Configurable flight data analysis for trends and statistics analysis -an embedded perspective of an efficient flight safety system

CM Ananda, Rakesh Kumar, Mainak Ghoshhajra

Aerospace Electronics and systems division

National Aerospace Laboratories (NAL), Council of Scientific and Industrial Research (CSIR), Bangalore, India

***Abstract*— Federal Aviation Administration (FAA) policy on Flight Operations Quality Assurance (FOQA) indicates that FOQA is a voluntary safety initiative encouraging airline participation in FOQA. It is in the public interest with a necessary requirement that airlines must document procedures for taking corrective action, when necessary in the interest of safety and airlines must provide FAA with access to aggregate trend data. FAA issues final FOQA rule, in what it called a major step towards reaching its "Safer Skies" goal of cutting the commercial aviation accidents rate by substantially. FOQA programs currently are conducted by airlines, certification authorities and engineering groups of airlines. FOQA is primarily a data collection, processing and analysis system used to improve the various disciplines of flight operations. The Digital Flight Data Recorder (DFDR) onboard provides a wealth of information for rest of the analysis. This information can lead to improvements in aircrew training, maintenance and conduct of safer flight operations. The system can analyse and report the various events, exceedences and reports including statistics for the airline operators.**

The paper presents the methodology of data processing for various fleet of aircrafts with controlled parameter limits and conditions with logical envelops bounded by derived mathematical approaches for the trends and statistics of various systems and components of aircraft using NAL's Flight Operation Quality Assurance software (NALFOQA). The quality assurance in terms of flight operations and avionics system diagnostics is realized by flight data analysis, which is the heart of the system. This Paper also presents about the flight safety issues of the aviation industry in particular to the quality assurance areas of aviation using the techniques of data processing and database management. Case studies of few aircraft parameter exceedences are also covered.

I. INTRODUCTION AND MOTIVATION

DFDR's / Solid State Flight Data Recorders (SSFDR's) are being successfully used on civil aircraft for decades. They're proven survival strategy of deploying away from the aircraft and hence the crash site, allows for quick location and economical recovery of recorder information, particularly in marine incidents, where the floating recorders can readily be retrieved from the surface of the ocean. Changes in the needs of accident investigators, and in aircraft use, application, performance monitoring, routing, and avionics have resulted in the current initiatives underway to revise aviation recorder standards, their quality and data analysis. Vast majority of information gained by FOQA cannot be found in any other way as it provides objective and "actionable" data for all equipped flights.

In today's technological era software plays an important role in managing and maintaining aircraft safety, performance and profit. The dramatic growth in air travel, which has occurred over the past several years, has placed a severe burden on air traffic control and airport facilities. The safety measures and profit margins of most airlines are under permanent pressure. Fierce competition, impact of fuel prices, and the overall safety factor emphasize the significance of operational efficiency. National Aerospace Laboratories (NAL), Bangalore has designed and developed a software tool called NALFOQA, which is being used by major airlines in the country for flight safety operations and quality assurance activities. NALFOQA focuses on the criticality issues to expose the hidden aspects of flight safety part of aircraft information management system in terms of its design criticality, flight operational features with justified usage, quality assurance facts and figures as focused on the recorded data and a voluminous types of reports, charts, graphs and statistical information for very effective flight operations with professionally documented results. NALFOQA software, basically a FOQA [1] tool as per Federal Aviation Administration (FAA) policy, developed in-house has helped in improving airlines performance, safety and economics. The objective of NALFOQA software, is to use flight data to detect technical flaws, unsafe practices, or conditions outside of desired operating procedures early enough to allow timely intervention to avert accidents or incidents. While the Civil aviation authorities of India are working hard to upgrade its facilities and train more air traffic controllers, air travellers continue to face increasing delays in both number and duration. In view of this, tool like NALFOQA has helped a lot to airlines sector in terms of improving their overall crew performance, safety implementation and better economy saving. Airlines that have started using NALFOQA system have documented a great deal of financial benefit, operational efficiency, reduced insurance premium, better safety levels as well as improved training and safety of operations.

II. ROLE OF FOQA IN AIRLINES OPERATION/ CIVIL AVIATION

The reason why the aircraft accident rate has stayed fairly flat since the mid-70' has caused many to speculate as

to why. First of all, - is it at an acceptable level? Or is "Zero Accidents" an attainable goal to strive for. FOQA plays an important role in the air safety or flight safety departments of Airline operators to enhance safety, performance and operators efficiency.

III. EMBEDDED PERSPECTIVE OF FOQA – INTEGRATED MONITORING SYSTEMS

Close monitoring of aircraft flight operations and systems has made continuous refinement of reliable designs and increased performance. Enabling this operational monitoring has been the continual development of even more sophisticated data recording analysis with growing capabilities to handle huge amount of raw data.

FOQA data can reveal

- If an airline's trends are out of the norm
- If anomaly is an isolated occurrence or one that has been previously detected by another carrier who may have already developed a solution.
- If occurrence is a significant event that requires prompt decision- making and actions when combined with historical data
- Allow the confirmation of problem areas identified by flight crews through voluntary safety reporting programs
- Flight training
- Airline safety improvement
- Human factors study
- Operational procedures review.

and many more safety, quality and trend features of each aircraft, airlines as whole.

IV. NALFOQA TOOL: AN OVERVIEW

NALFOQA is window-based software with good database support. Database forms the base for all the trend analysis system with lot of information processed and archived. The software needs to be equipped / configured for the aircraft behaviour in terms of the parameter details, phase limits and event limits. The sequence of operations to be carried out is aircraft / configuration creation, parameter configuration, phase configuration, event configuration, and airlines fleet cycle configuration. NALFOQA has the provision to have database facilities for the configuration [2].

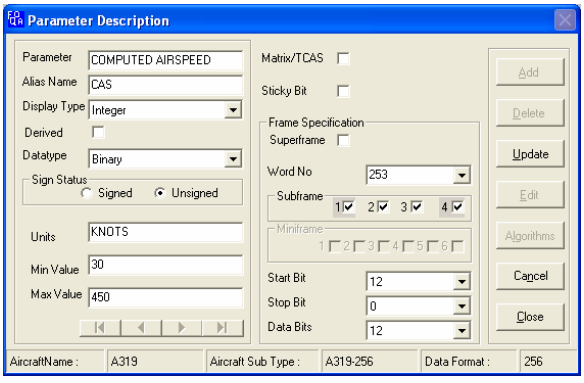

Fig 1 Parameter Configurations in NALFOQA

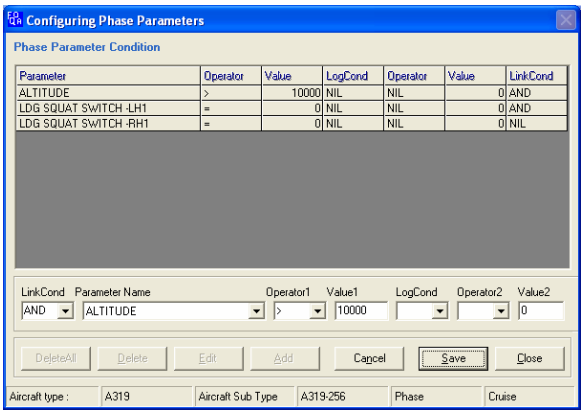

Fig 2 Phase Configurations in NALFOQA

This will be derived from the Aircraft Maintenance Manuals (AMM) [3], [4] of respective aircraft. The configuration of parameters in NALFOQA is exercised with special security password to protect the integrity of the database. The parameters so recorded falls into different types of signals, varied operating range, different resolution, varying recording bit occupancy for each parameter and the same signature need to be fed to the NALFOQA to understand the aircraft parameters for further analysis. The parameter configuration user interface of NALFOQA is shown in Fig 1. To investigate the incident for specific time of flight in terms of flight phases, the NALFOQA need to be configured for the cutting limits of various phases of the specific aircraft family. The phase configuration user interface of NALFOQA is shown in Fig 2.

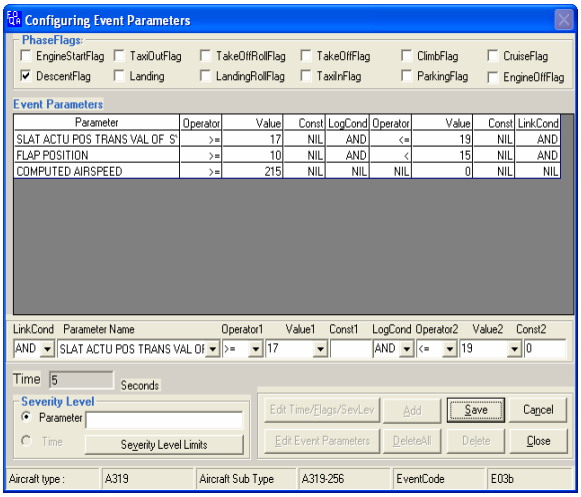

Fig 3 Event Configuration system of NALFOQA

The Digital Flight Data Recorder / Solid State Digital Flight Data Recorder parameter decoding is done after the parameter characteristics [5][6] is configured into NALFOQA. The decoding system with the digital display of continuous flight data will be displayed for incident/accident/operations analysis to the required level of resolution. The aircraft downloaded data directly from the DFDR is fed to

NALFOQA for data processing and analysis. The analysed data shows the number of sectors with the GMT time of take off and touchdown along with the corresponding airfields as shown in Fig 4. Any sector can be analysed further for the full time from engine start to engine off phase, based on the selection. The engineering values of the parameters can be displayed either in graphical or numerical display. The plot of a typical sector for a set of parameters is shown in Fig 5. Once NALFOQA detects the events, the event needs to be thoroughly analysed before the event is marked for tracking. This is done in many ways; however the software provides graphical and alphanumeric displays for validation of events.

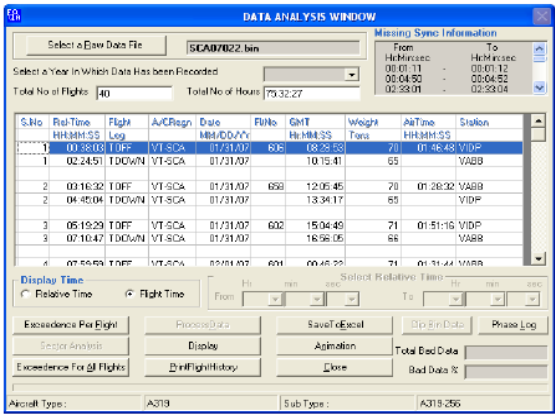

Fig 4 A Flight history window showing the details of different sectors

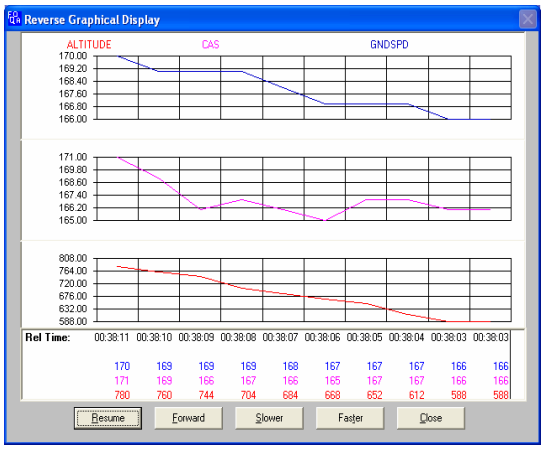

Fig 5 Graphical display of the parameters selected form the sectors

The software provides number of statistical and operational reports catering to various levels of requirement from airworthiness to engineering requirement. The entire processed data is stored into the master database for all statistical report generation. A typical monthly trend analysis report and event rate report is shown in Fig 6 and Fig 7. NALFOQA can be used for other types of report like event rate, trend rate, trend analysis, counselling, daily, monthly, quarterly, half yearly, yearly reports etc. Each of the analysis and the resulting report are being exhaustively used at various airlines for operations and incident/accident analysis point of view. Benchmark figure of NALFOQA for 200 hours of flight data is less than 90 seconds for complete analysis. The software is validated against similar software of Airbus like OEM's for performance and accuracy of the engineering value.

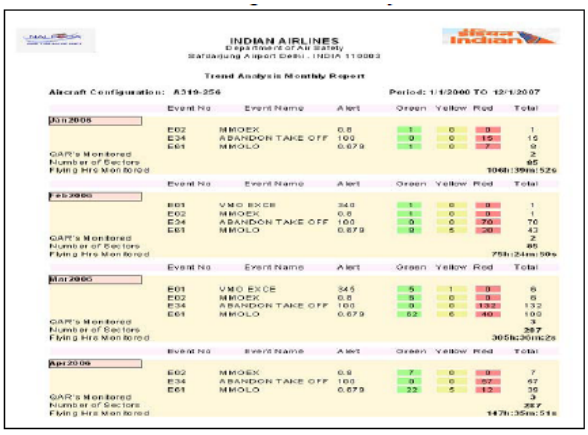

Fig 6 Textual report generated using NALFOQA software

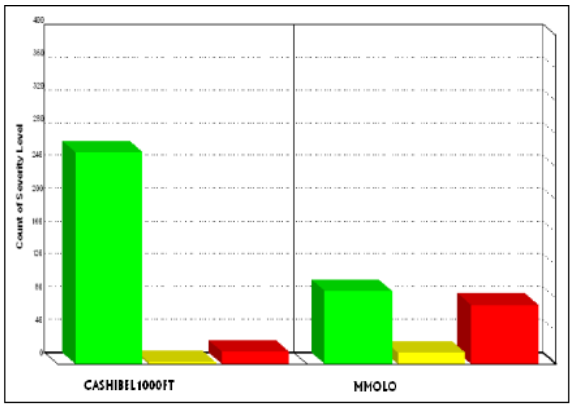

Fig 7 Graphical report generated using NALFOQA software

A. Growing steps of configurable NALFOQA towards Aircraft Integrated Management System concept

NALFOQA is being used at airlines for variety of aircrafts from Boeing and Airbus industry covering 64, 128, 256, 384, 512 and 1024 words per second format. It has proved to be one of the best tools for aircraft integrated data monitoring and analysis system. The software is designed to be an universal tool which can be easily configured for any aircraft with the characteristics of aircraft is known in terms of the Digital Flight Data Recorder (DFDR) / Solid State Flight Data Recorder (SSFDR) parameter specifications. The tool can be used as

- Aircraft integrated data monitoring and analysis system
- Incident / Accident analysis and report generation tool
- Aircraft performance monitoring system

- Pilots operations and quality monitoring and evaluation system
- Airlines statistics management system
- Post flight analysis and counselling tool
- Airlines efficiency management system
- Operations and quality control and management system

Incident:

NALFOQA software can be used for incident analysis in an efficient way. Annex 13 to the ICAO Chicago Convention defines an incident as an event linked to the operation of an aircraft, which is different from an accident, and jeopardized or could jeopardize the safety of the operation. It defines a serious incident as an incident whose circumstances indicate that an accident almost happened, and clarifies that the difference between an accident and a serious incident lies merely in the final outcome. Also an incident [7] defines as an occurrence, other than accident, associated with the operation of an aircraft, which affects or could affect the safety of operation. Indeed incident analysis is a major step, which will un-earth many issues of maintenance, operations and crew performance. Many practical examples reveal that if the incident analysis is carried out in systematic un-biased methodology, the operations efficiency and quality assurance objectives will definitely be fulfilled. This process enhances the systems efficiency in terms of maintainability, maintenance, preventive actions and reliability of the system.

Accident:

Accident analysis is more legal oriented where lot of activity need to be produced for verification and validation including the process itself in some cases. The data is looked at in a very critical manner to the bit level in case of corrupted/damaged data. NALFOQA can be used for this purpose in a sector analysis mode with bit wise data extraction capability as an optional analysis.

V. CASE STUDIES AND RESULTS

The following two scenarios demonstrate the incident analysis process using NALFOQA software. The data used for this analysis is the actual raw data of one of the commercial wide body aircrafts flying in Indian sky.

A. Case Study 1: Deviation of Glide Slope (GS) deviation

Glide slope deviation event during landing phase is quite critical as it can lead to hazardous scenario and hence the monitoring of this event is very important. This event also evaluates the performance skill of pilot and hence a good measurable event. A typical GS event exceedence detection using NALFOQA is shown in Fig 8. NALFOQA monitors the GS in landing phase for its nominal and the set trigger event value. Each trigger value also has severity bands called YELLOW, GREEN and RED indicating the severity of the event.

B. Case Study 2: Calibrated Air Speed (CAS) Exceedence

CAS exceedence event is another critical event, which has impact on the structure and other aircraft dynamics. CAS event is dependent on phase of flight, altitude level and other aircraft dynamics. Figure 9 shows a typical commercial flight at an altitude of below 10000 ft and CAS high below 10000 feet of altitude exceedence detection using NALFOQA.

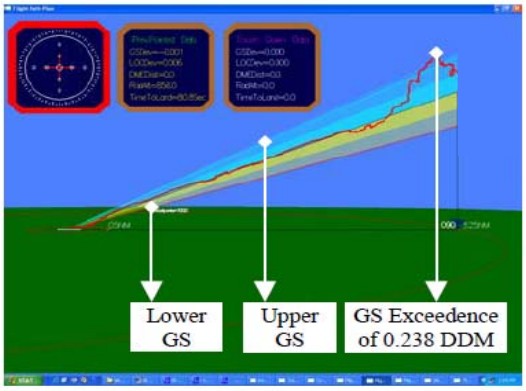

Fig 8 Glide slope deviation event analysis using NALFOQA

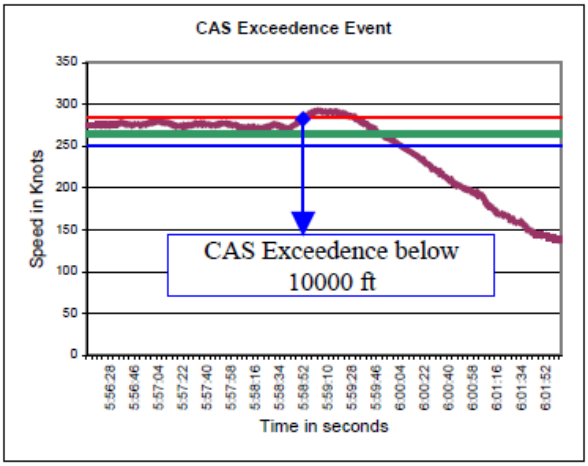

Figure 9 CAS HI event detection using NALFOQA

VI. CONCLUSIONS

The Digital Flight Data Recorder (DFDR) onboard provides a wealth of information that can lead to improvements in aircrew training, maintenance and conduct of safer flight operations. Proper analysis of the data helps in improving the crew performance, getting information about a flaw much before an actual accident occurs. In order to do the analysis of the huge coded data, of the 'BLACK BOX' NALFOQA software is successfully used for decompressing, analysing and converting to engineering units for monitoring, generating trend, generating report, or replaying the animated flight in 3D. Airlines that have started using NALFOQA system have documented a great deal of financial benefit, operational efficiency, reduced insurance premium, better safety levels as well as improved training and safety of

operations. NALFOQA focuses on the criticality issues to expose the hidden aspects of flight safety part of aircraft information management system. The design criticality, flight operational features with justified usage, quality assurance facts and figures as focused on the recorded data and voluminous types of reports, charts, graphs and statistical information can be very effectively highlighted and can be professionally documented for future reference. With additional data on aircraft systems and engine conditions, airlines are better able to achieve optimum fuel consumption and avoid unneeded engine maintenance. NALFOQA offers integrated solutions for managing safe and cost-effective flight operations – a requirement that is more important than ever before.

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Author

Shri. C.M. Ananda obtained his Engineering in Electronics Engineering in 1987 and Masters Degree in Software Systems from BITS, Pilani in 2003. He is currently pursuing his PhD in avionics Reconfigurable avionics architectures.
He is working at National Aerospace Laboratories since 1989 on Digital Autopilot, EICAS, and SWS for SARAS aircraft. His areas of interest are: Integrated Modular Avionics, Flight Critical System, Embedded distributed system, Re-configurable avionics architectures and Safety critical software. His research areas are re-configurable avionics architecture

All communication to:

Email ananda_cm@nal.res.in
Ph :+91 80 25086526
Cell :098457 98028