592.59	1401.20	14.62	21.61	553.95	2388.04	90
54	1	55	0.0009	-0.0000	100.0	518.67	642.41	1584.95	1401.58	14.62	21.61	554.45	2388.04	90
55	1	56	0.0007	-0.0002	100.0	518.67	642.49	1586.33	1400.76	14.62	21.61	553.98	2388.01	90
56	1	57	-0.0033	0.0000	100.0	518.67	642.13	1583.67	1402.79	14.62	21.61	553.42	2388.05	90
57	1	58	-0.0014	0.0001	100.0	518.67	641.90	1590.46	1397.99	14.62	21.61	554.14	2388.09	90
58	1	59	-0.0006	0.0002	100.0	518.67	642.33	1596.72	1403.51	14.62	21.61	554.62	2388.07	90
59	1	60	-0.0010	-0.0002	100.0	518.67	642.34	1582.75	1403.07	14.62	21.61	554.00	2388.06	90
60	1	61	0.0004	0.0005	100.0	518.67	642.10	1583.55	1405.52	14.62	21.61	554.09	2388.11	90
61	1	62	0.0004	0.0001	100.0	518.67	642.17	1581.59	1399.54	14.62	21.61	554.45	2388.10	90
62	1	63	0.0015	0.0002	100.0	518.67	642.60	1592.14	1395.38	14.62	21.61	553.48	2388.06	90
63	1	64	0.0017	0.0002	100.0	518.67	642.23	1584.51	1400.11	14.62	21.61	553.88	2388.10	90
64	1	65	-0.0000	0.0005	100.0	518.67	642.28	1584.72	1403.24	14.62	21.61	553.97	2388.03	90
65	1	66	-0.0007	-0.0004	100.0	518.67	642.50	1588.50	1399.52	14.62	21.61	554.00	2388.06	90
66	1	67	0.0016	-0.0004	100.0	518.67	642.33	1590.22	1403.02	14.62	21.61	554.31	2388.10	90
67	1	68	-0.0018	0.0000	100.0	518.67	642.51	1582.06	1404.42	14.62	21.61	554.04	2388.10	90
68	1	69	-0.0022	0.0005	100.0	518.67	642.44	1590.70	1401.24	14.62	21.61	554.65	2388.07	90
69	1	70	-0.0005	0.0002	100.0	518.67	642.22	1584.02	1402.78	14.62	21.61	554.01	2388.11	90
70	1	71	0.0016	-0.0003	100.0	518.67	642.21	1580.41	1403.09	14.62	21.61	554.06	2388.03	90
71	1	72	-0.0017	0.0001	100.0	518.67	642.41	1579.25	1406.81	14.62	21.61	553.76	2388.07	90
72	1	73	-0.0012	-0.0002	100.0	518.67	642.29	1592.04	1397.93	14.62	21.61	553.88	2388.03	90
73	1	74	0.0027	0.0001	100.0	518.67	642.96	1584.65	1401.48	14.62	21.61	554.03	2388.07	90
74	1	75	0.0009	-0.0004	100.0	518.67	641.96	1582.32	1394.82	14.62	21.61	553.60	2388.07	90
75	1	76	-0.0015	0.0002	100.0	518.67	642.21	1589.21	1398.94	14.62	21.61	553.66	2388.02	90
76	1	77	0.0022	0.0004	100.0	518.67	642.55	1586.30	1400.97	14.62	21.61	554.61	2388.06	90
77	1	78	0.0040	0.0002	100.0	518.67	641.99	1580.76	1404.10	14.62	21.61	553.47	2388.08	90
78	1	79	0.0022	-0.0002	100.0	518.67	642.12	1582.46	1403.93	14.62	21.61	553.77	2388.04	90
79	1	80	-0.0002	-0.0004	100.0	518.67	641.94	1591.96	1393.58	14.62	21.61	553.91	2388.06	90
80	1	81	-0.0018	-0.0004	100.0	518.67	642.73	1584.82	1402.04	14.62	21.61	553.88	2388.10	90
81	1	82	-0.0012	0.0001	100.0	518.67	642.04	1589.07	1399.17	14.62	21.61	554.18	2388.10	90
82	1	83	0.0004	0.0005	100.0	518.67	642.66	1588.05	1406.38	14.62	21.61	553.49	2388.08	90
83	1	84	0.0005	0.0002	100.0	518.67	642.64	1585.52	1406.60	14.62	21.61	553.91	2388.05	90
84	1	85	0.0025	0.0003	100.0	518.67	642.28	1590.12	1405.96	14.62	21.61	554.40	2388.01	90
85	1	86	-0.0012	0.0004	100.0	518.67	641.84	1588.80	1403.56	14.62	21.61	553.69	2388.10	90
86	1	87	0.0000	-0.0004	100.0	518.67	642.33	1586.69	1413.10	14.62	21.61	554.10	2388.14	90
87	1	88	0.0029	0.0003	100.0	518.67	641.96	1581.29	1406.09	14.62	21.61	554.48	2388.07	90
88	1	89	0.0008	-0.0001	100.0	518.67	642.24	1584.73	1402.22	14.62	21.61	553.91	2388.05	90
89	1	90	0.0017	-0.0001	100.0	518.67	642.67	1584.38	1412.93	14.62	21.61	552.88	2388.10	90
90	1	91	0.0025	-0.0004	100.0	518.67	641.98	1584.84	1404.76	14.62	21.61	553.54	2388.04	90
91	1	92	0.0010	-0.0002	100.0	518.67	642.89	1590.03	1400.77	14.62	21.61	553.81	2388.14	90
92	1	93	0.0032	0.0002	100.0	518.67	642.85	1593.74	1408.48	14.62	21.61	554.07	2388.07	90
93	1	94	-0.0021	0.0002	100.0	518.67	642.45	1583.27	1404.94	14.62	21.61	553.86	2388.15	90
94	1	95	0.0019	0.0003	100.0	518.67	642.86	1577.60	1410.10	14.62	21.61	553.91	2388.02	90
95	1	96	-0.0034	0.0001	100.0	518.67	642.19	1584.07	1395.16	14.62	21.61	553.34	2388.07	90
96	1	97	0.0035	-0.0003	100.0	518.67	642.07	1595.77	1407.81	14.62	21.61	553.40	2388.09	90
97	1	98	0.0006	0.0004	100.0	518.67	642.00	1591.11	1404.56	14.62	21.61	552.75	2388.06	90
98	1	99	-0.0005	-0.0000	100.0	518.67	642.46	1592.73	1406.13	14.62	21.61	553.76	2388.08	90
99	1	100	-0.0021	-0.0003	100.0	518.67	642.22	1589.63	1411.35	14.62	21.61	554.22	2388.07	90

	Engine	cycle	setting1	setting2	setting3	Fan Inlet Temperature (◦R)	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(Fan Inlet Pressure) (psia)	(Bypass-Duct Pressure) (psia)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(Phy Sp (
100	1	101	0.0012	0.0003	100.0	518.67	642.75	1584.18	1403.41	14.62	21.61	553.37	2388.06	90
101	1	102	0.0017	0.0005	100.0	518.67	642.85	1589.11	1403.42	14.62	21.61	553.42	2388.15	90
102	1	103	-0.0013	0.0001	100.0	518.67	642.21	1581.27	1403.21	14.62	21.61	553.64	2388.09	90
103	1	104	-0.0001	0.0001	100.0	518.67	642.29	1590.63	1406.25	14.62	21.61	553.66	2388.08	90
104	1	105	0.0024	0.0004	100.0	518.67	642.01	1588.28	1403.22	14.62	21.61	553.11	2388.09	90
105	1	106	0.0000	0.0001	100.0	518.67	642.68	1589.05	1404.45	14.62	21.61	553.60	2388.08	90
106	1	107	-0.0012	-0.0001	100.0	518.67	642.53	1595.13	1407.73	14.62	21.61	553.74	2388.07	90
107	1	108	0.0008	0.0001	100.0	518.67	643.49	1585.91	1399.47	14.62	21.61	554.43	2388.14	90
108	1	109	-0.0011	-0.0003	100.0	518.67	642.49	1586.45	1409.10	14.62	21.61	553.59	2388.10	90
109	1	110	-0.0000	0.0004	100.0	518.67	642.55	1590.01	1401.27	14.62	21.61	554.08	2388.13	90
110	1	111	0.0008	0.0004	100.0	518.67	642.67	1584.38	1408.11	14.62	21.61	553.49	2388.12	90
111	1	112	0.0005	0.0003	100.0	518.67	642.66	1586.46	1401.84	14.62	21.61	553.19	2388.06	90
112	1	113	0.0007	0.0001	100.0	518.67	642.68	1590.85	1406.59	14.62	21.61	552.91	2388.10	90
113	1	114	0.0003	0.0004	100.0	518.67	642.31	1588.42	1402.97	14.62	21.61	554.29	2388.07	90
114	1	115	-0.0017	0.0005	100.0	518.67	642.66	1594.84	1406.60	14.62	21.61	554.13	2388.11	90
115	1	116	-0.0020	-0.0003	100.0	518.67	642.64	1580.31	1401.99	14.62	21.61	554.40	2388.08	90
116	1	117	0.0005	0.0004	100.0	518.67	642.38	1589.77	1409.35	14.62	21.61	554.59	2388.10	90
117	1	118	-0.0006	-0.0004	100.0	518.67	642.34	1585.67	1409.34	14.62	21.61	554.25	2388.10	90
118	1	119	0.0013	0.0005	100.0	518.67	642.67	1596.80	1404.46	14.62	21.61	553.77	2388.10	90
119	1	120	-0.0024	0.0005	100.0	518.67	642.81	1593.78	1407.68	14.62	21.61	553.66	2388.10	90
120	1	121	-0.0033	0.0004	100.0	518.67	642.63	1593.56	1411.90	14.62	21.61	553.70	2388.07	90
121	1	122	0.0026	-0.0001	100.0	518.67	643.30	1593.68	1413.97	14.62	21.61	553.43	2388.15	90
122	1	123	0.0016	-0.0002	100.0	518.67	643.39	1586.66	1403.04	14.62	21.61	552.64	2388.12	90
123	1	124	0.0025	0.0002	100.0	518.67	642.48	1587.14	1402.28	14.62	21.61	552.26	2388.13	90
124	1	125	-0.0004	0.0005	100.0	518.67	642.96	1585.47	1406.42	14.62	21.61	552.44	2388.13	90
125	1	126	0.0016	0.0001	100.0	518.67	642.49	1582.64	1418.50	14.62	21.61	553.72	2388.05	90
126	1	127	-0.0010	0.0002	100.0	518.67	642.99	1586.90	1399.49	14.62	21.61	553.81	2388.09	90
127	1	128	-0.0006	0.0003	100.0	518.67	642.47	1593.87	1407.06	14.62	21.61	552.74	2388.13	90
128	1	129	-0.0033	0.0003	100.0	518.67	642.41	1591.33	1408.42	14.62	21.61	552.42	2388.09	90
129	1	130	-0.0007	0.0002	100.0	518.67	642.70	1585.90	1412.25	14.62	21.61	552.66	2388.13	90
130	1	131	0.0002	-0.0001	100.0	518.67	643.01	1585.78	1413.25	14.62	21.61	553.70	2388.11	90
131	1	132	0.0032	-0.0001	100.0	518.67	643.19	1596.06	1405.76	14.62	21.61	553.16	2388.17	90
132	1	133	0.0032	-0.0002	100.0	518.67	642.45	1592.64	1410.11	14.62	21.61	553.82	2388.11	90
133	1	134	-0.0014	0.0000	100.0	518.67	642.85	1583.62	1402.67	14.62	21.61	553.20	2388.11	90
134	1	135	-0.0017	0.0001	100.0	518.67	642.45	1585.55	1406.83	14.62	21.61	553.09	2388.14	90
135	1	136	0.0030	-0.0001	100.0	518.67	642.84	1584.72	1404.39	14.62	21.61	554.18	2388.06	90
136	1	137	-0.0011	0.0000	100.0	518.67	642.43	1594.69	1405.15	14.62	21.61	553.39	2388.14	90
137	1	138	-0.0011	0.0001	100.0	518.67	642.79	1589.82	1413.34	14.62	21.61	552.91	2388.11	90
138	1	139	-0.0014	0.0005	100.0	518.67	643.11	1592.28	1412.60	14.62	21.61	553.25	2388.06	90
139	1	140	-0.0006	-0.0001	100.0	518.67	643.05	1590.89	1408.36	14.62	21.61	552.15	2388.17	90
140	1	141	-0.0023	0.0005	100.0	518.67	642.39	1590.02	1415.25	14.62	21.61	553.45	2388.13	90
141	1	142	0.0026	0.0002	100.0	518.67	642.51	1595.29	1413.42	14.62	21.61	553.11	2388.10	90
142	1	143	-0.0005	-0.0003	100.0	518.67	642.77	1593.10	1404.21	14.62	21.61	553.62	2388.13	90
143	1	144	0.0025	-0.0004	100.0	518.67	643.09	1591.89	1405.76	14.62	21.61	553.77	2388.17	90
144	1	145	-0.0004	-0.0001	100.0	518.67	642.95	1594.92	1409.63	14.62	21.61	553.03	2388.13	90
145	1	146	0.0002	-0.0003	100.0	518.67	642.72	1586.75	1408.82	14.62	21.61	552.60	2388.12	90
146	1	147	0.0047	0.0001	100.0	518.67	642.25	1594.85	1409.96	14.62	21.61	553.09	2388.14	90
147	1	148	0.0010	-0.0004	100.0	518.67	643.02	1590.03	1411.89	14.62	21.61	552.84	2388.16	90
148	1	149	0.0025	0.0004	100.0	518.67	642.90	1592.78	1410.70	14.62	21.61	552.54	2388.17	90
149	1	150	0.0010	-0.0003	100.0	518.67	643.06	1589.01	1409.22	14.62	21.61	553.57	2388.12	90

	Engine	cycle	setting1	setting2	setting3	Fan Inlet Temperature (◦R)	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(Fan Inlet Pressure) (psia)	(Bypass-Duct Pressure) (psia)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(Phy Sp (
150	1	151	-0.0019	-0.0001	100.0	518.67	642.82	1592.39	1411.94	14.62	21.61	552.41	2388.14	90
151	1	152	0.0009	-0.0001	100.0	518.67	642.67	1598.60	1420.83	14.62	21.61	552.62	2388.18	90
152	1	153	0.0011	-0.0004	100.0	518.67	642.99	1589.17	1414.56	14.62	21.61	552.68	2388.14	90
153	1	154	-0.0012	0.0000	100.0	518.67	642.81	1597.03	1416.07	14.62	21.61	552.57	2388.14	90
154	1	155	-0.0033	0.0002	100.0	518.67	642.83	1590.40	1414.89	14.62	21.61	552.89	2388.16	90
155	1	156	-0.0020	0.0003	100.0	518.67	643.04	1585.61	1421.23	14.62	21.61	553.24	2388.26	90
156	1	157	-0.0018	0.0002	100.0	518.67	642.20	1598.04	1412.47	14.62	21.61	552.32	2388.14	90
157	1	158	-0.0023	0.0001	100.0	518.67	642.88	1596.82	1410.09	14.62	21.61	553.19	2388.20	90
158	1	159	-0.0006	0.0001	100.0	518.67	642.89	1589.54	1420.37	14.62	21.61	552.18	2388.13	90
159	1	160	-0.0006	-0.0004	100.0	518.67	643.45	1590.65	1418.08	14.62	21.61	551.87	2388.21	90
160	1	161	0.0008	0.0001	100.0	518.67	643.00	1594.20	1417.31	14.62	21.61	552.80	2388.18	90
161	1	162	-0.0005	0.0004	100.0	518.67	643.15	1592.22	1423.48	14.62	21.61	552.68	2388.15	90
162	1	163	0.0003	-0.0004	100.0	518.67	642.85	1600.54	1421.09	14.62	21.61	552.41	2388.20	90
163	1	164	0.0005	-0.0002	100.0	518.67	643.17	1598.96	1416.76	14.62	21.61	551.90	2388.17	90
164	1	165	0.0010	0.0004	100.0	518.67	642.76	1597.03	1408.09	14.62	21.61	552.79	2388.19	90
165	1	166	-0.0022	-0.0003	100.0	518.67	643.34	1596.72	1422.37	14.62	21.61	552.13	2388.22	90
166	1	167	0.0012	0.0003	100.0	518.67	643.02	1593.83	1414.72	14.62	21.61	552.57	2388.23	90
167	1	168	-0.0043	0.0002	100.0	518.67	642.68	1591.19	1415.70	14.62	21.61	552.09	2388.22	90
168	1	169	-0.0017	0.0004	100.0	518.67	643.20	1590.16	1418.05	14.62	21.61	552.71	2388.25	90
169	1	170	-0.0017	-0.0002	100.0	518.67	642.92	1592.71	1417.41	14.62	21.61	552.02	2388.21	90
170	1	171	0.0004	-0.0003	100.0	518.67	643.26	1592.06	1414.99	14.62	21.61	552.71	2388.20	90
171	1	172	-0.0014	-0.0003	100.0	518.67	643.33	1591.71	1413.73	14.62	21.61	551.69	2388.24	90
172	1	173	-0.0032	0.0002	100.0	518.67	642.97	1590.69	1425.27	14.62	21.61	552.13	2388.22	90
173	1	174	-0.0001	-0.0002	100.0	518.67	642.64	1599.81	1422.58	14.62	21.61	552.32	2388.22	90
174	1	175	0.0001	0.0002	100.0	518.67	643.61	1603.29	1422.52	14.62	21.61	551.64	2388.23	90
175	1	176	-0.0020	-0.0003	100.0	518.67	642.86	1592.27	1422.73	14.62	21.61	551.91	2388.23	90
176	1	177	-0.0038	-0.0003	100.0	518.67	643.79	1602.02	1423.99	14.62	21.61	551.93	2388.25	90
177	1	178	-0.0001	0.0002	100.0	518.67	643.38	1605.33	1424.65	14.62	21.61	552.18	2388.23	90
178	1	179	0.0023	-0.0003	100.0	518.67	642.86	1592.56	1429.45	14.62	21.61	551.57	2388.26	90
179	1	180	-0.0024	0.0000	100.0	518.67	643.58	1599.87	1417.14	14.62	21.61	552.91	2388.21	90
180	1	181	-0.0006	0.0005	100.0	518.67	643.44	1596.71	1420.64	14.62	21.61	551.83	2388.23	90
181	1	182	-0.0010	0.0003	100.0	518.67	644.21	1602.08	1426.62	14.62	21.61	551.90	2388.26	90
182	1	183	0.0001	0.0001	100.0	518.67	643.24	1597.23	1419.03	14.62	21.61	551.38	2388.21	90
183	1	184	0.0004	0.0003	100.0	518.67	644.07	1605.44	1432.52	14.62	21.61	551.00	2388.24	90
184	1	185	0.0008	0.0001	100.0	518.67	643.80	1603.46	1424.40	14.62	21.61	551.64	2388.29	90
185	1	186	0.0027	-0.0003	100.0	518.67	643.51	1595.16	1426.30	14.62	21.61	552.57	2388.21	90
186	1	187	-0.0047	-0.0000	100.0	518.67	643.32	1592.10	1427.27	14.62	21.61	551.08	2388.29	90
187	1	188	-0.0067	0.0003	100.0	518.67	643.75	1602.38	1422.78	14.62	21.61	551.94	2388.31	90
188	1	189	-0.0006	0.0002	100.0	518.67	644.18	1596.17	1428.01	14.62	21.61	550.70	2388.27	90
189	1	190	-0.0027	0.0001	100.0	518.67	643.64	1599.22	1425.95	14.62	21.61	551.29	2388.29	90
190	1	191	-0.0000	-0.0004	100.0	518.67	643.34	1602.36	1425.77	14.62	21.61	550.92	2388.28	90
191	1	192	0.0009	-0.0000	100.0	518.67	643.54	1601.41	1427.20	14.62	21.61	551.25	2388.32	90
192	2	1	-0.0018	0.0006	100.0	518.67	641.89	1583.84	1391.28	14.62	21.60	554.53	2388.01	90
193	2	2	0.0043	-0.0003	100.0	518.67	641.82	1587.05	1393.13	14.62	21.61	554.77	2387.98	90
194	2	3	0.0018	0.0003	100.0	518.67	641.55	1588.32	1398.96	14.62	21.60	555.14	2388.04	90
195	2	4	0.0035	-0.0004	100.0	518.67	641.68	1584.15	1396.08	14.62	21.61	554.25	2387.98	90
196	2	5	0.0005	0.0004	100.0	518.67	641.73	1579.03	1402.52	14.62	21.60	555.12	2388.03	90
197	2	6	-0.0010	0.0004	100.0	518.67	641.30	1577.50	1396.76	14.62	21.61	554.98	2388.04	90
198	2	7	0.0001	-0.0002	100.0	518.67	642.03	1587.49	1400.65	14.62	21.61	554.84	2388.05	90
199	2	8	0.0015	-0.0004	100.0	518.67	642.55	1590.41	1395.39	14.62	21.61	554.65	2388.01	90

	Engine	cycle	setting1	setting2	setting3	Fan Inlet Temperature (◦R)	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(Fan Inlet Pressure) (psia)	(Bypass-Duct Pressure) (psia)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(Phy Sp (
200	2	9	0.0017	-0.0004	100.0	518.67	641.98	1581.99	1395.01	14.62	21.60	554.69	2388.02	90
201	2	10	-0.0045	0.0002	100.0	518.67	641.99	1586.37	1394.86	14.62	21.60	554.63	2387.99	90
202	2	11	0.0006	0.0004	100.0	518.67	642.26	1589.21	1401.29	14.62	21.61	554.70	2388.01	90
203	2	12	0.0002	0.0006	100.0	518.67	641.64	1579.99	1401.90	14.62	21.61	554.57	2387.98	90
204	2	13	0.0007	0.0005	100.0	518.67	641.78	1586.77	1401.53	14.62	21.61	554.69	2387.94	90
205	2	14	-0.0024	-0.0004	100.0	518.67	641.66	1584.04	1395.46	14.62	21.61	554.47	2388.01	90
206	2	15	-0.0012	-0.0003	100.0	518.67	642.21	1579.84	1402.11	14.62	21.61	554.17	2388.02	90
207	2	16	-0.0010	0.0003	100.0	518.67	641.81	1581.99	1393.46	14.62	21.61	554.53	2387.99	90
208	2	17	0.0003	-0.0001	100.0	518.67	642.43	1583.58	1390.27	14.62	21.61	553.62	2388.04	90
209	2	18	0.0014	0.0001	100.0	518.67	641.95	1588.43	1400.25	14.62	21.61	554.83	2388.00	90
210	2	19	0.0025	0.0001	100.0	518.67	641.75	1576.84	1401.77	14.62	21.61	555.25	2388.02	90
211	2	20	0.0042	-0.0004	100.0	518.67	642.34	1582.94	1394.38	14.62	21.61	554.64	2388.00	90
212	2	21	-0.0023	0.0001	100.0	518.67	642.05	1579.51	1392.28	14.62	21.61	554.72	2388.03	90
213	2	22	0.0024	0.0006	100.0	518.67	642.16	1580.18	1397.67	14.62	21.61	554.35	2387.96	90
214	2	23	-0.0013	0.0003	100.0	518.67	642.37	1580.89	1387.50	14.62	21.61	554.69	2387.96	90
215	2	24	-0.0019	-0.0000	100.0	518.67	641.99	1580.97	1398.67	14.62	21.61	553.50	2387.98	90
216	2	25	0.0063	0.0001	100.0	518.67	641.81	1585.38	1396.62	14.62	21.61	554.14	2388.00	90
217	2	26	-0.0011	0.0003	100.0	518.67	641.87	1575.38	1392.30	14.62	21.61	554.03	2387.98	90
218	2	27	0.0006	0.0005	100.0	518.67	642.12	1585.44	1402.31	14.62	21.61	555.16	2388.03	90
219	2	28	0.0037	0.0005	100.0	518.67	642.04	1581.60	1397.45	14.62	21.61	554.77	2387.99	90
220	2	29	-0.0032	-0.0003	100.0	518.67	642.08	1583.78	1398.08	14.62	21.61	554.75	2388.00	90
221	2	30	0.0012	0.0000	100.0	518.67	641.78	1590.32	1395.07	14.62	21.61	554.62	2387.98	90
222	2	31	-0.0009	0.0005	100.0	518.67	641.97	1579.86	1390.94	14.62	21.61	554.80	2388.00	90
223	2	32	0.0013	-0.0001	100.0	518.67	641.58	1584.52	1391.11	14.62	21.61	554.56	2387.98	90
224	2	33	-0.0032	0.0004	100.0	518.67	641.79	1585.17	1396.15	14.62	21.61	553.62	2388.01	90
225	2	34	0.0042	0.0003	100.0	518.67	642.12	1584.08	1394.24	14.62	21.61	555.09	2388.00	90
226	2	35	0.0020	0.0002	100.0	518.67	641.37	1575.73	1392.55	14.62	21.61	554.73	2388.02	90
227	2	36	0.0013	0.0004	100.0	518.67	641.27	1581.56	1397.13	14.62	21.61	554.59	2388.02	90
228	2	37	0.0050	0.0005	100.0	518.67	642.10	1585.63	1396.29	14.62	21.61	555.01	2388.04	90
229	2	38	0.0013	0.0005	100.0	518.67	642.22	1585.15	1397.75	14.62	21.61	554.21	2388.00	90
230	2	39	-0.0018	0.0005	100.0	518.67	642.00	1585.69	1391.49	14.62	21.61	554.05	2388.00	90
231	2	40	0.0005	0.0005	100.0	518.67	642.02	1582.69	1398.38	14.62	21.61	554.07	2388.03	90
232	2	41	0.0015	0.0006	100.0	518.67	642.41	1578.97	1398.74	14.62	21.61	554.34	2388.04	90
233	2	42	0.0016	0.0005	100.0	518.67	642.27	1579.21	1392.13	14.62	21.61	553.98	2387.97	90
234	2	43	0.0027	0.0000	100.0	518.67	642.02	1580.59	1391.60	14.62	21.61	554.14	2388.04	90
235	2	44	0.0003	0.0003	100.0	518.67	642.01	1584.33	1398.69	14.62	21.61	554.16	2388.04	90
236	2	45	-0.0014	-0.0002	100.0	518.67	642.05	1586.41	1397.60	14.62	21.61	554.20	2388.05	90
237	2	46	0.0002	-0.0003	100.0	518.67	642.15	1575.45	1392.60	14.62	21.61	554.54	2388.00	90
238	2	47	0.0021	0.0003	100.0	518.67	642.40	1583.85	1396.46	14.62	21.61	554.96	2388.04	90
239	2	48	0.0006	-0.0001	100.0	518.67	642.09	1586.71	1397.95	14.62	21.61	554.67	2387.99	90
240	2	49	-0.0006	0.0005	100.0	518.67	642.85	1583.86	1396.50	14.62	21.61	554.04	2388.04	90
241	2	50	-0.0002	-0.0004	100.0	518.67	642.02	1577.86	1399.78	14.62	21.61	554.73	2388.00	90
242	2	51	0.0008	0.0003	100.0	518.67	642.03	1585.34	1393.06	14.62	21.61	555.02	2388.02	90
243	2	52	-0.0010	-0.0001	100.0	518.67	641.52	1588.48	1401.66	14.62	21.60	554.76	2388.00	90
244	2	53	-0.0023	-0.0001	100.0	518.67	642.00	1584.90	1397.09	14.62	21.61	554.33	2388.05	90
245	2	54	0.0004	-0.0003	100.0	518.67	641.58	1583.46	1405.33	14.62	21.61	554.42	2388.01	90
246	2	55	-0.0035	-0.0004	100.0	518.67	642.33	1585.59	1387.16	14.62	21.60	554.54	2388.02	90
247	2	56	-0.0035	0.0002	100.0	518.67	641.84	1587.04	1388.97	14.62	21.61	554.72	2388.02	90
248	2	57	-0.0003	-0.0001	100.0	518.67	642.50	1584.13	1389.62	14.62	21.61	553.87	2388.05	90
249	2	58	-0.0000	-0.0002	100.0	518.67	642.30	1582.93	1389.91	14.62	21.61	554.46	2388.03	90

	Engine	cycle	setting1	setting2	setting3	Fan Inlet Temperature (◦R)	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(Fan Inlet Pressure) (psia)	(Bypass-Duct Pressure) (psia)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(Phy Sp (
250	2	59	0.0032	-0.0000	100.0	518.67	642.48	1584.24	1397.95	14.62	21.61	554.60	2388.08	90
251	2	60	0.0014	-0.0002	100.0	518.67	642.09	1584.57	1396.84	14.62	21.61	554.06	2388.04	90
252	2	61	-0.0044	0.0001	100.0	518.67	642.41	1585.45	1399.71	14.62	21.61	555.08	2388.03	90
253	2	62	-0.0017	-0.0001	100.0	518.67	641.81	1577.87	1401.66	14.62	21.61	554.52	2388.03	90
254	2	63	-0.0014	0.0005	100.0	518.67	641.91	1575.83	1395.05	14.62	21.61	554.63	2388.00	90
255	2	64	-0.0000	0.0001	100.0	518.67	641.66	1581.65	1401.46	14.62	21.61	554.93	2388.02	90
256	2	65	0.0008	0.0000	100.0	518.67	641.70	1582.59	1395.40	14.62	21.60	554.28	2388.00	90
257	2	66	0.0005	-0.0002	100.0	518.67	642.26	1584.60	1394.01	14.62	21.61	554.11	2388.06	90
258	2	67	-0.0036	-0.0001	100.0	518.67	642.17	1587.63	1395.44	14.62	21.61	554.99	2388.10	90
259	2	68	0.0008	0.0001	100.0	518.67	642.50	1577.16	1399.27	14.62	21.61	554.07	2387.97	90
260	2	69	-0.0004	0.0000	100.0	518.67	642.73	1586.47	1399.73	14.62	21.61	554.35	2388.01	90
261	2	70	0.0005	-0.0002	100.0	518.67	641.76	1593.24	1397.30	14.62	21.61	554.47	2388.05	90
262	2	71	-0.0004	0.0002	100.0	518.67	642.39	1586.68	1403.09	14.62	21.61	555.01	2388.00	90
263	2	72	-0.0007	-0.0001	100.0	518.67	642.48	1583.11	1393.85	14.62	21.61	554.54	2388.03	90
264	2	73	-0.0004	-0.0001	100.0	518.67	641.73	1586.57	1400.98	14.62	21.61	554.41	2388.01	90
265	2	74	-0.0013	0.0001	100.0	518.67	642.39	1584.04	1396.13	14.62	21.60	555.36	2388.01	90
266	2	75	0.0025	0.0004	100.0	518.67	641.64	1578.27	1390.64	14.62	21.60	555.45	2387.95	90
267	2	76	-0.0037	0.0001	100.0	518.67	642.01	1586.91	1399.66	14.62	21.61	554.05	2388.05	90
268	2	77	0.0003	0.0000	100.0	518.67	641.97	1588.54	1395.38	14.62	21.61	554.06	2388.02	90
269	2	78	0.0004	-0.0001	100.0	518.67	642.44	1587.20	1394.24	14.62	21.61	554.83	2387.99	90
270	2	79	0.0021	0.0004	100.0	518.67	641.62	1585.59	1398.51	14.62	21.61	554.19	2388.00	90
271	2	80	0.0027	-0.0000	100.0	518.67	641.37	1588.33	1394.00	14.62	21.61	554.94	2387.99	90
272	2	81	0.0006	-0.0001	100.0	518.67	641.72	1578.31	1390.12	14.62	21.61	555.25	2388.02	90
273	2	82	0.0035	-0.0001	100.0	518.67	641.86	1587.24	1402.78	14.62	21.61	554.17	2388.01	90
274	2	83	0.0000	-0.0004	100.0	518.67	641.73	1585.18	1398.81	14.62	21.61	554.18	2388.07	90
275	2	84	-0.0037	-0.0004	100.0	518.67	642.41	1586.46	1402.26	14.62	21.61	554.86	2388.06	90
276	2	85	0.0002	0.0004	100.0	518.67	641.73	1588.31	1398.33	14.62	21.60	554.50	2387.97	90
277	2	86	0.0004	-0.0000	100.0	518.67	641.85	1579.31	1399.12	14.62	21.61	554.51	2388.02	90
278	2	87	0.0019	-0.0002	100.0	518.67	642.36	1582.64	1399.51	14.62	21.61	554.77	2387.95	90
279	2	88	0.0007	-0.0002	100.0	518.67	642.23	1587.88	1398.17	14.62	21.60	554.71	2388.01	90
280	2	89	0.0017	0.0005	100.0	518.67	641.95	1584.62	1394.07	14.62	21.61	554.18	2388.00	90
281	2	90	0.0019	-0.0003	100.0	518.67	642.06	1580.77	1405.34	14.62	21.61	554.10	2387.98	90
282	2	91	-0.0007	-0.0002	100.0	518.67	642.09	1583.57	1399.47	14.62	21.61	553.79	2388.02	90
283	2	92	-0.0006	0.0005	100.0	518.67	642.36	1584.87	1399.17	14.62	21.60	554.28	2388.02	90
284	2	93	0.0019	-0.0004	100.0	518.67	642.21	1591.68	1392.48	14.62	21.61	553.92	2388.05	90
285	2	94	0.0000	0.0005	100.0	518.67	642.10	1585.62	1395.39	14.62	21.61	554.53	2388.03	90
286	2	95	-0.0022	0.0002	100.0	518.67	642.56	1579.26	1402.79	14.62	21.61	553.99	2388.05	90
287	2	96	-0.0026	0.0006	100.0	518.67	642.42	1576.94	1399.59	14.62	21.61	554.40	2387.97	90
288	2	97	0.0008	0.0001	100.0	518.67	642.04	1586.12	1400.50	14.62	21.61	554.42	2388.02	90
289	2	98	-0.0001	0.0003	100.0	518.67	641.73	1587.84	1401.08	14.62	21.61	554.57	2388.04	90
290	2	99	-0.0034	-0.0004	100.0	518.67	642.04	1585.48	1400.97	14.62	21.61	554.43	2388.05	90
291	2	100	0.0076	-0.0001	100.0	518.67	642.04	1586.01	1402.72	14.62	21.61	554.48	2388.00	90
292	2	101	0.0031	-0.0000	100.0	518.67	641.96	1582.66	1397.81	14.62	21.61	555.07	2387.98	90
293	2	102	0.0016	0.0001	100.0	518.67	642.44	1590.24	1407.05	14.62	21.60	554.44	2388.03	90
294	2	103	-0.0022	0.0002	100.0	518.67	642.05	1587.75	1392.16	14.62	21.61	554.44	2388.11	90
295	2	104	-0.0034	0.0002	100.0	518.67	642.41	1582.04	1397.31	14.62	21.61	554.91	2388.00	90
296	2	105	-0.0050	0.0004	100.0	518.67	641.94	1585.65	1397.45	14.62	21.61	554.81	2388.02	90
297	2	106	0.0002	-0.0004	100.0	518.67	641.87	1584.61	1402.62	14.62	21.61	553.96	2388.06	90
298	2	107	0.0011	-0.0001	100.0	518.67	642.52	1581.70	1402.93	14.62	21.61	554.21	2387.96	90
299	2	108	0.0014	0.0004	100.0	518.67	642.24	1578.45	1396.25	14.62	21.61	554.29	2388.03	90

	Engine	cycle	setting1	setting2	setting3	Fan Inlet Temperature (◦R)	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(Fan Inlet Pressure) (psia)	(Bypass-Duct Pressure) (psia)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(Phy Sp (
300	2	109	0.0014	0.0000	100.0	518.67	642.12	1590.41	1392.90	14.62	21.61	553.72	2388.12	90
301	2	110	-0.0013	-0.0002	100.0	518.67	642.29	1583.30	1398.47	14.62	21.61	554.50	2388.07	90
302	2	111	0.0039	0.0000	100.0	518.67	642.24	1576.85	1393.76	14.62	21.61	554.42	2387.99	90
303	2	112	-0.0023	-0.0002	100.0	518.67	642.49	1588.35	1397.20	14.62	21.61	554.33	2388.01	90
304	2	113	-0.0030	0.0000	100.0	518.67	641.95	1584.21	1404.74	14.62	21.61	554.07	2388.01	90
305	2	114	-0.0005	-0.0002	100.0	518.67	642.13	1576.56	1397.05	14.62	21.61	555.10	2388.01	90
306	2	115	-0.0041	-0.0001	100.0	518.67	642.16	1583.27	1401.33	14.62	21.61	554.37	2388.01	90
307	2	116	-0.0010	0.0004	100.0	518.67	642.38	1577.87	1398.39	14.62	21.61	554.45	2387.97	90
308	2	117	-0.0031	-0.0000	100.0	518.67	641.97	1583.84	1395.40	14.62	21.61	554.60	2388.02	90
309	2	118	-0.0013	0.0004	100.0	518.67	641.95	1580.49	1400.99	14.62	21.61	553.96	2388.01	90
310	2	119	0.0000	-0.0002	100.0	518.67	642.67	1585.06	1401.87	14.62	21.61	554.32	2388.00	90
311	2	120	-0.0001	0.0004	100.0	518.67	642.01	1589.61	1394.39	14.62	21.61	554.42	2388.05	90
312	2	121	0.0027	0.0003	100.0	518.67	642.04	1580.19	1391.52	14.62	21.61	554.51	2387.96	90
313	2	122	0.0011	0.0003	100.0	518.67	642.08	1585.52	1405.27	14.62	21.61	553.82	2388.01	90
314	2	123	-0.0010	-0.0004	100.0	518.67	642.11	1588.59	1403.23	14.62	21.61	554.31	2388.04	90
315	2	124	-0.0002	0.0004	100.0	518.67	642.37	1583.12	1399.26	14.62	21.61	554.58	2388.04	90
316	2	125	-0.0015	0.0001	100.0	518.67	642.71	1586.32	1397.94	14.62	21.61	554.81	2388.01	90
317	2	126	0.0006	0.0005	100.0	518.67	642.07	1587.45	1403.41	14.62	21.61	554.03	2387.96	90
318	2	127	-0.0002	-0.0004	100.0	518.67	642.26	1586.65	1400.81	14.62	21.61	554.08	2387.99	90
319	2	128	-0.0008	0.0000	100.0	518.67	641.54	1592.20	1397.34	14.62	21.60	554.16	2388.01	90
320	2	129	0.0007	0.0004	100.0	518.67	641.66	1590.59	1400.25	14.62	21.60	554.60	2388.07	90
321	2	130	0.0035	-0.0003	100.0	518.67	642.06	1584.83	1409.98	14.62	21.61	554.42	2387.99	90
322	2	131	-0.0001	0.0001	100.0	518.67	641.96	1587.61	1394.26	14.62	21.61	554.88	2388.01	90
323	2	132	0.0002	0.0006	100.0	518.67	642.01	1586.66	1398.78	14.62	21.61	554.40	2388.13	90
324	2	133	-0.0016	-0.0004	100.0	518.67	642.84	1581.22	1393.87	14.62	21.61	554.21	2388.04	90
325	2	134	0.0026	0.0001	100.0	518.67	642.76	1586.44	1406.20	14.62	21.60	553.88	2388.02	90
326	2	135	0.0009	-0.0002	100.0	518.67	642.02	1580.12	1404.56	14.62	21.61	554.52	2388.01	90
327	2	136	0.0010	-0.0003	100.0	518.67	642.06	1582.91	1402.67	14.62	21.61	554.50	2388.05	90
328	2	137	0.0044	-0.0004	100.0	518.67	642.46	1585.36	1406.79	14.62	21.61	554.42	2388.01	90
329	2	138	0.0012	0.0004	100.0	518.67	642.34	1585.19	1398.95	14.62	21.61	555.03	2387.99	90
330	2	139	-0.0003	0.0005	100.0	518.67	642.63	1590.88	1400.87	14.62	21.61	554.24	2388.06	90
331	2	140	0.0014	-0.0001	100.0	518.67	642.29	1593.70	1403.14	14.62	21.61	554.86	2388.09	90
332	2	141	0.0019	0.0003	100.0	518.67	642.07	1585.09	1403.25	14.62	21.61	554.70	2388.05	90
333	2	142	-0.0007	0.0004	100.0	518.67	641.91	1586.41	1401.27	14.62	21.61	554.18	2388.08	90
334	2	143	0.0001	0.0004	100.0	518.67	642.31	1588.88	1400.49	14.62	21.61	554.05	2388.03	90
335	2	144	-0.0005	0.0002	100.0	518.67	642.02	1584.35	1401.21	14.62	21.61	553.96	2388.03	90
336	2	145	-0.0021	0.0001	100.0	518.67	642.01	1582.72	1403.53	14.62	21.61	554.10	2387.97	90
337	2	146	0.0043	-0.0001	100.0	518.67	642.52	1590.06	1405.09	14.62	21.61	554.25	2388.05	90
338	2	147	0.0004	-0.0001	100.0	518.67	642.27	1588.78	1394.58	14.62	21.61	554.16	2388.05	90
339	2	148	0.0018	0.0004	100.0	518.67	642.65	1584.50	1398.30	14.62	21.61	554.32	2388.02	90
340	2	149	-0.0020	-0.0003	100.0	518.67	642.03	1587.88	1404.41	14.62	21.61	553.84	2388.04	90
341	2	150	-0.0021	0.0004	100.0	518.67	642.62	1585.43	1393.74	14.62	21.61	554.13	2388.01	90
342	2	151	0.0051	-0.0004	100.0	518.67	642.54	1590.21	1398.31	14.62	21.61	553.66	2387.98	90
343	2	152	-0.0004	0.0003	100.0	518.67	642.38	1583.49	1400.90	14.62	21.61	553.86	2388.06	90
344	2	153	0.0043	0.0002	100.0	518.67	641.96	1594.33	1397.52	14.62	21.61	553.78	2388.09	90
345	2	154	0.0012	0.0001	100.0	518.67	642.34	1591.30	1413.28	14.62	21.60	554.45	2388.01	90
346	2	155	-0.0022	-0.0003	100.0	518.67	642.17	1580.93	1397.45	14.62	21.61	553.84	2388.06	90
347	2	156	-0.0045	0.0004	100.0	518.67	642.15	1578.73	1399.13	14.62	21.61	554.70	2388.04	90
348	2	157	-0.0014	-0.0004	100.0	518.67	642.04	1588.70	1400.63	14.62	21.61	553.71	2388.07	90
349	2	158	0.0014	0.0001	100.0	518.67	641.99	1586.95	1404.68	14.62	21.61	554.67	2388.02	90

	Engine	cycle	setting1	setting2	setting3	Fan Inlet Temperature (◦R)	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(Fan Inlet Pressure) (psia)	(Bypass-Duct Pressure) (psia)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(Phy Sp (
350	2	159	-0.0018	-0.0003	100.0	518.67	641.81	1593.89	1399.71	14.62	21.61	553.70	2388.04	90
351	2	160	0.0033	-0.0003	100.0	518.67	642.53	1585.65	1409.72	14.62	21.61	554.65	2388.07	90
352	2	161	-0.0031	0.0003	100.0	518.67	642.08	1586.65	1396.32	14.62	21.61	554.18	2388.05	90
353	2	162	0.0028	0.0003	100.0	518.67	641.71	1588.83	1401.23	14.62	21.61	553.95	2388.06	90
354	2	163	0.0007	0.0004	100.0	518.67	642.88	1589.56	1396.20	14.62	21.61	553.96	2388.08	90
355	2	164	0.0043	0.0003	100.0	518.67	642.82	1588.23	1405.50	14.62	21.61	554.31	2387.99	90
356	2	165	-0.0043	0.0004	100.0	518.67	642.17	1588.55	1402.96	14.62	21.61	553.71	2388.03	90
357	2	166	-0.0068	0.0002	100.0	518.67	641.79	1589.09	1394.26	14.62	21.61	553.71	2388.03	90
358	2	167	0.0005	-0.0001	100.0	518.67	642.25	1588.74	1395.35	14.62	21.61	553.62	2388.01	90
359	2	168	-0.0026	-0.0003	100.0	518.67	642.55	1593.95	1404.01	14.62	21.61	554.32	2388.04	90
360	2	169	-0.0004	0.0003	100.0	518.67	642.26	1581.85	1406.06	14.62	21.61	553.06	2388.06	90
361	2	170	0.0025	0.0004	100.0	518.67	642.14	1577.26	1405.93	14.62	21.61	553.84	2388.03	90
362	2	171	0.0012	0.0005	100.0	518.67	642.21	1587.94	1410.34	14.62	21.61	553.84	2388.03	90
363	2	172	-0.0041	0.0004	100.0	518.67	642.07	1589.42	1398.26	14.62	21.61	553.69	2388.06	90
364	2	173	0.0003	-0.0002	100.0	518.67	642.66	1589.00	1403.22	14.62	21.61	554.64	2388.04	90
365	2	174	-0.0009	-0.0003	100.0	518.67	642.34	1588.01	1403.24	14.62	21.61	553.76	2388.08	90
366	2	175	-0.0005	0.0005	100.0	518.67	642.46	1584.58	1398.37	14.62	21.61	554.01	2388.02	90
367	2	176	-0.0010	-0.0004	100.0	518.67	642.32	1585.73	1405.47	14.62	21.61	554.15	2388.04	90
368	2	177	0.0004	-0.0001	100.0	518.67	642.35	1586.88	1400.31	14.62	21.61	554.59	2388.06	90
369	2	178	0.0031	0.0003	100.0	518.67	642.43	1590.29	1404.39	14.62	21.61	553.83	2388.04	90
370	2	179	-0.0024	-0.0001	100.0	518.67	642.33	1584.55	1399.30	14.62	21.61	553.86	2388.03	90
371	2	180	-0.0011	0.0000	100.0	518.67	642.50	1593.51	1402.27	14.62	21.61	554.21	2388.11	90
372	2	181	0.0003	-0.0002	100.0	518.67	642.01	1585.87	1399.24	14.62	21.61	554.29	2388.03	90
373	2	182	-0.0000	-0.0002	100.0	518.67	642.39	1586.42	1406.61	14.62	21.61	553.63	2388.03	90
374	2	183	-0.0015	-0.0002	100.0	518.67	642.60	1584.95	1406.15	14.62	21.61	554.35	2388.08	90
375	2	184	0.0037	0.0000	100.0	518.67	642.43	1585.66	1408.13	14.62	21.61	554.99	2388.04	90
376	2	185	-0.0020	0.0004	100.0	518.67	642.66	1581.09	1407.11	14.62	21.61	554.53	2388.02	90
377	2	186	-0.0004	0.0002	100.0	518.67	642.80	1582.46	1404.35	14.62	21.61	554.42	2388.05	90
378	2	187	0.0019	0.0002	100.0	518.67	642.69	1588.88	1407.54	14.62	21.61	553.32	2388.08	90
379	2	188	0.0024	0.0002	100.0	518.67	642.64	1582.97	1402.72	14.62	21.61	554.26	2388.07	90
380	2	189	0.0003	0.0002	100.0	518.67	642.81	1583.54	1403.09	14.62	21.61	554.03	2388.03	90
381	2	190	0.0013	0.0004	100.0	518.67	642.48	1592.50	1405.73	14.62	21.61	554.40	2388.06	90
382	2	191	-0.0009	0.0004	100.0	518.67	642.23	1584.59	1407.64	14.62	21.61	553.42	2388.04	90
383	2	192	0.0003	0.0002	100.0	518.67	642.18	1589.95	1404.07	14.62	21.60	553.09	2388.03	90
384	2	193	-0.0021	-0.0003	100.0	518.67	642.13	1588.28	1399.59	14.62	21.61	553.54	2388.09	90
385	2	194	-0.0003	-0.0003	100.0	518.67	643.10	1592.38	1404.64	14.62	21.61	553.86	2388.05	90
386	2	195	-0.0026	0.0004	100.0	518.67	643.24	1591.55	1410.18	14.62	21.61	553.22	2388.01	90
387	2	196	0.0003	0.0004	100.0	518.67	642.64	1591.39	1408.59	14.62	21.61	554.31	2388.15	90
388	2	197	0.0018	0.0005	100.0	518.67	642.55	1588.64	1403.29	14.62	21.61	554.07	2388.07	90
389	2	198	-0.0051	0.0003	100.0	518.67	643.21	1596.17	1402.91	14.62	21.61	553.94	2388.05	90
390	2	199	0.0026	0.0001	100.0	518.67	642.44	1587.17	1409.39	14.62	21.61	554.06	2388.09	90
391	2	200	-0.0017	0.0000	100.0	518.67	642.74	1589.73	1406.28	14.62	21.61	553.13	2388.08	90
392	2	201	0.0021	0.0002	100.0	518.67	642.31	1595.57	1400.92	14.62	21.61	554.25	2388.04	90
393	2	202	-0.0001	0.0003	100.0	518.67	642.56	1589.47	1408.72	14.62	21.61	554.14	2388.14	90
394	2	203	0.0048	0.0001	100.0	518.67	641.95	1593.02	1410.33	14.62	21.61	553.20	2388.05	90
395	2	204	0.0012	0.0003	100.0	518.67	642.46	1591.84	1404.01	14.62	21.61	553.94	2388.02	90
396	2	205	-0.0021	0.0003	100.0	518.67	642.65	1586.59	1409.11	14.62	21.61	552.83	2388.07	90
397	2	206	-0.0004	-0.0003	100.0	518.67	642.51	1588.18	1411.14	14.62	21.61	553.86	2388.03	90
398	2	207	-0.0003	-0.0004	100.0	518.67	642.73	1591.04	1402.94	14.62	21.61	553.06	2388.05	90
399	2	208	0.0004	0.0004	100.0	518.67	642.60	1590.29	1407.93	14.62	21.61	553.09	2388.05	90

	Engine	cycle	setting1	setting2	setting3	Fan Inlet Temperature (◦R)	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(Fan Inlet Pressure) (psia)	(Bypass-Duct Pressure) (psia)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(Phy Sp (
400	2	209	0.0040	0.0002	100.0	518.67	642.27	1590.92	1409.20	14.62	21.61	553.66	2388.09	90
401	2	210	-0.0050	0.0001	100.0	518.67	642.88	1583.56	1396.99	14.62	21.61	553.50	2388.10	90
402	2	211	-0.0017	-0.0002	100.0	518.67	642.80	1584.65	1409.23	14.62	21.61	552.47	2388.08	90
403	2	212	0.0005	-0.0004	100.0	518.67	642.54	1586.71	1406.43	14.62	21.61	553.32	2388.13	90
404	2	213	-0.0039	-0.0000	100.0	518.67	642.39	1594.64	1407.38	14.62	21.61	554.04	2388.09	90
405	2	214	0.0017	-0.0002	100.0	518.67	642.39	1588.17	1402.21	14.62	21.61	553.86	2388.09	90
406	2	215	-0.0004	0.0005	100.0	518.67	642.97	1591.44	1411.63	14.62	21.61	553.75	2388.09	90
407	2	216	-0.0021	0.0005	100.0	518.67	642.46	1583.46	1408.68	14.62	21.61	553.01	2388.08	90
408	2	217	0.0023	0.0005	100.0	518.67	643.30	1585.11	1407.97	14.62	21.61	553.22	2388.10	90
409	2	218	0.0033	-0.0002	100.0	518.67	642.91	1592.69	1412.70	14.62	21.61	553.09	2388.12	90
410	2	219	0.0029	0.0001	100.0	518.67	642.88	1592.52	1412.91	14.62	21.61	553.28	2388.02	90
411	2	220	-0.0036	-0.0002	100.0	518.67	642.87	1600.76	1406.68	14.62	21.61	552.92	2388.09	90
412	2	221	0.0032	-0.0001	100.0	518.67	643.09	1586.57	1408.21	14.62	21.61	553.77	2388.12	90
413	2	222	0.0010	0.0001	100.0	518.67	643.16	1590.78	1411.66	14.62	21.61	553.56	2388.10	90
414	2	223	-0.0002	0.0003	100.0	518.67	643.06	1596.47	1406.28	14.62	21.61	553.91	2388.06	90
415	2	224	-0.0010	0.0001	100.0	518.67	642.86	1592.47	1414.63	14.62	21.61	553.17	2388.13	90
416	2	225	0.0014	-0.0000	100.0	518.67	642.68	1590.59	1409.87	14.62	21.61	553.96	2388.12	90
417	2	226	-0.0018	0.0002	100.0	518.67	643.23	1601.02	1408.90	14.62	21.61	553.45	2388.05	90
418	2	227	0.0014	0.0004	100.0	518.67	642.80	1587.46	1410.40	14.62	21.61	553.73	2388.11	90
419	2	228	-0.0017	0.0001	100.0	518.67	642.67	1592.83	1406.88	14.62	21.61	553.35	2388.11	90
420	2	229	0.0008	-0.0001	100.0	518.67	642.32	1593.83	1407.69	14.62	21.61	553.00	2388.13	90
421	2	230	-0.0002	0.0004	100.0	518.67	642.68	1593.67	1412.71	14.62	21.61	553.43	2388.09	90
422	2	231	-0.0004	-0.0001	100.0	518.67	642.99	1593.78	1404.68	14.62	21.61	552.61	2388.13	90
423	2	232	0.0027	0.0004	100.0	518.67	642.98	1590.33	1411.66	14.62	21.61	553.53	2388.11	90
424	2	233	-0.0023	-0.0004	100.0	518.67	642.96	1599.65	1413.34	14.62	21.61	553.49	2388.07	90
425	2	234	-0.0022	-0.0002	100.0	518.67	643.49	1588.68	1412.07	14.62	21.61	553.31	2388.12	90
426	2	235	0.0019	0.0002	100.0	518.67	642.63	1594.54	1406.42	14.62	21.61	552.42	2388.12	90
427	2	236	-0.0044	0.0003	100.0	518.67	643.01	1598.16	1410.66	14.62	21.61	553.52	2388.15	90
428	2	237	0.0027	0.0004	100.0	518.67	643.14	1593.05	1419.76	14.62	21.61	552.78	2388.11	90
429	2	238	-0.0018	-0.0000	100.0	518.67	643.13	1599.64	1413.73	14.62	21.61	552.98	2388.11	90
430	2	239	0.0026	-0.0003	100.0	518.67	642.73	1598.37	1417.49	14.62	21.61	553.05	2388.13	90
431	2	240	-0.0017	-0.0002	100.0	518.67	642.61	1599.71	1406.54	14.62	21.61	553.18	2388.11	90
432	2	241	-0.0026	0.0001	100.0	518.67	643.14	1598.65	1418.33	14.62	21.61	552.36	2388.16	90
433	2	242	-0.0008	0.0004	100.0	518.67	643.77	1593.70	1408.71	14.62	21.61	553.07	2388.13	90
434	2	243	0.0042	-0.0002	100.0	518.67	643.04	1593.98	1411.41	14.62	21.61	552.71	2388.09	90
435	2	244	-0.0013	0.0005	100.0	518.67	642.88	1595.99	1413.04	14.62	21.61	552.68	2388.13	90
436	2	245	-0.0016	0.0005	100.0	518.67	642.70	1590.93	1418.05	14.62	21.61	552.75	2388.15	90
437	2	246	0.0001	0.0003	100.0	518.67	642.85	1589.74	1420.20	14.62	21.61	552.57	2388.12	90
438	2	247	-0.0013	-0.0002	100.0	518.67	642.88	1601.20	1413.56	14.62	21.61	552.46	2388.10	90
439	2	248	0.0048	0.0001	100.0	518.67	643.06	1599.41	1417.22	14.62	21.61	552.52	2388.08	90
440	2	249	0.0013	-0.0004	100.0	518.67	643.79	1599.77	1419.19	14.62	21.61	551.56	2388.17	90
441	2	250	-0.0029	0.0004	100.0	518.67	643.15	1598.28	1415.35	14.62	21.61	553.00	2388.16	90
442	2	251	-0.0017	-0.0003	100.0	518.67	642.47	1598.68	1418.61	14.62	21.61	552.01	2388.16	90
443	2	252	-0.0040	0.0004	100.0	518.67	642.83	1596.89	1422.69	14.62	21.61	552.51	2388.11	90
444	2	253	0.0009	-0.0002	100.0	518.67	643.01	1596.43	1416.12	14.62	21.61	553.07	2388.14	90
445	2	254	-0.0009	0.0005	100.0	518.67	643.31	1593.88	1423.55	14.62	21.61	551.99	2388.15	90
446	2	255	0.0012	0.0006	100.0	518.67	643.48	1598.25	1412.73	14.62	21.61	553.26	2388.15	90
447	2	256	-0.0044	0.0004	100.0	518.67	642.92	1598.83	1421.46	14.62	21.61	552.68	2388.12	90
448	2	257	0.0000	-0.0002	100.0	518.67	643.06	1593.17	1426.94	14.62	21.61	552.19	2388.14	90
449	2	258	0.0007	-0.0000	100.0	518.67	642.93	1599.77	1421.07	14.62	21.61	552.71	2388.11	90

	Engine	cycle	setting1	setting2	setting3	Fan Inlet Temperature (◦R)	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(Fan Inlet Pressure) (psia)	(Bypass-Duct Pressure) (psia)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(Phy Sp (
450	2	259	0.0006	-0.0003	100.0	518.67	642.78	1597.65	1416.63	14.62	21.61	552.58	2388.12	90
451	2	260	0.0027	0.0001	100.0	518.67	642.94	1593.51	1419.41	14.62	21.61	552.02	2388.17	90
452	2	261	-0.0009	0.0003	100.0	518.67	643.69	1594.00	1419.92	14.62	21.61	552.31	2388.09	90
453	2	262	0.0068	-0.0002	100.0	518.67	643.05	1588.30	1418.20	14.62	21.61	553.01	2388.14	90
454	2	263	-0.0023	0.0001	100.0	518.67	643.16	1592.32	1422.82	14.62	21.61	552.81	2388.20	90
455	2	264	-0.0017	0.0005	100.0	518.67	643.47	1610.10	1424.48	14.62	21.61	552.17	2388.18	90
456	2	265	-0.0035	0.0004	100.0	518.67	643.03	1593.48	1420.27	14.62	21.61	552.45	2388.18	90
457	2	266	0.0020	-0.0001	100.0	518.67	643.14	1591.54	1422.54	14.62	21.61	551.84	2388.10	90
458	2	267	-0.0000	0.0003	100.0	518.67	642.96	1602.23	1422.12	14.62	21.61	552.61	2388.11	90
459	2	268	0.0006	-0.0000	100.0	518.67	643.10	1602.53	1419.61	14.62	21.61	552.10	2388.16	90
460	2	269	-0.0002	-0.0002	100.0	518.67	643.11	1594.52	1419.23	14.62	21.61	551.28	2388.20	90
461	2	270	0.0005	-0.0002	100.0	518.67	643.12	1604.32	1424.27	14.62	21.61	551.75	2388.20	90
462	2	271	0.0001	0.0002	100.0	518.67	643.87	1607.43	1425.06	14.62	21.61	551.73	2388.22	90
463	2	272	-0.0004	0.0001	100.0	518.67	643.27	1600.02	1426.70	14.62	21.61	552.44	2388.22	90
464	2	273	-0.0036	-0.0003	100.0	518.67	643.71	1598.88	1418.55	14.62	21.61	552.47	2388.15	90
465	2	274	-0.0000	0.0004	100.0	518.67	643.18	1598.98	1427.83	14.62	21.61	551.25	2388.20	90
466	2	275	0.0010	0.0001	100.0	518.67	643.67	1595.30	1421.80	14.62	21.61	551.86	2388.21	90
467	2	276	-0.0018	0.0004	100.0	518.67	643.82	1605.46	1429.66	14.62	21.61	551.43	2388.16	90
468	2	277	0.0017	-0.0004	100.0	518.67	643.91	1601.47	1424.78	14.62	21.61	552.45	2388.22	90
469	2	278	-0.0000	-0.0003	100.0	518.67	643.44	1597.61	1423.67	14.62	21.61	551.49	2388.19	90
470	2	279	0.0006	0.0005	100.0	518.67	643.64	1594.80	1426.95	14.62	21.61	551.16	2388.19	90
471	2	280	-0.0061	-0.0000	100.0	518.67	643.63	1594.21	1422.89	14.62	21.61	551.84	2388.24	91
472	2	281	-0.0009	-0.0003	100.0	518.67	643.60	1598.25	1424.36	14.62	21.61	551.44	2388.18	90
473	2	282	0.0012	-0.0000	100.0	518.67	643.94	1598.56	1426.87	14.62	21.61	552.29	2388.23	90
474	2	283	0.0046	0.0002	100.0	518.67	643.78	1602.03	1429.67	14.62	21.61	551.46	2388.16	90
475	2	284	-0.0006	0.0001	100.0	518.67	643.91	1601.35	1430.04	14.62	21.61	551.96	2388.22	90
476	2	285	-0.0007	0.0004	100.0	518.67	643.67	1596.84	1431.17	14.62	21.61	550.85	2388.20	90
477	2	286	-0.0010	-0.0003	100.0	518.67	643.44	1603.63	1429.57	14.62	21.61	551.61	2388.18	91
478	2	287	-0.0005	0.0006	100.0	518.67	643.85	1608.50	1430.84	14.62	21.61	551.66	2388.20	91
479	3	1	0.0008	0.0005	100.0	518.67	642.04	1584.20	1398.13	14.62	21.61	553.96	2388.06	90
480	3	2	-0.0010	0.0000	100.0	518.67	642.66	1587.04	1398.62	14.62	21.61	554.76	2388.05	90
481	3	3	0.0013	-0.0002	100.0	518.67	642.07	1580.75	1401.10	14.62	21.61	554.51	2388.03	90
482	3	4	0.0008	-0.0002	100.0	518.67	642.50	1580.12	1395.76	14.62	21.61	554.48	2388.07	90
483	3	5	0.0020	0.0004	100.0	518.67	641.97	1581.48	1394.05	14.62	21.61	554.14	2388.01	90
484	3	6	-0.0010	-0.0003	100.0	518.67	642.65	1581.26	1397.98	14.62	21.61	554.86	2388.08	90
485	3	7	-0.0018	-0.0003	100.0	518.67	642.62	1583.68	1405.76	14.62	21.61	554.29	2388.06	90
486	3	8	0.0017	-0.0005	100.0	518.67	642.23	1581.60	1401.86	14.62	21.61	554.11	2388.00	90
487	3	9	0.0000	0.0003	100.0	518.67	642.60	1581.04	1398.30	14.62	21.61	554.61	2387.99	90
488	3	10	-0.0009	0.0003	100.0	518.67	642.72	1582.20	1400.07	14.62	21.61	554.28	2388.00	90
489	3	11	-0.0009	0.0002	100.0	518.67	641.94	1591.43	1400.59	14.62	21.61	554.88	2388.03	90
490	3	12	-0.0029	0.0003	100.0	518.67	642.61	1583.92	1404.93	14.62	21.61	553.45	2388.06	90
491	3	13	0.0002	0.0003	100.0	518.67	642.63	1583.25	1403.52	14.62	21.61	555.25	2388.03	90
492	3	14	0.0000	0.0004	100.0	518.67	642.16	1591.03	1396.35	14.62	21.61	554.31	2388.02	90
493	3	15	-0.0015	0.0001	100.0	518.67	641.83	1585.29	1398.77	14.62	21.61	554.36	2388.05	90
494	3	16	-0.0064	-0.0002	100.0	518.67	642.65	1589.05	1392.15	14.62	21.61	554.17	2388.05	90
495	3	17	-0.0018	-0.0001	100.0	518.67	642.78	1588.94	1395.76	14.62	21.61	553.74	2388.00	90
496	3	18	-0.0013	-0.0005	100.0	518.67	642.26	1584.36	1402.30	14.62	21.61	554.52	2388.00	90
497	3	19	0.0029	-0.0004	100.0	518.67	642.05	1580.67	1402.82	14.62	21.61	553.99	2388.03	90
498	3	20	-0.0020	-0.0002	100.0	518.67	642.25	1580.73	1394.57	14.62	21.61	554.54	2388.06	90
499	3	21	-0.0006	0.0004	100.0	518.67	642.18	1586.78	1398.83	14.62	21.61	554.32	2388.02	90

In [10]:
```
jet_data.tail(5)
```

Out[10]:

	Engine	cycle	setting1	setting2	setting3	Fan Inlet Temperature (◦R)	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(Fan Inlet Pressure) (psia)	(Bypass-Duct Pressure) (psia)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(I
20626	100	196	-0.0004	-0.0003	100.0	518.67	643.49	1597.98	1428.63	14.62	21.61	551.43	2388.19	
20627	100	197	-0.0016	-0.0005	100.0	518.67	643.54	1604.50	1433.58	14.62	21.61	550.86	2388.23	
20628	100	198	0.0004	0.0000	100.0	518.67	643.42	1602.46	1428.18	14.62	21.61	550.94	2388.24	
20629	100	199	-0.0011	0.0003	100.0	518.67	643.23	1605.26	1426.53	14.62	21.61	550.68	2388.25	
20630	100	200	-0.0032	-0.0005	100.0	518.67	643.85	1600.38	1432.14	14.62	21.61	550.79	2388.26	

In [11]:
```
jet_id_and_rul.head()
```

Out[11]:

	Engine	cycle
0	1	192
1	2	287
2	3	179
3	4	189
4	5	269

Understanding the data

In [12]:
```
jet_data.shape
```

Out[12]:
```
(20631, 28)
```

In [13]:
```
jet_data.describe()
```

Out[13]:

	Engine	cycle	setting1	setting2	setting3	Fan Inlet Temperature (◦R)	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(Fan Inlet Pressure) (psia)	(E Pr
count	20631.000000	20631.000000	20631.000000	20631.000000	20631.0	2.063100e+04	20631.000000	20631.000000	20631.000000	2.063100e+04	20631.
mean	51.506568	108.807862	-0.000009	0.000002	100.0	5.186700e+02	642.680934	1590.523119	1408.933782	1.462000e+01	21.
std	29.227633	68.880990	0.002187	0.000293	0.0	6.537152e-11	0.500053	6.131150	9.000605	3.394700e-12	0.
min	1.000000	1.000000	-0.008700	-0.000600	100.0	5.186700e+02	641.210000	1571.040000	1382.250000	1.462000e+01	21.
25%	26.000000	52.000000	-0.001500	-0.000200	100.0	5.186700e+02	642.325000	1586.260000	1402.360000	1.462000e+01	21.
50%	52.000000	104.000000	0.000000	0.000000	100.0	5.186700e+02	642.640000	1590.100000	1408.040000	1.462000e+01	21.
75%	77.000000	156.000000	0.001500	0.000300	100.0	5.186700e+02	643.000000	1594.380000	1414.555000	1.462000e+01	21.
max	100.000000	362.000000	0.008700	0.000600	100.0	5.186700e+02	644.530000	1616.910000	1441.490000	1.462000e+01	21.

In [14]:
```
jet_data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 20631 entries, 0 to 20630
Data columns (total 28 columns):
 #   Column                                  Non-Null Count  Dtype
---  ------                                  --------------  -----
 0   Engine                                  20631 non-null  int64
 1   cycle                                   20631 non-null  int64
 2   setting1                                20631 non-null  float64
 3   setting2                                20631 non-null  float64
 4   setting3                                20631 non-null  float64
 5   Fan Inlet Temperature (◦R)              20631 non-null  float64
 6   (LPC Outlet Temperature) (◦R)           20631 non-null  float64
 7   (HPC Outlet Temperature) (◦R)           20631 non-null  float64
 8   (LPT Outlet Temperature) (◦R)           20631 non-null  float64
 9   (Fan Inlet Pressure) (psia)             20631 non-null  float64
 10  (Bypass-Duct Pressure) (psia)           20631 non-null  float64
 11  (HPC Outlet Pressure) (psia)            20631 non-null  float64
 12  (Physical Fan Speed) (rpm)              20631 non-null  float64
 13  (Physical Core Speed) (rpm)             20631 non-null  float64
 14  (Engine Pressure Ratio(P50/P2)          20631 non-null  float64
 15  (HPC Outlet Static Pressure) (psia)     20631 non-null  float64
 16  (Ratio of Fuel Flow to Ps30) (pps/psia) 20631 non-null  float64
 17  (Corrected Fan Speed) (rpm)             20631 non-null  float64
 18  (Corrected Core Speed) (rpm)            20631 non-null  float64
 19  (Bypass Ratio)                          20631 non-null  float64
 20  (Burner Fuel-Air Ratio)                 20631 non-null  float64
 21  (Bleed Enthalpy)                        20631 non-null  int64
 22  (Required Fan Speed)                    20631 non-null  int64
 23  (Required Fan Conversion Speed)         20631 non-null  float64
 24  (High-Pressure Turbines Cool Air Flow)  20631 non-null  float64
 25  (Low-Pressure Turbines Cool Air Flow)   20631 non-null  float64
 26  Sensor1                                 0 non-null      float64
 27  Sensor2                                 0 non-null      float64
dtypes: float64(24), int64(4)
memory usage: 4.4 MB
```

In [15]:
```
# sensor 22 and sensor 23 are empty columns, hence we drop these columns
jet_data.drop(['Sensor1','Sensor2'],axis=1,inplace=True)
```

Data Manipulation The test data does not have RUL column so for model validation purposes we will add the column externally in the dataframe

In [16]:
```
#add a new colun of RUL in jet_data
jet_data['RUL']=[np.nan]*len(jet_data)
```

In [17]:
```
#adding RUL values to RUL column
i=1 # start with engine no 1
max_cycles=jet_id_and_rul[jet_id_and_rul['Engine']==i]['cycle']
m=max_cycles
for j in range (0,jet_data.shape[0]):
    if jet_data.iloc[j]['Engine']==i:
        jet_data.at[j,"RUL"]=m
        m=m-1
    else:
        i=i+1
        m=jet_id_and_rul[jet_id_and_rul['Engine']==i]['cycle']
        jet_data.at[j,"RUL"]=m
        m=m-1
```

In [18]:
```
jet_data.head(205)
```

Out[18]:

	Engine	cycle	setting1	setting2	setting3	Fan Inlet Temperature (◦R)	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(Fan Inlet Pressure) (psia)	(Bypass-Duct Pressure) (psia)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(Phy Sp (
0	1	1	-0.0007	-0.0004	100.0	518.67	641.82	1589.70	1400.60	14.62	21.61	554.36	2388.06	90
1	1	2	0.0019	-0.0003	100.0	518.67	642.15	1591.82	1403.14	14.62	21.61	553.75	2388.04	90
2	1	3	-0.0043	0.0003	100.0	518.67	642.35	1587.99	1404.20	14.62	21.61	554.26	2388.08	90
3	1	4	0.0007	0.0000	100.0	518.67	642.35	1582.79	1401.87	14.62	21.61	554.45	2388.11	90
4	1	5	-0.0019	-0.0002	100.0	518.67	642.37	1582.85	1406.22	14.62	21.61	554.00	2388.06	90
5	1	6	-0.0043	-0.0001	100.0	518.67	642.10	1584.47	1398.37	14.62	21.61	554.67	2388.02	90
6	1	7	0.0010	0.0001	100.0	518.67	642.48	1592.32	1397.77	14.62	21.61	554.34	2388.02	90
7	1	8	-0.0034	0.0003	100.0	518.67	642.56	1582.96	1400.97	14.62	21.61	553.85	2388.00	90
8	1	9	0.0008	0.0001	100.0	518.67	642.12	1590.98	1394.80	14.62	21.61	553.69	2388.05	90
9	1	10	-0.0033	0.0001	100.0	518.67	641.71	1591.24	1400.46	14.62	21.61	553.59	2388.05	90
10	1	11	0.0018	-0.0003	100.0	518.67	642.28	1581.75	1400.64	14.62	21.61	554.54	2388.05	90
11	1	12	0.0016	0.0002	100.0	518.67	642.06	1583.41	1400.15	14.62	21.61	554.52	2388.09	90
12	1	13	-0.0019	0.0004	100.0	518.67	643.07	1582.19	1400.83	14.62	21.61	553.44	2388.12	90
13	1	14	0.0009	-0.0000	100.0	518.67	642.35	1592.95	1399.16	14.62	21.61	554.48	2388.09	90
14	1	15	-0.0018	-0.0003	100.0	518.67	642.43	1583.82	1402.13	14.62	21.61	553.64	2388.11	90
15	1	16	0.0006	0.0005	100.0	518.67	642.13	1587.98	1404.50	14.62	21.61	553.94	2388.05	90
16	1	17	0.0002	0.0002	100.0	518.67	642.58	1584.96	1399.95	14.62	21.61	553.80	2388.06	90
17	1	18	-0.0031	-0.0001	100.0	518.67	642.62	1591.04	1396.12	14.62	21.61	554.20	2388.05	90
18	1	19	0.0032	-0.0003	100.0	518.67	641.79	1587.56	1400.35	14.62	21.61	554.18	2388.04	90
19	1	20	-0.0037	0.0001	100.0	518.67	643.04	1581.11	1405.23	14.62	21.61	554.81	2388.05	90
20	1	21	-0.0012	0.0001	100.0	518.67	642.37	1586.07	1398.13	14.62	21.61	554.08	2388.11	90
21	1	22	0.0002	0.0000	100.0	518.67	642.77	1592.93	1400.57	14.62	21.61	553.63	2388.04	90
22	1	23	0.0034	-0.0003	100.0	518.67	642.14	1588.19	1394.75	14.62	21.61	553.98	2388.05	90
23	1	24	-0.0010	0.0003	100.0	518.67	642.38	1590.83	1398.81	14.62	21.61	553.49	2388.12	90
24	1	25	0.0023	-0.0004	100.0	518.67	642.77	1594.10	1399.39	14.62	21.61	554.00	2388.02	90
25	1	26	0.0000	0.0002	100.0	518.67	642.16	1589.08	1396.07	14.62	21.61	554.11	2388.07	90
26	1	27	-0.0012	-0.0004	100.0	518.67	642.44	1590.47	1401.84	14.62	21.61	554.07	2388.02	90
27	1	28	-0.0024	0.0005	100.0	518.67	642.35	1582.84	1399.13	14.62	21.61	554.68	2388.12	90
28	1	29	0.0012	-0.0001	100.0	518.67	641.91	1584.83	1400.99	14.62	21.61	554.25	2388.05	90
29	1	30	-0.0022	0.0000	100.0	518.67	642.20	1593.52	1396.08	14.62	21.61	554.37	2388.07	90
30	1	31	0.0014	0.0005	100.0	518.67	642.02	1584.18	1396.90	14.62	21.61	554.13	2388.08	90
31	1	32	0.0005	-0.0003	100.0	518.67	642.33	1591.38	1400.36	14.62	21.61	554.96	2388.04	90
32	1	33	-0.0042	-0.0004	100.0	518.67	642.71	1588.40	1402.43	14.62	21.61	554.61	2388.04	90
33	1	34	0.0015	-0.0001	100.0	518.67	642.54	1581.47	1400.48	14.62	21.61	554.30	2388.03	90
34	1	35	0.0003	0.0002	100.0	518.67	642.44	1590.00	1403.00	14.62	21.61	554.30	2388.04	90
35	1	36	-0.0004	-0.0002	100.0	518.67	642.54	1581.72	1405.54	14.62	21.61	554.53	2388.01	90
36	1	37	-0.0004	-0.0000	100.0	518.67	641.99	1579.11	1398.90	14.62	21.61	554.63	2388.07	90
37	1	38	-0.0018	-0.0002	100.0	518.67	641.93	1589.60	1399.50	14.62	21.61	554.70	2388.08	90
38	1	39	-0.0030	-0.0001	100.0	518.67	642.01	1583.21	1400.69	14.62	21.61	553.97	2388.02	90
39	1	40	-0.0000	-0.0004	100.0	518.67	642.24	1582.08	1401.77	14.62	21.61	554.57	2388.06	90
40	1	41	0.0033	0.0004	100.0	518.67	642.40	1591.31	1403.21	14.62	21.61	553.72	2388.06	90
41	1	42	0.0005	-0.0004	100.0	518.67	642.12	1584.66	1401.38	14.62	21.61	553.94	2388.08	90
42	1	43	-0.0027	0.0005	100.0	518.67	642.24	1591.52	1406.05	14.62	21.61	553.68	2388.03	90
43	1	44	-0.0001	0.0002	100.0	518.67	641.93	1586.94	1401.20	14.62	21.61	554.15	2388.04	90
44	1	45	-0.0013	-0.0000	100.0	518.67	642.53	1582.42	1399.16	14.62	21.61	553.83	2388.08	90
45	1	46	0.0003	0.0001	100.0	518.67	642.43	1588.29	1401.27	14.62	21.61	553.76	2388.06	90
46	1	47	0.0000	0.0005	100.0	518.67	642.21	1580.32	1402.89	14.62	21.61	554.38	2388.06	90
47	1	48	0.0019	0.0001	100.0	518.67	641.89	1588.51	1399.16	14.62	21.61	554.02	2388.08	90
48	1	49	-0.0014	0.0005	100.0	518.67	642.23	1584.35	1397.76	14.62	21.61	554.23	2388.07	90
49	1	50	-0.0032	-0.0001	100.0	518.67	642.77	1588.49	1403.62	14.62	21.61	553.92	2388.06	90

	Engine	cycle	setting1	setting2	setting3	Fan Inlet Temperature (◦R)	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(Fan Inlet Pressure) (psia)	(Bypass-Duct Pressure) (psia)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(Phy Sp (
50	1	51	-0.0010	0.0003	100.0	518.67	642.81	1585.54	1400.42	14.62	21.61	553.73	2388.02	90
51	1	52	0.0018	-0.0001	100.0	518.67	642.76	1583.77	1395.57	14.62	21.61	553.04	2388.04	90
52	1	53	0.0021	-0.0001	100.0	518.67	642.61	1579.82	1402.26	14.62	21.61	554.16	2388.05	90
53	1	54	-0.0002	0.0005	100.0	518.67	642.42	1592.59	1401.20	14.62	21.61	553.95	2388.04	90
54	1	55	0.0009	-0.0000	100.0	518.67	642.41	1584.95	1401.58	14.62	21.61	554.45	2388.04	90
55	1	56	0.0007	-0.0002	100.0	518.67	642.49	1586.33	1400.76	14.62	21.61	553.98	2388.01	90
56	1	57	-0.0033	0.0000	100.0	518.67	642.13	1583.67	1402.79	14.62	21.61	553.42	2388.05	90
57	1	58	-0.0014	0.0001	100.0	518.67	641.90	1590.46	1397.99	14.62	21.61	554.14	2388.09	90
58	1	59	-0.0006	0.0002	100.0	518.67	642.33	1596.72	1403.51	14.62	21.61	554.62	2388.07	90
59	1	60	-0.0010	-0.0002	100.0	518.67	642.34	1582.75	1403.07	14.62	21.61	554.00	2388.06	90
60	1	61	0.0004	0.0005	100.0	518.67	642.10	1583.55	1405.52	14.62	21.61	554.09	2388.11	90
61	1	62	0.0004	0.0001	100.0	518.67	642.17	1581.59	1399.54	14.62	21.61	554.45	2388.10	90
62	1	63	0.0015	0.0002	100.0	518.67	642.60	1592.14	1395.38	14.62	21.61	553.48	2388.06	90
63	1	64	0.0017	0.0002	100.0	518.67	642.23	1584.51	1400.11	14.62	21.61	553.88	2388.10	90
64	1	65	-0.0000	0.0005	100.0	518.67	642.28	1584.72	1403.24	14.62	21.61	553.97	2388.03	90
65	1	66	-0.0007	-0.0004	100.0	518.67	642.50	1588.50	1399.52	14.62	21.61	554.00	2388.06	90
66	1	67	0.0016	-0.0004	100.0	518.67	642.33	1590.22	1403.02	14.62	21.61	554.31	2388.10	90
67	1	68	-0.0018	0.0000	100.0	518.67	642.51	1582.06	1404.42	14.62	21.61	554.04	2388.10	90
68	1	69	-0.0022	0.0005	100.0	518.67	642.44	1590.70	1401.24	14.62	21.61	554.65	2388.07	90
69	1	70	-0.0005	0.0002	100.0	518.67	642.22	1584.02	1402.78	14.62	21.61	554.01	2388.11	90
70	1	71	0.0016	-0.0003	100.0	518.67	642.21	1580.41	1403.09	14.62	21.61	554.06	2388.03	90
71	1	72	-0.0017	0.0001	100.0	518.67	642.41	1579.25	1406.81	14.62	21.61	553.76	2388.07	90
72	1	73	-0.0012	-0.0002	100.0	518.67	642.29	1592.04	1397.93	14.62	21.61	553.88	2388.03	90
73	1	74	0.0027	0.0001	100.0	518.67	642.96	1584.65	1401.48	14.62	21.61	554.03	2388.07	90
74	1	75	0.0009	-0.0004	100.0	518.67	641.96	1582.32	1394.82	14.62	21.61	553.60	2388.07	90
75	1	76	-0.0015	0.0002	100.0	518.67	642.21	1589.21	1398.94	14.62	21.61	553.66	2388.02	90
76	1	77	0.0022	0.0004	100.0	518.67	642.55	1586.30	1400.97	14.62	21.61	554.61	2388.06	90
77	1	78	0.0040	0.0002	100.0	518.67	641.99	1580.76	1404.10	14.62	21.61	553.47	2388.08	90
78	1	79	0.0022	-0.0002	100.0	518.67	642.12	1582.46	1403.93	14.62	21.61	553.77	2388.04	90
79	1	80	-0.0002	-0.0004	100.0	518.67	641.94	1591.96	1393.58	14.62	21.61	553.91	2388.06	90
80	1	81	-0.0018	-0.0004	100.0	518.67	642.73	1584.82	1402.04	14.62	21.61	553.88	2388.10	90
81	1	82	-0.0012	0.0001	100.0	518.67	642.04	1589.07	1399.17	14.62	21.61	554.18	2388.10	90
82	1	83	0.0004	0.0005	100.0	518.67	642.66	1588.05	1406.38	14.62	21.61	553.49	2388.08	90
83	1	84	0.0005	0.0002	100.0	518.67	642.64	1585.52	1406.60	14.62	21.61	553.91	2388.05	90
84	1	85	0.0025	0.0003	100.0	518.67	642.28	1590.12	1405.96	14.62	21.61	554.40	2388.01	90
85	1	86	-0.0012	0.0004	100.0	518.67	641.84	1588.80	1403.56	14.62	21.61	553.69	2388.10	90
86	1	87	0.0000	-0.0004	100.0	518.67	642.33	1586.69	1413.10	14.62	21.61	554.10	2388.14	90
87	1	88	0.0029	0.0003	100.0	518.67	641.96	1581.29	1406.09	14.62	21.61	554.48	2388.07	90
88	1	89	0.0008	-0.0001	100.0	518.67	642.24	1584.73	1402.22	14.62	21.61	553.91	2388.05	90
89	1	90	0.0017	-0.0001	100.0	518.67	642.67	1584.38	1412.93	14.62	21.61	552.88	2388.10	90
90	1	91	0.0025	-0.0004	100.0	518.67	641.98	1584.84	1404.76	14.62	21.61	553.54	2388.04	90
91	1	92	0.0010	-0.0002	100.0	518.67	642.89	1590.03	1400.77	14.62	21.61	553.81	2388.14	90
92	1	93	0.0032	0.0002	100.0	518.67	642.85	1593.74	1408.48	14.62	21.61	554.07	2388.07	90
93	1	94	-0.0021	0.0002	100.0	518.67	642.45	1583.27	1404.94	14.62	21.61	553.86	2388.15	90
94	1	95	0.0019	0.0003	100.0	518.67	642.86	1577.60	1410.10	14.62	21.61	553.91	2388.02	90
95	1	96	-0.0034	0.0001	100.0	518.67	642.19	1584.07	1395.16	14.62	21.61	553.34	2388.07	90
96	1	97	0.0035	-0.0003	100.0	518.67	642.07	1595.77	1407.81	14.62	21.61	553.40	2388.09	90
97	1	98	0.0006	0.0004	100.0	518.67	642.00	1591.11	1404.56	14.62	21.61	552.75	2388.06	90
98	1	99	-0.0005	-0.0000	100.0	518.67	642.46	1592.73	1406.13	14.62	21.61	553.76	2388.08	90
99	1	100	-0.0021	-0.0003	100.0	518.67	642.22	1589.63	1411.35	14.62	21.61	554.22	2388.07	90

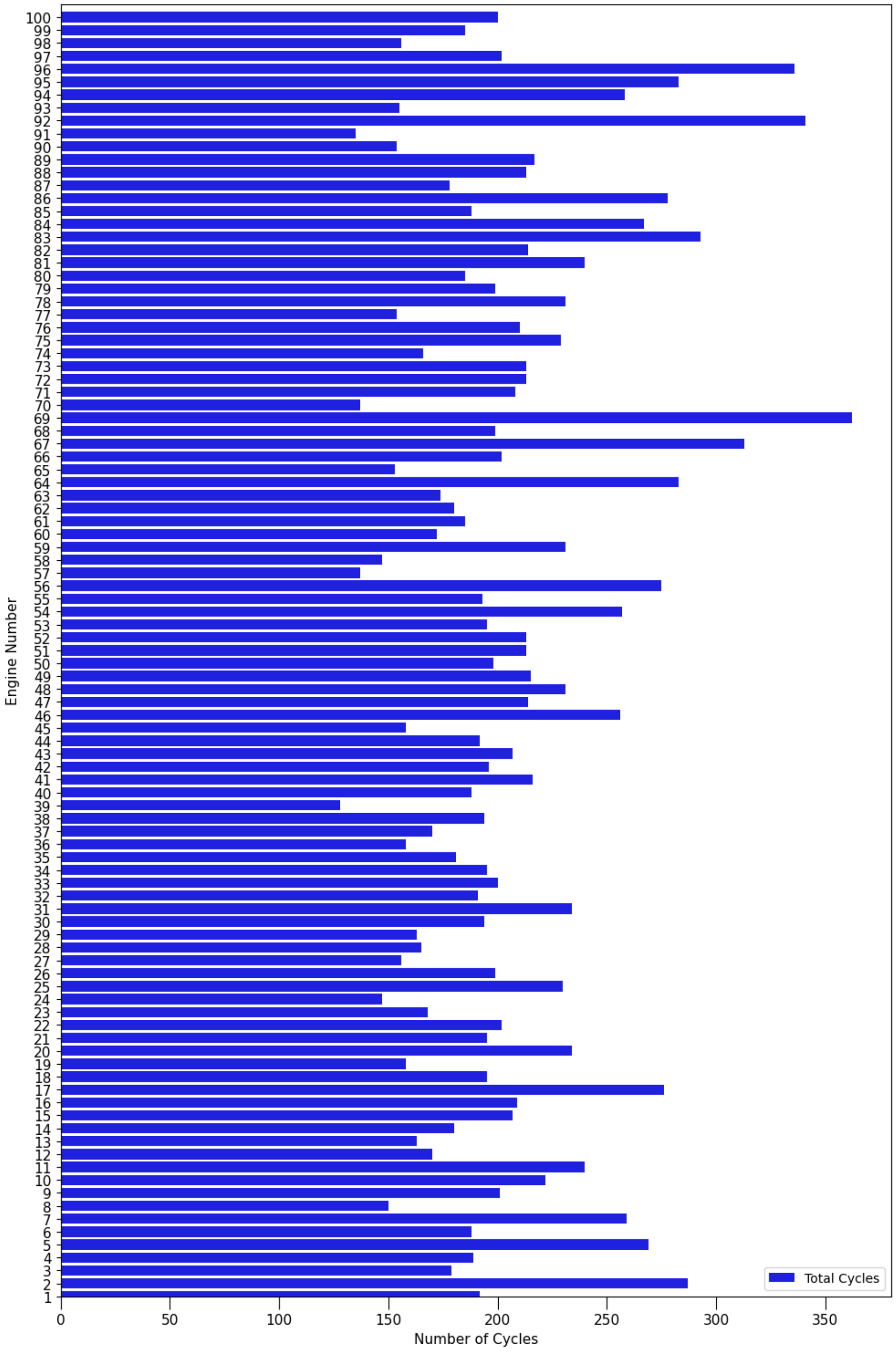
	Engine	cycle	setting1	setting2	setting3	Fan Inlet Temperature (◦R)	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(Fan Inlet Pressure) (psia)	(Bypass-Duct Pressure) (psia)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(Phy Sp (
100	1	101	0.0012	0.0003	100.0	518.67	642.75	1584.18	1403.41	14.62	21.61	553.37	2388.06	90
101	1	102	0.0017	0.0005	100.0	518.67	642.85	1589.11	1403.42	14.62	21.61	553.42	2388.15	90
102	1	103	-0.0013	0.0001	100.0	518.67	642.21	1581.27	1403.21	14.62	21.61	553.64	2388.09	90
103	1	104	-0.0001	0.0001	100.0	518.67	642.29	1590.63	1406.25	14.62	21.61	553.66	2388.08	90
104	1	105	0.0024	0.0004	100.0	518.67	642.01	1588.28	1403.22	14.62	21.61	553.11	2388.09	90
105	1	106	0.0000	0.0001	100.0	518.67	642.68	1589.05	1404.45	14.62	21.61	553.60	2388.08	90
106	1	107	-0.0012	-0.0001	100.0	518.67	642.53	1595.13	1407.73	14.62	21.61	553.74	2388.07	90
107	1	108	0.0008	0.0001	100.0	518.67	643.49	1585.91	1399.47	14.62	21.61	554.43	2388.14	90
108	1	109	-0.0011	-0.0003	100.0	518.67	642.49	1586.45	1409.10	14.62	21.61	553.59	2388.10	90
109	1	110	-0.0000	0.0004	100.0	518.67	642.55	1590.01	1401.27	14.62	21.61	554.08	2388.13	90
110	1	111	0.0008	0.0004	100.0	518.67	642.67	1584.38	1408.11	14.62	21.61	553.49	2388.12	90
111	1	112	0.0005	0.0003	100.0	518.67	642.66	1586.46	1401.84	14.62	21.61	553.19	2388.06	90
112	1	113	0.0007	0.0001	100.0	518.67	642.68	1590.85	1406.59	14.62	21.61	552.91	2388.10	90
113	1	114	0.0003	0.0004	100.0	518.67	642.31	1588.42	1402.97	14.62	21.61	554.29	2388.07	90
114	1	115	-0.0017	0.0005	100.0	518.67	642.66	1594.84	1406.60	14.62	21.61	554.13	2388.11	90
115	1	116	-0.0020	-0.0003	100.0	518.67	642.64	1580.31	1401.99	14.62	21.61	554.40	2388.08	90
116	1	117	0.0005	0.0004	100.0	518.67	642.38	1589.77	1409.35	14.62	21.61	554.59	2388.10	90
117	1	118	-0.0006	-0.0004	100.0	518.67	642.34	1585.67	1409.34	14.62	21.61	554.25	2388.10	90
118	1	119	0.0013	0.0005	100.0	518.67	642.67	1596.80	1404.46	14.62	21.61	553.77	2388.10	90
119	1	120	-0.0024	0.0005	100.0	518.67	642.81	1593.78	1407.68	14.62	21.61	553.66	2388.10	90
120	1	121	-0.0033	0.0004	100.0	518.67	642.63	1593.56	1411.90	14.62	21.61	553.70	2388.07	90
121	1	122	0.0026	-0.0001	100.0	518.67	643.30	1593.68	1413.97	14.62	21.61	553.43	2388.15	90
122	1	123	0.0016	-0.0002	100.0	518.67	643.39	1586.66	1403.04	14.62	21.61	552.64	2388.12	90
123	1	124	0.0025	0.0002	100.0	518.67	642.48	1587.14	1402.28	14.62	21.61	552.26	2388.13	90
124	1	125	-0.0004	0.0005	100.0	518.67	642.96	1585.47	1406.42	14.62	21.61	552.44	2388.13	90
125	1	126	0.0016	0.0001	100.0	518.67	642.49	1582.64	1418.50	14.62	21.61	553.72	2388.05	90
126	1	127	-0.0010	0.0002	100.0	518.67	642.99	1586.90	1399.49	14.62	21.61	553.81	2388.09	90
127	1	128	-0.0006	0.0003	100.0	518.67	642.47	1593.87	1407.06	14.62	21.61	552.74	2388.13	90
128	1	129	-0.0033	0.0003	100.0	518.67	642.41	1591.33	1408.42	14.62	21.61	552.42	2388.09	90
129	1	130	-0.0007	0.0002	100.0	518.67	642.70	1585.90	1412.25	14.62	21.61	552.66	2388.13	90
130	1	131	0.0002	-0.0001	100.0	518.67	643.01	1585.78	1413.25	14.62	21.61	553.70	2388.11	90
131	1	132	0.0032	-0.0001	100.0	518.67	643.19	1596.06	1405.76	14.62	21.61	553.16	2388.17	90
132	1	133	0.0032	-0.0002	100.0	518.67	642.45	1592.64	1410.11	14.62	21.61	553.82	2388.11	90
133	1	134	-0.0014	0.0000	100.0	518.67	642.85	1583.62	1402.67	14.62	21.61	553.20	2388.11	90
134	1	135	-0.0017	0.0001	100.0	518.67	642.45	1585.55	1406.83	14.62	21.61	553.09	2388.14	90
135	1	136	0.0030	-0.0001	100.0	518.67	642.84	1584.72	1404.39	14.62	21.61	554.18	2388.06	90
136	1	137	-0.0011	0.0000	100.0	518.67	642.43	1594.69	1405.15	14.62	21.61	553.39	2388.14	90
137	1	138	-0.0011	0.0001	100.0	518.67	642.79	1589.82	1413.34	14.62	21.61	552.91	2388.11	90
138	1	139	-0.0014	0.0005	100.0	518.67	643.11	1592.28	1412.60	14.62	21.61	553.25	2388.06	90
139	1	140	-0.0006	-0.0001	100.0	518.67	643.05	1590.89	1408.36	14.62	21.61	552.15	2388.17	90
140	1	141	-0.0023	0.0005	100.0	518.67	642.39	1590.02	1415.25	14.62	21.61	553.45	2388.13	90
141	1	142	0.0026	0.0002	100.0	518.67	642.51	1595.29	1413.42	14.62	21.61	553.11	2388.10	90
142	1	143	-0.0005	-0.0003	100.0	518.67	642.77	1593.10	1404.21	14.62	21.61	553.62	2388.13	90
143	1	144	0.0025	-0.0004	100.0	518.67	643.09	1591.89	1405.76	14.62	21.61	553.77	2388.17	90
144	1	145	-0.0004	-0.0001	100.0	518.67	642.95	1594.92	1409.63	14.62	21.61	553.03	2388.13	90
145	1	146	0.0002	-0.0003	100.0	518.67	642.72	1586.75	1408.82	14.62	21.61	552.60	2388.12	90
146	1	147	0.0047	0.0001	100.0	518.67	642.25	1594.85	1409.96	14.62	21.61	553.09	2388.14	90
147	1	148	0.0010	-0.0004	100.0	518.67	643.02	1590.03	1411.89	14.62	21.61	552.84	2388.16	90
148	1	149	0.0025	0.0004	100.0	518.67	642.90	1592.78	1410.70	14.62	21.61	552.54	2388.17	90
149	1	150	0.0010	-0.0003	100.0	518.67	643.06	1589.01	1409.22	14.62	21.61	553.57	2388.12	90

	Engine	cycle	setting1	setting2	setting3	Fan Inlet Temperature (◦R)	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(Fan Inlet Pressure) (psia)	(Bypass-Duct Pressure) (psia)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(Phy Sp (
150	1	151	-0.0019	-0.0001	100.0	518.67	642.82	1592.39	1411.94	14.62	21.61	552.41	2388.14	90
151	1	152	0.0009	-0.0001	100.0	518.67	642.67	1598.60	1420.83	14.62	21.61	552.62	2388.18	90
152	1	153	0.0011	-0.0004	100.0	518.67	642.99	1589.17	1414.56	14.62	21.61	552.68	2388.14	90
153	1	154	-0.0012	0.0000	100.0	518.67	642.81	1597.03	1416.07	14.62	21.61	552.57	2388.14	90
154	1	155	-0.0033	0.0002	100.0	518.67	642.83	1590.40	1414.89	14.62	21.61	552.89	2388.16	90
155	1	156	-0.0020	0.0003	100.0	518.67	643.04	1585.61	1421.23	14.62	21.61	553.24	2388.26	90
156	1	157	-0.0018	0.0002	100.0	518.67	642.20	1598.04	1412.47	14.62	21.61	552.32	2388.14	90
157	1	158	-0.0023	0.0001	100.0	518.67	642.88	1596.82	1410.09	14.62	21.61	553.19	2388.20	90
158	1	159	-0.0006	0.0001	100.0	518.67	642.89	1589.54	1420.37	14.62	21.61	552.18	2388.13	90
159	1	160	-0.0006	-0.0004	100.0	518.67	643.45	1590.65	1418.08	14.62	21.61	551.87	2388.21	90
160	1	161	0.0008	0.0001	100.0	518.67	643.00	1594.20	1417.31	14.62	21.61	552.80	2388.18	90
161	1	162	-0.0005	0.0004	100.0	518.67	643.15	1592.22	1423.48	14.62	21.61	552.68	2388.15	90
162	1	163	0.0003	-0.0004	100.0	518.67	642.85	1600.54	1421.09	14.62	21.61	552.41	2388.20	90
163	1	164	0.0005	-0.0002	100.0	518.67	643.17	1598.96	1416.76	14.62	21.61	551.90	2388.17	90
164	1	165	0.0010	0.0004	100.0	518.67	642.76	1597.03	1408.09	14.62	21.61	552.79	2388.19	90
165	1	166	-0.0022	-0.0003	100.0	518.67	643.34	1596.72	1422.37	14.62	21.61	552.13	2388.22	90
166	1	167	0.0012	0.0003	100.0	518.67	643.02	1593.83	1414.72	14.62	21.61	552.57	2388.23	90
167	1	168	-0.0043	0.0002	100.0	518.67	642.68	1591.19	1415.70	14.62	21.61	552.09	2388.22	90
168	1	169	-0.0017	0.0004	100.0	518.67	643.20	1590.16	1418.05	14.62	21.61	552.71	2388.25	90
169	1	170	-0.0017	-0.0002	100.0	518.67	642.92	1592.71	1417.41	14.62	21.61	552.02	2388.21	90
170	1	171	0.0004	-0.0003	100.0	518.67	643.26	1592.06	1414.99	14.62	21.61	552.71	2388.20	90
171	1	172	-0.0014	-0.0003	100.0	518.67	643.33	1591.71	1413.73	14.62	21.61	551.69	2388.24	90
172	1	173	-0.0032	0.0002	100.0	518.67	642.97	1590.69	1425.27	14.62	21.61	552.13	2388.22	90
173	1	174	-0.0001	-0.0002	100.0	518.67	642.64	1599.81	1422.58	14.62	21.61	552.32	2388.22	90
174	1	175	0.0001	0.0002	100.0	518.67	643.61	1603.29	1422.52	14.62	21.61	551.64	2388.23	90
175	1	176	-0.0020	-0.0003	100.0	518.67	642.86	1592.27	1422.73	14.62	21.61	551.91	2388.23	90
176	1	177	-0.0038	-0.0003	100.0	518.67	643.79	1602.02	1423.99	14.62	21.61	551.93	2388.25	90
177	1	178	-0.0001	0.0002	100.0	518.67	643.38	1605.33	1424.65	14.62	21.61	552.18	2388.23	90
178	1	179	0.0023	-0.0003	100.0	518.67	642.86	1592.56	1429.45	14.62	21.61	551.57	2388.26	90
179	1	180	-0.0024	0.0000	100.0	518.67	643.58	1599.87	1417.14	14.62	21.61	552.91	2388.21	90
180	1	181	-0.0006	0.0005	100.0	518.67	643.44	1596.71	1420.64	14.62	21.61	551.83	2388.23	90
181	1	182	-0.0010	0.0003	100.0	518.67	644.21	1602.08	1426.62	14.62	21.61	551.90	2388.26	90
182	1	183	0.0001	0.0001	100.0	518.67	643.24	1597.23	1419.03	14.62	21.61	551.38	2388.21	90
183	1	184	0.0004	0.0003	100.0	518.67	644.07	1605.44	1432.52	14.62	21.61	551.00	2388.24	90
184	1	185	0.0008	0.0001	100.0	518.67	643.80	1603.46	1424.40	14.62	21.61	551.64	2388.29	90
185	1	186	0.0027	-0.0003	100.0	518.67	643.51	1595.16	1426.30	14.62	21.61	552.57	2388.21	90
186	1	187	-0.0047	-0.0000	100.0	518.67	643.32	1592.10	1427.27	14.62	21.61	551.08	2388.29	90
187	1	188	-0.0067	0.0003	100.0	518.67	643.75	1602.38	1422.78	14.62	21.61	551.94	2388.31	90
188	1	189	-0.0006	0.0002	100.0	518.67	644.18	1596.17	1428.01	14.62	21.61	550.70	2388.27	90
189	1	190	-0.0027	0.0001	100.0	518.67	643.64	1599.22	1425.95	14.62	21.61	551.29	2388.29	90
190	1	191	-0.0000	-0.0004	100.0	518.67	643.34	1602.36	1425.77	14.62	21.61	550.92	2388.28	90
191	1	192	0.0009	-0.0000	100.0	518.67	643.54	1601.41	1427.20	14.62	21.61	551.25	2388.32	90
192	2	1	-0.0018	0.0006	100.0	518.67	641.89	1583.84	1391.28	14.62	21.60	554.53	2388.01	90
193	2	2	0.0043	-0.0003	100.0	518.67	641.82	1587.05	1393.13	14.62	21.61	554.77	2387.98	90
194	2	3	0.0018	0.0003	100.0	518.67	641.55	1588.32	1398.96	14.62	21.60	555.14	2388.04	90
195	2	4	0.0035	-0.0004	100.0	518.67	641.68	1584.15	1396.08	14.62	21.61	554.25	2387.98	90
196	2	5	0.0005	0.0004	100.0	518.67	641.73	1579.03	1402.52	14.62	21.60	555.12	2388.03	90
197	2	6	-0.0010	0.0004	100.0	518.67	641.30	1577.50	1396.76	14.62	21.61	554.98	2388.04	90
198	2	7	0.0001	-0.0002	100.0	518.67	642.03	1587.49	1400.65	14.62	21.61	554.84	2388.05	90
199	2	8	0.0015	-0.0004	100.0	518.67	642.55	1590.41	1395.39	14.62	21.61	554.65	2388.01	90

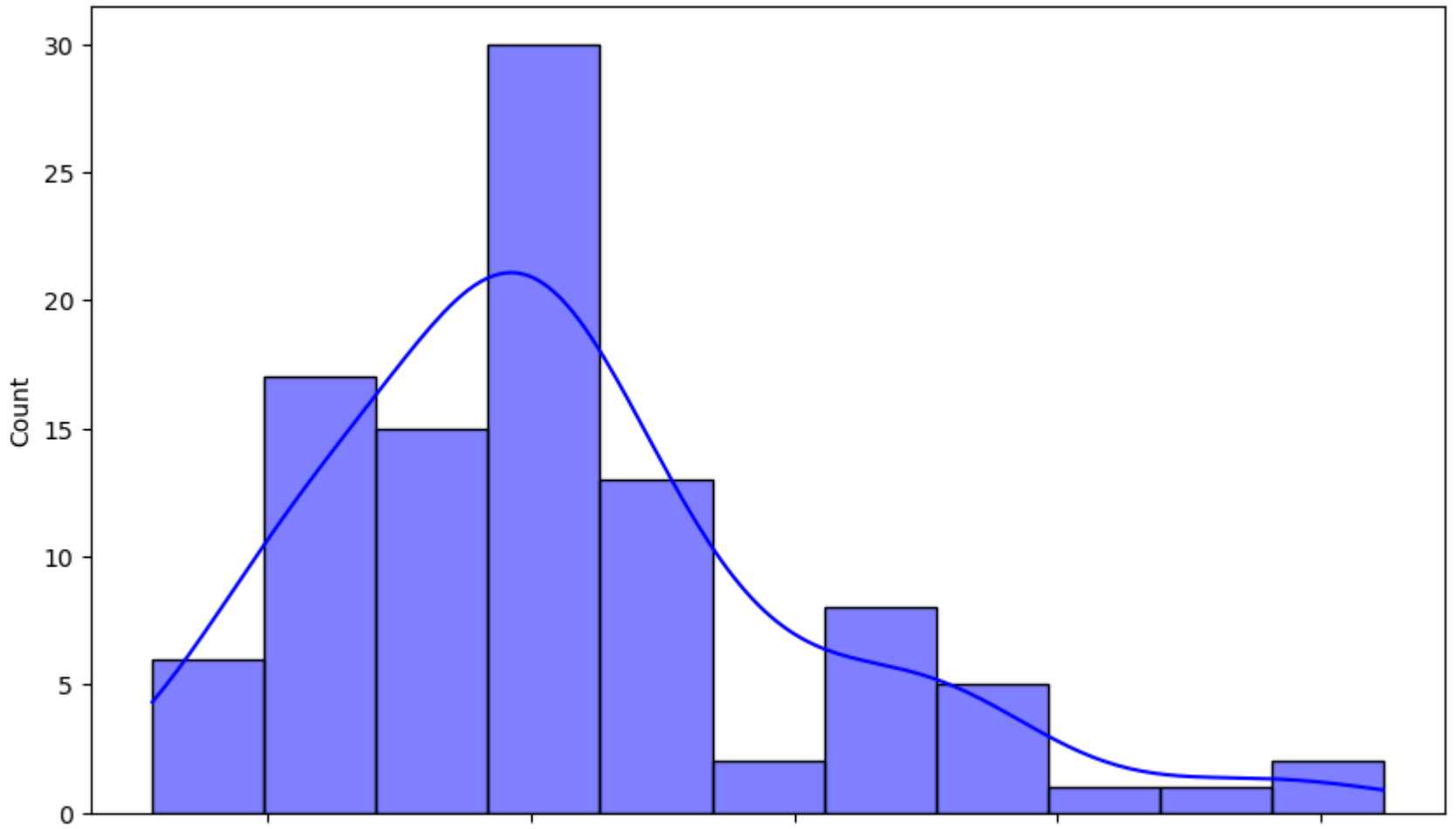
	Engine	cycle	setting1	setting2	setting3	Fan Inlet Temperature (◦R)	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(Fan Inlet Pressure) (psia)	(Bypass-Duct Pressure) (psia)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(Phy Sp (
200	2	9	0.0017	-0.0004	100.0	518.67	641.98	1581.99	1395.01	14.62	21.60	554.69	2388.02	90
201	2	10	-0.0045	0.0002	100.0	518.67	641.99	1586.37	1394.86	14.62	21.60	554.63	2387.99	90
202	2	11	0.0006	0.0004	100.0	518.67	642.26	1589.21	1401.29	14.62	21.61	554.70	2388.01	90
203	2	12	0.0002	0.0006	100.0	518.67	641.64	1579.99	1401.90	14.62	21.61	554.57	2387.98	90
204	2	13	0.0007	0.0005	100.0	518.67	641.78	1586.77	1401.53	14.62	21.61	554.69	2387.94	90

Visualizing Data

In [19]:
```
#create a bar graph to visualise number of cycles of each jet engine

# Create a subplot with a specified size
f, ax = plt.subplots(figsize=(10, 15))


# Create a horizontal bar plot
sns.barplot(x="cycle", y="Engine", data=jet_id_and_rul, label="Total Cycles", color="blue", orient='h')

# Add a legend to the plot
ax.legend(ncol=2, loc="lower right", frameon=True)

# Set limits for the y-axis
ax.set(ylim=(0, 100))


# Customize tick parameters
ax.tick_params(labelsize=11)
ax.tick_params(length=10, axis='x')

# Set labels for the y-axis and x-axis
ax.set_ylabel("Engine Number", fontsize=11)
ax.set_xlabel("Number of Cycles", fontsize=11)

# Adjust layout and display the plot
plt.tight_layout()
plt.show()
```

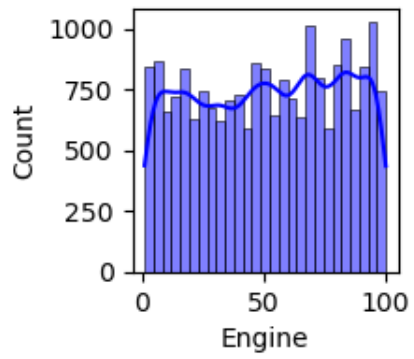


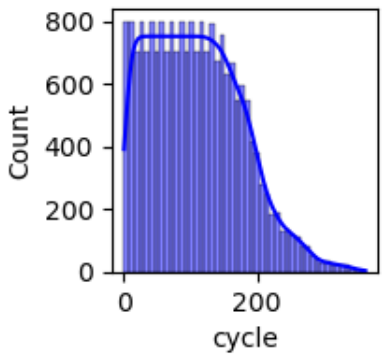
In [20]:
```
#to find the disribution of no of cycles after which jet engine fails
plt.figure(figsize=(10, 6))
sns.histplot(jet_id_and_rul["cycle"], kde = True, color='blue')
plt.show()
print("Mean number of cycles after which jet engine fails is", jet_id_and_rul["cycle"].mean())
```

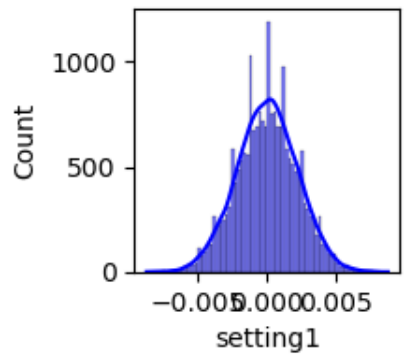


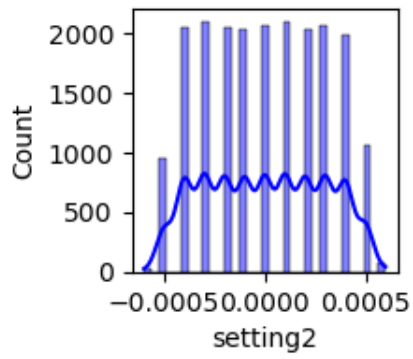

```
Mean number of cycles after which jet engine fails is 206.31
```

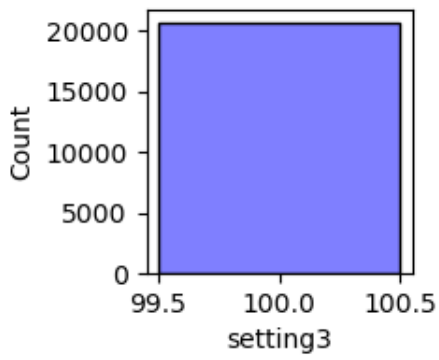
In [21]:
```
#create subplots to find data distribution of each sensor input
plt.figure(figsize=(10,15))
for i,v in enumerate(jet_data.columns):
    plt.subplot(7,4,i+1)
    sns.histplot(jet_data[v],kde=True,color='Blue')
plt.tight_layout()
plt.show()
```

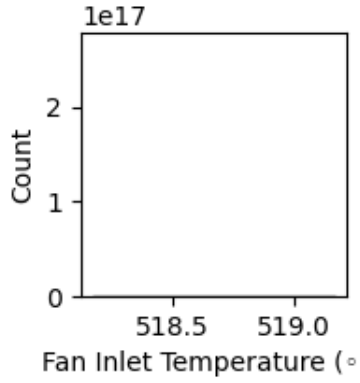


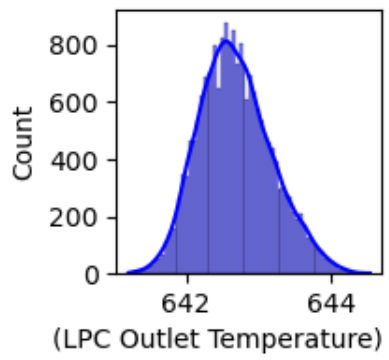


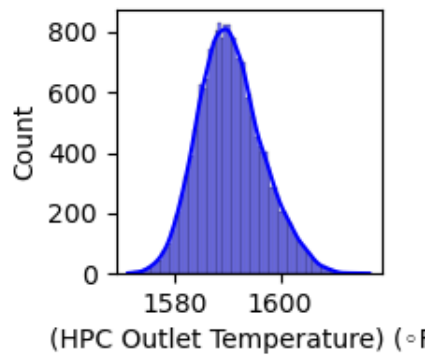


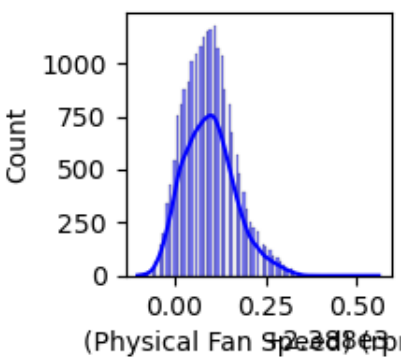


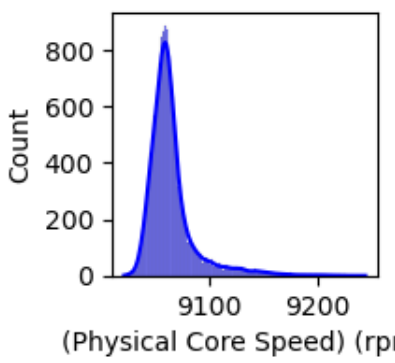


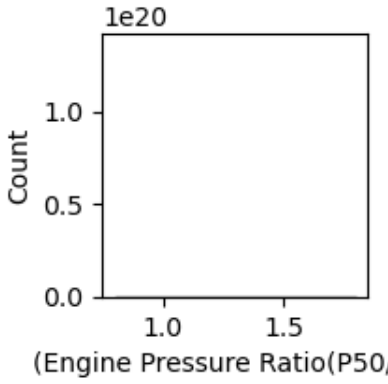


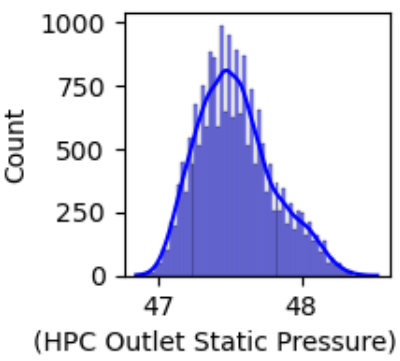


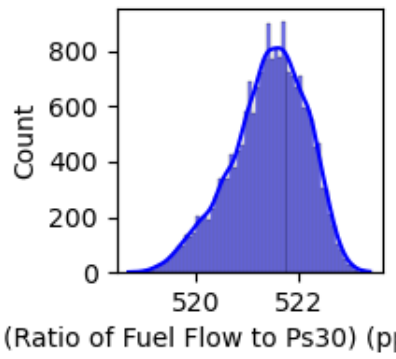


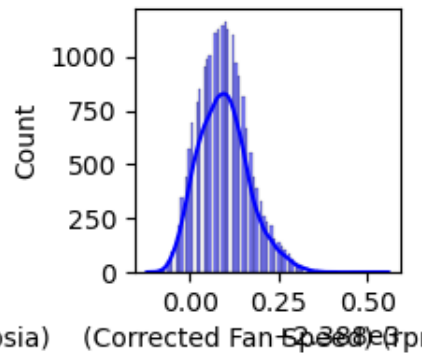


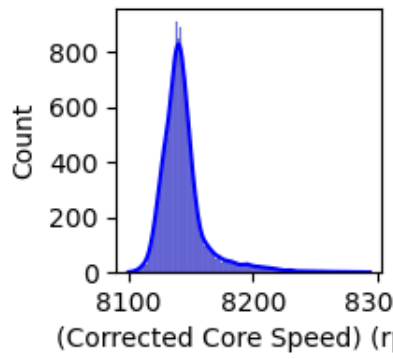


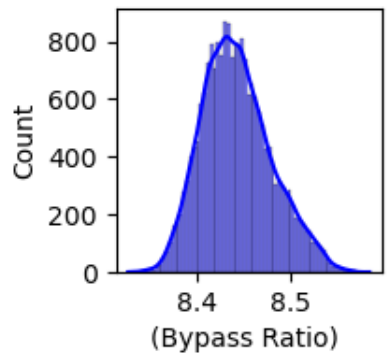


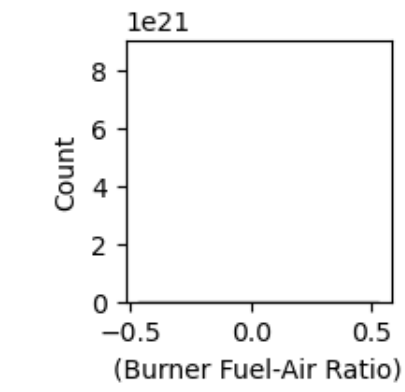


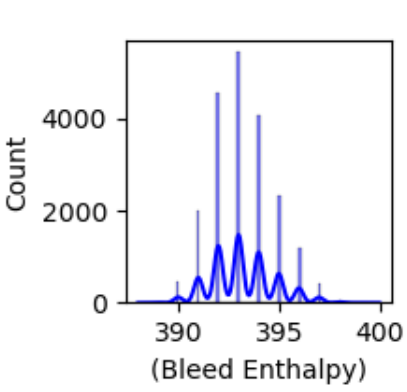


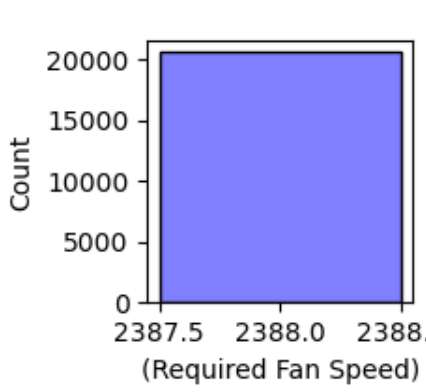


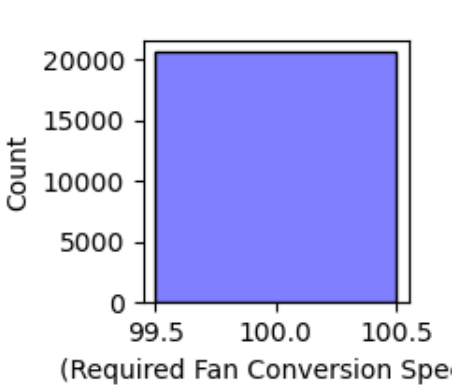


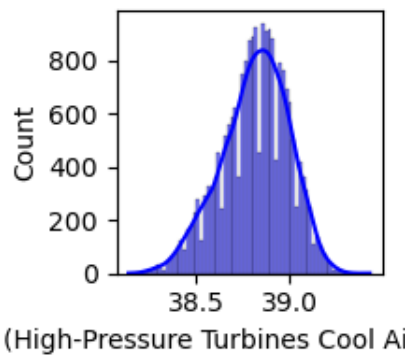


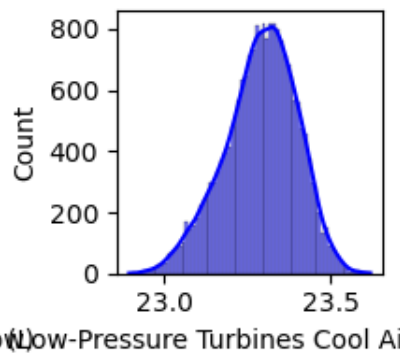


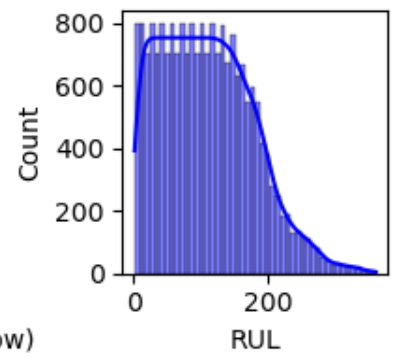




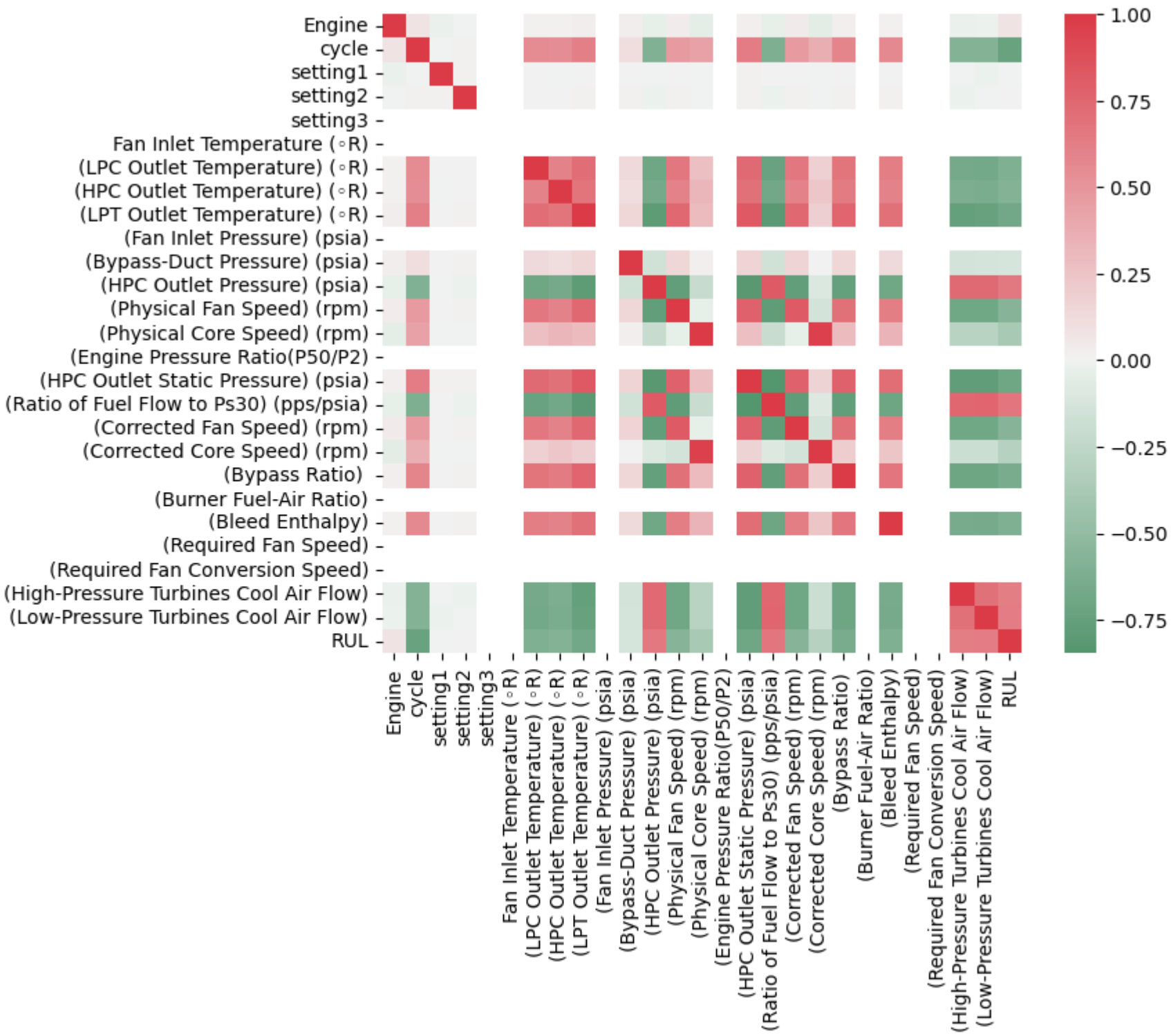








In [22]:
```
#lets find out correlation of all inputs with respect to RUL
plt.figure(figsize=(8,6))
cmap=sns.diverging_palette(500,10,as_cmap=True)
sns.heatmap(jet_data.corr(),cmap=cmap,center=0,square=True)
plt.show()
```



from the above chart, we find that "engine",'setting1','setting2','setting3','fan_inlet temperature','fan_inlet pressure',(Bypass-Duct Pressure) (psia),'engine pressure ratio','burner fuel air ratio','required fan speed','required fan conversion speed' are not significant wrt RUL

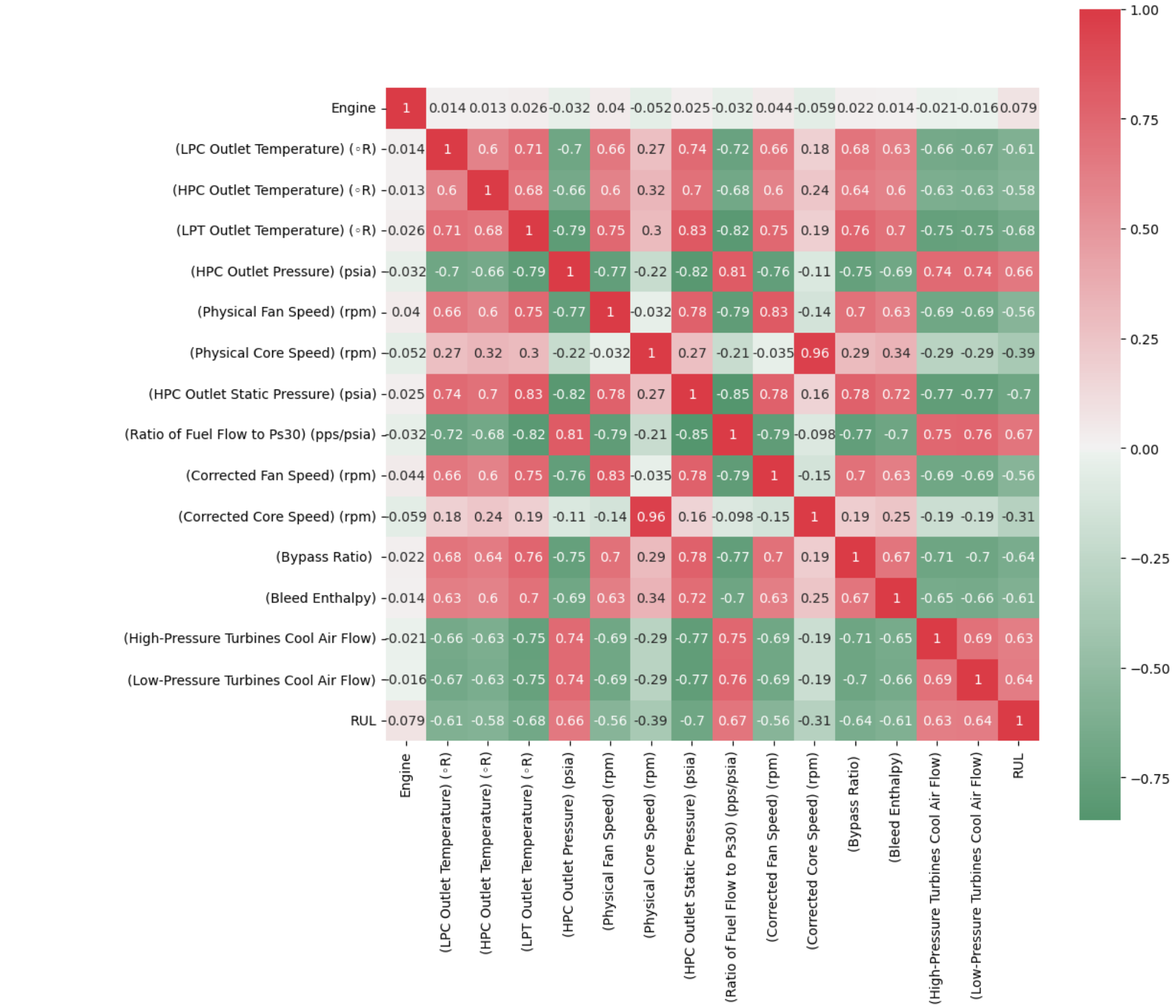
In [23]:
```
#dropping the above columns
jet_relevant_data=jet_data.drop(['cycle','setting1','setting2','setting3','Fan Inlet Temperature (◦R)','(Bypass-Duct Pressure) (p
                                 '(Fan Inlet Pressure) (psia)','(Engine Pressure Ratio(P50/P2)','(Burner Fuel-Air Ratio)',
                                 '(Required Fan Speed)','(Required Fan Conversion Speed)'],axis=1)
```

In [24]:
```
jet_relevant_data.head()
```

Out[24]:

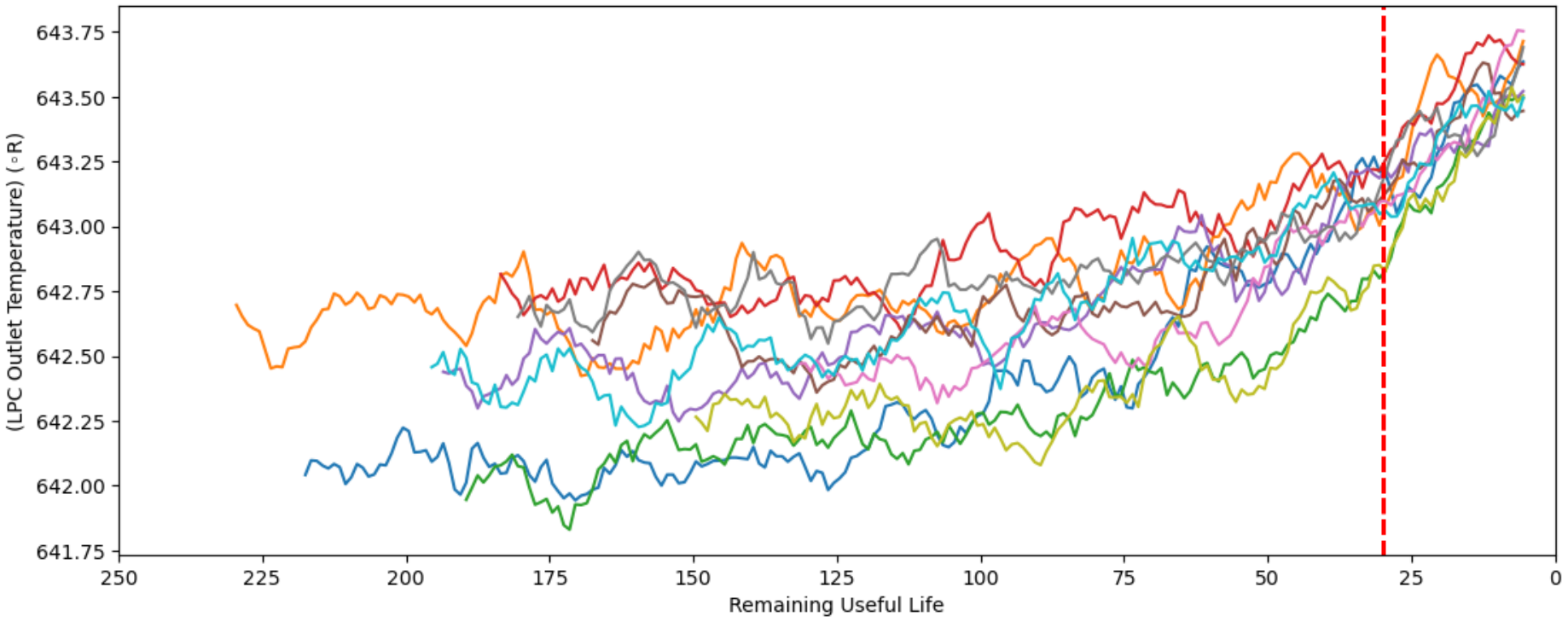
	Engine	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(Physical Core Speed) (rpm)	(HPC Outlet Static Pressure) (psia)	(Ratio of Fuel Flow to Ps30) (pps/psia)	(Corrected Fan Speed) (rpm)	(Corrected Core Speed) (rpm)	(Bypass Ratio)	(Bleed Enthalpy)	!
0	1	641.82	1589.70	1400.60	554.36	2388.06	9046.19	47.47	521.66	2388.02	8138.62	8.4195	392	
1	1	642.15	1591.82	1403.14	553.75	2388.04	9044.07	47.49	522.28	2388.07	8131.49	8.4318	392	
2	1	642.35	1587.99	1404.20	554.26	2388.08	9052.94	47.27	522.42	2388.03	8133.23	8.4178	390	
3	1	642.35	1582.79	1401.87	554.45	2388.11	9049.48	47.13	522.86	2388.08	8133.83	8.3682	392	
4	1	642.37	1582.85	1406.22	554.00	2388.06	9055.15	47.28	522.19	2388.04	8133.80	8.4294	393	

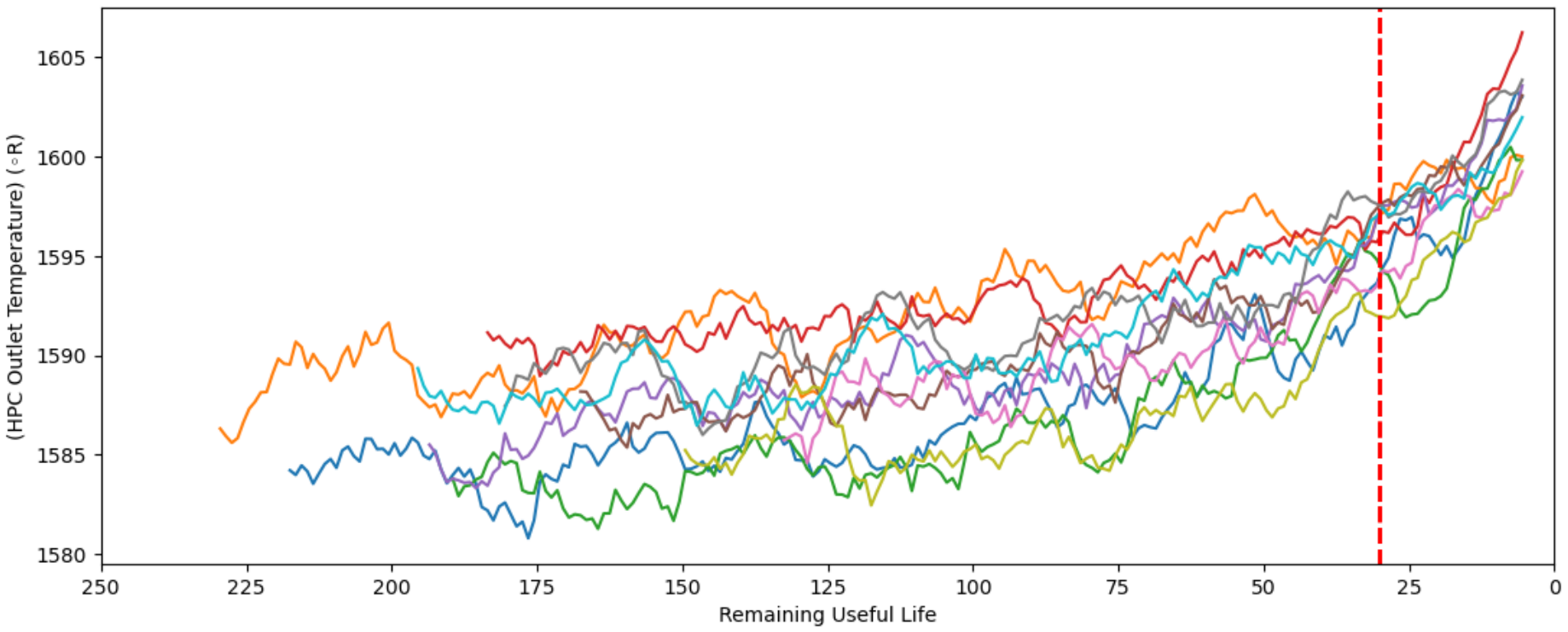
In [25]:
```
#rechecking corelation in jet_relevant_data'
plt.figure(figsize=(11,11))
cmap=(sns.diverging_palette(500,10,as_cmap=True))
sns.heatmap(jet_relevant_data.corr(),cmap=cmap,annot=True,center=0,square=True)
plt.show()
```

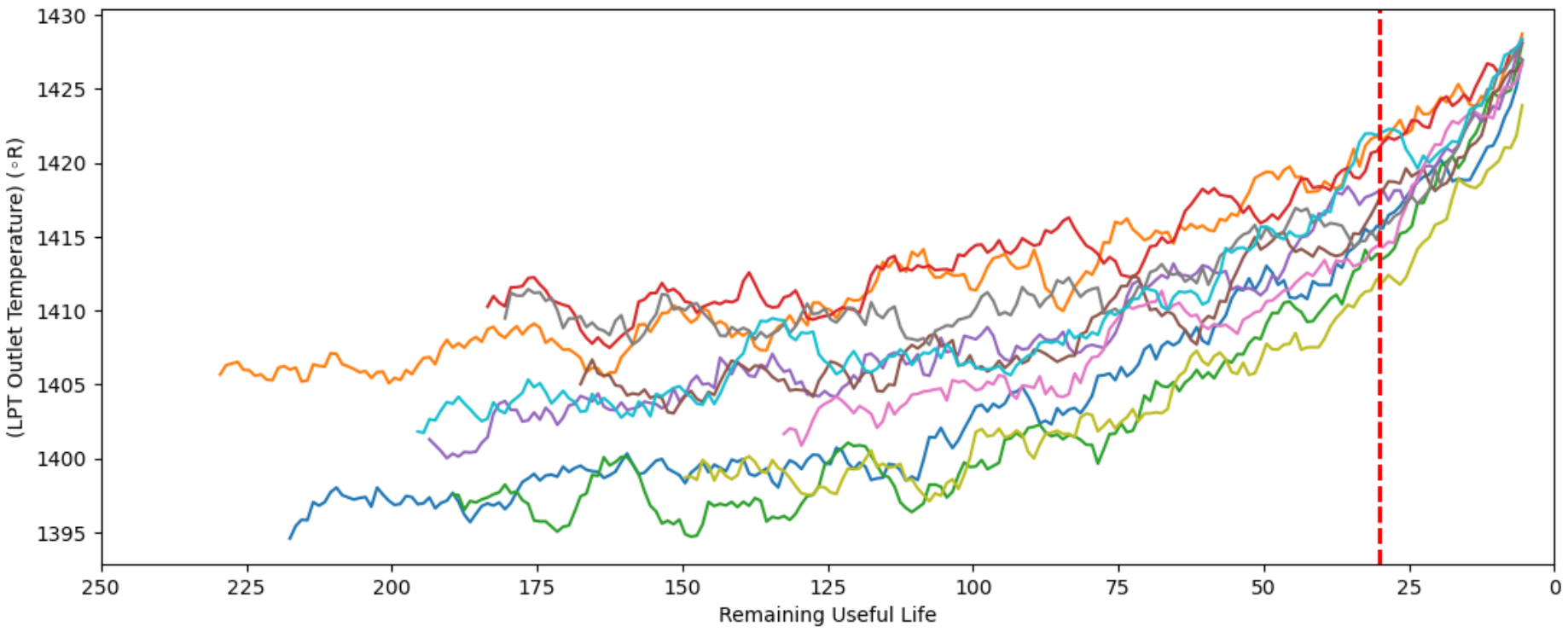


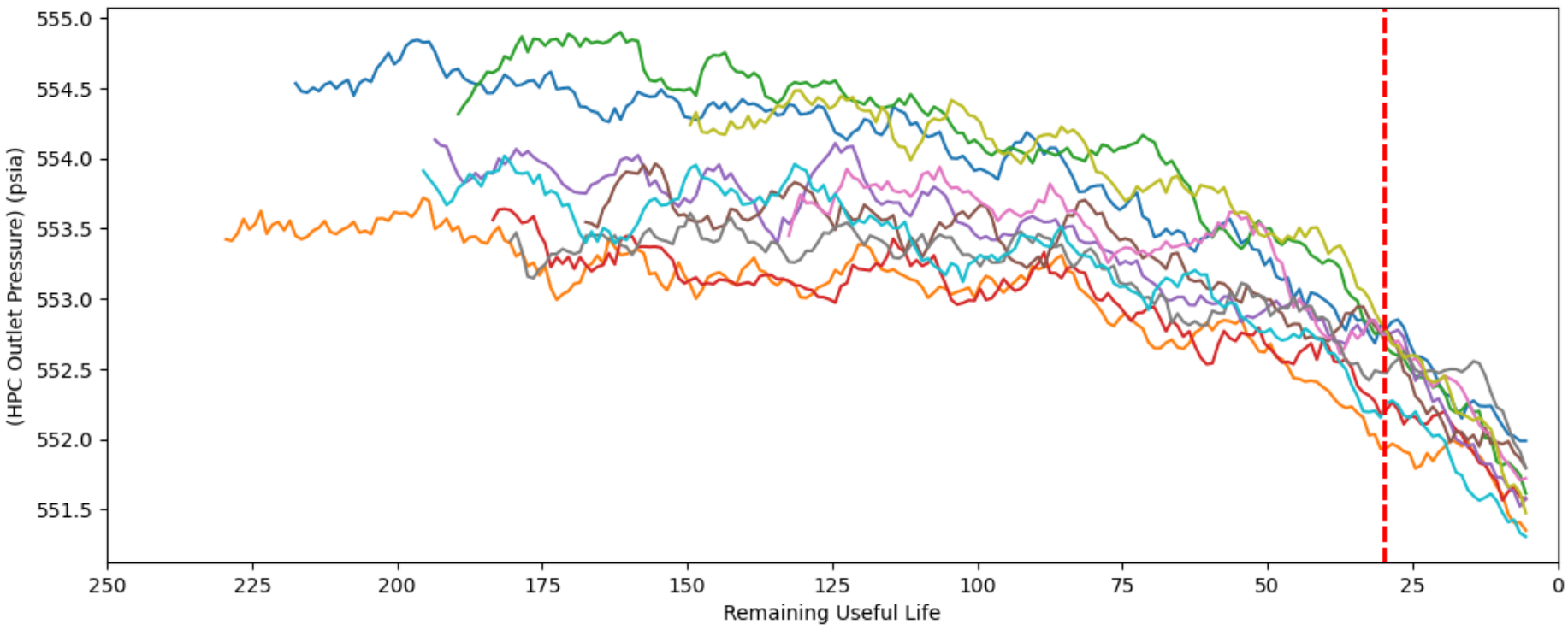
In [26]:
```python
# plot sensor data wrt remaining usefull life
# creating function to plot individual sensor data
def plot_sensor(sensor,X):
    plt.figure(figsize=(13, 5))

    for i in X['Engine'].unique():
        if i % 10 == 0:  # Plot every 10th engine
            plt.plot('RUL', sensor,data=X[X['Engine']==i].rolling(10).mean())

            # Add a vertical line at RUL = 30
            plt.axvline(30, color='red', linestyle='dashed', linewidth=2)

    # Reverse the x-axis so RUL counts down to zero
    plt.xlim(250, 0)

    # Set x-axis ticks
    plt.xticks(np.arange(0, 275, 25))

    # Set labels and title
    plt.ylabel(sensor)
    plt.xlabel('Remaining Useful Life')
```

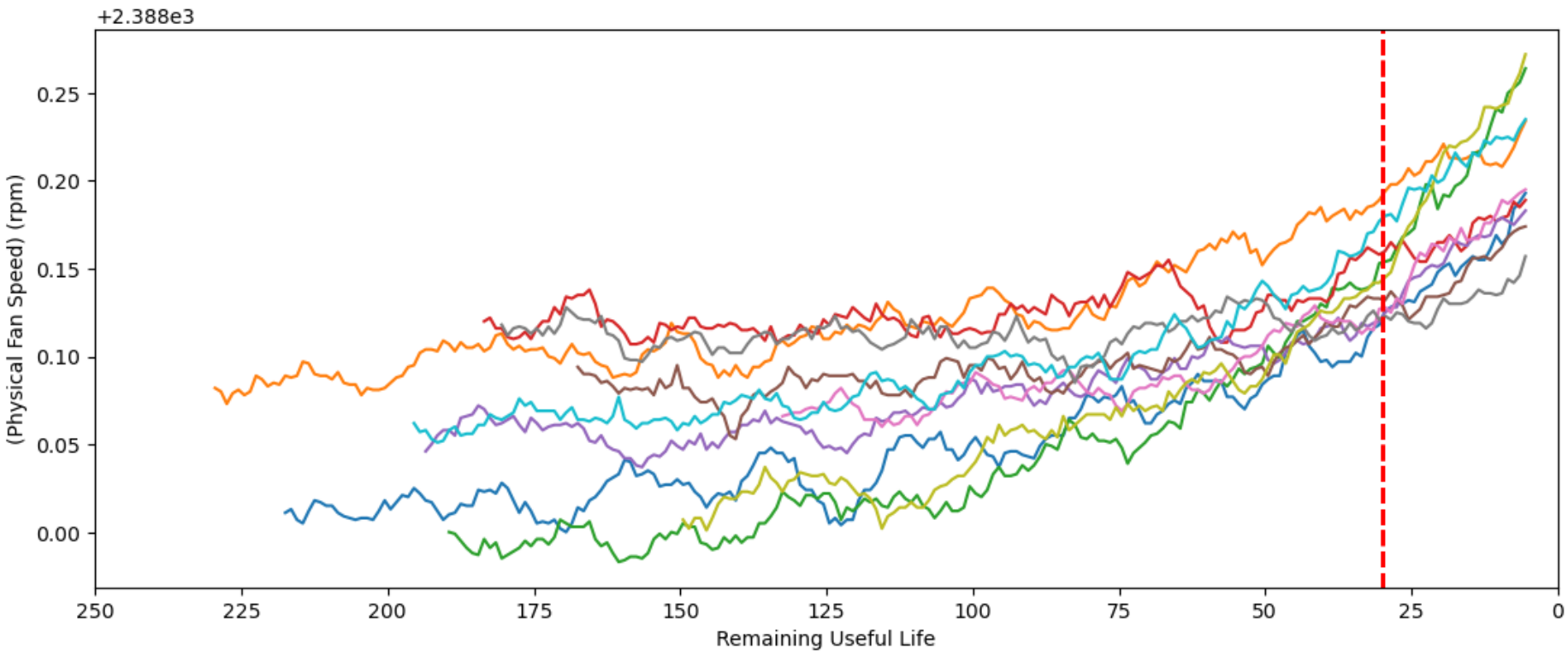
In [27]:
```python
for sensor in jet_relevant_data.drop(['Engine', 'RUL'], axis=1).columns:
    plot_sensor(sensor, jet_relevant_data)
```

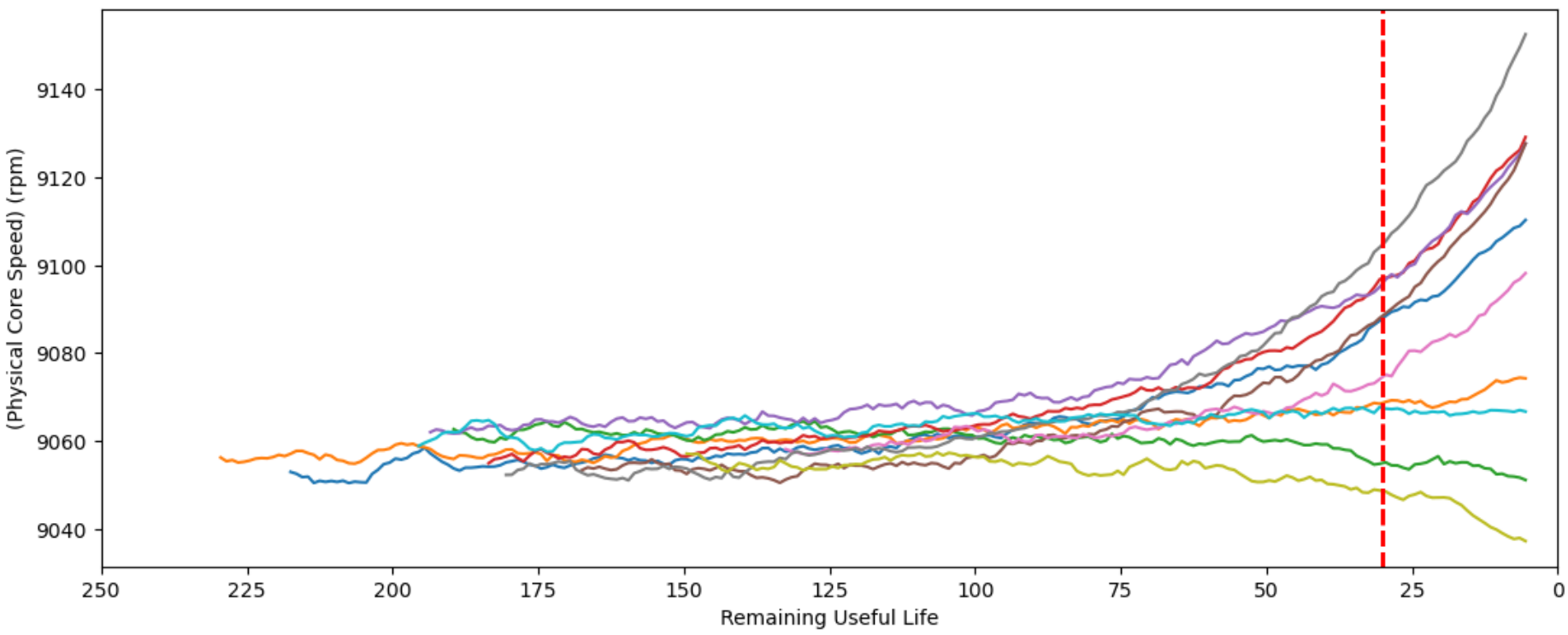

643.75
643.50
643.25
643.00
642.75
642.50
642.25
642.00
641.75
(LPC Outlet Temperature) (◦R)
250
225
200
175
150
125
100
75
50
25
0
Remaining Useful Life

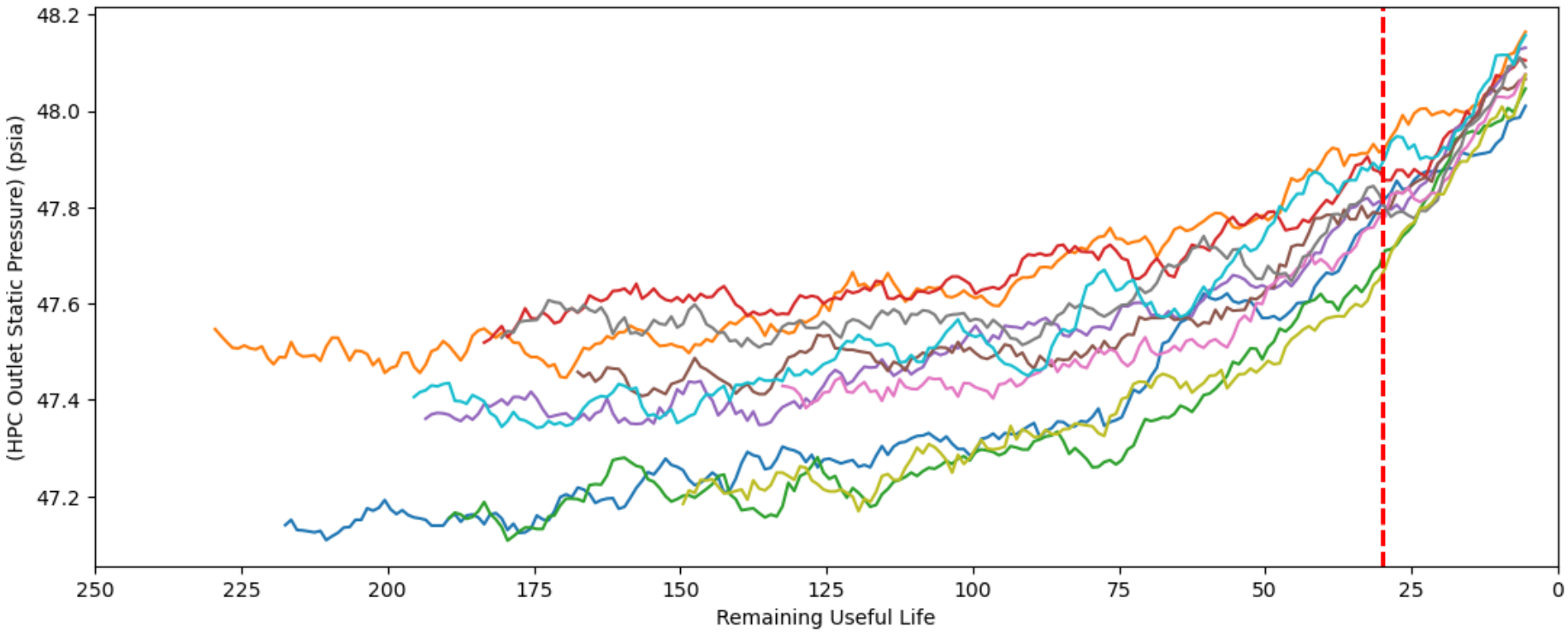

1605
1600
1595
1590
1585
1580
(HPC Outlet Temperature) (◦R)
250
225
200
175
150
125
100
75
50
25
0
Remaining Useful Life

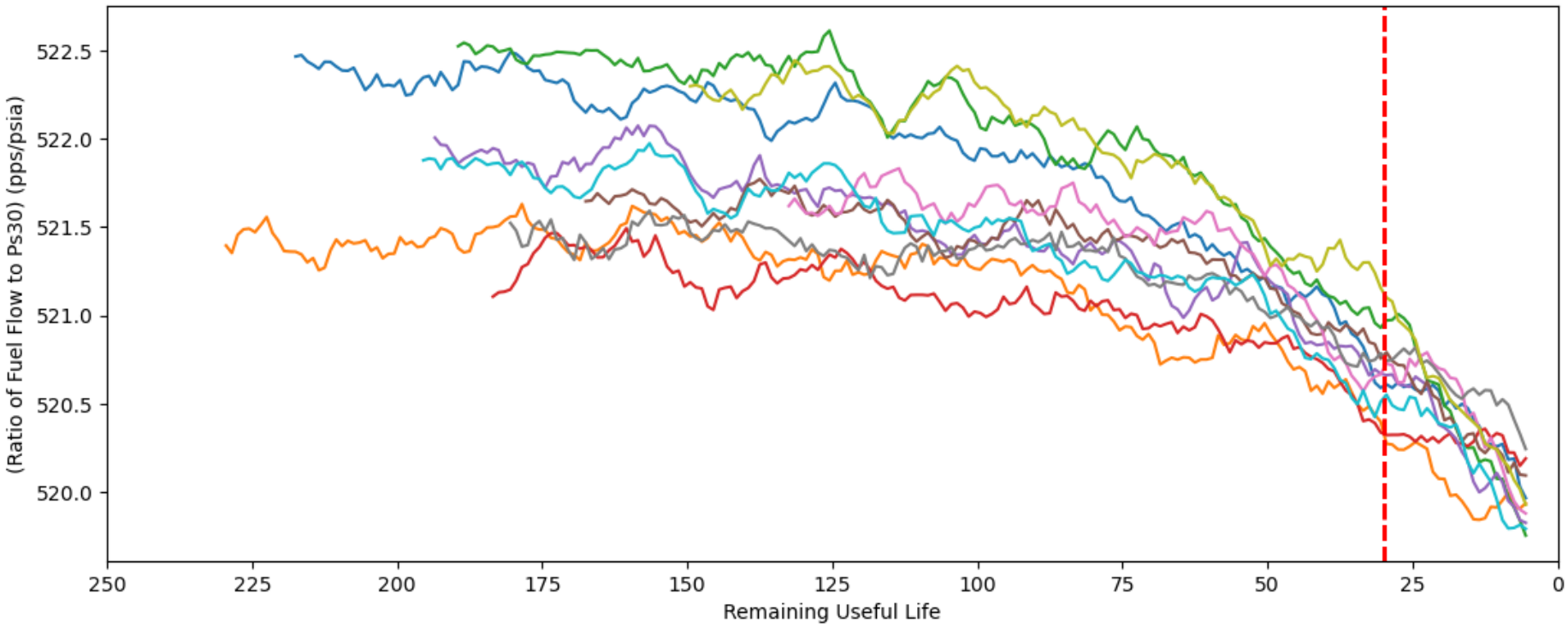

1430
1425
1420
1415
1410
1405
1400
1395
(LPT Outlet Temperature) (◦R)
250
225
200
175
150
125
100
75
50
25
0
Remaining Useful Life

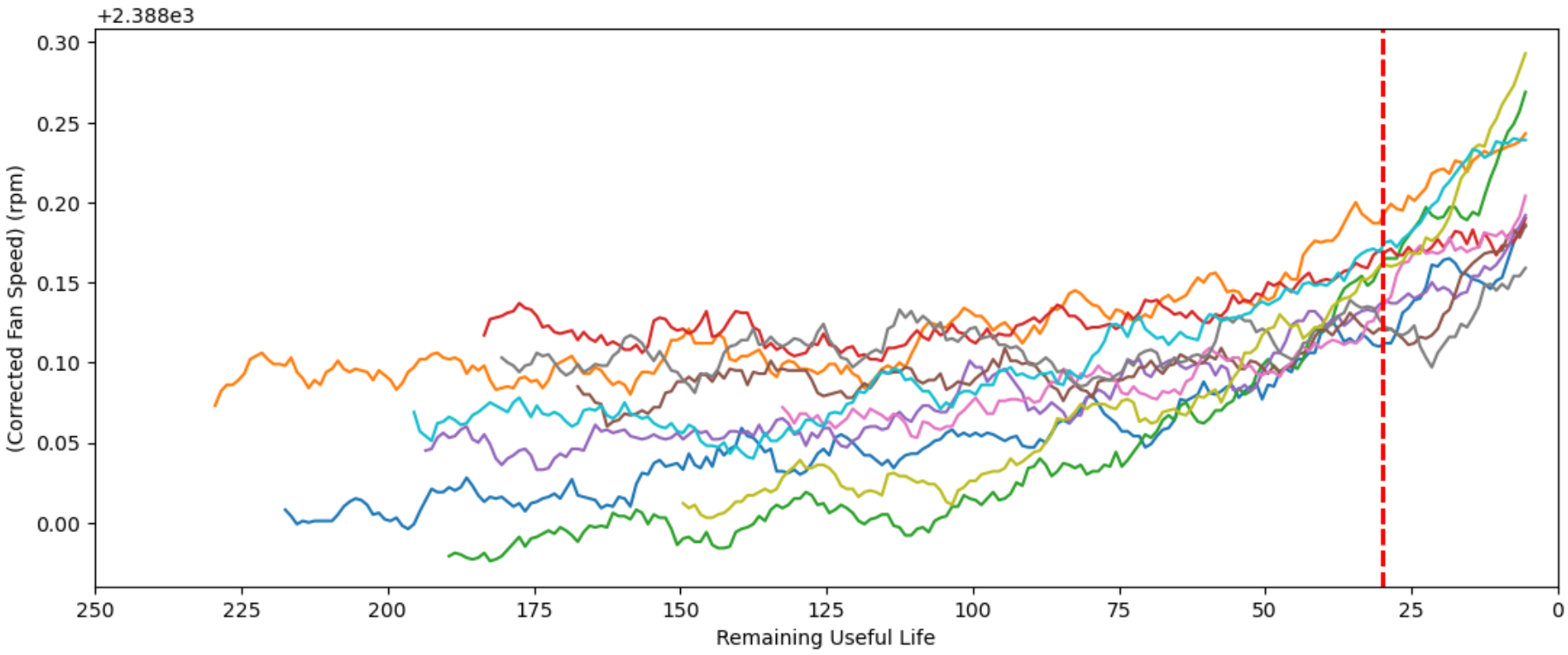

555.0
554.5
554.0
553.5
553.0
552.5
552.0
551.5
(HPC Outlet Pressure) (psia)
250
225
200
175
150
125
100
75
50
25
0
Remaining Useful Life

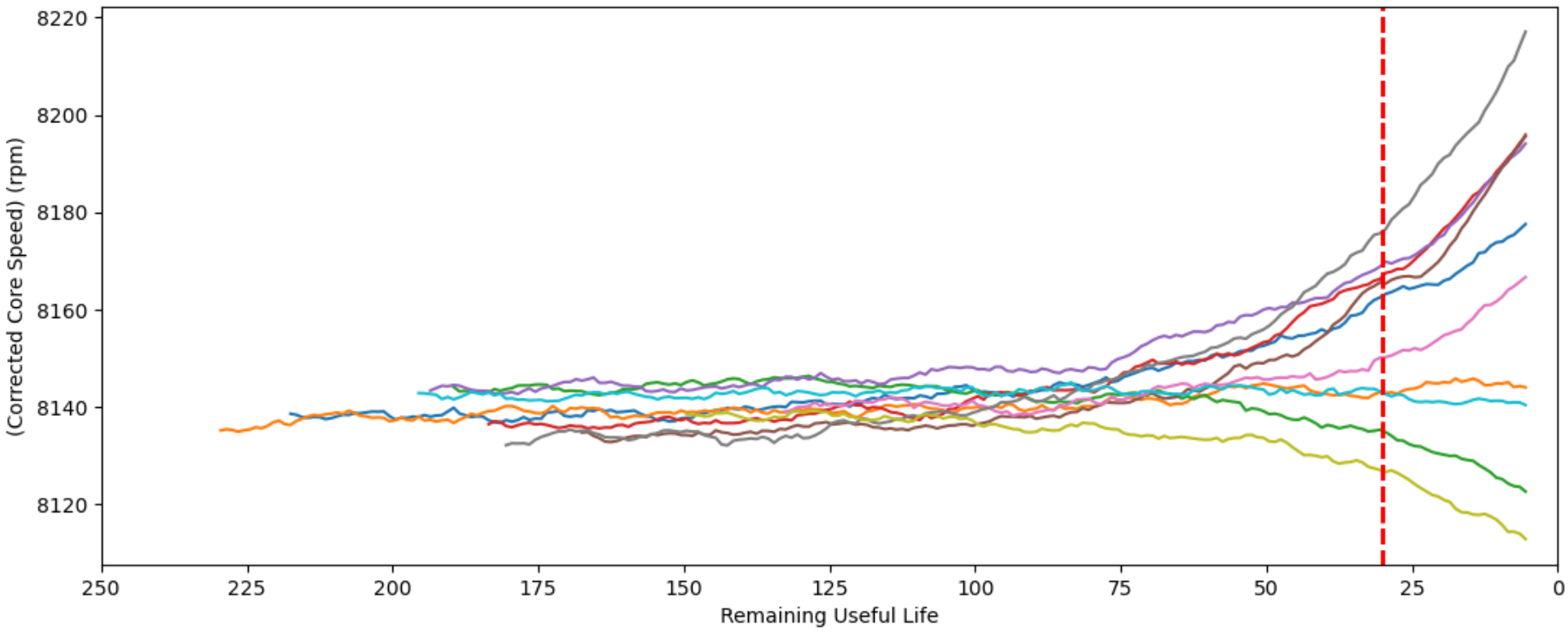

+2.388e3
0.25
0.20
0.15
0.10
0.05
0.00
(Physical Fan Speed) (rpm)
250
225
200
175
150
125
100
75
50
25
0
Remaining Useful Life

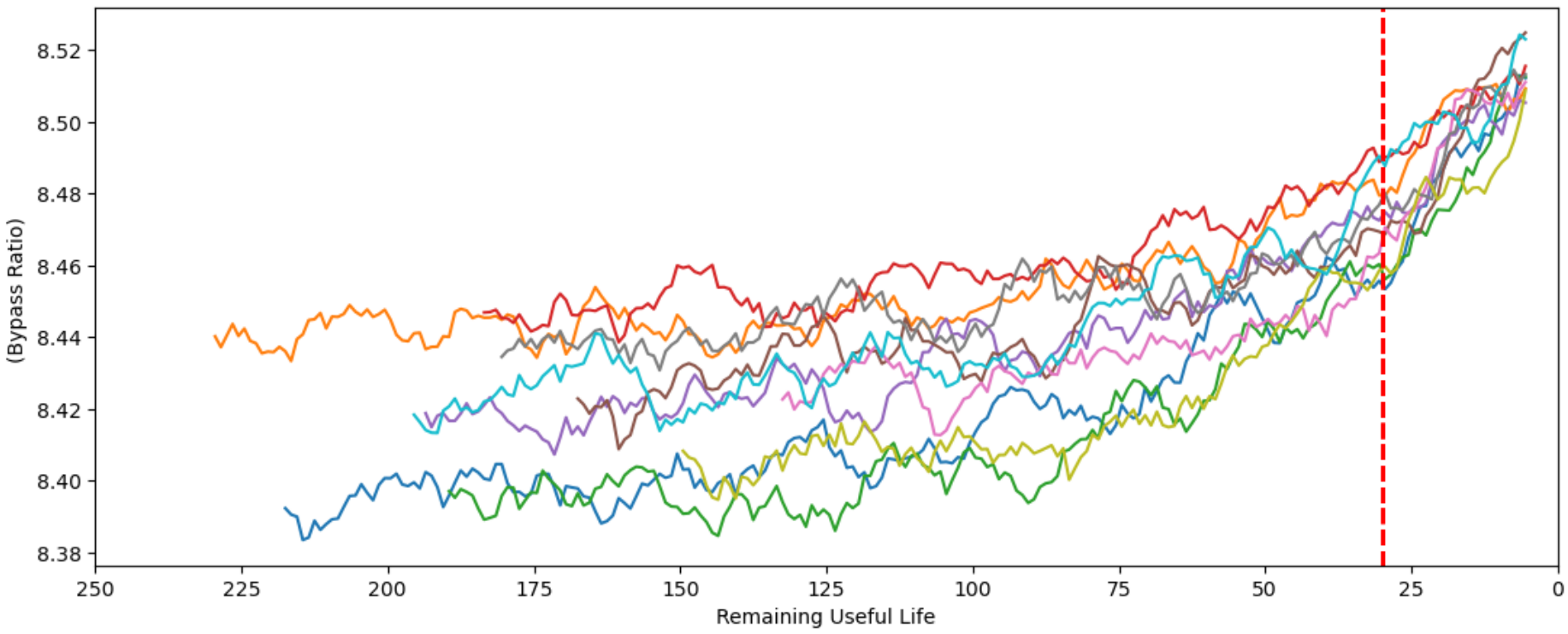

9140
9120
9100
9080
9060
9040
(Physical Core Speed) (rpm)
250
225
200
175
150
125
100
75
50
25
0
Remaining Useful Life

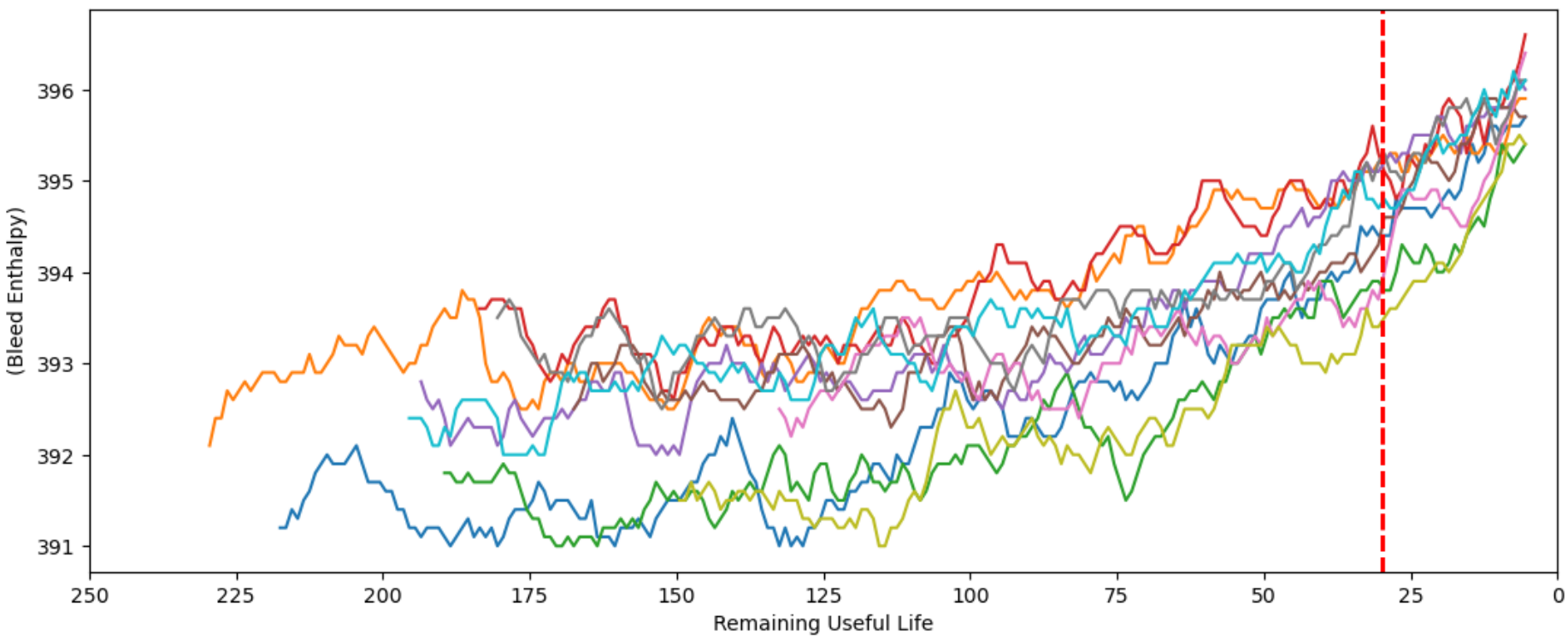

48.2
48.0
47.8
47.6
47.4
47.2
(HPC Outlet Static Pressure) (psia)
250
225
200
175
150
125
100
75
50
25
0
Remaining Useful Life

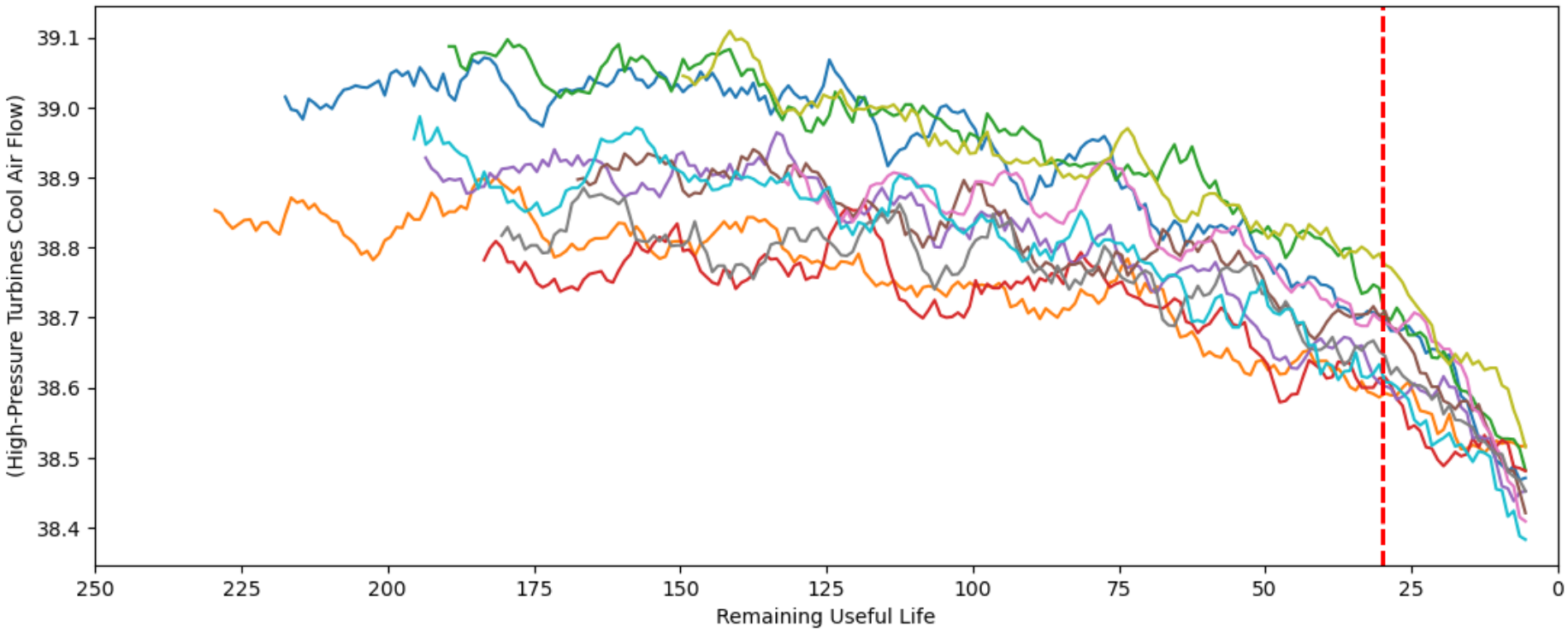

522.5
522.0
521.5
521.0
520.5
520.0
(Ratio of Fuel Flow to Ps30) (pps/psia)
250
225
200
175
150
125
100
75
50
25
0
Remaining Useful Life

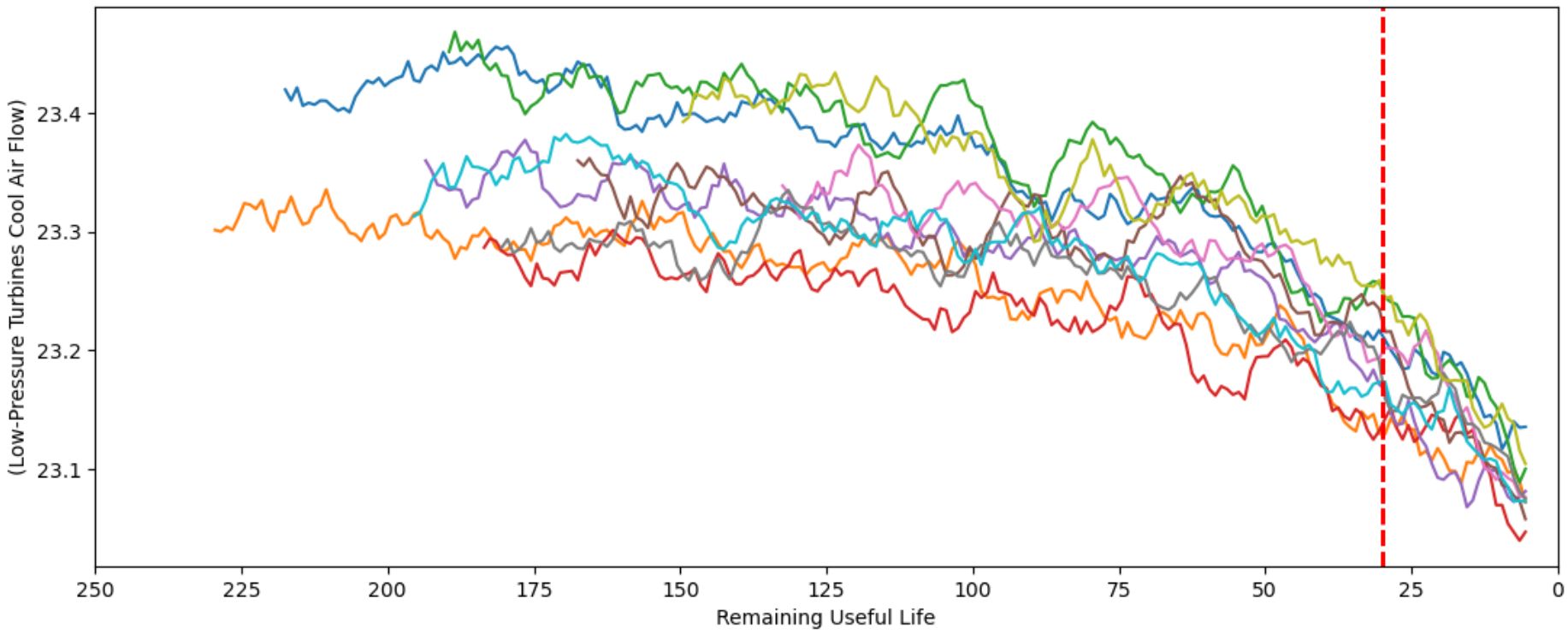

+2.388e3
0.30
0.25
0.20
0.15
0.10
0.05
0.00
(Corrected Fan Speed) (rpm)
250
225
200
175
150
125
100
75
50
25
0
Remaining Useful Life


(Corrected Core Speed) (rpm)
8220
8200
8180
8160
8140
8120
250
225
200
175
150
125
100
75
50
25
0
Remaining Useful Life


(Bypass Ratio)
8.52
8.50
8.48
8.46
8.44
8.42
8.40
8.38
250
225
200
175
150
125
100
75
50
25
0
Remaining Useful Life


(Bleed Enthalpy)
396
395
394
393
392
391
250
225
200
175
150
125
100
75
50
25
0
Remaining Useful Life





In [28]:
```
#from the above chart we can see that corrected core speed sensor behaves differently for different engines
jet_relevant_data.drop(['(Corrected Core Speed) (rpm)','(Physical Core Speed) (rpm)'],axis=1,inplace=True)
```

In [29]:
```
jet_relevant_data.head()
```

Out[29]:

	Engine	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(HPC Outlet Static Pressure) (psia)	(Ratio of Fuel Flow to Ps30) (pps/psia)	(Corrected Fan Speed) (rpm)	(Bypass Ratio)	(Bleed Enthalpy)	(High-Pressure Turbines Cool Air Flow)	(Low-Pressure Turbines Cool Air Flow)	R
0	1	641.82	1589.70	1400.60	554.36	2388.06	47.47	521.66	2388.02	8.4195	392	39.06	23.4190	192
1	1	642.15	1591.82	1403.14	553.75	2388.04	47.49	522.28	2388.07	8.4318	392	39.00	23.4236	191
2	1	642.35	1587.99	1404.20	554.26	2388.08	47.27	522.42	2388.03	8.4178	390	38.95	23.3442	190
3	1	642.35	1582.79	1401.87	554.45	2388.11	47.13	522.86	2388.08	8.3682	392	38.88	23.3739	189
4	1	642.37	1582.85	1406.22	554.00	2388.06	47.28	522.19	2388.04	8.4294	393	38.90	23.4044	188

In [30]:
```
jet_relevant_data.iloc[1].tolist()
```

Out[30]:
```
[1.0,
 642.15,
 1591.82,
 1403.14,
 553.75,
 2388.04,
 47.49,
 522.28,
 2388.07,
 8.4318,
 392.0,
 39.0,
 23.4236,
 191.0]
```

In [31]:
```
jet_relevant_data.iloc[180].tolist()
```

Out[31]:
```
[1.0,
 643.44,
 1596.71,
 1420.64,
 551.83,
 2388.23,
 48.1,
 520.43,
 2388.23,
 8.472,
 397.0,
 38.34,
 23.1652,
 12.0]
```

In [32]:
```
#importing scaler
from sklearn.preprocessing import StandardScaler
ss=StandardScaler()
```

In [33]:
```
#applying scaler except on engine and RUL
scaled_data=ss.fit_transform(jet_relevant_data.drop(['Engine','RUL'],axis=1))
scaled_data = pd.DataFrame(scaled_data, columns=jet_relevant_data.drop(['Engine', 'RUL'], axis=1).columns)
```

In [34]:
```
scaled_data['Engine'] = jet_relevant_data['Engine']
scaled_data['RUL'] = jet_relevant_data['RUL']
```

In [35]:
```
scaled_data.head()
```

Out[35]:

	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(HPC Outlet Static Pressure) (psia)	(Ratio of Fuel Flow to Ps30) (pps/psia)	(Corrected Fan Speed) (rpm)	(Bypass Ratio)	(Bleed Enthalpy)	(High-Pressure Turbines Cool Air Flow)	(Low-Pressure Turbines Cool Air Flow)	Engine
0	-1.721725	-0.134255	-0.925936	1.121141	-0.516338	-0.266467	0.334262	-1.058890	-0.603816	-0.781710	1.348493	1.194427	1
1	-1.061780	0.211528	-0.643726	0.431930	-0.798093	-0.191583	1.174899	-0.363646	-0.275852	-0.781710	1.016528	1.236922	1
2	-0.661813	-0.413166	-0.525953	1.008155	-0.234584	-1.015303	1.364721	-0.919841	-0.649144	-2.073094	0.739891	0.503423	1
3	-0.661813	-1.261314	-0.784831	1.222827	0.188048	-1.539489	1.961302	-0.224597	-1.971665	-0.781710	0.352598	0.777792	1
4	-0.621816	-1.251528	-0.301518	0.714393	-0.516338	-0.977861	1.052871	-0.780793	-0.339845	-0.136018	0.463253	1.059552	1

In [36]:
```
# making a copy for model development
df=scaled_data.copy()
```

In [37]:
```
#Setting last 30 cycles as limit for failure prediction
cycle=30
#creating function for binary classification
RUL_T=lambda x:1 if x<=cycle else 0
```

In [38]:
```
df['label']=[np.nan]*df.shape[0]
```

In [39]:
```
for i in range(0,df.shape[0]):
    a=df.loc[i,'RUL']
    df.at[i,'label']=RUL_T(a)
```

In [40]:
```
df.head()
```

Out[40]:

	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(HPC Outlet Static Pressure) (psia)	(Ratio of Fuel Flow to Ps30) (pps/psia)	(Corrected Fan Speed) (rpm)	(Bypass Ratio)	(Bleed Enthalpy)	(High-Pressure Turbines Cool Air Flow)	(Low-Pressure Turbines Cool Air Flow)	Engine
0	-1.721725	-0.134255	-0.925936	1.121141	-0.516338	-0.266467	0.334262	-1.058890	-0.603816	-0.781710	1.348493	1.194427	1
1	-1.061780	0.211528	-0.643726	0.431930	-0.798093	-0.191583	1.174899	-0.363646	-0.275852	-0.781710	1.016528	1.236922	1
2	-0.661813	-0.413166	-0.525953	1.008155	-0.234584	-1.015303	1.364721	-0.919841	-0.649144	-2.073094	0.739891	0.503423	1
3	-0.661813	-1.261314	-0.784831	1.222827	0.188048	-1.539489	1.961302	-0.224597	-1.971665	-0.781710	0.352598	0.777792	1
4	-0.621816	-1.251528	-0.301518	0.714393	-0.516338	-0.977861	1.052871	-0.780793	-0.339845	-0.136018	0.463253	1.059552	1

In [41]:
```
df.tail(5)
```

Out[41]:

	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(HPC Outlet Static Pressure) (psia)	(Ratio of Fuel Flow to Ps30) (pps/psia)	(Corrected Fan Speed) (rpm)	(Bypass Ratio)	(Bleed Enthalpy)	(High-Pressure Turbines Cool Air Flow)	(Low-Pressure Turbines Cool Air Flow)	Engi
20626	1.618000	1.216258	2.188375	-2.189329	1.315066	1.980044	-2.607969	2.278282	1.425294	2.446751	-1.805173	-2.921113	1
20627	1.717992	2.279706	2.738351	-2.833345	1.878576	1.867718	-2.350355	1.722087	1.913240	1.155367	-2.856395	-1.203764	1
20628	1.478011	1.946971	2.138377	-2.742957	2.019453	2.054927	-1.902919	2.000184	3.265092	3.092444	-2.081810	-3.292481	1
20629	1.098043	2.403666	1.955051	-3.036719	2.160330	3.178182	-2.363913	1.861136	2.579834	1.155367	-2.911722	-2.085072	1
20630	2.337940	1.607712	2.578358	-2.912435	2.301208	2.466787	-2.865584	2.278282	1.638604	1.801059	-2.469103	-2.194080	1

In [42]:
```
df.iloc[1].tolist()
```

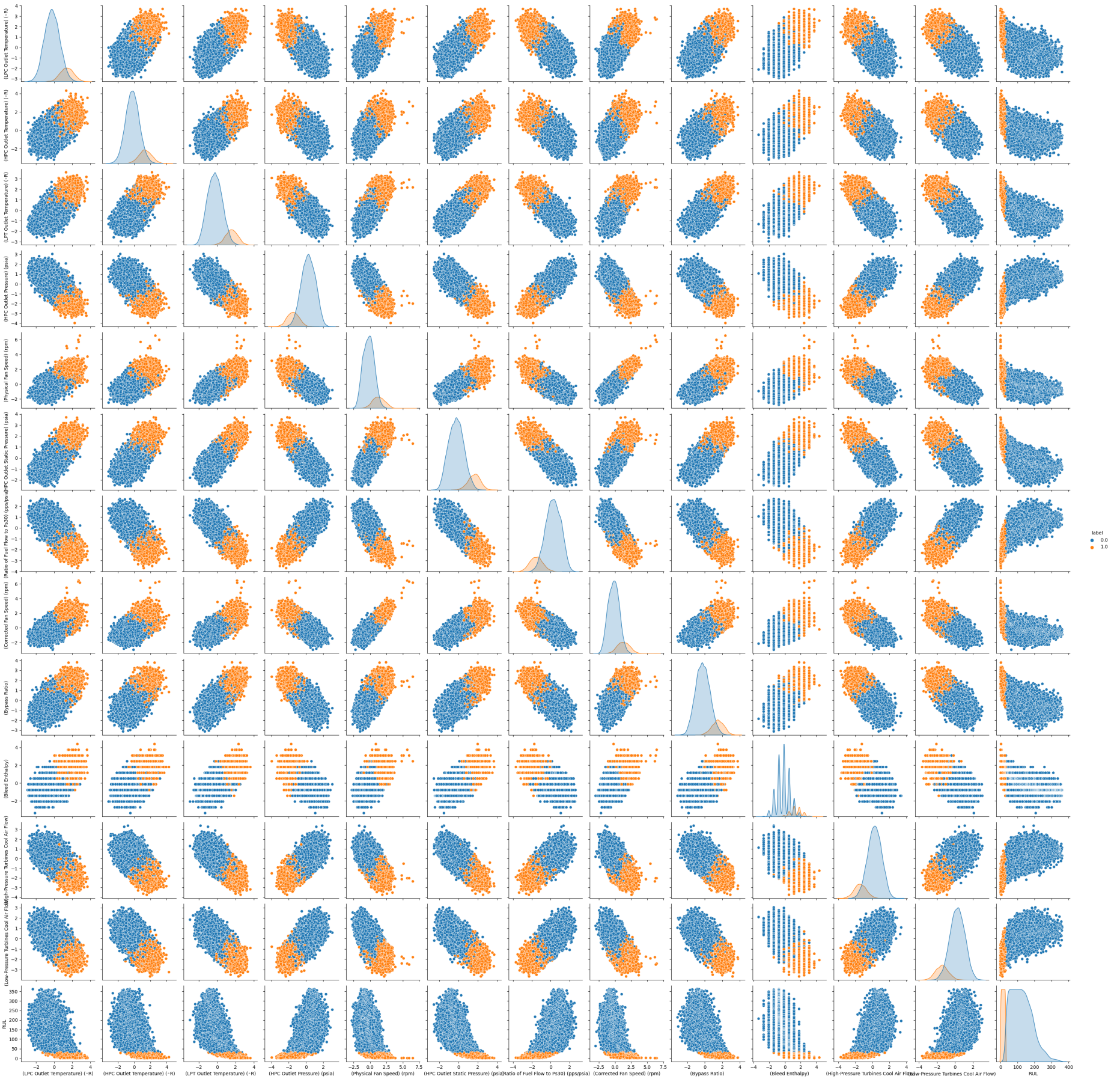
Out[42]:
```
[-1.0617797067522012,
 0.2115284938758204,
 -0.6437258660491735,
 0.431930175249528,
 -0.7980929993508061,
 -0.19158292532444912,
 1.1748993222074802,
 -0.36364599790254193,
 -0.27585181070180737,
 -0.7817097857218288,
 1.0165279304068096,
 1.2369219607271347,
 1.0,
 191.0,
 0.0]
```

In [43]:
```
df.columns
```

Out[43]:
```
Index(['(LPC Outlet Temperature) (◦R)', '(HPC Outlet Temperature) (◦R)', '(LPT Outlet Temperature) (◦R)', '(HPC Outlet Pressure) (psia)', '(Physical Fan Speed) (rpm)', '(HPC Outlet Static Pressure) (psia)', '(Ratio of Fuel Flow to Ps30) (pps/psia)', '(Corrected Fan Speed) (rpm)', '(Bypass Ratio) ', '(Bleed Enthalpy)', '(High-Pressure Turbines Cool Air Flow)', '(Low-Pressure Turbines Cool Air Flow)', 'Engine', 'RUL', 'label'], dtype='object')
```

In [44]:
```
#to understand the distribution of safe and unsafe data points
plt.figure(figsize=(13,20))
sns.pairplot(df.drop(['Engine'], axis=1), hue="label")
plt.show()
```

```
<Figure size 1300x2000 with 0 Axes>
```



In [45]:
```
#preparing inputs and outputs for model
X=df.drop(['Engine','RUL','label'],axis=1)
Y=df['label']
```

In [46]:
```
X.head()
```

Out[46]:

	(LPC Outlet Temperature) (◦R)	(HPC Outlet Temperature) (◦R)	(LPT Outlet Temperature) (◦R)	(HPC Outlet Pressure) (psia)	(Physical Fan Speed) (rpm)	(HPC Outlet Static Pressure) (psia)	(Ratio of Fuel Flow to Ps30) (pps/psia)	(Corrected Fan Speed) (rpm)	(Bypass Ratio)	(Bleed Enthalpy)	(High-Pressure Turbines Cool Air Flow)	(Low-Pressure Turbines Cool Air Flow)
0	-1.721725	-0.134255	-0.925936	1.121141	-0.516338	-0.266467	0.334262	-1.058890	-0.603816	-0.781710	1.348493	1.194427
1	-1.061780	0.211528	-0.643726	0.431930	-0.798093	-0.191583	1.174899	-0.363646	-0.275852	-0.781710	1.016528	1.236922
2	-0.661813	-0.413166	-0.525953	1.008155	-0.234584	-1.015303	1.364721	-0.919841	-0.649144	-2.073094	0.739891	0.503423
3	-0.661813	-1.261314	-0.784831	1.222827	0.188048	-1.539489	1.961302	-0.224597	-1.971665	-0.781710	0.352598	0.777792
4	-0.621816	-1.251528	-0.301518	0.714393	-0.516338	-0.977861	1.052871	-0.780793	-0.339845	-0.136018	0.463253	1.059552

In [47]:
```
Y.head()
```

Out[47]:
```
0    0.0
1    0.0
2    0.0
3    0.0
4    0.0
Name: label, dtype: float64
```

In [48]:
```
#train test split
from sklearn.model_selection import train_test_split
X_train,X_test,Y_train,Y_test=train_test_split(X,Y,test_size=0.2,random_state=1)
```

In [49]:
```
print(X_train.shape)
print(X_test.shape)
print(Y_train.shape)
print(Y_test.shape)
```

```
(16504, 12)
(4127, 12)
(16504,)
(4127,)
```

Model Building

We will try building model with following algorithms and select best model out of them 1) Logistic_regression 2) Support vector classifier 3) random forest classifier 4) decision tree

In [50]:
```
#Importing model training algorithms
from sklearn.linear_model import LogisticRegression
from sklearn.svm import SVC
from sklearn.ensemble import RandomForestClassifier
from sklearn.tree import DecisionTreeClassifier
from sklearn.model_selection import GridSearchCV
from sklearn.model_selection import cross_val_score
```

In [51]:
```
classifiers={"Logisitic Regression": LogisticRegression(),
    "Support Vector Classifier": SVC(kernel="poly"),
    'Random Forest Classifier':RandomForestClassifier(max_features=1),
             "Decision tree":DecisionTreeClassifier()
            }
```

In [52]:
```
#lets find out which model has best training score
for model_name,model in classifiers.items():
    model.fit(X_train,Y_train)
    training_score=cross_val_score(model,X_train,Y_train,cv=5)
    print(model_name,'has a training score of',round(training_score.mean(),2)*100,'% accuracy score')
```

```
Logisitic Regression has a training score of 96.0 % accuracy score
Support Vector Classifier has a training score of 96.0 % accuracy score
Random Forest Classifier has a training score of 95.0 % accuracy score
Decision tree has a training score of 93.0 % accuracy score
```

In [53]:
```
#lets find best parameters for each model

#1) Logistic Regression
log_reg_params = {"penalty": ['l2'], 'C': [0.001, 0.01, 0.1, 1, 10, 100, 1000]}
grid_log_reg=GridSearchCV(LogisticRegression(),log_reg_params,cv=5)
grid_log_reg.fit(X_train, Y_train)
print(grid_log_reg.best_params_)
```

```
{'C': 1, 'penalty': 'l2'}
```

In [54]:
```
# 2) SVC
svc_params = {'C': [0.5, 0.7, 0.9, 1], 'kernel': ['rbf', 'poly', 'sigmoid', 'linear']}
grid_svc = GridSearchCV(SVC(), svc_params,cv=5)
grid_svc.fit(X_train, Y_train)
print(grid_svc.best_params_)
```

```
{'C': 0.5, 'kernel': 'poly'}
```

In [55]:
```
# 3) Random Forest Classifier
RFC_parms={'max_features':list(range(1, 18))}
grid_RFC = GridSearchCV(RandomForestClassifier(),RFC_parms,cv=5)
grid_RFC.fit(X_train,Y_train)
print(grid_RFC.best_params_)
```

```
{'max_features': 3}
```

In [56]:
```
# 4) Decision Tree Classifier
tree_params = {"criterion": ["gini", "entropy"], "max_depth": list(range(2,4,1)),
               "min_samples_leaf": list(range(5,7,1))}
grid_tree = GridSearchCV(DecisionTreeClassifier(), tree_params,cv=5)
grid_tree.fit(X_train,Y_train)
print(grid_tree.best_params_)
```

```
{'criterion': 'gini', 'max_depth': 3, 'min_samples_leaf': 5}
```

In [57]:
```
#setting the model with above parameters
lr=LogisticRegression(C= 1, penalty = 'l2')
svc=SVC(random_state=1,C=0.5,kernel='poly')
rfc=RandomForestClassifier(random_state=1,max_features= 16)
dtc=DecisionTreeClassifier(random_state=1,criterion='gini',max_depth=3, min_samples_leaf=5)
```

In [58]:
```
from sklearn.metrics import classification_report,confusion_matrix
```

In [59]:
```
#create a function to test model
def create_model(model):
    model.fit(X_train,Y_train)
    print('Training accuracy',round(model.score(X_train,Y_train),3)*100)
    Y_pred=model.predict(X_test)
    print(classification_report(Y_test,Y_pred))
    print(confusion_matrix(Y_test,Y_pred))
```

In [60]:
```
# check testing score of logarithmic regression
create_model(lr)
```

```
Training accuracy 95.6
              precision    recall  f1-score   support

         0.0       0.97      0.97      0.97      3512
         1.0       0.84      0.81      0.82       615

    accuracy                           0.95      4127
   macro avg       0.90      0.89      0.90      4127
weighted avg       0.95      0.95      0.95      4127

[[3418   94]
 [ 118  497]]
```

In [61]:
```
#check testing score of support vector mechanism
create_model(svc)
```

```
Training accuracy 95.8
              precision    recall  f1-score   support

         0.0       0.96      0.98      0.97      3512
         1.0       0.87      0.77      0.82       615

    accuracy                           0.95      4127
   macro avg       0.91      0.88      0.89      4127
weighted avg       0.95      0.95      0.95      4127

[[3438   74]
 [ 139  476]]
```

In [62]:
```
#check testing score of random forest classifier
create_model(rfc)
```

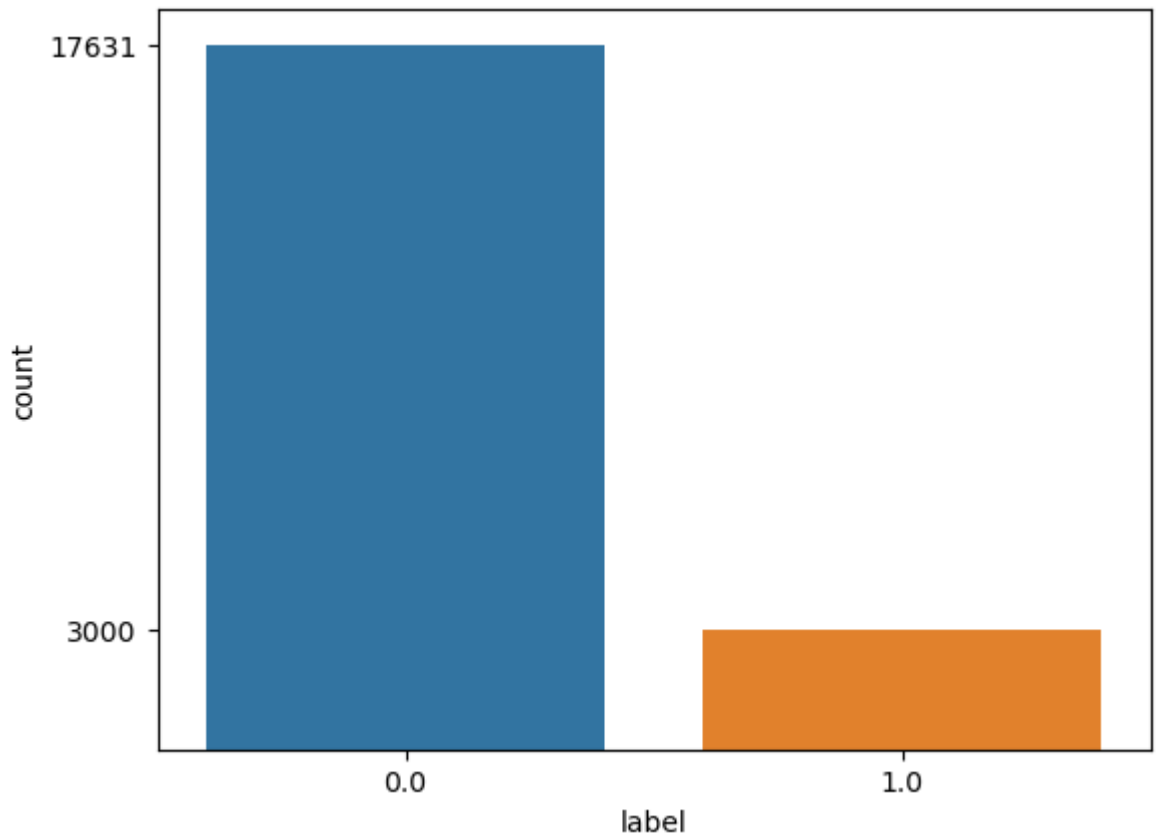
```
Training accuracy 100.0
              precision    recall  f1-score   support

         0.0       0.96      0.97      0.97      3512
         1.0       0.85      0.79      0.82       615

    accuracy                           0.95      4127
   macro avg       0.90      0.88      0.89      4127
weighted avg       0.95      0.95      0.95      4127

[[3424   88]
 [ 130  485]]
```

In [63]:
```
#check testing score of decision tree classifier
create_model(dtc)
```

```
Training accuracy 94.69999999999999
              precision    recall  f1-score   support

         0.0       0.96      0.97      0.96      3512
         1.0       0.80      0.76      0.78       615

    accuracy                           0.94      4127
   macro avg       0.88      0.86      0.87      4127
weighted avg       0.93      0.94      0.94      4127

[[3397  115]
 [ 150  465]]
```

We get a recall score of 81% with logistic regression. Precison and recall score is less for label 1 (i.e preventive maintenence required) and is good for 0 (i.e preventive maintenence not required). lets find the count of both labels

In [64]:
```
#How many samples of 0th and 1 class
f=df['label'].value_counts()
sns.countplot(data=df,x='label')
plt.yticks(f)
plt.show()
```



In [65]:
```
Y_train.value_counts()
```

Out[65]:
```
0.0    14119
1.0     2385
Name: label, dtype: int64
```

In [66]:
```
# we see that there is huge imbalance in count of label 0 and 1. Hence we balance with random over sampler.
```

In [67]:
```
from imblearn.over_sampling import RandomOverSampler
```

In [68]:
```
#create object of RandomOverSampler class
ros=RandomOverSampler(random_state=1)
#fit_resample() inbuilt method of RandomOverSample class
X_train_ros,Y_train_ros=ros.fit_resample(X_train,Y_train)
```

In [69]:
```
#check balance or not
Y_train_ros.value_counts()
```

Out[69]:
```
0.0    14119
1.0    14119
Name: label, dtype: int64
```

In [70]:
```
X_train_ros.shape,X_train.shape
```

Out[70]:
```
((28238, 12), (16504, 12))
```

In [71]:
```
#similar process on testing data
#check on testing data
Y_test.value_counts()
```

Out[71]:
```
0.0    3512
1.0     615
Name: label, dtype: int64
```

In [72]:
```
#Apply random over sampler to testing data
X_test_ros,Y_test_ros=ros.fit_resample(X_test,Y_test)
```

In [73]:
```
#check balances or not
Y_test_ros.value_counts()
```

Out[73]:
```
0.0    3512
1.0    3512
Name: label, dtype: int64
```

In [74]:
```
#lets find best parameters for each model

#1) Logistic Regression
log_reg_params = {"penalty": ['l2'], 'C': [0.001, 0.01, 0.1, 1, 10, 100, 1000]}
grid_log_reg_ros=GridSearchCV(LogisticRegression(),log_reg_params,cv=5)
grid_log_reg_ros.fit(X_train_ros, Y_train_ros)
print(grid_log_reg_ros.best_params_)
```

```
{'C': 0.01, 'penalty': 'l2'}
```

In [75]:
```
# 2) SVC
svc_params = {'C': [0.5, 0.7, 0.9, 1], 'kernel': ['rbf', 'poly', 'sigmoid', 'linear']}
grid_svc_ros = GridSearchCV(SVC(), svc_params,cv=5)
grid_svc_ros.fit(X_train_ros, Y_train_ros)
print(grid_svc_ros.best_params_)
```

```
{'C': 1, 'kernel': 'rbf'}
```

In [76]:
```
# 3) Random Forest Classifier
RFC_parms={'max_features':list(range(1, 18))}
grid_RFC_ros = GridSearchCV(RandomForestClassifier(),RFC_parms,cv=5)
```

```
grid_RFC_ros.fit(X_train_ros,Y_train_ros)
print(grid_RFC_ros.best_params_)
```

```
{'max_features': 2}
```

In [77]:
```
# 4) Decision Tree Classifier
tree_params = {"criterion": ["gini", "entropy"], "max_depth": list(range(2,4,1)),
               "min_samples_leaf": list(range(5,7,1))}
grid_tree_ros = GridSearchCV(DecisionTreeClassifier(), tree_params,cv=5)
grid_tree_ros.fit(X_train_ros,Y_train_ros)
print(grid_tree_ros.best_params_)
```

```
{'criterion': 'gini', 'max_depth': 3, 'min_samples_leaf': 5}
```

In [78]:
```
#setting the model with above parameters
lr=LogisticRegression(C= 1.0, penalty = 'l2')
svc=SVC(random_state=1,C=1,kernel='rbf')
rfc=RandomForestClassifier(random_state=1,max_features= 1)
dtc=DecisionTreeClassifier(random_state=1,criterion='gini',max_depth=3, min_samples_leaf=5)
```

In [79]:
```
#create a function to test model
def create_model(model):
    model.fit(X_train_ros,Y_train_ros)
    print('Training accuracy',round(model.score(X_train_ros,Y_train_ros),3)*100)
    #print('Testing accuracy',round(model.score(X_train,Y_train),3)*100)
    Y_pred=model.predict(X_test_ros)
    print(classification_report(Y_test_ros,Y_pred))
    print(confusion_matrix(Y_test_ros,Y_pred))
```

In [80]:
```
# check testing score of logistic regression
create_model(lr)
```

```
Training accuracy 93.7
              precision    recall  f1-score   support

         0.0       0.94      0.92      0.93      3512
         1.0       0.93      0.95      0.94      3512

    accuracy                           0.93      7024
   macro avg       0.94      0.93      0.93      7024
weighted avg       0.94      0.93      0.93      7024

[[3244  268]
 [ 190 3322]]
```

In [81]:
```
# check testing score of support vectore classifier
create_model(svc)
```

```
Training accuracy 94.3
              precision    recall  f1-score   support

         0.0       0.96      0.91      0.94      3512
         1.0       0.92      0.96      0.94      3512

    accuracy                           0.94      7024
   macro avg       0.94      0.94      0.94      7024
weighted avg       0.94      0.94      0.94      7024

[[3213  299]
 [ 124 3388]]
```

In [82]:
```
#check testing score of random forest classifier
create_model(rfc)
```

```
Training accuracy 100.0
              precision    recall  f1-score   support

         0.0       0.87      0.97      0.91      3512
         1.0       0.96      0.85      0.90      3512

    accuracy                           0.91      7024
   macro avg       0.91      0.91      0.91      7024
weighted avg       0.91      0.91      0.91      7024

[[3393  119]
 [ 517 2995]]
```

In [83]:
```
#check testing score of decision tree classifier
create_model(dtc)
```

```
Training accuracy 92.7
              precision    recall  f1-score   support

         0.0       0.91      0.91      0.91      3512
         1.0       0.91      0.91      0.91      3512

    accuracy                           0.91      7024
   macro avg       0.91      0.91      0.91      7024
weighted avg       0.91      0.91      0.91      7024

[[3187  325]
 [ 317 3195]]
```

This time we find the best recall score of 96% with support vector classifier.

In [84]:
```
#to store object of model and object of standard scaler class but in binary format
import pickle
```

In [85]:
```
#exporting standard scaler file
file1=open("scale.pkl",'wb')
#syntax pickle.dump(object, temp file)
pickle.dump(ss,file1)
file1.close()

#exporting model file
file2=open('supportvectorclassifier.pkl','wb')
pickle.dump(svc,file2)
file2.close()
```