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Critical Data Analysis of Flight Data Recorder for Safety of Flight

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***Abstract*— This paper presents a novel approach to perform effective analysis of critical data analysis stored in crash protected memory module. This module retains recent 25 hours of digital flight data and timing information. The data stored in it consist of information related with the various parameters applicable for current status of the behavior of the aircraft and avionics equipment.**

The proposed approach provides a way to analyze the critical data for further action of investigation. The analysis also help pilot to take measures to avoid crashes. The graphical analysis helps to compare various critical parameters all together to take better decision during flight and post flight.

Keywords—Data Analysis, safety, critical systems, embedded systems, reliability

I. INTRODUCTION

Flight data monitoring and data analysis is the systematic, pro-active use of digital flight data from routine operations to improve aviation safety within an intrinsically non-punitive and just safety culture[1].

The flight data analysis programmes assist an operator to identify, quantify, assesses and address operational risks. Since 1970, the various regulations group has helped to develop and support such system and used flight data monitoring information to support a range of airworthiness and operational safety. A flight data analysis system allows an operator to compare their standard operating procedures with those actually achieved in everyday flights. A feedback on data analysis is also a part of safety management system that allow timely corrective action to be taken where safety may be compromised by significant deviation from standard of operations [2]

II. LITERATURE REVIEW

A lot of work is being carried out in the field of flight data monitoring and analysis. Digital flight data are of various type which are acquired from aircraft sensors to the flight data acquisition system through standard interfaces and further routed to the crash protected digital flight data recorder (FDR).

It is common practice to investigate the reason for accident/incident. The flight data of various parameters are downloaded and decoded into engineering units for further analysis of events in tabular form. Also various types of graphs are plotted for these parameters for analyzing the events, carrying out the detailed research.

Aircraft Data Recovery and Analysis Software(ADRAS) a software package which enables the airlines to perform their own analysis of flight data removed from the solid state FDR products. This program operates on a 486 class personal computer in a MS Windows operating environment. The Windows user interface provides an easily understood menu driven readout and analysis tool that requires minimal operator training. ADRAS is a full featured analysis tool which performs readout of the flight recorder data, as well as reconstruction of the data into formats which are useful in the analysis process.

- Display formats include both tabular listings and Analog (strip chart) presentation.
- Results may be viewed on the computer screen, printed, and/or stored as a disk file.
- Logical search features enable the operator to search for and display specific events.
- Control features enable the operator to zoom in on details or switch display formats.
- A database construction and editing tool enables operator modification of parameter tables

The current work is different from the literature surveyed as it focuses on the effective data analysis for a safety critical systems in the stipulated time of frame with high reliability. The analysis depicts complete pictures of pass/fail and exceedance summary of all parameters included ARINC-429/MIL-1553 data bus recorded in crash proof memory module.[1]

III. A BRIEF OVERVIEW OF THE APPROACH

Flight data monitoring and analysis have various important component from acquisition and conversion from raw to engineering data. The information flow is shown in the following figure:

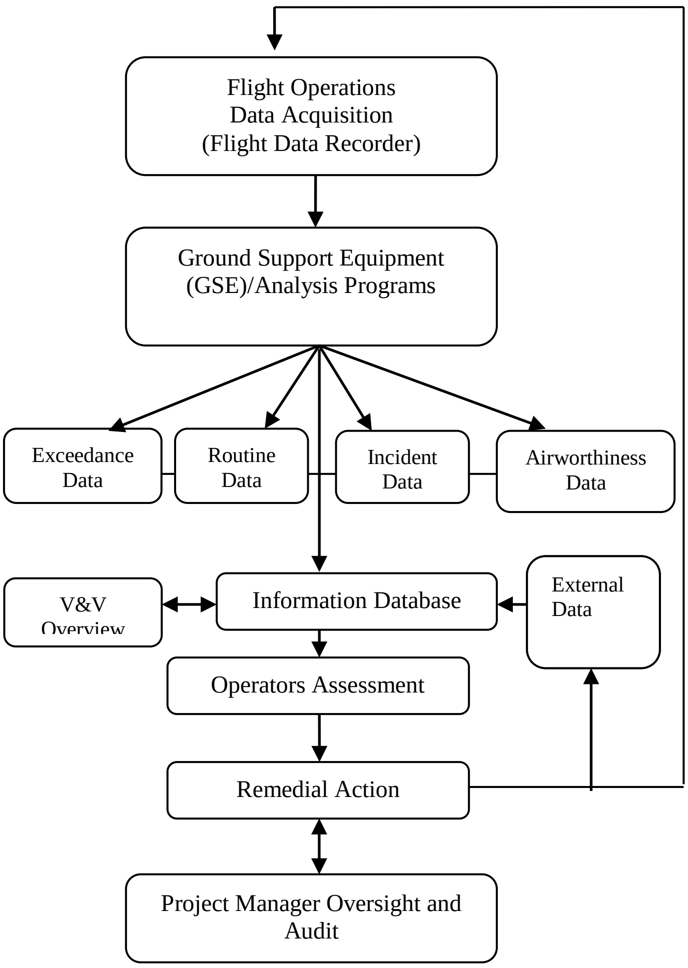

Figure 1: Informationflow for data analysis

1. Ground-Based Data Replay and Analysis Programs

Flight data is obtained from the aircraft's digital system by flight data acquisition unit (FDAU) and routed to crash protected Digital Flight Data Recorder (FDR). In addition to this mandatory data 'stream' a second output is generated to a non-mandatory recorder. The output is often more comprehensive than that of the crash-protected flight recorder due to increased capacity of the recorder. The stored data is replayed through a suite of computer programs starting with one that converts the raw binary data into engineering units. Aircraft, recorder and media data quality checks, plus other checks are carried out and recorded for trending purposes. Verification and validation procedures are critical at this stage to increase the reliability of output.[10]

Traditionally the data has been processed through analysis programs, retained for a set period of time for safety report follow-up and then destroyed. However, the data, or at least a significant promotion of the parameters, should be retained for amalgamation into longer term historical views of operations which are now considered to be essential.

This may be held in either raw or processed form and can also be retained in an archive rather directly on line to speed up the on-going analysis of data.

2. Exceedance or Event Detection

Exceedence or eventdetection is the standard flight data monitoring algorithm methodology that searches the data for deviations from flight manual limits, standard operating procedures and good airmanship. There is normally a set of core events that cover the main areas of interest that are fairly standard across operators. Example events may be high take-off rotation rate, Ground Proximity Warning(GPWS), Flap limit speed exceedence etc.

3. Routine Data

Increansingly, data is retained from all flights and not just the significant ones producing events. This enables the monitoring of more subtle trends and tendensies before the trigger levels are reached. A selection of measures, that are sufficient to characterise each flight, should be retained such to allow comparative analysis of a wide range of aspects of operational variability.

4. Incident Investigation Data

Flight data monitoring has been found to be very useful during the follow-up of mandatory occurrences and other technical reports. The data adds report to the flight crew review quantifying the impressions gathered from the recollections of data.

Engine monitoring programs use measures of engine operations to monitor efficiency and predict future performance. These programs are normally supplied by the engine manufacturer and feed their own databases.

5. Continued Airworthiness Data

Routine and event both data can be utilized to assist the continued airworthiness function. However, care must be taken to ensure the access to the data and its use is properly controlled.

Engine monitoring programs use measures of engine operation to monitor efficiency and predict future performance. Operator should consider the potential benefits of including the wider use of this data within their continued airworthiness programmes.

6. The Information Database

All the information gathered should be kept either in a central database or in linked databases that allow cross-referencing of the various types of data. These links should include air safety and technical fault reporting systems to provide a complete view of the operation. [10]

7. Assessment and Follow-up with remedial action

This is the critical part of the process. In this process the system is put in place to detect, validate and distribute the information; the information finally reaches the place where the operational safety and continued airworthiness benefits may be realized.

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Once a hazard or potential hazard has been identified, then the first step has to decide if the level of risk is acceptable. If not, then appropriate action to reduce the effect should be investigated along with an assessment of the wider effects of any proposed changes. This should be carried out to ensure the risk is not moved elsewhere. The responsibility for ensuring action is taken must be clearly defined and those identified must be fully empowered.[11]

8. Continued Monitoring

After any action taken, an active monitoring should be on the original issues or problems and careful assessment made of other hazards in the area of change. Part of the assessment of the failure effects of changes should be an attempt to identify unintended consequences of the potential relocation of risks. This, plus a general check on all surrounding measures is required before 'signing off' the changes as successful. This confirmation, or otherwise, would be expected to be fed into a high level management group whose responsibility is to ensure effective remedial action takes place.[10][11]

9. Safety Management System

Safety management is a systematic approach to manage safety, including the necessary organizational structures, accountabilities, policies and procedures. This includes the systematic management of the risk associated with flight operations to achieve high levels of safety performance Safety management system is an explicit element of the corporate management system that sets out a company's safety policy and defines how it intends to manage safety as an integral part of its overall business.[7]

There are four essential prerequisites for a safety management system. These are

- A Corporate commitment from senior management towards safety.
- An effective organization for delivery safety
- Systems to achieve safety assurance
- A positive safety culture

The system required also include:

- Arrangement for the analysis of flight data
- Enhanced safety events/issue reports
- Internal safety incident investigations leading to corrective/preventive action
- Effective safety data for performance analysis
- Arrangement for ongoing safety promotion
- Periodic review of the SMS
- Active monitoring by line managers

10. Risk Identification

Risk is defined as the combination of probability, or frequency of occurrence of defined hazard and the severity of the consequences of the occurrence. Typical classification of the system of safety criticality is shown below:[6]

Activation Definition	Meaning	Value
Catastrophic	Failure conditions which would prevent continued safe flight and landing.	5
Hazardous	A large reduction in safety margins, physical distress or a workload such that organizations can not be relied upon to perform their tasks accurately or completely, serious injury or death to a number of people. Major equipment damage.	4
Major	Failure conditions which would reduce the capability of the aircraft or the ability of the crew to cope with adverse operating conditions to the extent that there would be, for example, a significant reduction in safety margins or functional capabilities, a significant increase in crew workload or in conditions impairing crew efficiency, or discomfort to occupants, possibly including injuries	3
Minor	Failure conditions which would not significantly reduce aircraft safety, and which would involve crew actions that are well within their capabilities. Minor incident	2
No Effect	Little consequence. Failure conditions which do not affect the operational capability.	1

IV. IMPLEMENTATION OF THE CRITICAL DATA ANALYSIS AND MONITORING SYSTEM

The real-time data of various aircraft parameters recorded in the flight data recorder (FDR) are downloaded and replayed on the ground with the help of the software called ground support equipment. The application software will run on the Host PC and will acquire the recorded data from the FDR through interface like Ethernet or RS422 serial link. The time tag information recorded on FDR is used as an absolute reference. The recorded data is acquired from the FDR for further processing. The processed data is stored in the hard disk for further analysis and retrieval.

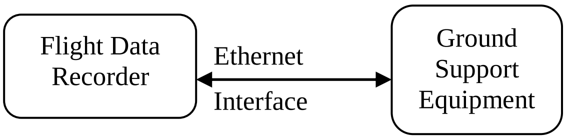

Figure: 2 Ground Support Equipment Setup

The Ground Support Equipment (GSE) is a laptop based Ground Handling System which is capable of retrieving Aircraft & Audio Data recorded in Flight Data Recorder through Ethernet interface. Speed of replayed data is at least 10 times of A/c data recording time and 2 times of audio recording time.

The replay is done based on Sortie count stored in FDR. The recorded raw data replayed from FDR is then processed by GSE in prescribed format which will be stored in laptop for

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post flight data analysis. The analysis of Aircraft and Audio data is done either in graphical or tabular mode with the help of GSE software.

Tabular Analysis:

This capability shall show aircraft parameters details in Tabular form. It will perform the tabular analysis of data retrieved from FDR for a selected sortie with respect to time recorded in FDR. Analysis can be done on all parameters(Analog, Discrete, Frequency) for any of one resolution of 16, 8, 4, 2, 1, 1/2, 1/4, 1/8 and 1/16 sample per second for the selected time duration. Conversion from raw to engineering value will be done on the basis of calibration of parameters. Tabular analysis shows the values of different parameters with respect to elapse time of the sortie at every second. (Figure 3)[8]

	FLP	FR1	FR2	FR3	FR4	TKP	WPN	UC1	ALT	RHT	IAS	NAX	LAX	AOA	PTD	TPP	TPS	PTP	OAT
	DISCI	DISCI	DISCI	DISCI	DISCI	DISCI	DISCI	DISCRI	FT	FT	KNOTS	G	G	DEG	DEG	DEG	DEG	DEG	DEG-C
00:00:00	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.83	-0.53	-1.56	0.34	39.21
00:00:01	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.83	-0.58	-1.56	0.34	38.80
00:00:02	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.83	-0.58	-1.56	0.34	39.21
00:00:03	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.83	-0.58	-1.56	0.34	39.62
00:00:04	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.86	-0.58	-1.56	0.34	39.21
00:00:05	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.83	-0.58	-1.56	0.34	39.21
00:00:06	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.83	-0.58	-1.56	0.34	38.80
00:00:07	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.83	-0.58	-1.56	0.34	39.21
00:00:08	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.83	-0.58	-1.56	0.34	39.21
00:00:09	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.87	0.02	-5.66	-8.86	-0.58	-1.56	0.34	38.80
00:00:10	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.83	-0.58	-1.56	0.34	39.21
00:00:11	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.83	-0.58	-1.56	0.34	38.80
00:00:12	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.86	-0.58	-1.56	0.34	38.80
00:00:13	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.83	-0.58	-1.56	0.34	38.80
00:00:14	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.87	0.02	-5.66	-8.80	-0.58	-1.56	0.34	39.21
00:00:15	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.87	0.02	-5.66	-8.80	-0.58	-1.51	0.34	39.21
00:00:16	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.80	-0.58	-1.51	0.34	38.80
00:00:17	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.80	-0.58	-1.51	0.34	39.21
00:00:18	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.87	0.02	-5.66	-8.83	-0.58	-1.51	0.34	38.39
00:00:19	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.80	-0.58	-1.51	0.34	39.21
00:00:20	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.92	0.02	-5.66	-8.80	-0.58	-1.51	0.34	38.39
00:00:21	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.80	-0.58	-1.51	0.34	39.21
00:00:22	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.80	-0.58	-1.51	0.34	38.80
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00:00:24	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.87	0.02	-5.66	-8.83	-0.58	-1.51	0.34	38.80
00:00:25	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.83	-0.58	-1.51	0.34	38.80
00:00:26	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.80	-0.58	-1.51	0.34	39.21
00:00:27	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.80	-0.58	-1.51	0.34	38.80
00:00:28	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.80	-0.58	-1.51	0.34	39.21
00:00:29	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.80	-0.58	-1.51	0.34	38.80
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00:00:32	OFF	OFF	OFF	OFF	OFF	ON	OFF	UP	2952.19	0.00	15.80	0.90	0.02	-5.66	-8.80	-0.58	-1.51	0.34	38.80

Figure: 3 Tabular data analysis of flight parameters

Graphical Analysis:

This capability shall show aircraft parameters details in Graphical form. It will perform the graphical analysis of data retrieved from FDR of a selected sortie with respect to time recorded in FDR. Analysis can be done on selected analog and discrete parameters for a user selected time duration and resolution per second. Conversion from raw to engineering value will be done on the basis of calibration pf parameters. User can also carry out error analysis i.e. during power on test and continuous test during flight. The graphical display shall be in following display plots:

Normal Plot: Display of aircraft data per second one sample scrollable in both horizontal and vertical directions. (Figure 4)

Quick Plot: Display of data of complete sortie duration in a single page (in compressed mode) scrollable only vertically to see the plot of all the parameters. (Figure 5)

Expanded/Zoomed Plot: Display of plot in zoom mode to see either 2/4/8/16 samples per second and shall be scrollable horizontally and vertically.(Figure 6)[8]

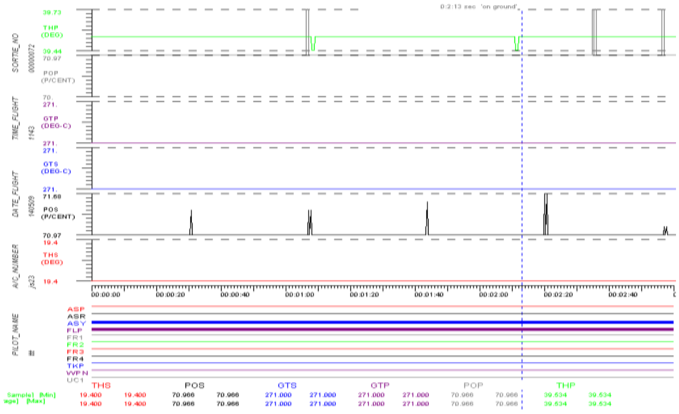

Figure: 4 Graphical data analysis of flight parameters-Normal Plot

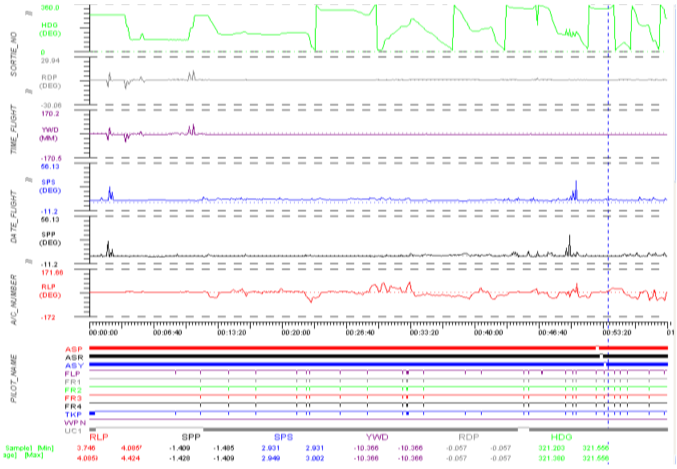

Figure: 5 Graphical data analysis of flight parameters-Quick Plot

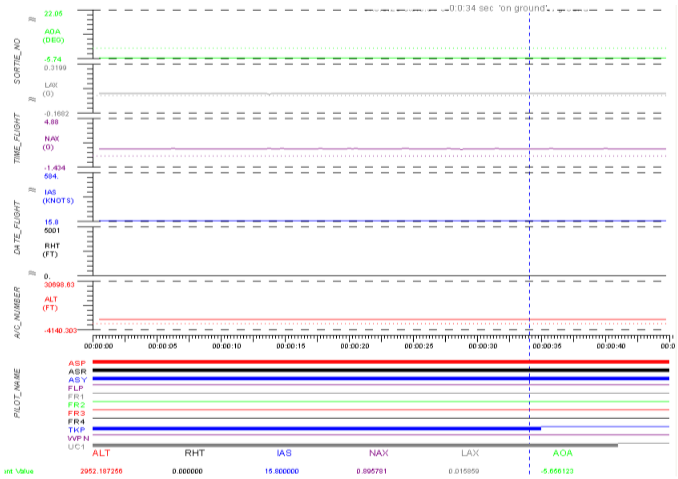

Figure: 6 Graphical data analysis of flight parameters-Expanded/Zoomed Plot

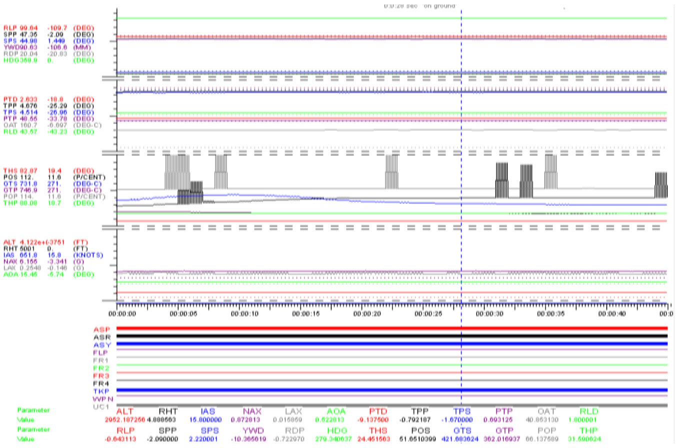

Figure: 7 Graphical data analysis of flight parameters-Expanded with overlapped Plot

Report Generation

1. It generates the maxima and minima of all the aircraft parameters in complete sortie duration.

2. It generates the summary report of data which will assist in quick analysis of flight data. It consists of following important features:

- Display the duration of aircraft on ground
- Display the duration of aircraft in air
- Display the duration for which engine temperature crosses threshold limit in a sortie
- Fatigue meter calculation of crossing various 'g' levels through software

3. It generates the exceedance report of aircraft data in which user shall enter the threshold and placard values of engine parameters and software report the time duration whenever it is violated.[9][10]

Summary of Parameters shown in Graphical and Tabular Analysis:

Para. code	Parameter full name	Para. code	Parameter full name
ALT	Altitude	OAT	Outside air temperature
AOA	Angle of attack	THP	Throttle position port
GTS	Turbine gas temperature starboard	THS	Throttle position port starboard
GTP	Turbine gas temperature port	TPP	Tail plane position port
HDG	Heading	TPS	Tail plane position starboard
IAS	Airspeed	YWD	Yaw demand
LAX	Lateral acceleration	ASP	Pitch auto stab
NAX	Normal acceleration	ASR	Roll auto stab
POP	Rpm port	ASY	Yaw auto stab
POS	Rpm starboard	FLP	Flap event
PTD	Pitch demand	FR1	Fire wrg no1 engine
PTP	Pitch angle	FR2	Fire wrg no2 engine
RDP	Rudder position	FR3	Fire wrg no3 engine
RHT	Radio altitude	FR4	Fire wrg no4 engine
RLD	Stick demand roll	TKP	Low fuel pressure wrg
RLP	Bank angle	WPN	Weapon release
SPP	Spoiler position port	GPX	Ground proximity wrg
SPS	Spoiler position starboard	UC1	U/c selection

V. EFFECTIVENESS OF THEPRESENT IMPLEMENTED APPROACH

The effectiveness of the approach can be realized only by comparing the data with the different existing approach on the same application in which the analysis is to perform. We used the conventional approach for the same aerospace application.

The conventional approach is described in the earlier section and the data collected by implementing the present ground support equipment software for flight data analysis in tabular and graphical form. The flight data analysis in tabular form has very important capability to analyze the engineering values of all the parameters to see the actual behavior of the parameters so that the decision may be taken for next flight with safety measures. It has also capability of grouping of critical parameters for analysis so that all critical parameters shall show their behavior in comparison with other critical parameters.

The Ground support software has capability of generating Quick flight analysis & their reports for post flight Aircraft Health Monitoring.

The Software has capability of generation of complete Flight profile in single page, generates summary report and exceedance report of all parameters on one click. These features helps in making ready for flight within much lesser time hence reducing the turn-around time.

The Ground Support Software has verified and validated at each step of its implementation so that there is no chance of error in data conversion from raw to engineering and calibration of all critical and non-critical parameters. In data analysis, the validation of parameters ranges with respect to display of tabular and graphical analysis is properly done and their report is generated for summarizing the parameters behaviors and exceedance report of the parameters. The next flight shall be safely takeoff based on satisfactory flight data analysis report.[3][4][5]

VI. RESULTS AND CONCLUSION

This paper presents an efficient strategy to carry out the flight data analysis in Tabular and Graphical form with proper validation of flight data and their calibration. The outcome of the ground support system software is retrieval of flight data from FDR and convert in suitable engineering format for their analysis and health monitoring of the aircraft.

The analysis of the post flight data evaluate system performance and reduces operator efforts for making aircraft ready for next flight within less time.

This approach has a lot of scope in ground support equipment applications software for displaying various flight data report including exceedance based on available recorded data.

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