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Flight Data Analysis (FDA), a Predictive Tool for Safety Management System (SMS)

Introduction

A Flight Data Analysis (FDA) program, also known as Flight Data Monitoring (FDM) or Flight Operation Quality Assurance (FOQA) is designed to enhance Flight Safety by:

- **Identifying an airline's operational safety risks**

FDA is based on the routine analysis of data recorded during revenue flights. These data are compared against pre-defined envelopes and values, to check whether the aircraft has been flown outside the scope of the standard operating procedures (safety events).

- **Taking the necessary actions to reduce these risks**

When a safety event is highlighted by the program, statistical analysis will assess whether it is isolated or part of a trend. Appropriate action is then taken in order to take corrective actions if needed.

This article briefly describes the recorders evolution, which allowed evolving from a reactive to a predictive hazard identification methodology. Each step of an FDA program will then be detailed and for each step, best practices will be highlighted.

History of Recorders

During World War II the US National Advisory Committee for Aeronautics (NACA) installed recorders in fighters, bombers and transport aircraft to collect indicated airspeed and load factor data in order to improve structural design.

Later in the sixties, regulatory authorities mandated the fitting of Flight Data Recorders (FDR) into large commercial aircraft for accident investigation. The first FDRs ([fig.1](#)) could only engrave 5 parameters onto a non-reusable metal foil: heading, altitude, airspeed, vertical acceleration and time.

Recorders technology then improved significantly - from analogue to digital on tape ([fig.2](#)), then to solid state ([fig.3](#)) able to record over 3,000 parameters. In the meantime, Flight Data Monitoring processes were encouraged and sometime requested by authorities.

Today, while Flight Data Recorders (FDR) or Digital Flight Data Recorders (DFDR) are dedicated to accident investigation ([fig.4](#)), Flight Data Analysis programs extract data from easily accessible Quick Access Recorders (QAR) or Digital ACMS* Recorders (DAR). QARs are exact copies of the DFDRs while DARs allow to customize the recorded parameters.

*Aircraft Condition Monitoring System



Figure 1
First generation, metal foil recorder



Figure 2
Second generation, tape recorder



Figure 3
Third generation, solid state recorder



Figure 4
Flight Data Recorders (FDR)

Hazard Identification Methodologies

The ICAO SMS Manual defines three methodologies for identifying hazards:

- **Reactive** - Through analysis of past incidents or accidents

Hazards are identified through investigation of safety occurrences. Incidents and accidents are potential indicators of systems' deficiencies and therefore can be used to determine the hazards that were both contributing to the event or are latent.

- **Proactive** - Through analysis of the airline's activities

The goal is to identify hazards before they materialize into incidents or accidents and to take the necessary actions to reduce the associated safety risks. A proactive process is based upon the notion that safety events can be minimized by identifying safety risks within the system before it fails, and taking the necessary actions to mitigate such safety risks.

- **Predictive** - Through data gathering in order to identify possible negative future outcomes or events.

The predictive process captures system performance as it happens in normal operations to identify potential future problems. This requires continuous capturing of routine operational data in real time. Predictive processes are best accomplished by trying to find trouble, not just waiting for it to show up. Therefore, predictive process strongly searches for safety information that may be indicative of emerging safety risks from a variety of sources.

As illustrated in the history paragraph above, FDR logically led to FDA and the reactive process evolved into a predictive process. The main asset of an efficient FDA is to be able to jump directly to the predictive process without passing through the incident or accident reactive process case. In other words, FDA prediction process aims at avoiding material and/or human costs by being ahead of any safety precursors before an incident or accident occurs..

FDA: the full Method and its best Practices

Flight Data Recording



Flight Data Downloading



Flight Data Recording

Information coming from aircraft sensors, onboard computers and other instruments is recorded into the dedicated FDA recorder (QAR, DAR ...). These Data are recorded as binary raw data files which are sequenced in frames and subframes. Each subframe is divided into a number of "words", each one with a fixed number of bits. A parameter is recorded on one or several bits of one or more words. To save memory space, a parameter value is generally not recorded as such, but converted using a conversion function defined by the aircraft manufacturer.

BEST PRACTICE

High ratio of monitored flights

- Flights should be monitored as much as possible to make the analysis as valuable as possible, 90% should be a minimum.

Calibrated data

- Depending of what data is available and what needs to be monitored, the choice of recorded parameters must be carried out carefully.
- These selected parameters should be recorded at the optimum frequency depending on the parameter sensitivity (sampling rate).

Recorders reliability

- A solid maintenance process must be implemented to maintain the recorders at a high level of efficiency through regular testing and calibrating.

Flight Data Downloading

When the aircraft arrives at the gate, data are either extracted by maintenance staff via optical disc or Personal Computer Memory Card International Association (PCMCIA) card, or automatically via a wireless link (fig.5 & 6).



Figure 5
Wireless ground link box

BEST PRACTICE

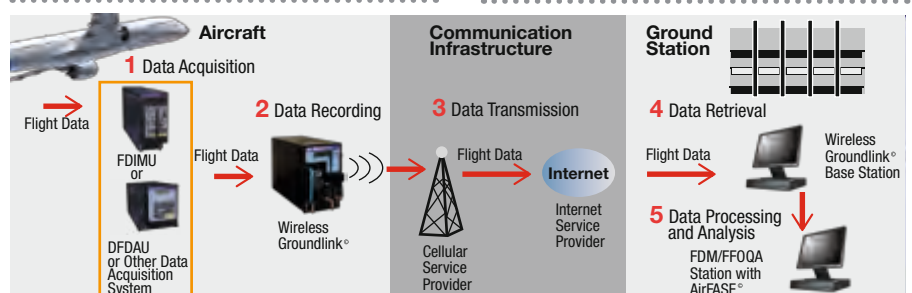
Recovering reliability

- The maintenance data recovery process should be secured through a useful and understood process.

Recommended automated wireless downloading

- It guarantees a high rate of downloaded flights by avoiding overloaded memories and thus partial loss of flight data.

Figure 6
Example of Wireless ground link system



Flight Data Processing



Flight Data Analysis



Safety Risk Management, Communication and Improvement Monitoring

Flight Data Processing

To transcribe the recorded parameters into exploitable values, raw data must be processed in order to recover the actual values (fig.7 & 8). An automatic filtering helps rejecting corrupted data. Some values must be derived from processed parameters because not recorded as such.

Events are automatically weighted according to risk (low, medium or high) with fine tuned algorithms. Several events can be associated to unveil an undesirable situation (for example: path high in approach at 1,200 feet + path high in approach at 800 feet + path high in approach at 400 feet = continuously high path during final).

```
0000 0040 0F82 0F52 0010 0FF8 0FFC
0000 0FDC 0000 0000 0FC1 0FF8
0700 0700 001C 0004 00FA 0020 0FFC
0FF0 0000 0000 0000 0000 0000 0570
0000 0000 0000 0000 0020 0000 0003
0010 0000 0000 0000 0000 0000 0000
0000 0000 0000 0020 00FA 0760 0497
0FF0 0FFC 0007 0010 0000 0400 0000
0000 0000 0054 0FF0 0010 0FF0 0FFC
0000 0FF0 0FD0 0470 0490 0430 0C00
```

Figure 7

Example of Hexadecimal uncompressed raw data

BEST PRACTICE

Good data resolution

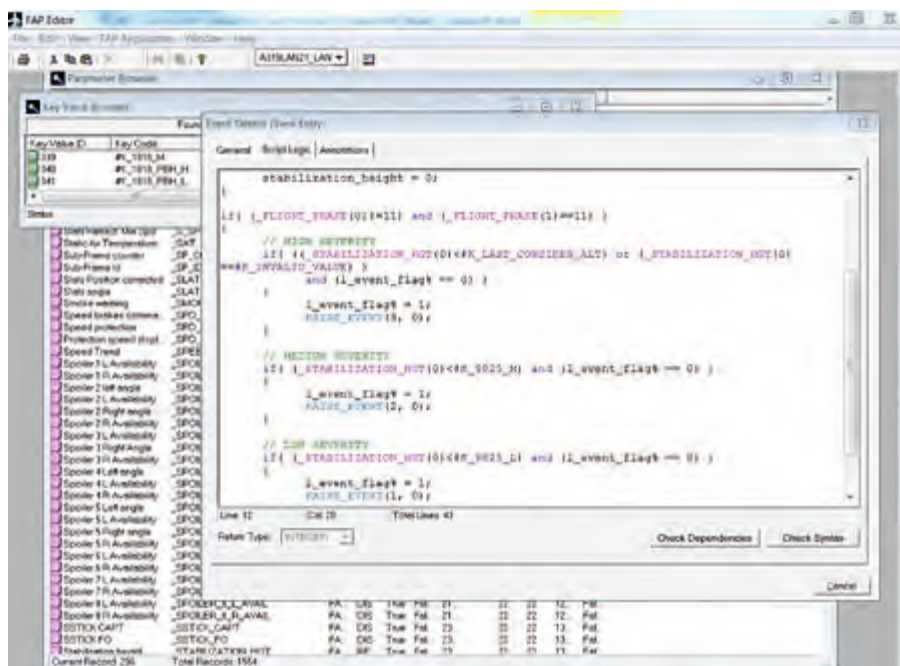
- Selected data must be reliable and pertinent, they should benefit from a large number of measuring points (for example, to be able to trace the exact touch down point at landing, the vertical acceleration must be recorded at a high frequency ratio).
- The decoding program, used for actual exploitable values recovery, must be refined and validated by expert pilots for operational legibility.

Calibrated and validated event definition

- The event development and algorithms of computation need to be simple and operationally meaningful.
- Their detection thresholds need to be calibrated and verified by using various means like simulators, cross comparison and/or flights.

Figure 8

Example of event algorithm in development environment



Flight Data Analysis

Analysts manually filter the developed flights to reject the inconsistent ones and therefore guarantee the robustness of the data base.

They look for all high deviation magnitude events in order to assess any serious safety concern and take appropriate corrective action (fig.9 to 15).

Correlation with all other means like mandatory or voluntary reports for example, will multiply the analysis efficiency.

All reliable events are stored into the database and are investigated on a regular basis to highlight any trend that could show a latent or potential risk.

BEST PRACTICE

Appropriate analysis

- A filtering is necessary, it is usually difficult and time consuming (for example all non-revenue flights like training flights must be removed from the analysis data base in order not to induce wrong statistical figures – training flights more frequently generate some particular types of events).

- A single flight with high deviation level must be analyzed following the steps of the proactive process.

- To understand and interpret the results properly, pilots who are conversant with flight data analysis and proficient on the aircraft type must be involved for their operational expertise.

- Statistics on a large number of flights must be done on a regular basis following the steps of the predictive process.

Competent Flight Data Analysis team members

- FDA team members should have an in-depth knowledge of SOPs, aircraft handling characteristics, aerodromes and routes to place the FDA data in a credible context

- All FDA team members need appropriate training or experience for their respective area of data analysis



Figure 9
Example of an FDA tool: AirFASE



Figure 10
Example of airport visualization



Figure 11
Example of arrival chart visualization

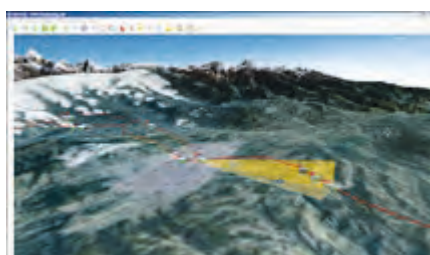


Figure 12
Example of RNP-AR arrival visualization



Figure 13
Example of flight replay

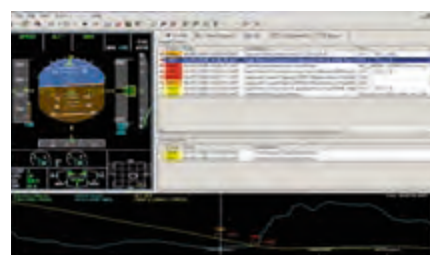


Figure 14
Example of flight replay



Figure 15
Example of list and trace

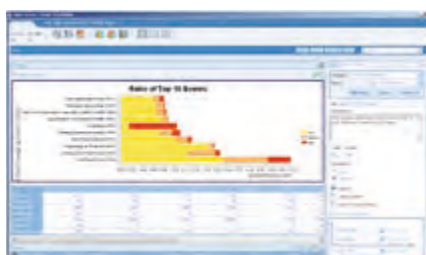


Figure 16
Example of statistical analysis

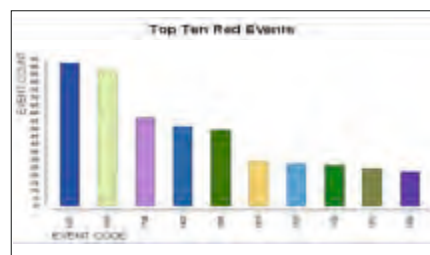


Figure 17
Example of statistical analysis

Safety Risk Management, Communication and Improvement Monitoring

The process starts with the identification of hazards and their potential consequences. The safety risks are then assessed against the threat of potential damage related to the hazard. These risks are weighted in terms of probability and severity (fig.16 & 17). If the assessed safety risks are deemed not to be tolerable, appropriate corrective action is taken.

When an issue emerges, when a mitigation action has been decided by competent people, it must be communicated to the whole air operation community to share all related safety information. Knowledge is a good protection against any potential risk.

On the other hand an adequate monitoring process must be started to validate the efficiency of the mitigation action. This aims to guarantee the effective closing of the loop.

BEST PRACTICE

Competent safety risk assessment team members

- The people in charge of assessing the safety risks must have a good knowledge and background on flight operations and must have been especially trained to perform an efficient risk assessment.

Feedback to operations

- Mankind survived and developed principally due to its ability to communicate and share any risk knowledge. It is still valid in the aviation environment and information on any safety concern must be widely spread out.

Conclusion

As part of an airline Safety Management System, Flight Data Analysis is a very powerful tool. This is true if used properly, which implies that All FDA team members are trained and competent in their area of analysis and risk assessment.

Amongst others practices it should be demonstrated that:

- The recorders health are monitored,
- High ratios of flights are recorded and analyzed,
- The analysis data base is filtered,
- Pilot expertise is used for to validate the decoding process and understand the fine analysis.

Finally, proper analysis / identification of right priorities / definition of mitigating actions and their associated action plan are the essential elements to obtain the maximum benefit from Flight Data Analysis tools and processes.

Safety first

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for the enhancement of safe flight through
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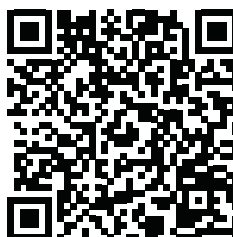
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A350 XWB
*A350 XWB over
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