Sample
Analysis

Team Members
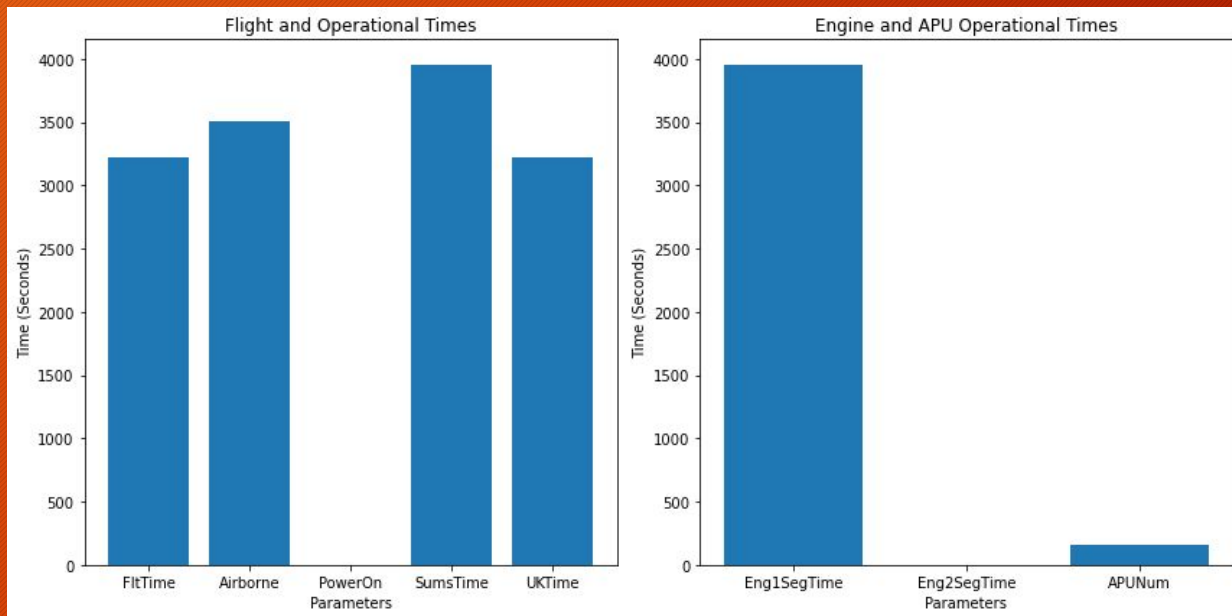REDACTED

REDACTED

Redacted

Description: The dataset contains flight segment data for a single flight, covering various operational metrics such as flight time, engine duration, and gross weight.

Data Source: File Redacted parsed as a tab-separated text file.

Number of Records: 1 flight segment

Key Columns:

- Model: Aircraft Type/Name
- REDACTED: Tail number or identifier
- FlStartDate, FlEndDate: Flight start and end dates
- FltTime, Airborne, PowerOn: Various operational times (in seconds)
- MinGW, MaxGW: Minimum and maximum gross weight

Redacted

Flight Start Date/Time: REDACTED, 15:45:06
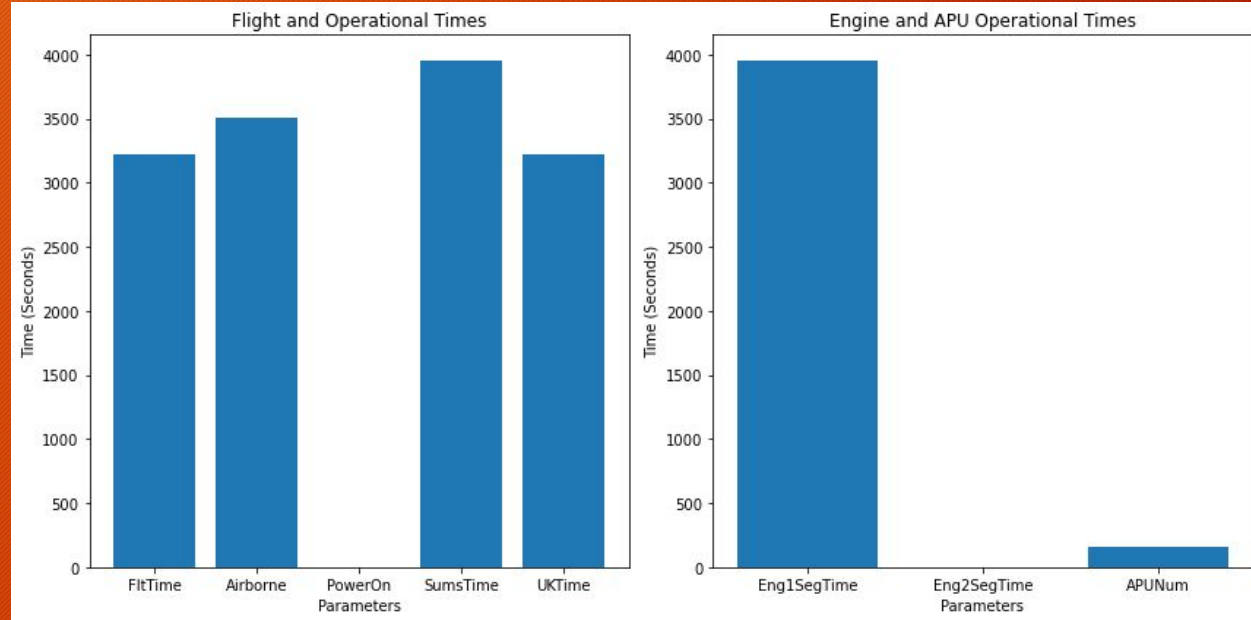
Flight End Date/Time: REDACTED, 16:51:01

Total Flight Time: 3220 seconds

Airborne Duration: 3501 seconds

Power On Duration: 1 second

Minimum Gross Weight: REDACTED lbs

Maximum Gross Weight: 36911 lbs

Redacted

Description: This dataset captures detailed ground operation parameters over multiple time intervals, measuring various flight dynamics such as yaw rate, pitch, roll, velocity, and engine torque. Each record corresponds to a specific ground operation segment with associated min, REDACTED, average, start, and end values for each parameter.

Data Source: File Redacted

Number of Records: 8 segments

Key Columns:

- RgmID: Ground operation regime ID number
- Start, End: Start and end times for the operation segment
- Nx, Ny, Nz: Acceleration in the X, Y, Z axes (REDACTED, Min, Avg, Start, End)
- REDACTED, REDACTED, YawDeg: Angular displacement (degrees) in Roll, Pitch, and REDACTED axes (REDACTED, Min, Avg, Start, End)
- AltR_ft: Altitude in feet (REDACTED, Min, Avg, Start, End)
- EngTQ%, RPM%: REDACTED and RPM percentages (REDACTED, Min, Avg, Start, End)
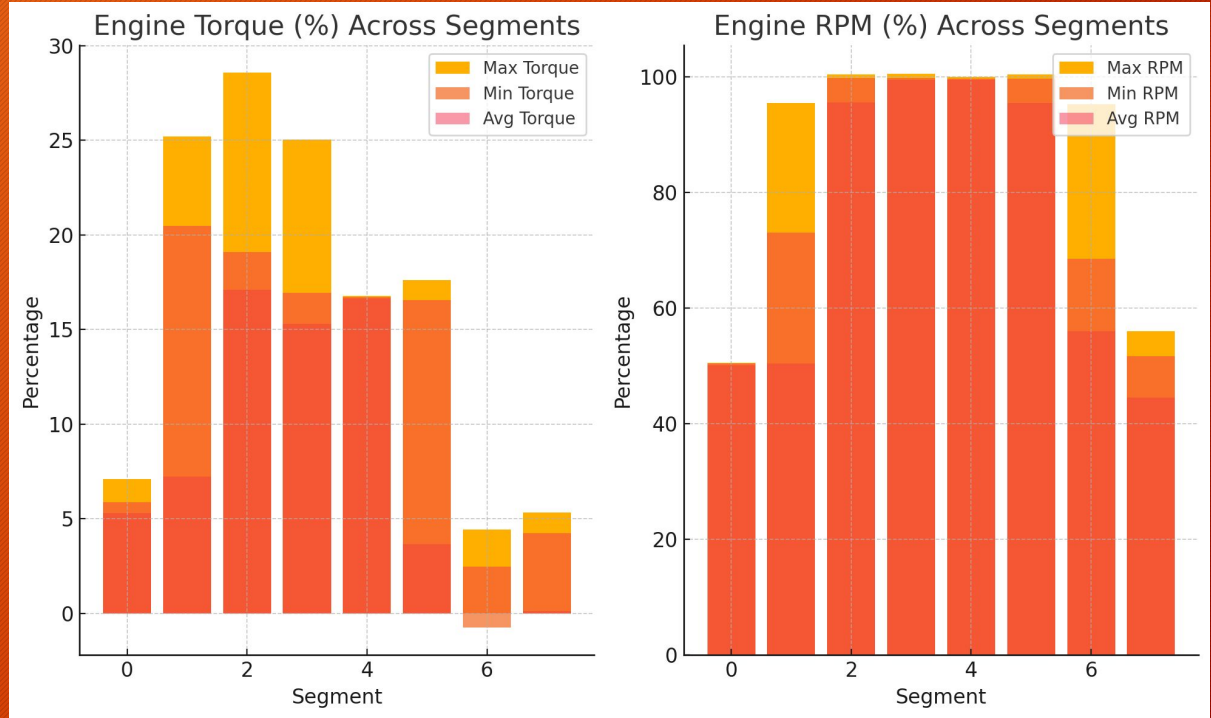
Redacted

Total Segments Analyzed: 8

REDACTED:

Regime ID: 1

Start Time: 0.00 seconds

End Time: 39.31 seconds

REDACTED (g): 0.0400

Min Ny (g): -0.0100

REDACTED (g): 0.0000

REDACTED (ft): 48.4700

REDACTED (%): 50.4600

REDACTED (dps): REDACTED: 2.1300, Min: 2.1100, Avg: 2.1200

Redacted

Total Segments Analyzed: 8

REDACTED:

Regime ID: 1

Start Time: 0.00 seconds

End Time: 39.31 seconds

REDACTED (g): 0.0400

Min Ny (g): -0.0100

REDACTED (g): 0.0000

REDACTED (ft): 48.4700

REDACTED (%): 50.4600

REDACTED (dps): REDACTED: 2.1300, Min: 2.1100, Avg: 2.1200

Index	#	Start	End	Nx_max	min	avg	start	end	Ny_max	min_1	avg_1	start_1	end_1	Nz_max	min_2	avg_2	start_2	end_2	AirSpdKt_max	min_3	avg_3	start_3
count	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
mean	4.5	2359…	244…	0.04875	0.0…	0.0425	0.03875	0.045	0.00125	-0.02…	-0.00…	-0.00…	-0.00…	0	0	0	0	0	0.7075	0.1025	0.3425	0.24
std	2.4…	1928…	187…	0.0180772	0.0…	0.0…	0.00…	0.0…	0.013562	0.013562	0.003…	0.017…	0.016…	0	0	0	0	0	0.894152	0.173184	0.604406	0.242251
min	1	0	39.…	0.04	0.01	0.02	0.03	0.04	-0.01	-0.04	-0.01	-0.04	-0.04	0	0	0	0	0	0.07	0	0.05	0.05
25%	2.75	51.1…	348…	0.04	0.04	0.04	0.04	0.04	-0.01	-0.03…	-0.01	-0.01	-0.01	0	0	0	0	0	0.145	0.025	0.09	0.06
50%	4.5	3693…	371…	0.04	0.04	0.04	0.04	0.04	-0.005	-0.015	-0.01	-0.01	-0.01	0	0	0	0	0	0.475	0.04	0.14	0.15
75%	6.25	3752…	382…	0.045	0.04	0.045	0.04	0.04	0.0125	-0.01	-0.01	-0.005	-0.00…	0	0	0	0	0	0.7825	0.07	0.21	0.3
max	8	3842…	388…	0.09	0.04	0.06	0.04	0.08	0.02	-0.01	0	0.02	0.02	0	0	0	0	0	2.77	0.52	1.83	0.69

Redacted

| Index	#	Start	End	Nx_max	min	avg	start	end	Ny_max	min_1	avg_1	start_1	end_1	Nz_max	min_2	avg_2	start_2	end_2	AirSpdKt_max	min_3	avg_3	start_3
count	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
mean	4.5	2359…	244…	0.04875	0.0…	0.0425	0.03875	0.045	0.00125	-0.02…	-0.00…	-0.00…	-0.00…	0	0	0	0	0	0.7075	0.1025	0.3425	0.24
std	2.4…	1928…	187…	0.0180772	0.0…	0.0…	0.00…	0.0…	0.013562	0.013562	0.003…	0.017…	0.016…	0	0	0	0	0	0.894152	0.173184	0.604406	0.242251
min	1	0	39…	0.04	0.01	0.02	0.03	0.04	-0.01	-0.04	-0.01	-0.04	-0.04	0	0	0	0	0	0.07	0	0.05	0.05
25%	2.75	51.1…	348…	0.04	0.04	0.04	0.04	0.04	-0.01	-0.03…	-0.01	-0.01	-0.01	0	0	0	0	0	0.145	0.025	0.09	0.06
50%	4.5	3693…	371…	0.04	0.04	0.04	0.04	0.04	-0.005	-0.015	-0.01	-0.01	-0.01	0	0	0	0	0	0.475	0.04	0.14	0.15
75%	6.25	3752…	382…	0.045	0.04	0.045	0.04	0.04	0.0125	-0.01	-0.01	-0.005	-0.00…	0	0	0	0	0	0.7825	0.07	0.21	0.3
max	8	3842…	388…	0.09	0.04	0.06	0.04	0.08	0.02	-0.01	0	0.02	0.02	0	0	0	0	0	2.77	0.52	1.83	0.69

Redacted

Description: This dataset records the estimated gross weight (GW) of an aircraft at various time intervals during a specific flight segment. It includes details such as the flight data file name, segment number, index number, time of estimation, and the estimated gross weight.

Data Source: File Redacted

Number of Records: 9 entries

Key Columns:

- FileN: Input flight data file name
- SegNum: Flight segment number within the input flight data file
- REDACTED: Index number (sequence number of the estimated gross weight output)
- GwtTime: Time at which estimated gross weight is output (in seconds)
- esGW: Estimated gross weight (in pounds)
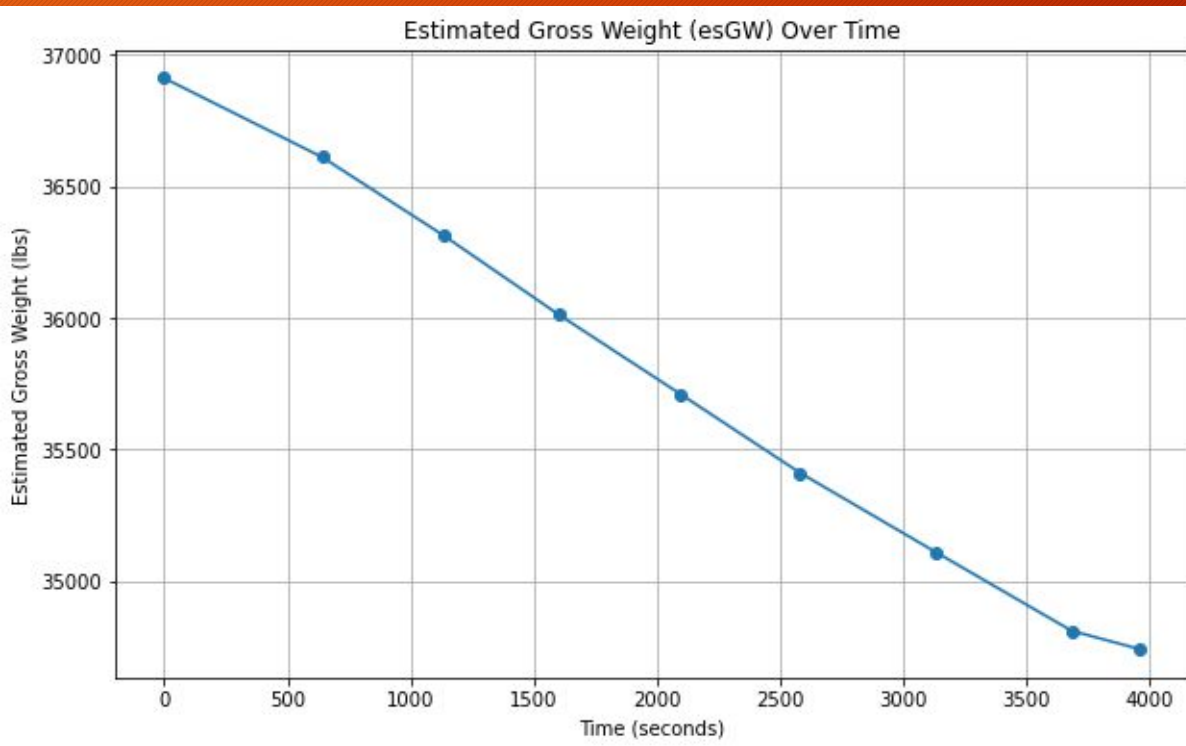
Redacted

Total Segments Analyzed: 1

REDACTED:

- **File Name:** Redacted
- **Segment Number:** 1
- **REDACTED:** 36911 lbs
- **Final Gross Weight:** REDACTED lbs
- **Time Range:** 0.00 seconds to 3955.19 seconds
- **Total Weight Loss:** REDACTED lbs over the flight segment
- **Analysis:** The estimated gross weight of the aircraft decreases steadily over time, reflecting fuel consumption or other weight loss factors during the flight.

| Index	SegNum	GwtNum	GwtTime	esGW
count	9	9	9	9
mean	1	5	2091.17	35736.7
std	0	2.73861	1366.86	782.067
min	1	1	0	34742
25%	1	3	1137.38	35111
50%	1	5	2093.75	35711
75%	1	7	3128.63	36311
max	1	9	3955.19	36911

Redacted

Description: This dataset captures the sequence of identified flight regimes and configurations along with their basic attributes such as start time, end time, and duration.

Data Source: File Redacted

Number of Records: 258 flight regime events

Key Columns:

- REDACTED: Redactedevent sequential number
- RgmNum: Regime number
- RgmID: Flight regime ID
- ComfId: Aircraft configuration ID
- StartTime, EndTime: Flight regime start and end times (Redacted relative time, in seconds)
- Duration: Flight regime duration (in seconds)
- REDACTED: Regime type
- REDACTED: Regime name (e.g., REDACTED, Hovering: Steady)

Duration of Flight Regimes
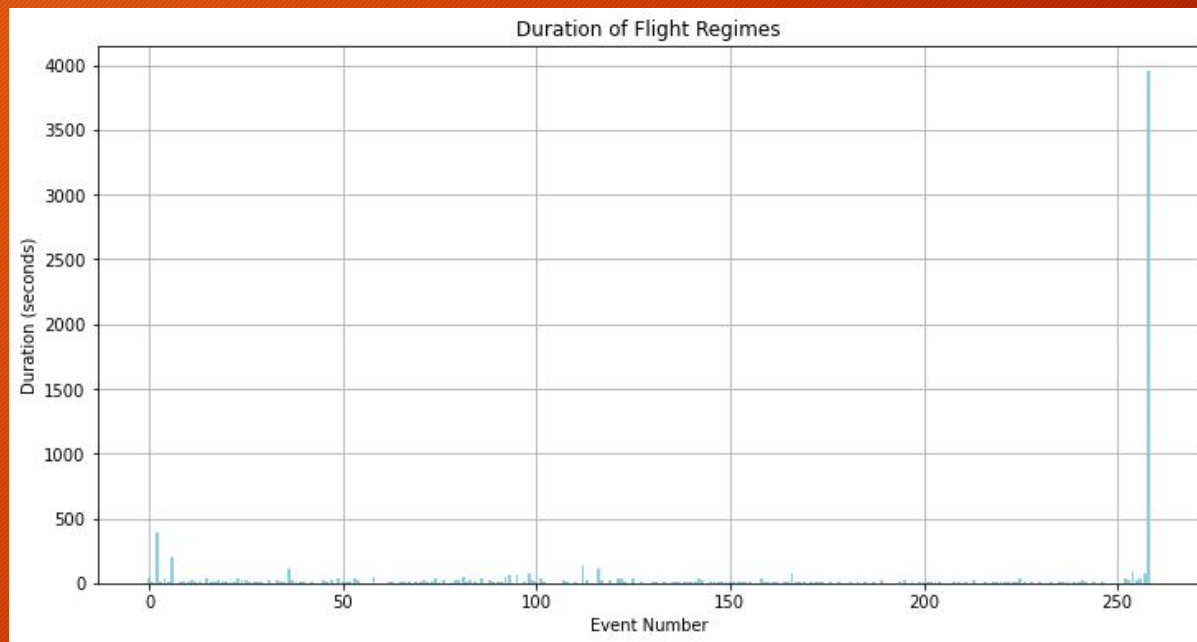
Redacted

Title: Summary Statistics
Content:

- **Total Flight Regimes Analyzed:** 258
- **REDACTED:**
  - **Event Number:** 0
  - **Regime Number:** 3
  - **Regime ID:** 2
  - **Start Time:** 0.00 seconds
  - **End Time:** 39.31 seconds
  - **Duration:** 39.31 seconds
  - **Regime Name:** Steady Ground Idle

| Index	EvtNum	RgmNum	ComfId	StartTime	EndTime	Duration	RgmType
count	259	259	259	259	259	259	259
mean	129	72.251	15.471	2363.45	2393.95	30.5034	0.23166
std	74.9111	43.863	61.4381	1017.8	1005.66	246.887	0.498449
min	0	2	11	0	39.31	0.5	0
25%	64.5	31	11	1452.88	1460.35	3.44	0
50%	129	97	11	2686.25	2689.38	7.06	0
75%	193.5	102	11	3259.22	3270.69	16.06	0
max	258	215	999	3883.13	3955.19	3955.19	4

Redacted

Description: This dataset captures five attribute values (maximum, minimum, average, start value, and end value) of 16 parameters of interest related to flight regimes. Each parameter is associated with various flight regimes identified in the Redacted file.

Data Source: File Redacted

Number of Records: 45 regimes

Key Columns:

- Redacted: Flight regime ID
- Redacted: Aircraft configuration ID
- Columns for each parameter like REDACTED, AirSpdKt, REDACTED, etc., each with five attributes (REDACTED, min, avg, start, end) for different metrics like roll angle, airspeed, climb rate, pitch angle, REDACTED, etc.
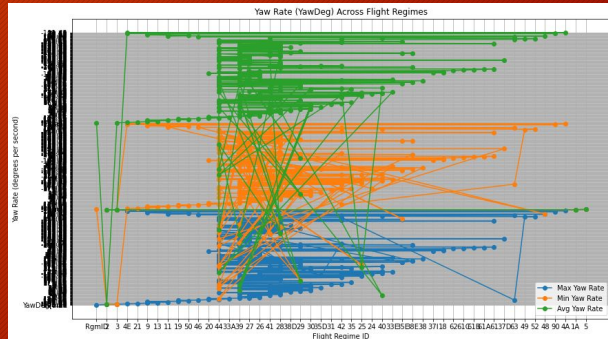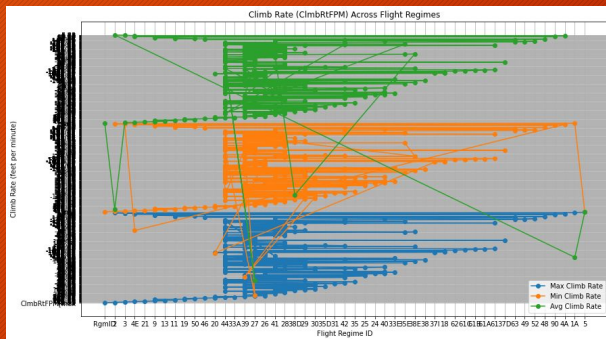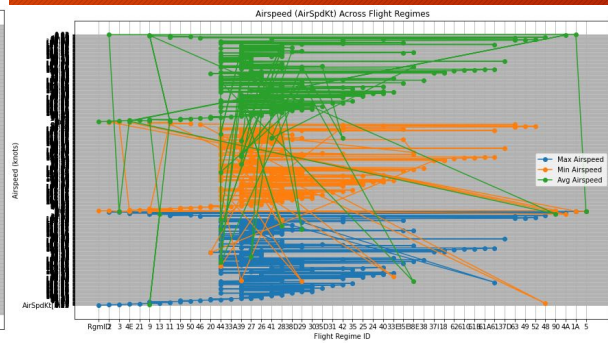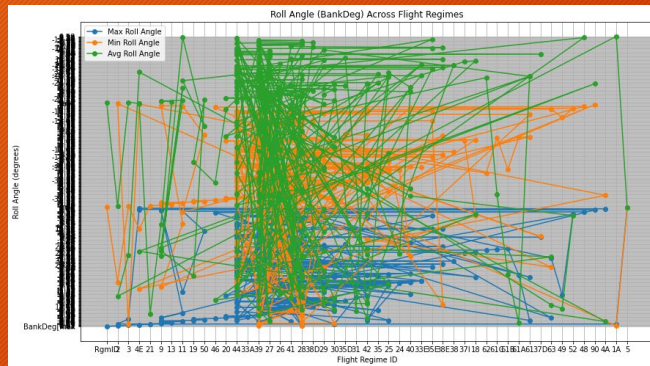
Redacted

Title: Summary Statistics
Content:

- **Total Flight Regimes Analyzed:** 45
- **REDACTED:**
  - **Regime ID:** 2
  - **Configuration ID:** 28
  - **Roll Angle (REDACTED)**
    REDACTED/Min/Avg: 0.53 / 0.47 / 0.51 degrees
  - **Airspeed (AirSpdKt)**
    REDACTED/Min/Avg: 0.25 / 0.13 / 0.21 knots
  - **REDACTED (ClmbRtFPM)**
    Max/Min/Avg: -12.79 / -25.45 / -20.87 feet per minute
  - **REDACTED (YawDeg)**
    Max/Min/Avg: 0.07 / -1.94 / -0.44 degrees per second

| Index	RgmID	CfgID	BankDeg_max	BankDeg_min	BankDeg_avg	BankDeg_start	BankDeg_end
count	260	260	260	260	260	260	260
unique	49	4	194	215	209	220	215
top	44	11	0.48	-0.70	-0.08	0.68	0.05
freq	46	248	5	4	4	3	4

Redacted

Description: This dataset captures the remaining useful life (RUL) calculated by REDACTED for high cycle and low cycle damages associated with flight regimes. The dataset records RUL for specific keys during flight regimes in the previous file and includes flight cycles (Regime ID = 999) and power cycles (Regime ID = 998).

Data Source: File Redacted

Number of Records: 231 flight regime events

Key Columns:

- Rgm#: Flight regime number
- RgmID: Flight regime ID
- Cfg#: Aircraft configuration number
- REDACTED: Regime duration
- REDACTED: Regime type
- hcdDmg#: High cycle damage for keys (e.g., hcdDmg7 for Key 7)
- lcdDmg#: Low cycle damage for keys (e.g., lcdDmg7 for Key 7)

High and Low Cycle Damage for Key 7 Across Regimes
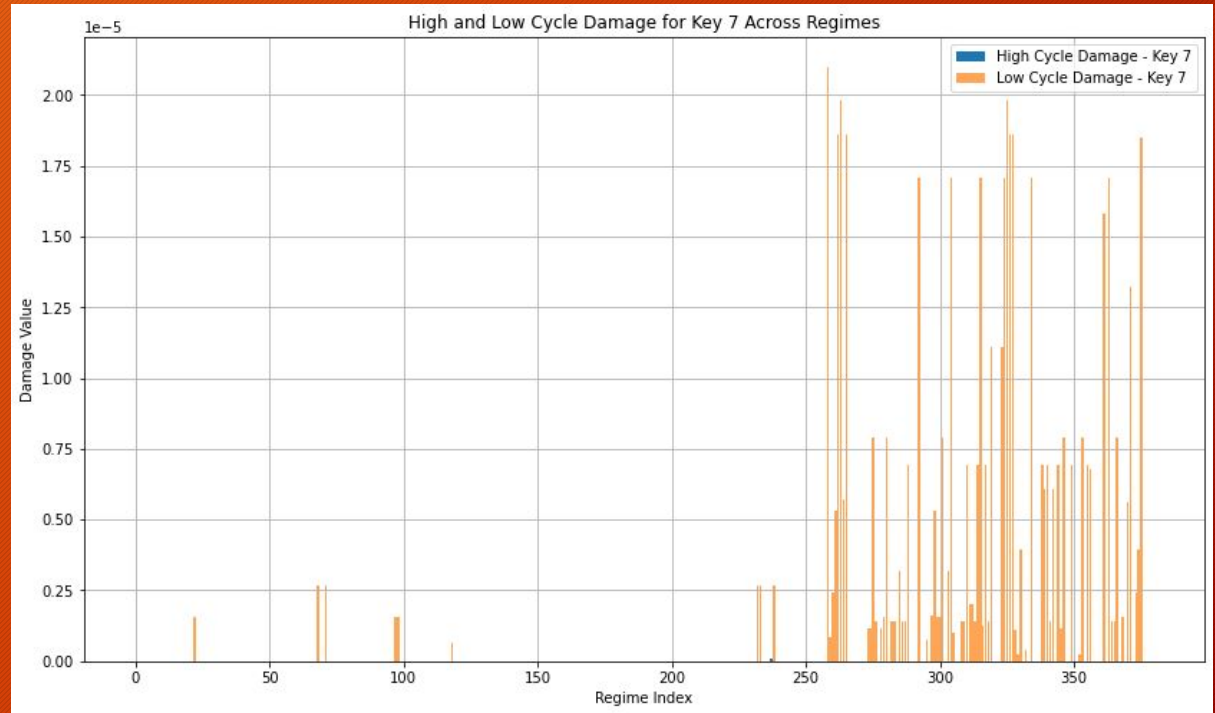
Redacted

Title: Summary Statistics
Content:

- **Total REDACTED:** 231
- **REDACTED:**
  - **Regime Number:** 30
  - **Regime ID:** 27
  - **Configuration Number:** 11
  - **Duration:** 4.06 seconds
  - **High Cycle Damage Key 7 (hcdDmg7):** 0.00E+000
  - **Low Cycle Damage Key 7 (lcdDmg7):** 0.00E+000

Index	#	Rgm#	Cfg#	Durtn	RgmType	hcdDmg7	lcdDmg7	hcdDmg12	lcdDmg12	hcdDmg18	lcdDmg18	hcdDmg20	lcdDmg20
count	380	380	380	380	380	380	380	380	380	380	380	380	380
mean	189.5	52.1105	328.329	20.7904	1.75	2.35263e-10	1.40923e-06	2.27653e-07	2.10444e-06	0	4.51711e-06	0	3.96237e-06
std	109.841	46.6934	461.123	204.195	2.26202	4.58612e-09	3.92384e-06	1.43322e-06	6.8325e-06	0	1.55045e-05	0	2.31047e-05
min	0	2	11	0	0	0	0	0	0	0	0	0	0
25%	94.75	9	11	0	0	0	0	0	0	0	0	0	0
50%	189.5	31	11	3.5	0	0	0	0	0	0	0	0	0
75%	284.25	97	998	10.5	5	0	0	0	9.89e-07	0	0	0	0
max	379	215	999	3955.19	5	8.94e-08	2.1e-05	1.85e-05	4.42e-05	0	0.000182	0	0.0002

Redacted

Index	#	Rgm#	Cfg#	Durtn	RgmType	hcdDmg7	lcdDmg7	hcdDmg12	lcdDmg12	hcdDmg18	lcdDmg18	hcdDmg20	lcdDmg20
count	380	380	380	380	380	380	380	380	380	380	380	380	380
mean	189.5	52.1105	328.329	20.7904	1.75	2.35263e-10	1.40923e-06	2.27653e-07	2.10444e-06	0	4.51711e-06	0	3.96237e-06
std	109.841	46.6934	461.123	204.195	2.26202	4.58612e-09	3.92384e-06	1.43322e-06	6.8325e-06	0	1.55045e-05	0	2.31047e-05
min	0	2	11	0	0	0	0	0	0	0	0	0	0
25%	94.75	9	11	0	0	0	0	0	0	0	0	0	0
50%	189.5	31	11	3.5	0	0	0	0	0	0	0	0	0
75%	284.25	97	998	10.5	5	0	0	0	9.89e-07	0	0	0	0
max	379	215	999	3955.19	5	8.94e-08	2.1e-05	1.85e-05	4.42e-05	0	0.000182	0	0.0002

Redacted

Description: This dataset captures the cycle counting results of various parameters, such as engine torque (EngTQ), rotor speed (RtrSpd), and other flight metrics across different cycle types (REDACTED and REDACTED). The data includes metrics like cycle range, mean, minimum, and maximum values.

Data Source: File Redacted

Number of Records: 195 cycles

Key Columns:

- fileN: Data file name
- SegNum#: Flight number within the input flight data file
- yyyCycNum#: Sequential number for cycle counts for the parameter
- REDACTED: Cycle type (REDACTED or REDACTED)
- REDACTED, CycMean, REDACTED, CycMax: Cycle range, mean, minimum, and maximum values

Cycle Range, Mean, Min, and Max Values for Whole Cycles

Redacted

Total Cycles Analyzed: 195

Sample Cycle Information:

- **REDACTED:** Redacted
- **Cycle Type:** REDACTED
- **Cycle Range:** 2.88
- **Cycle Mean:** 0.52
- **Cycle Min:** -0.92
- **Cycle REDACTED:** 1.96

| Index	SegNum#	yyCycNum:	CycRange	CycMean	CycMin	CycMax
count	195	195	195	195	195	195
mean	1	98	3.75313	0.967692	-0.908974	2.84421
std	0	56.4358	2.97992	5.79749	5.93891	6.03233
min	1	1	2.19	-9.44	-12	-7.66
25%	1	49.5	2.39	-3.845	-5.19	-2.55
50%	1	98	2.82	0.11	-1.38	1.89
75%	1	146.5	3.805	6.04	4.415	7.765
max	1	195	27.86	12.19	10.5	15.86

Redacted

Description: This dataset records peak and valley results of a particular parameter measured across different time points during a flight. Each record indicates whether the measured value represents a peak or a valley.

Data Source: File Redacted

Number of Records: 589 peak/valley events

Key Columns:

- fileN: Input flight data file name
- SegNum#: Flight number within the input flight data file
- yyyPVNum#: Sequential record number for peak/valley data for the parameter
- PVTime: Time that peak or valley occurs
- REDACTED: Value of the parameter at peak or valley
- REDACTED: Type (peak or valley)

Histogram of Peak and Valley Values
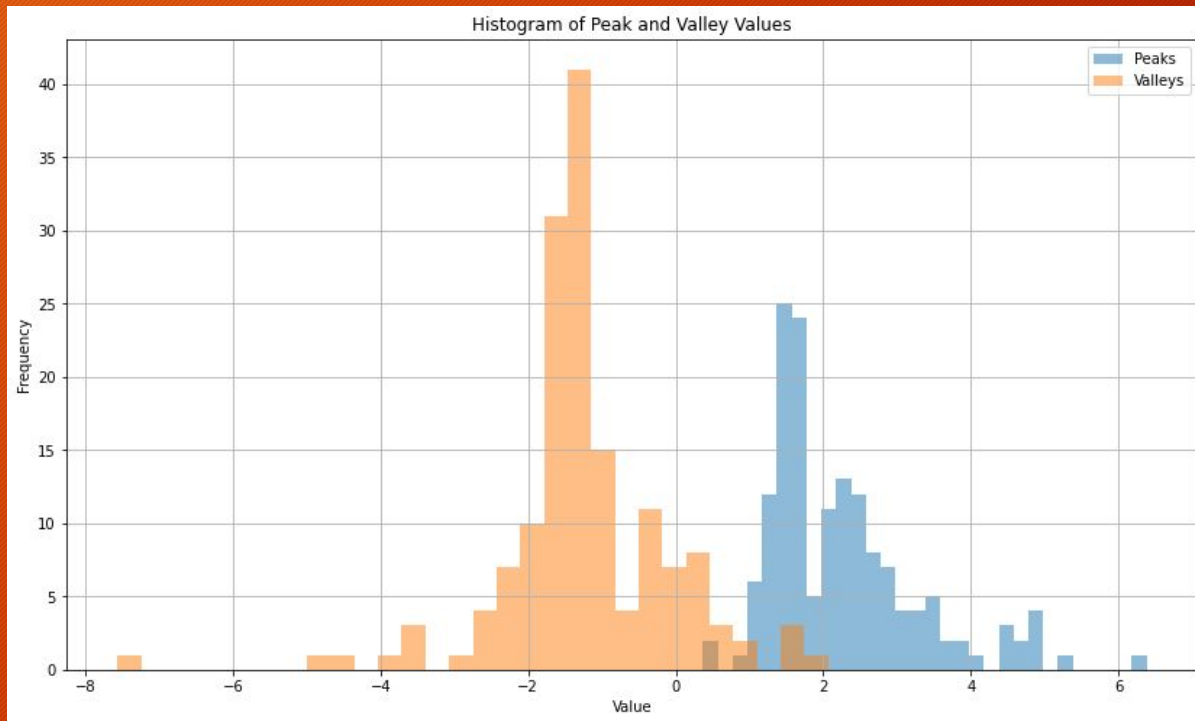
Redacted

Total Events Analyzed: 589

REDACTED:

- **File Name:** Redacted
- **Segment Number:** 1
- **Time (PVTime):** 452.94 seconds
- **Value (REDACTED):** 3.66
- **Type:** Peak

Index	SegNum#	/yyPVNum#	PVTime	PVValue
count	310	310	310	310
mean	1	155.5	2495.24	0.506903
std	0	89.6335	881.744	2.06188
min	1	1	456.38	-7.56
25%	1	78.25	1877.16	-1.3225
50%	1	155.5	2581.38	1.04
75%	1	232.75	3315.68	2.06
max	1	310	3707.13	6.38

Redacted

Description: The datasets capture the low cycle loads for maneuver-to-maneuver (REDACTED) sequences of resultant regimes associated with failure modes for various key numbers. The data represents load values over time.
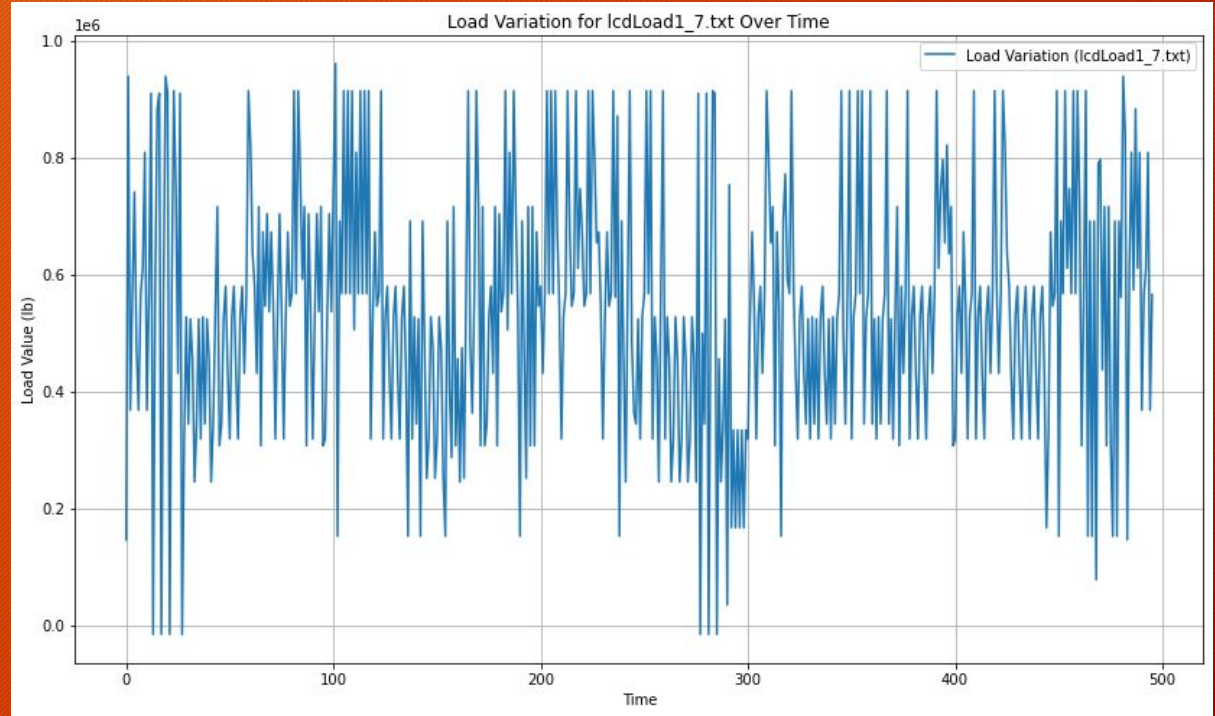
Data Source: Files Redacted

Number of Records:

- Redacted: 496 records
- Redacted: 495 records
- Redacted: 495 records
- Redacted: 495 records

Key Columns:

- Time: Time sequence (indicating different time points during flight)
- Redacted Low cycle load at the respective time point

Redacted

Description: The datasets capture the low cycle loads for maneuver-to-maneuver (REDACTED) sequences of resultant regimes associated with failure modes for various key numbers. The data represents load values over time.
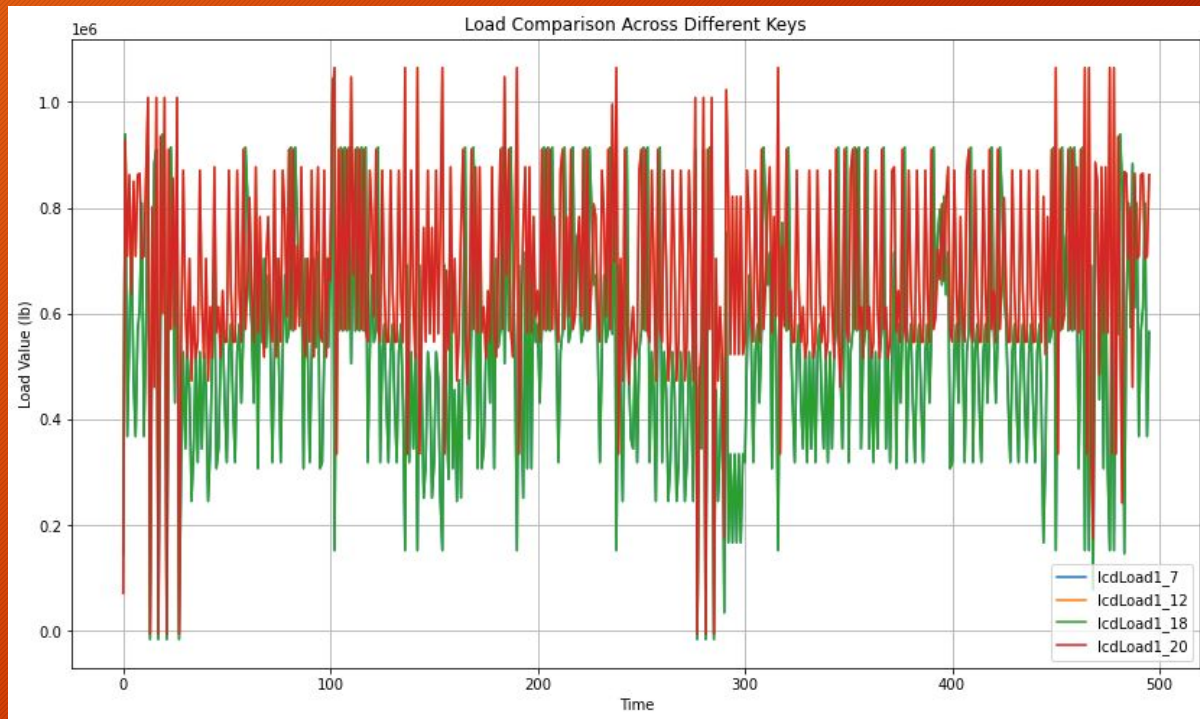
Data Source: Files Redacted

Number of Records:

- Redacted: 496 records
- Redacted: 495 records
- Redacted: 495 records
- Redacted: 495 records

Key Columns:

- Time: Time sequence (indicating different time points during flight)
- Redacted: Low cycle load at the respective time point

Load Comparison Across Different Keys

Redacted

Total Records Analyzed:

- Redacted 496
- Redacted: 495
- Redacted: 495
- Redacted: 495

Sample Load Values (from Redacted):

- **Time (REDACTED):** 146437.2
- **REDACTED (REDACTED):** 146437.2 lb
- **Time (495):** 565527.2
- **REDACTED (495):** 565527.2 lb

Index	Time	lcdLoad
count	496	496
mean	247.5	674982
std	143.327	193791
min	0	-5459
25%	123.75	546707
50%	247.5	612687
75%	371.25	870546
max	495	1.06442e+06

Redacted

Total Records Analyzed:

- Redacted 496
- Redacted: 495
- Redacted: 495
- Redacted: 495

Sample Load Values (from Redacted):

- **Time (REDACTED):** 146437.2
- **REDACTED (REDACTED):** 146437.2 lb
- **Time (495):** 565527.2
- **REDACTED (495):** 565527.2 lb

Index	Time	lcdLoad
count	496	496
mean	247.5	536753
std	143.327	214093
min	0	-15119.5
25%	123.75	344556
50%	247.5	536484
75%	371.25	672690

Redacted

Total Records Analyzed:

- Redacted: 496
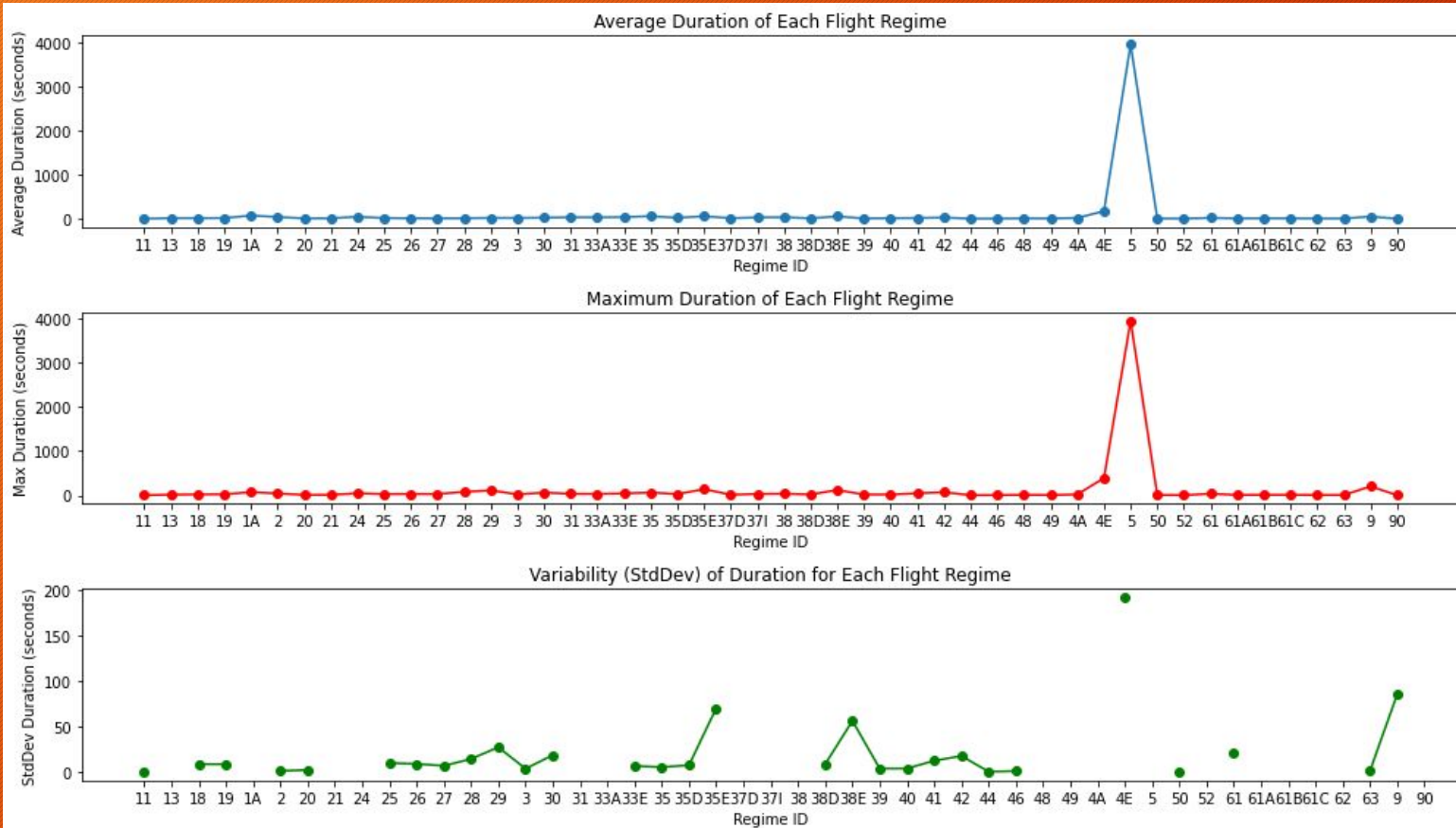- Redacted: 495
- Redacted: 495
- Redacted: 495

Sample Load Values (from Redacted):

- **Time (REDACTED):** 146437.2
- **REDACTED (REDACTED):** 146437.2 lb
- **Time (495):** 565527.2
- **REDACTED (495):** 565527.2 lb

Index	Time	lcdLoad
count	496	496
mean	247.5	674902
std	143.327	193513
min	0	-5459
25%	123.75	546707
50%	247.5	612687
75%	371.25	870546

Redacted

Total Records Analyzed:

- Redacted: 496
- Redacted: 495
- Redacted: 495
- Redacted: 495

Sample Load Values (from Redacted):

- **Time (REDACTED):** 146437.2
- **REDACTED (REDACTED):** 146437.2 lb
- **Time (495):** 565527.2
- **REDACTED (495):** 565527.2 lb

Index	Time	lcdLoad
count	496	496
mean	247.5	536747
std	143.327	213850
min	0	-15119.5
25%	123.75	344556
50%	247.5	536484
75%	371.25	672690

New Features

Duration of Flight Regimes

Average Duration of Each Flight Regime

Maximum Duration of Each Flight Regime

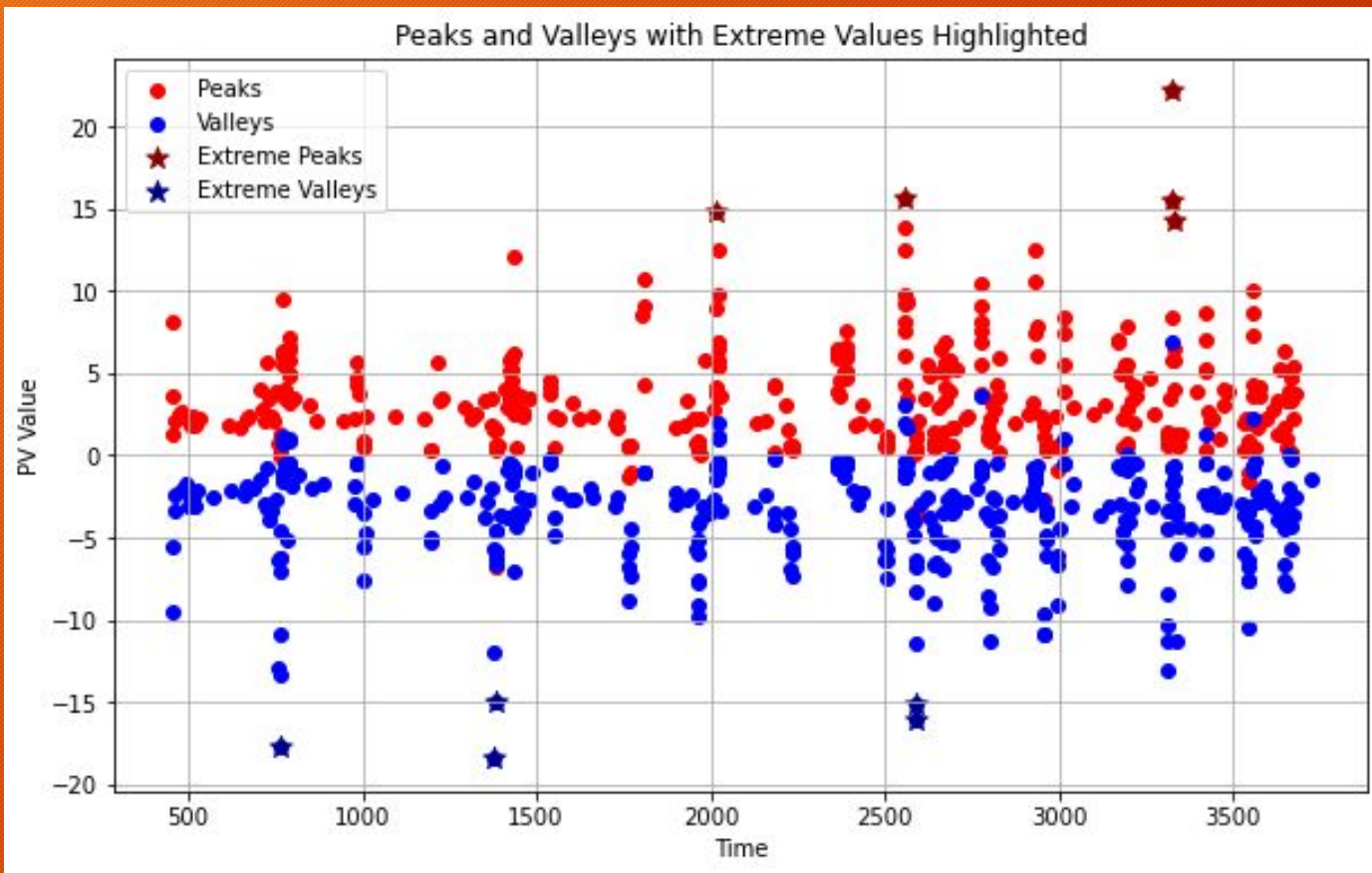Variability (StdDev) of Duration for Each Flight Regime
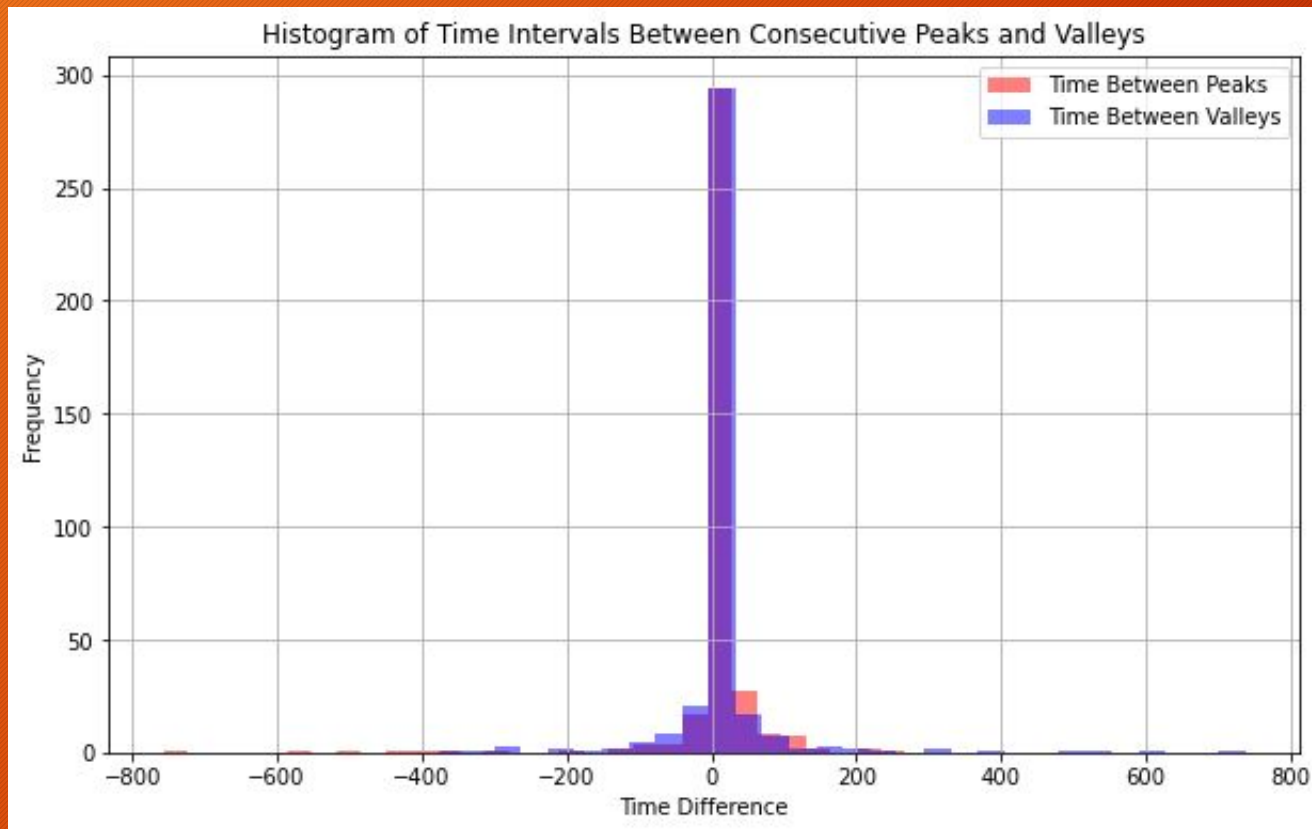
Duration of Flight Regimes

The duration of flight regimes is critical in understanding the operational context of an aircraft. According to REDACTED (REDACTED), understanding the time spent in different flight regimes allows for a more accurate reconstruction of the usage spectrum, which is essential for assessing the fatigue and wear experienced by different components (p. REDACTED). By capturing the duration of these regimes, we can identify patterns in usage that might lead to accelerated wear and tear on specific parts of the helicopter, which is essential for designing effective maintenance schedules.

Moreover, REDACTED et al. (REDACTED) emphasize that the precise identification of time spent in each flight regime can be directly linked to the fatigue damage accumulated by various helicopter structures (p. REDACTED). This linkage enables the prediction of when a component is likely to fail, allowing for preemptive maintenance. This feature is particularly useful in a Condition-Based Maintenance (REDACTED) strategy, where maintenance actions are triggered based on the actual condition of the equipment rather than on a fixed schedule, thus potentially extending the lifespan of components and reducing maintenance costs.

REDACTED

Peaks and Valleys with Extreme Values Highlighted

REDACTED

Histogram of Time Intervals Between Consecutive Peaks and Valleys

REDACTED

REDACTED and valleys in operational data often represent critical events where the system experiences extreme conditions, such as maximum stress or strain. REDACTED. (REDACTED) note that extracting features from such time-domain data, including maximum, minimum, and peak-to-peak values, significantly enhances the ability to diagnose faults by capturing the most critical aspects of the system's behavior (p. REDACTED). These features can be used to identify abnormal conditions that might indicate the onset of a fault, allowing for early intervention before the issue becomes more severe.

Additionally, REDACTED. (REDACTED) demonstrate that integrating these time-domain features with machine learning algorithms, such as decision trees, improves diagnostic accuracy and reduces the time required for training the model (p. REDACTED). This is particularly valuable in complex systems like the REDACTED, where quick and accurate fault detection is crucial for maintaining operational safety and efficiency.

Feature Engineering

By combining the duration of flight regimes with peaks and valleys data, we can develop a comprehensive understanding of the operational conditions that lead to wear and tear, allowing for more precise predictions of component lifespan and better maintenance planning. This approach not only improves safety but also optimizes maintenance schedules, potentially leading to significant cost savings.

The integration of flight regime duration and peaks and valleys features offers a robust framework for enhancing the predictive maintenance and operational efficiency of the REDACTED helicopter. These features provide critical insights into the operational stresses experienced by the aircraft, enabling more accurate and timely maintenance interventions.

References

REDACTED, F., Coral, REDACTED, REDACTED, REDACTED, REDACTED, Baldi, A., Mariani, U., & Mezzanzanica, D. (REDACTED). A Multivariate Time-Series Segmentation Framework for Flight Condition Recognition. IEEE Transactions on REDACTED, 59(3), REDACTED. REDACTEDTAES.2022.3215115

Ji, D., REDACTED, REDACTED, & Wang, REDACTED (REDACTED). Research on the motor fault diagnosis method based on feature engineering and machine learning. REDACTED 7th International Conference on Intelligent Computing and REDACTED), REDACTED. doi:10.1109/ICSP54964.REDACTED.9778415