

Flight Data Monitoring

CAP 739



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Foreword

1. This Document outlines good practice relating to first establishing and then obtaining worthwhile safety benefits from an Operator's Flight Data Monitoring (FDM) programme. This document replaces the first issue of CAP 739 published in 2003.
2. **Chapters added:-**
 - FDM Technologies
 - Statistics in FDM
 - FDM in Small Fleets and Business Aviation
 - Helicopter FDM
 - National FDM Forums
 - FDM use in Alternative Training & Qualification Programmes (ATQP)
 - Regulatory Oversight of FDM
3. **Fully revised chapters:-**
 - FDM within a Safety Management System
 - Legislation and Requirements related to FDM Information
 - Legislation Related to FDM Information
 - New Appendices: C and E

Useful Reference Material

NOTE: Many of these documents are periodically revised. Please ensure you refer to the latest version.

- Acceptable Means of Compliance and Guidance Material (GM) (AMC) to Part-ORO. EASA
- Annex 6 Part 1. Flight Data Analysis. ICAO
- ARMS Methodology for Operational Risk Assessment. ARMS WG 2010
- CAAP 42L-4(0): Flight Recorder Maintenance. CASA Australia
- CAA PAPER 2002/02: Final Report on the Helicopter Operations Monitoring Programme (HOMP) Trial. UK CAA
- CAA PAPER 2004/12: Final Report on the Follow-on Activities to the HOMP Trial. UK-CAA
- CAP 382. The Mandatory Occurrence Reporting Scheme. UK CAA
- CAP 360 Part 1. Air Operator's Certificate - Operation of Aircraft. UK CAA
- CAP 731 Approval, Operational Serviceability and Readout of Flight Data Recorder Systems. UK CAA 2nd edition 2011
- DO160. Environmental Conditions and Test Procedures for Airborne Equipment. RTCA
- Doc 9859. Safety Management Manual. ICAO
- ED-14 Environmental Conditions and Test Procedures for Airborne Equipment. EUROCAE
- ED-55 Minimum Operational Specifications for Flight Data Recorder Systems. EUROCAE
- ED-112 Minimum Operational Performance Specification For Crash Protected Airborne Recorder Systems
- ED-155 MOPS Minimum Operational Performance Specification For Lightweight Recording Systems

- EU-OPS 1.160. Preservation, Production and Use of Flight Recorder Recordings.
- EU-OPS 1.037. Accident Prevention and Flight Safety Programmes.
- Guidance for National Aviation Authorities Setting up a National Flight Data Monitoring forum. European Authority's coordination group on Flight Data Monitoring
- Helicopter Flight Data Monitoring Industry Best Practices. Apr 2012, Version 1.1. Global HFDM Steering Group
- Part-ORO.AOC.130 Flight data monitoring - aeroplanes
- Part-ORO: AMC1 ORO.AOC.130 Flight data monitoring - aeroplanes
- Part-ORO: GM1 ORO.AOC.130 Flight data monitoring - aeroplanes
- Part-ORO: AMC1 ORO.FC.A.245 Alternative training and qualification programme
- Part-ORO AMC1 ORO.GEN.200 Management System
- Safety Management Systems - Guidance to Organisations Version 3 (July 2010). UK CAA
- Specifications 10 & 10A: Flight Data Recorder for Aeroplane Accidents Investigation. UK CAA
- Temporary Guidance Leaflet No 44

CHAPTER 1

Introduction

- 1.1 **Flight Data Monitoring (FDM) 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.**
- 1.2 Flight Data Monitoring (FDM) programmes assist an operator to identify, quantify, assess and address operational risks. Since the 1970's the CAA's Safety Regulation Group (SRG) has helped develop and support such systems and used FDM information to support a range of airworthiness and operational safety tasks. Through this co-operative development work many farsighted operators voluntarily demonstrated the safety benefits of FDM such that the International Civil Aviation Organization (ICAO) made FDM a standard for all Air Transport operations of aircraft over 27 tonnes with effect 1st January 2005. The UK, in continuing its policy of applying ICAO standards, made this a requirement under UK law and FDM is now a requirement under European legislation. Further, ICAO also recommends the application FDM to Air Transport operations in aircraft of over 20 tonnes maximum weight and also to helicopters over 7 tonnes (or over 9 pax) with a flight data recorder.
- 1.3 The UK Air Navigation Order (ANO) 2009 Article 94 requires the establishment and maintenance of an Accident Prevention and Flight Safety Programme (AP&FSP) and includes the requirement for FDM. The content of safety programmes, including FDM, will need to be confirmed as acceptable by the CAA's Flight Operations Inspectors.
- 1.4 It is recognised that there is a wide range of operators covered by these requirements and that there is no 'one size fits all' system. The size and age of aircraft may determine the parameters available for analysis. The programme effectiveness and efficiency of a small fleet or operation may be helped by pooling analysis within a group of similar operations. While retaining responsibility for risk assessment and action, some operators may wish to contract out the basic analysis due to lack of expertise or resources.
- 1.5 As an aid to operators, **Appendix E** provides a checklist of guiding principles and pointed questions that highlight some of the fundamental

concepts that should be considered when putting one of these proactive safety processes in place. These principles are stated in TGL44.

- 1.6 **This document outlines good practice and indicates what may constitute an operator's FDM programme system that is acceptable to the CAA. It is intended to be regularly reviewed and revised by CAA in consultation with Industry as widespread FDM experience and application continues to develop.**

Document Structure

- 1.7 This document includes the following elements:
- Chapter 1: Introduction
 - Chapter 2: Objectives of an Operator's FDM System
 - Chapter 3: Description of a Typical FDM System
 - Chapter 4: FDM within a Safety Management System
 - Chapter 5: FDM Technologies
 - Chapter 6: Planning and Introduction of FDM
 - Chapter 7: Organisation and Control of FDM Information
 - Chapter 8: Interpretation and Use of FDM Information
 - Chapter 9: Statistics in FDM
 - Chapter 10: FDM in Small Fleets and Business Aviation
 - Chapter 11: Helicopter Flight Data Monitoring (HFDM)
 - Chapter 12: National FDM Forums
 - Chapter 13: FDM use in Alternative Training & Qualification Programmes (ATQP)
 - Chapter 14: Legislation and Requirements related to FDM
 - Chapter 15: Legislation Related to FDM Information
 - Chapter 16: Mandatory Occurrence Reporting and FDM
 - Chapter 17: Maintaining Aircraft FDM systems
 - Chapter 18: Regulatory Oversight of FDM

Purpose of this Document

- 1.8 This document is designed to meet the following objectives:
- Give guidance on the policy, preparation and introduction of FDM within an operator.
 - Outline CAA's view on how FDM may be embodied within an operator's Safety Management System.
 - Describe the principles that should underpin an FDM system acceptable to the CAA.

Useful Terms, Definitions and Abbreviations

- 1.9 A list of useful terms, definitions and abbreviations associated with FDM is given in Appendix A to this document.

Comments on this Document

- 1.10 This document has been developed by the Safety Performance section of the CAA Safety Regulation Group's Group Safety Services Division in consultation with other SRG specialists. **It is intended that this should be a living document so SRG welcome change proposals, comments and additions from Industry.** Please write to:

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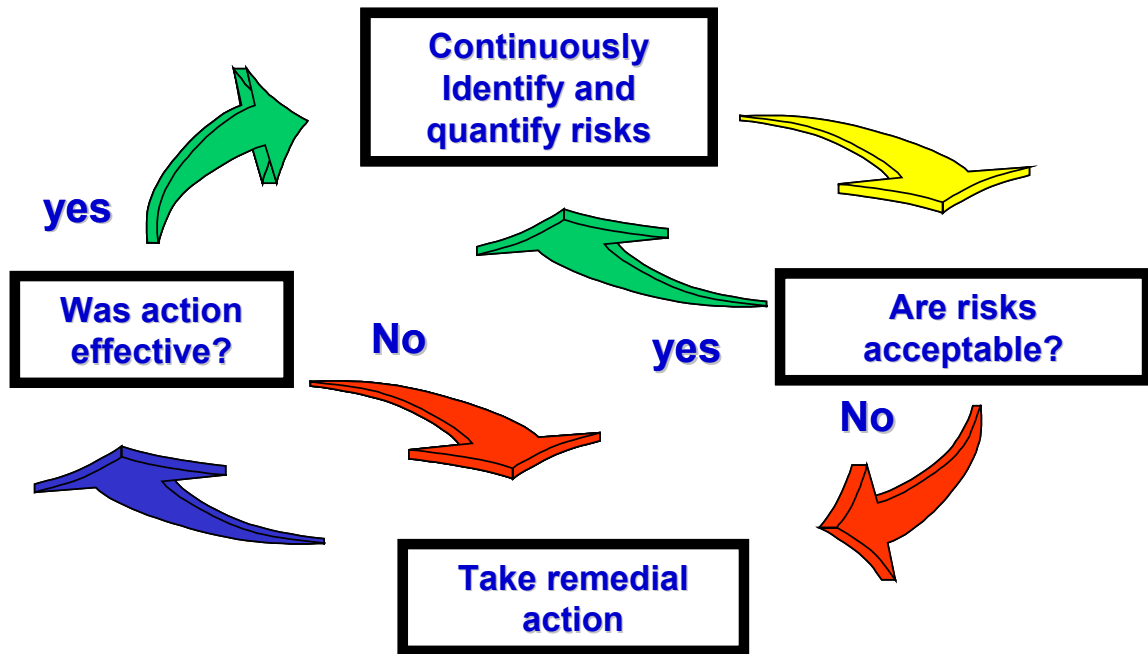
CHAPTER 2

Objectives of an Operator's FDM System

- 2.1 An FDM system allows an operator to compare their Standard Operating Procedures (SOPs) with those actually achieved in everyday line flights.
- 2.2 A feedback loop, that should be part of a Safety Management System (SMS), will allow timely corrective action to be taken where safety may be compromised by significant deviation from SOPs.
- 2.3 Shown below is a list of steps outlining an FDM feedback loop, including examples illustrating how these may appear in practice:
1. **Identify areas of operational risk and quantify current safety margins.**
 - Initially an FDM system will be used as part of an operator's System Safety Assessment to identify deviations from SOPs or areas of risk and measure current safety margins. This will establish a baseline operational measure against which to detect and measure any change.
 - **Example:** Current rates of rejected take-offs, hard landings, unstable approaches.
 2. **Identify and quantify changing operational risks by highlighting when non-standard, unusual or unsafe circumstances occur.**
 - In addition to highlighting changes from the baseline, the system should enable the user to determine when non-standard, unusual or basically unsafe circumstances occur in operations.
 - **Example:** Increases in event rates mentioned in (1), new events, new locations.
 3. **To use the FDM information on the frequency of occurrence, combined with an estimation of the level of severity, to assess the risks and to determine which are or may become unacceptable if the discovered trend continues.**

- Information on the frequency of occurrence, along with estimations of the level of risk present, is then used to determine if the individual or fleet risk level is acceptable. Primarily the system should be used to deduce whether there is a trend towards unacceptable risk prior to it reaching such a level. If the level of risk becomes unacceptable that could indicate the SMS process has failed.
 - **Example:** A new procedure has introduced high rates of descent that are approaching the threshold for triggering GPWS warnings. The SMS process should have predicted this.
4. **To put in place appropriate risk mitigation to provide remedial action once an unacceptable risk, either actually present or predicted by trending, has been identified.**
- Once an unacceptable risk, either actually present or predicted by trending, has been identified, then appropriate risk mitigation should be used to put in place remedial actions. This should be accomplished while bearing in mind that the risk must not simply be transferred elsewhere in the system.
 - **Example:** Having found high rates of descent the Standard Operating Procedures (SOPs) are changed to improve control of the optimum/maximum rates of descent being used.
5. **Confirm the effectiveness of any remedial action by continued monitoring.**
- Once a remedial action has been put in place, it is critical that its effectiveness is monitored, confirming that it has both reduced the original identified risk and not transferred the hazard elsewhere.
 - **Example:** Confirm that the other measures at the airfield with high rates of descent do not change for the worse after changes in approach procedures.

Figure 1: FDM is a closed loop system



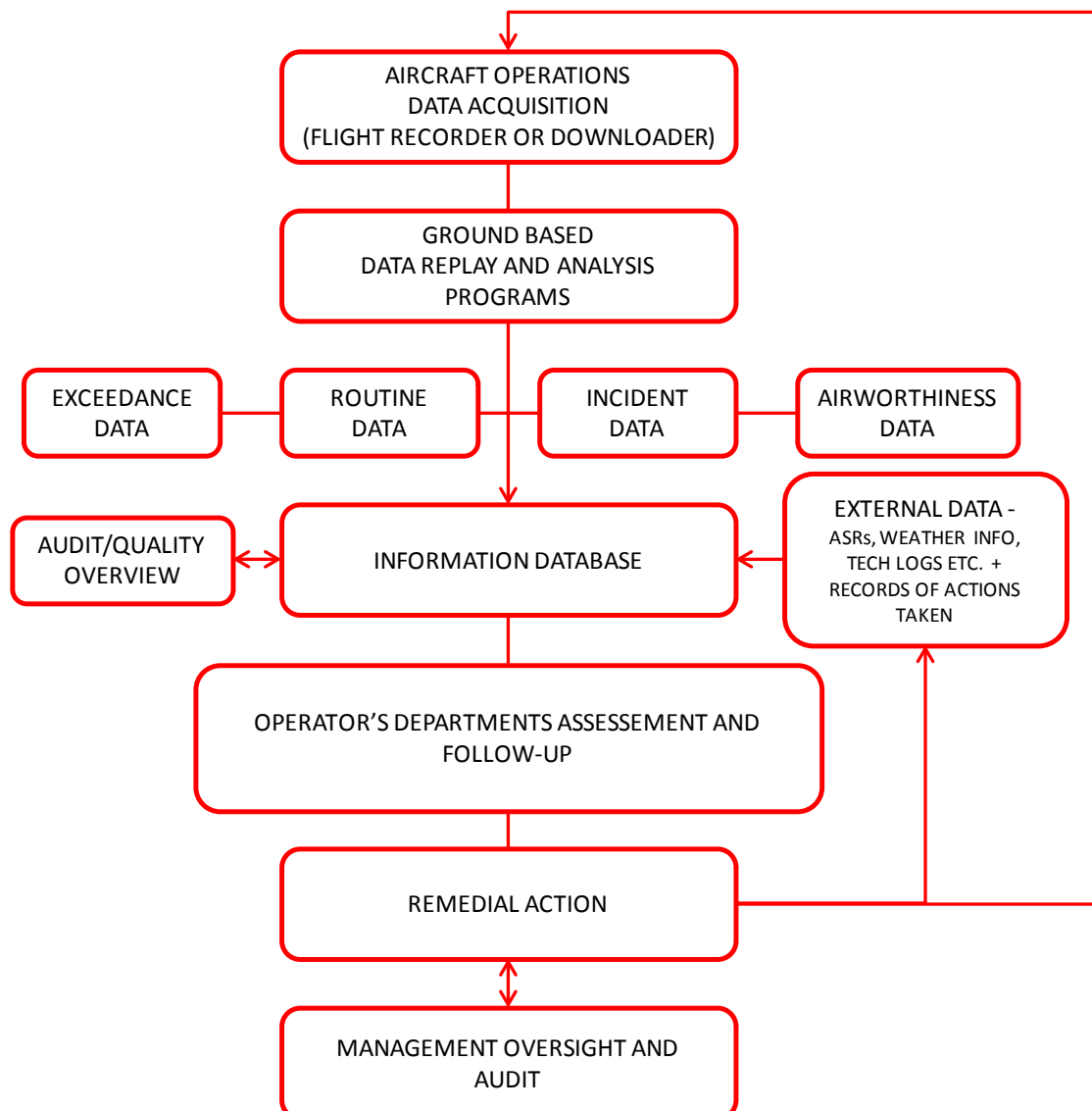
CHAPTER 3

Description of a Typical FDM System

System Outline - Information flow

- 3.1 This chapter describes the principal components of a typical FDM system. This is not necessarily an optimum system but one that reflects current practice. Details of other options are shown in subsequent chapters.

Figure 1: Information flow

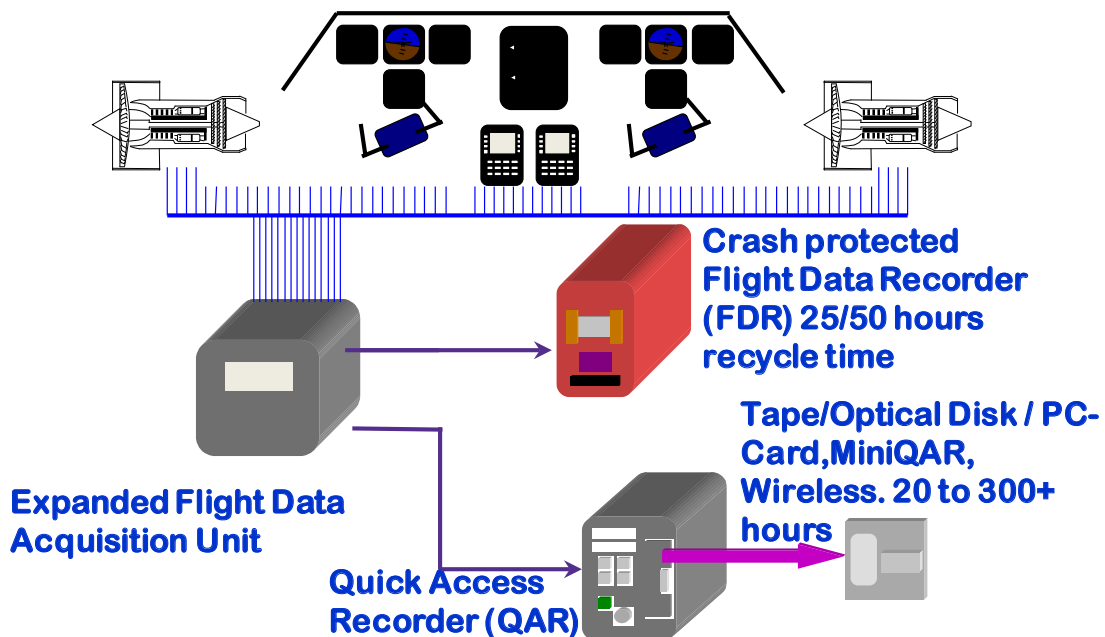


Aircraft Operations - Data Acquisition

- 3.2 Data is obtained from the aircraft's digital systems by a Flight Data Acquisition Unit (FDAU) and routed to the crash protected Digital Flight Data Recorder (DFDR). In addition to this mandatory data 'stream', a second output is generated to a non-mandatory recorder. This output is often more comprehensive than that of the crash-protected flight recorder due to the increased capacity of this recorder. Unlike the DFDR, this recorder has an easily removable recording medium (hence the name - Quick Access Recorder - QAR), previously tape or optical disk, today more often memory cards or even a wireless system that requires no physical removal of media.

Figure 2: A Flight Data Recording System

A Flight Data Recording System



- 3.3 The QAR media is ideally replaced at the end of each day or sometimes after a period of several days have elapsed, dependent on media capacity and data recovery strategy, and sent to a central point for replay and analysis. This normally takes place at the operator's major hub airport for convenience.

- 3.4 As an alternative to the QAR, some operators routinely download information contained on the crash-protected flight recorder. This should not be carried out on the older, tape based devices because of serviceability issues. However, downloading from the modern solid-state recorder is reliable and fast.
- 3.5 The latest technology enables the data to be downloaded straight from an onboard storage device e.g. a wireless QAR, to an operator's file server via wireless links. This greatly reduces the logistical problems associated with the movement of media or physical downloading tasks.
- 3.6 Chapter 5 gives an outline of some of the current technologies applicable to FDM.

Ground-Based Data Replay and Analysis Programs

- 3.7 The data media is logged in and 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.
- 3.8 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 proportion 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 than directly on line to speed up the on-going analysis of data.

The Information

- 3.9 FDM information can take a range of different forms and these are described below:

Exceedence or Event Detection

- 3.10 Exceedence or event detection is the standard FDM algorithmic 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. See Appendix B section 1 which describes a typical basic operational event set and section 2 for a more comprehensive set of fixed wing events. Similarly Appendix C shows the equivalent standard set for Helicopters.
- 3.11 **Example events:** High take-off rotation rate, stall warning, GPWS warning, flap limit speed exceedence, fast approach, high/low on glideslope, hard landing.

Routine Data Measurements

- 3.12 Increasingly, data is retained from all flights and not just the significant ones producing events. This enables the monitoring of more subtle trends and tendencies 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.
- 3.13 **Example measurements:** take-off weight; flap setting; speed and heights; temperature; rotation and take-off speeds vs scheduled speeds; maximum pitch rate and attitude during rotation; landing gear retraction and extension speeds; heights and times; maximum normal acceleration at touchdown; touchdown distances; maximum braking used.
- 3.14 **Example analysis:** Pitch rates from high vs low take-off weights; pilot technique during good vs bad weather approaches; touchdown distances on short vs long runways.

Incident Investigation Data

- 3.15 FDM data has been found to be very useful during the follow-up of mandatory occurrences and other technical reports. The data adds to the picture painted by the flight crew report, quantifying the impressions gathered from the recollections after the heat of the moment. System status and performance can add further clues to cause and effect.

- 3.16 FDM data obtained for use in this way falls under the mandatory requirements of EU-OPS and hence de-identification of the data, required to maintain FDM confidentiality, does not usually apply. As the crew have already filed reports then this is reasonable in an open, proactive safety culture that provides constructive feedback. Data security is however still very important.
- 3.17 **Examples of Incidents where FDM data could be useful:** vortex wake encounters; all flight control problems; system failures that affect operations; emergencies such as high speed rejected take-offs; TCAS or GPWS triggered manoeuvres.

Continued Airworthiness Investigation Data

- 3.18 Both routine and event data can be utilised to assist the continued airworthiness function. However, care must be taken to ensure the access to the data and its use is properly controlled.
- 3.19 Engine monitoring programs use measures of engine operation to monitor efficiency and predict future performance. These programs are normally supplied by the engine manufacturer and feed their own databases. Operators should consider the potential benefits of including the wider use of this data within their continued airworthiness programmes.
- 3.20 **Examples of continued airworthiness uses:** Engine thrust levels; airframe drag measurement; avionic and other system performance monitoring; flying control performance; brake and landing gear usage, prediction of fatigue damage to structures.

The Information Database

- 3.21 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. The overarching system should be able to automatically highlight links between the information held in several systems on a particular event/incident.
- 3.22 **Example of links:** A hard landing should produce a crew report, an FDM event and also an airworthiness report. The crew report will provide the context, the FDM event the quantitative description and the airworthiness report the result.

Operator's Departments - Assessment and Follow-up

- 3.23 This is the critical part of the process. Given the systems are put in place to detect, validate and distribute the information; the information finally reaches the areas where the operational safety and continued airworthiness benefits may be realised. The data must be assessed using firsthand knowledge of the operational or airworthiness context in which it is set. Final validation done at this informed level may still weed out some erroneous data.
- 3.24 **Example of follow-up:** During a routine analysis of go-arounds it was found that one had a delay of over 30 seconds between flap selection and raising the gear.

Remedial Action

- 3.25 Once a hazard or potential hazard has been identified, then the first step has to be 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.
- 3.26 **Example of Remedial Action:** In the go-around case described above, the operator included go-arounds in the next simulator check sessions. These highlighted to the crews how easy it was to miss the gear action if the important 'positive climb' callout was missed by the non-handling pilot. It stressed the importance of a team effort during go-arounds.

Continued Monitoring

- 3.27 Once any action is taken, then an active monitor should be placed on the original problem and a careful assessment made of other hazards in the area of change. Part of the assessment of the fuller effects of changes should be an attempt to identify unintended consequences or the potential relocation of risks. This, plus a general check on all surrounding measures is required before 'signing off' the change 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.

CHAPTER 4

FDM within a Safety Management System

- 4.1 The principles behind successful Safety Management Systems (SMS) are the same as those for FDM programmes. FDM functions much more effectively within a fully integrated risk management system. This chapter gives an outline of how an FDM programme functions within a Safety Management System and provides it with consistent, reliable data on exposure and risks. Finally, there is a brief discussion about the Operational Risk Assessment (ORA) methodology and practical tools that the ARMS (Aviation Risk Management Solutions) Industry working group proposed.

Safety Management Systems (SMS)

What is a Safety Management System?

- 4.2 Based on the ICAO Annex 6 Pt I recommended practice, EU-OPS 1.037 states that 'an operator shall establish an accident prevention and flight safety programme, which may be integrated with the Quality System, including programmes to achieve and maintain risk awareness by all persons involved in operations'. ICAO Doc 9859 (Safety Management Manual) gives appropriate guidance material and describes a risk management process that forms the basis of an operator's SMS.
- 4.3 The CAA has published "Safety Management Systems - Guidance to Organisations" on its website to assist operators and other organisations to develop effective and comprehensive systems for managing safety. It defines safety management as:
- 4.4 '**Safety Management**' is defined as a systematic approach to managing safety, including the necessary organisational structures, accountabilities, policies and procedures. This includes the systematic management of the risks associated with flight operations to achieve high levels of safety performance.
- 4.5 A '**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.

- 4.6 There are four essential prerequisites for a Safety Management System. These are:
- A corporate commitment from senior management towards safety,
 - An effective organisation for delivering safety,
 - Systems to achieve safety assurance, and
 - A positive safety culture.
- 4.7 The systems required may include:
- Arrangements for the analysis of Flight Data.
 - Enhanced Safety Event/Issue Reports.
 - Internal Safety Incident Investigations leading to corrective / preventative Action.
 - Effective Safety Data for Performance Analysis.
 - Arrangements for ongoing Safety Promotion.
 - Periodic review of the SMS.
 - Active Monitoring by Line Managers.

The Safety Culture

Safety Management Policy

- 4.8 The operator should have a top-level commitment to a business objective that minimises the aviation accident risk to an acceptable level. There will be a commitment to a pro-active approach to systematic safety management that all levels of individual involved are aware of and are held accountable for.

Open Safety Conscience

- 4.9 The FDM programme can best function in an environment where there is already a positive safety culture. A willingness to pinpoint potential risks in oneself, others and third parties in such a way that remedial actions are taken in a non-punitive manner is essential. This is where establishing a just culture is an important part of the safety culture. Through the following of clear procedures, anyone involved in cases of possible gross negligence will receive fair treatment and proportionate remedial action to prevent a reoccurrence.

Involvement at all Levels

- 4.10 The safety monitoring process involves all levels within an organisation. Anyone believing they have identified a potential risk should feel able to report and expect follow-up action to be considered. Generally in FDM programmes the principal source of involvement is of course the flight deck crew, although ATC, maintenance etc. will occasionally be involved. From the line pilot to the fleet manager all have responsibility to report.

Learning not Blaming

- 4.11 As with all safety reporting systems involving people's shortfalls or errors, it is difficult to overcome the natural human tendency to cover up mistakes. It is therefore essential to do away with the stigma attached to reporting safety events or as is the case with FDM, being approached about circumstances detected by the FDM system. Methods used in successful safety reporting systems should be employed here.

FDM Integrated within the Safety Management System

- 4.12 An FDM programme held remote from all other safety systems of an Operation will not be as beneficial as one that is linked with other safety monitoring systems. This other information gives context to the FDM data which will, in return, provide quantitative information to support investigations that otherwise would be based on subjective reports that may be less reliable. Safety reporting, avionic and systems maintenance, engine monitoring, ATC and scheduling are just a few of the areas that could benefit. However, a limitation of FDM data is that it only tells you what happened and needs the situational context to understand why an event happened. This is where across all departments a positive safety culture can greatly assist in establishing the causal and contributory factors.

The Safety Culture Covers all Safety Monitoring Systems

- 4.13 The culture must cover, bring together and integrate information from the many diverse sources of data within the operator. FDM, internal safety reporting, Technical and Continued Airworthiness Reporting, Ground Incidents, Design and finally Human Error Reporting systems must be linked together to produce a best estimate of operational risks. Where necessary these links may have to be configured to restrict data identification while still passing on useful information.

Management and Crew's Responsibility to Act upon Knowledge

- 4.14 Once a hazard has been identified then a documented and traceable risk assessment, and subsequent decision must be made. Either remedial action should be taken by the operator, along with a projection of the likely reduced risk, or a justification for maintaining current status recorded. Without this process in place, the consequences of not acting upon risk information may be severe. The FDM process would be expected to be continually audited for fulfilment of this aspect by a high level safety board or similar group.

Good Written Agreements - Detailed as Necessary and Strong on Principles

- 4.15 It is important that the underlying principles to be applied are understood by all parties and signed up to, early in the process. Once this is done, when problems or conflicts of interest arise, they form the foundation of practical solutions. Everyone involved should know the limits which the agreements place on them. In uncertain cases there should be an accepted procedure by which a course of action can be approved.
- 4.16 **Appendix D** gives an example of a typical agreement detailing the procedures to be used and the operator-crew agreement.

Risk Identification

Definition of Risk, Probability and Safety Criticality

- 4.17 Risk is defined as the combination of probability, or frequency of occurrence of a defined hazard and the severity of the consequences of the occurrence. An example of a typical classification system of safety criticality is shown below.
- 4.18 First, severity is categorised as follows (Source: Safety Management Systems - Guidance to Organisations. CAA):

Aviation Definition	Meaning	Value
Catastrophic	Aircraft / Equipment destroyed. Multiple deaths.	5
Hazardous	A large reduction in safety margins, physical distress or a workload such that organisations cannot be relied upon to perform their tasks accurately or completely. Serious injury or death to a number of people. Major equipment damage.	4
Major	A significant reduction in safety margins, a reduction in the ability of organisations to cope with adverse operating conditions as a result of an increase in workload, or as a result of conditions impairing their efficiency. Serious incident. Injury to persons.	3
Minor	Nuisance. Operating limitations. Use of emergency procedures. Minor incident.	2
Negligible	Little consequence.	1

4.19 Secondly, the probability of occurrence, or likelihood, can be defined in both quantitative and qualitative terms as follows (Source: Safety Management Systems - Guidance to Organisations. CAA):

Quantitative Definition	Meaning	Value
Frequent (1 to 10 ⁻³ per hour)	Likely to occur many times	5
Occasional (10 ⁻³ to 10 ⁻⁵ per hour)	Likely to occur sometimes	4
Remote (10 ⁻⁵ to 10 ⁻⁷ per hour)	Unlikely, but may possibly occur	3
Improbable (<10 ⁻⁷ to 10 ⁻⁹ per hour)	Very unlikely to occur	2
Extremely improbable (<10 ⁻⁹ per hour)	Almost inconceivable that the event will occur	1

- 4.20 Finally, these two aspects are brought together in a risk tolerability matrix that defines the maximum rate of occurrence allowed for any particular effect of event. The table below shows the minimum safety performance standards that should be applied, although depending on the safety significance given to each risk the actual standards required may be higher.

Figure 1 Example of a Risk Tolerability Matrix (Source: Safety Management Systems - Guidance to Organisations. CAA)

Severity						
Catastrophic	5	5 Review	10 Unacceptable	15 Unacceptable	20 Unacceptable	25 Unacceptable
Hazardous	4	4 Acceptable	8 Review	12 Unacceptable	16 Unacceptable	20 Unacceptable
Major	3	3 Acceptable	6 Review	9 Review	12 Unacceptable	12 Unacceptable
Minor	2	2 Acceptable	4 Acceptable	6 Review	8 Review	10 Unacceptable
Negligible	1	1 Acceptable	2 Acceptable	3 Acceptable	4 Acceptable	5 Review
		Extremely improbable	Improbable	Remote	Occasional	Frequent
		1	2	3	4	5
		Likelihood				

Determining what is Acceptable

- 4.21 In practical terms, this would normally be established using a risk tolerability matrix as shown above in the table taken from the CAA's Safety Management Systems - Guidance for Organisations. While this approach can offer guidance to the safety analyst, much rests on the appreciation of the seriousness of the incident and, most critically, upon the understanding of potential risk. Just because there was a safe outcome to a particular incident scenario, does not necessarily make it a low severity incident. The mitigating component may not always be present. Present and potential risk is discussed further in this chapter.
- 4.22 **Examples of incidents with a high risk potential that on the (good) day resulted in no damage:** A very severe wind-shear, rather than resulting in a prompt go-around, is flown through to landing; a long landing after a hurried approach did not result in an overrun because that particular runway had a good braking coefficient; a crew's slow response to a GPWS Glideslope warning was not a problem as the aircraft was on the centreline and not on a terrain critical approach.

The Initial Risk Assessment

- 4.23 Knowledge of the current operation is needed to formulate an assessment of the total risks falling upon the operator. This can be gained, in part, using a carefully implemented FDM programme that will provide information and measures to support expert opinion and experience. All available sources of safety data should be utilised to better model the risk environment (see example below on Boeing 767 hard landing at Bristol). The better the understanding of risk, especially at the less obvious lower risk levels, the more likely that potential risks will be highlighted and mitigation techniques can be developed in those areas.
- 4.24 **Example:** the probability of a CFIT accident may be arrived at by examining a combination of world accident trends, operator's safety reports, FDM exceedence data, FDM routine measurements, airport assessments etc.

Giving a Baseline against which to Measure Change

- 4.25 The results of the FDM analysis used in the initial assessment will then form the baseline against which to measure future changes. It will be able to identify both shortfalls and improvements in risks.
- 4.26 **Example:** the distribution of touchdown points can be used to detect changes in pilot technique, long touchdowns on short runways, changes in turn-off availability resulting in heavy braking, high threshold speeds due to changed ATC requirements.
- 4.27 **Example of the need for this:** The AAIB recently investigated an incident (Ref EW/C2010/10/01) involving a Boeing 767 hard landing at Bristol International Airport. Upon investigation of the incident it was discovered through historic data that the operator had an unusually high rate of hard landings at Runway 09 versus the other runway at Bristol Airport. Prior to this incident the operator had carried out their analysis on an airport by airport basis, the results of which did not indicate an unusually high rate at Bristol. The operator had not analysed and aggregated their hard landing data for individual runways as part of their routine analysis of FDM data, thus the high rate at Runway 09 was not identified. In addition to this it was discovered that the operator had not set a threshold limit, above which action should be taken, for the rate of hard landings. AAIB made two specific recommendations, **2012-014** and **2012-015**, with regard to FDM and data analysis.

- 4.28 In light of this incident the CAA recommend that all operators ensure that they are analysing their FDM data relating to landings not only by airport, but also by runway. This will ensure that any adverse trends specific to one runway are more readily identifiable. When routinely monitoring data trends, it is important to be able to identify significant changes or deviations from what is deemed to be acceptable. Establishing limits aid in the decision making process of whether any action is required. The CAA recommends that operators should establish trigger levels and maximum rates beyond which action should be taken to reduce the occurrence of issues such as individually hard landings or abnormally frequent firm landings. This should be accomplished with the support of aircraft manufacturers and take into consideration both Airworthiness (structural) and Operational (pilot proficiency) perspectives.

Historical and Predicted Risks

- 4.29 The link between measurable past risk levels and potential future risks is important but difficult to quantify. While historical data on realised risk (i.e. when the risk of something undesirable occurring manifests as an undesirable outcome) is useful, it only serves to identify mitigation targets. This is the traditional approach to accident investigation and follow-up. FDM, and indeed all other risk defining data needs to be rather more subtly analysed and extrapolated forward to become a predictive tool. With imaginative and methodical analysis, historical data can enable the analyst to develop causal factor models that can help identify lower level precursors beyond the causal factors.
- 4.30 **Example:** heavy braking during taxiing vs ground collisions; touchdown points vs overruns/undershoots; unstabilised approaches vs GPWS or CFIT, TCAS warnings vs Midair collisions.

Measuring Actual and Potential Risk

- 4.31 Many safety performance indicators looking at risk deduce the probability of physical harm based on incidents and measures in the past. While this will allow an SMS failure to be detected after the event, what is really required is a predictive monitoring system. The aim of this would be to flag up the trend of a much lower level measure towards the exceedence of an acceptable level of hazard before that level has been reached.

- 4.32 **Example:** changing distributions of runway distance remaining at touchdown vs calculated stopping distance may indicate a trend towards a potential overrun.

Looking for Trends Towards Unacceptable Levels of Risk Covered by SMS

- 4.33 A method should be established to detect any trend towards unacceptable risk prior to it reaching that level. Thus allowing timely action to be taken to prevent the breaching of acceptable limits.
- 4.34 **Example:** if there was an increase in the underlying distribution of threshold speeds then there would be a higher probability of go-arounds. Individual exceedences would indicate higher risk instances.

Recording Safety Breaches of SMS Risk Mitigation Procedures

- 4.35 Where SMS has identified a hazard and it is considered that the risk has been sufficiently reduced by mitigation laid down in SOPs, it is important that any failure in these defences should be identified, investigated and recorded. The Safety Assurance processes within the SMS should be continuously monitoring and assessing the effectiveness of the risk mitigations.
- 4.36 **Example:** unstable approaches below the SOP defined minimum acceptable height without a go-around may indicate a training shortfall or unclear SOP.

Highlighting Risk Areas not Identified by SMS

- 4.37 The SMS process depends on a combination of recognised sources on risk combined with a safety net that will catch unpredicted risks before they are realised. The generalised FDM programme will help form one layer of this net. When SOPs have failed to prevent a hazardous occurrence then sufficient information must be provided to enable an investigation to be carried out and the identification of appropriate remedial action.
- 4.38 **Example:** by looking for altitude deviations a wide range of potential problems may be detected including: changed or difficult ATC clearances and commands, TCAS warnings, pilot errors, turbulence, etc.

How an SMS can Benefit from FDM

FDM Provides Definitive Risk Data to Validate Assumptions

- 4.39 The success of any SMS requires knowledge of actual operations and cannot be achieved using assumed safety performance. One cannot know with any certainty that, because one audit point, say a check flight, measures up to standards, that the other 1000 flights will also be satisfactory. In monitoring all flights, FDM can help to fill in this missing information and assist in the definition of what is normal practice. This gives assurance that SMS is managing actual rather than perceived safety issues.
- 4.40 FDM also provides data that might not be reported through the normal internal occurrence reporting system. This depends on an organisation's safety culture and just culture policies.

A Summary of SMS Benefits from the Implementation of FDM

1. Gives knowledge of actual operations rather than assumed.
2. Gives a depth of knowledge beyond accidents and incidents.
3. Setting up an FDM program gives insight into operations.
4. Helping define the buffer between normal and unacceptable operations.
5. Indicates potential as well as actual hazards.
6. Provides risk-modelling information.
7. Indicates trends as well as levels of risk.
8. Can provide evidence of safety improvements.
9. Feeds data to cost-benefit studies.
10. Provides a continuous and independent audit of safety standards.
11. Can help identify area where flight crew training can be further improved

How FDM can Benefit from Incorporation within an SMS

SMS Provides a Structured Environment for an FDM Implementation

- 4.41 The scope of FDM has increased gradually over the last 30 years as analysis techniques and data recording technologies have improved. The processes used in the past have tended to be rather ad hoc, locally implemented and controlled by informal procedures with less than ideal 'check and balance' records after issues have been raised and acted upon. Having said that, despite this lack of established process, many significant safety issues have been raised and resolved.
- 4.42 Today, FDM should provide a more quantitative risk picture to the organisation to help it manage its risks and measure the success of its mitigation actions.

A Summary of FDM Benefits from the Incorporation within an SMS

1. Formal recognition and buy-in by operator's management.
2. Formalisation of assessment and action process.
3. Integration with other safety information.
4. Auditable benefits and evidence of 'best endeavours'.
5. Assists regulatory oversight of the pro-active SMS process.

Operational Risk Assessment Methodology

- 4.43 Risk assessment methods are still developing and a number have moved beyond what was originally covered by ICAO some time ago. An example of such developments is the ARMS method.

Aviation Risk Management Solutions (ARMS)

- 4.44 An industry working group, ARMS, developed an improved methodology for Operational Risk Assessment (ORA) which has been well received by both operators and other aviation organisations. This is described in detail in a report that also provides guidance and examples for safety professionals on how to apply the method. In addition to the method itself, the report reviews the difficulties in using the older methods and describes the ARMS working group.

Download from: <http://www.easa.eu.int/essi/documents/Methodology.pdf>

- 4.45 The executive summary describes the approach as follows:
The methodology defines an overall process for Operational Risk Assessment and describes each step. The assessment process starts with Event Risk Classification (ERC), which is the first review of events in terms of urgency and the need for further investigation. This step also attaches a risk value to each event - which is necessary for creating safety statistics reflecting risk. The next step is data analysis in order to identify current Safety Issues. These Safety Issues are then risk assessed in detail through the Safety Issue Risk Assessment (SIRA). The whole process ensures that any necessary safety actions are identified, creates a Register for following up risks and actions and provides a Safety Performance Monitoring function. SIRA can also be used to make Safety Assessment, which is a requirement of the "Management of Change" element of the SMS.

Bow-Tie Model

- 4.46 FDM data can also potentially assist in risk modelling. An increasing popular method of modelling risk is the Bow-Tie Safety Risk Model. This is a visual tool to assist with identifying and communicating risk controls, highlighting their effectiveness, identifying measures to monitor their performance and driving safety improvement actions which should feed into an organisation's SMS. This safety risk model helps identify the dependencies on controls and whether the controls are robust to prevent events. The controls within the model also identify pre-cursor and leading indicator data. FDM data can be used to monitor some of these and can inform this model by providing quantitative evidence to rationalise the acceptability of particular aspects of an operation as effective risk controls or barriers. Likewise FDM data can be used to monitor for continued effectiveness and identify potential degradation of these and monitor for changes in other existing or newly identified factors that may escalate the risk.

CHAPTER 5

FDM Technologies

- 5.1 FDM relies upon the reliable acquisition, recording and transmission of accurate and appropriate data into the analysis program suite. This chapter gives a brief outline of some of the current technologies applicable to FDM.

Data Recording Technology

Crash-Protected Flight Recorders (DFDRs)

- 5.2 The mandatory, crash-protected Digital Flight Data Recorder is normally referred to as the DFDR. In the past, some operators have started programmes by downloading data from the crash-protected flight recorder. This method of obtaining data can give a foundation on which to test run prior to a full QAR system. The limiting factor here is the time available before the data is overwritten – typically 25 or 50 flying hours. **Tape based DFDRs should not be used for regular FDM downloads as playback will likely affect the serviceability of the tape media within the crash-protected flight recorder.** However, this is not the case with solid state recorders which have been successfully used to run FDM programmes.
- 5.3 DFDR downloads are already required from all operators for the investigation of Mandatory Occurrence reports. (Details of the EU-OPS 1 Subpart B 1.160 requirements are given in Chapter 14). Subject to CAA approval and procedural limitations, it may be possible that QAR data may be an acceptable substitute if the QAR holds all the required DFDR data parameters.
- 5.4 EU-OPS 1.715-1.727 Flight data recorders – describes the carriage requirements for aircraft first issued with an individual Certificate of Airworthiness on various dates with the latest standards applying to those issued on or after 1 April 1998. The parameters needed to meet EU-OPS 1.715 are defined in appendices to each of the specified paragraphs. Further information can be found in EUROCAE Minimum Operational Performance Specification for Flight Data Recorder Systems, Document ED 55 and ED 112. A new document, ED155, provides specifications for lightweight recorders applicable to smaller aircraft and helicopters.

- 5.5 In the UK some Air Operator Certificate holders still work to the ANO 2009 Schedule 4, Scales P and S and hence to the earlier CAA Airworthiness Specifications 10 and 10A.
- 5.6 Types of crash-protected flight recorders include:
- **Tape Based - (DFDR Digital Flight Data Recorder)** – typical capacity 25 hours at 64/128 WPS (words per second), minimum download time 30 minutes, problems of tape spooling due to high speed downloads - **frequent downloads/replays affect serviceability**.
 - **Solid State – (SSFDR)** – typical capacity 25/50 hours at 64/128 WPS but trend to increasing this capacity, minimum download time five minutes, no effect on serviceability. Many SSFDRs are supplied with small hand held download units.
 - **Combined Voice and Data - (SSCVDFDR)** - solid state with both voice and data modules. Data specification as for basic SSFDR. Voice records of accidents or incidents must not be made available to any unauthorised staff as these records are protected by law in the UK. This type of DFDR is most commonly used on helicopters and smaller aircraft but may also be fitted in pairs on larger aircraft to provide redundancy when replacing the two separate voice and data recorders.

Quick Access Recorders (QARs)

- 5.7 Quick Access Recorders are normally fitted on a 'no hazard-no credit' basis. They should satisfy the environmental test requirements for equipment specified in the latest versions of ED 14 or DO160. General standards, naming conventions etc. specified in ED 55 or ED112 should be applied where appropriate to enable common software and interpretation with the DFDR system.
- **Tape (QAR)** - This was the original medium for FDM work. These vary with tape length and recording density to give capacities between 10 hours at 64 WPS to 20 hours at 256 WPS or more. The tapes need specialist replay hardware and data transfer is up to 100 times real time. These recorders are no longer in production and media/playback infrastructure will be hard to find.

- **Optical disk (OQAR)** - A technology that uses a combination of laser and ferro-magnetic technologies, OQAR recorders use 3½ inch Magneto-Optical (MO) disks to store flight data. Developed from standard PC technology with environmental protection, vendors provided these devices, each with their own proprietary style of recording and with different maximum MO disk capacities. Capacity normally far exceeds required time between downloads if download occurs at regular intervals. Data files are accessible by special MO disk readers that are now hard to source and require decoding into engineering units by suitable ground data replay and analysis software. Data transfer rates are much higher than for tape. These recorders are no longer in production.
- **PCMCIA (CQAR or PQAR)** - Mainly using flash memory, this is a very reliable and compact medium that lends itself to small installations such as commuter aircraft or helicopters. Capacity was originally not as high as OQAR but has now overtaken the capacity of MO disks. They are relatively high value and because of their size, the cards are easier to lose. Aircraft data acquisition hardware such as Digital Flight Data Acquisition Units (DFDAU) and Data Management Units (DMU) have a PC card slot where properly-formatted PCMCIA cards can be used for FDM purposes.
- **Mini QAR (MQAR)** - These were originally small solid-state recorders that are normally plugged into the auxiliary output from the crash-protected flight recorder. Today removable memory cards are frequently used. These devices have a large recording capacity and provide a simple QAR installation at low cost. This removes the pressure for frequent downloads before the crash-protected flight recorder 's data is overwritten.
- **Solid state QAR (SSQAR)** – Some Flight Data Acquisition Units (FDAU) have the capacity to retain data ready for fast download to a portable device or via wireless link directly into an operator's system.

- **Wireless QAR (WQAR)** – These systems provide a fast and automatic means of data transfer that do away with the logistical complexities and overheads needed when physical media is used. The systems can either use mobile phone technology or short range transmission to an airport based local area networks. Once the aircraft is parked and the engines have been shut down the systems transfer encrypted QAR data to an FDM data server ready for automated processing. WQARs should have protection measures to ensure any mobile phone technology utilized does not interfere with other aircraft systems and installation of such systems would have to be approved by the CAA.
- **Important Note:** In all the above technologies care should be taken not to have excessive temporary memory buffering. There have been at least two cases where UK accident investigations have found that important QAR parameters were lost due to recording buffers of up to 120 seconds. The UK AAIB report states: “Although its primary purpose is not for accident investigation, data from HFDM and FDM programmes has frequently been used in accident investigations. Use of memory buffers in these systems is not unusual but can present limitations when data is recovered. There are currently no requirements for these systems to minimise the use of memory buffers, and advisory material for HFDM does not currently exist.”
Therefore the UK CAA recommends that “buffering of QAR data should be minimised, ideally to 10 seconds or less”.

Maintenance Recorder Downloads

- 5.8 Previously standard PC floppy disks and nowadays other media are used to download system information associated with maintenance tasks and records. These are normally used by the Airborne Condition Monitoring Systems (ACMS) present on many aircraft. The system allows a small amount of data, usually limited to snapshots, to be downloaded.

Onboard Analysis

- 5.9 A few operators have experimented with on-board monitoring programmes that perform analysis in real time. This has the advantage that only small amounts of data, surrounding the interesting event, need to be transferred. The disadvantage is that if this snapshot is the only data available, then information on the pre and post incident context is lost. Alternatively, it is possible to use on-board analysis as the trigger mechanism for a post-flight action to download all the data stored for analysis.

Dataframes

- 5.10 When setting up or running a programme for new or existing aircraft, it is important to take the relative capabilities of the dataframes of the aircraft fleet into account, in terms of parameter coverage and resolution. Either of these factors can influence the quality and options available for creating measures and events in the program based on certain parameters. Certain parameters used in FDM events may require greater degrees of accuracy than others. Where a parameter is sampled at a less than desirable frequency, interpolation may be considered where appropriate.

CHAPTER 6

Planning and Introduction of FDM

- 6.1 This chapter describes the development and implementation of FDM within an operator. It is recognised that there are a wide range of operators covered by the FDM requirements and that there is no 'one size fits all' system. The size and age of aircraft may determine the parameters available for analysis. The programme effectiveness and efficiency of a small fleet or operation may be helped by pooling analysis within a group of similar operations. While retaining responsibility for risk assessment and action, some operators may wish to contract out the basic analysis due to lack of expertise or resources.

FDM Guiding Principles Checklist

- 6.2 As an aid to operators, **Appendix E** provides a checklist of guiding principles that highlight some of the fundamental concepts that should be considered when putting one of these pro-active safety processes in place.
- 6.3 By understanding these principles the reader will be able to construct a practical and effective FDM programme that takes into account the lessons learnt from over 40 years experience. Each principle contains a description of its objectives and also the processes that are expected to indicate and support its application in practice in the form of a questionnaire.
- 6.4 These principles are reflected in EU-OPS 1.037 Advisory Circular Joint (ACJ)/TGL-44.

Principles covered:

1. Definition
2. Accountability
3. Objectives
4. Flight Recorder Analysis Techniques
5. Flight Recorder Analysis Assessment and Process Control Tools
6. Education and Publication
7. Accident and Incident Data Requirements
8. Significant Risk Bearing Incidents Detected by FDM
9. Data Recovery Strategy
10. Data Retention Strategy
11. Data Access and Security
12. Procedure Document
13. Airborne Systems and Equipment

FDM Programme Costs and Benefits

- 6.5 Much has been said about the safety benefits of FDM programmes and this has been followed by evidence of potential cost savings to offset the, not insignificant, set-up and running costs. It is not appropriate to give detailed cost breakdowns as these vary considerably dependent upon the scale and complexity of the operation. However, **Appendix F** gives indications of areas of cost and benefit that should be considered when the business case is being constructed.
- 6.6 By far the largest cost element to be considered is the unacceptable cost of having an accident that could have been prevented. This (theoretical) cost has in the past driven individual operators out of business. Even if this is not the case there will be significant loss of revenue through loss of public confidence, loss of utility of an aircraft and a reduction in company stock-market value.
- 6.7 The more tangible costs are non-recurring set up costs and running costs. The latter will include both the support costs of engineers and technical staff plus the operational staff needed to assess the data and make decisions upon actions required.

- 6.8 Finally, there are a wide range of potential benefits additional to the primary safety benefit. When used imaginatively, the data has been found to produce significant engineering and operational savings. When planning this, care must be taken to ensure the security of identified data to stop inappropriate crew contact or identification on operational matters.

The Implementation Plan

- 6.9 This is a broad guide to the major steps involved in putting an FDM programme in place. The key steps are getting buy in at the top level of management, a good team with crew participation, clear objectives and specification and finally, rigorous testing and verification procedures for the resulting data.
1. Confirm CEO approval and support for FDM implementation.
 2. Identify Key team members.
 3. Agree Aims and Objectives.
 4. Develop crew agreements and involvement.
 5. Conduct feasibility study and develop business plan - people, processes, software and hardware.
 6. Obtain funding and organisational approval.
 7. Survey key areas in Operation for targets of opportunity.
 8. Produce detailed specification and place contracts.
 9. Put in place operating procedures.
 10. Installation of airborne equipment (if required).
 11. Provision of ground analysis station.
 12. Conduct staff training.
 13. Test data acquisition and analysis, complete manuals.
 14. Produce Completion Report.

Aims and Objectives

Define Objectives of Programme

- 6.10 As with any project there is a need to define the direction and objectives of the work. A pre-planned, staged approach is recommended so that the foundations are in place for future expansion into other areas. Use building blocks that will allow expansion, diversification and evolution through experience.
- 6.11 **Example:** Start with a modular system looking initially at basic safety related issues only but with engine health monitoring etc. added in the second phase. Ensure compatibility with other systems.

Set Both Short and Long Term Goals

- 6.12 A staged set of objectives starting from the first week's replay, moving through early production reports into regular routine analysis, allows the system to 'tick-off' achievements.

Examples:

- 6.13 **Short term (S1)** Establish data download procedure, test replay software, identify aircraft defects. **(S2)** Validate and investigate exceedance data. **(S3)** Establish a User acceptable routine report format to highlight individual exceedances and also statistics.
- 6.14 **Medium term (M1)** Produce annual report - include key performance indicators. **(M2)** Add other modules to analysis (e.g. Continued Airworthiness). **(M3)** Plan for next fleet to be added to programme. **(M4)** Network information across company information systems.
- 6.15 **Long Term (L1)** Ensure FDM provision for any proposed 'Advanced Qualification Program' style training. **(L2)** Use utilisation and condition monitoring to reduce spares holdings.

Aim for Known 'Hot Spots'

- 6.16 In the initial stages it is useful to focus on a few known areas of interest that will help prove the system's effectiveness. This is rather more likely to get early success than a 'scatter-gun' approach which, if properly constructed, should eventually hit these spots but will probably not get results as quickly.

- 6.17 **Example:** Hurried approaches at particular airports, rough runways, fuel usage, poor autopilot reliability. Analysis of known problem airports may generate monitoring methods for all locations.

Do not Oversell First Phase

- 6.18 Everyone has to understand the objectives of the programme. If the expectations of the information users are too high then the project will always fail. By keeping the objectives within reach at each stage of the project then the steps are easier and less likely to fail.

Record Successes and Failures

- 6.19 Having set staged objectives of the project then all successes and failures should be recorded. This will form the basis of a review of the project and the foundation of future work.

The FDM Team

- 6.20 UK experience has shown that the 'team' required to run an FDM programme can vary in size from one person with say a five aircraft fleet, to a small department looking after scores of aircraft. The description below describes the various roles within a larger system in some detail. Most of the aspects covered will still be required in a smaller scale system but would be handled by one individual in a 'multi-role' function. In this case other areas, for example engineering, would provide part-time support.
- 6.21 In addition to their existing subject area expertise, all staff should be given at least basic training in the specific area of FDM data analysis. It is essential that a regular, realistic amount of time is allocated to FDM tasks. Lack of manpower resources usually results in underperformance or even failure of the whole programme.
- 6.22 In the case of a very small operator the day to day running of the programme may be contracted out to a third party, thus removing the data handling and basic analysis tasks. However, sufficient expertise must remain within the operation to control, assess and act upon the processed information received back from the other company. Responsibility for action may not be delegated.

Team Leader

- 6.23 This person will be trusted by and given the full support of both management and crews. They may have direct crew contact in situations that require diplomatic skills. They will be able to act independently of other line management to make recommendations that will be seen by all to have a high level of integrity and impartiality. The individual will have good analytical, presentation and management skills.

Flight Operations Interpreter

- 6.24 This person will normally be a practising or very recent pilot, possibly a senior Captain or trainer, who knows the company's route network and aircraft. Their in-depth knowledge of SOPs, aircraft handling characteristics, airfields and routes will be used to place the FDM data in context.

Airworthiness Interpreter

- 6.25 This person will interpret FDM data on technical aspects of the aircraft operation. They will be familiar with the powerplant, structures and systems departments' requirements for information and also any existing monitoring techniques employed by the operator.

Crew Liaison Officer

- 6.26 This person will be the link between the fleet or training managers and aircrew involved in circumstances highlighted by FDM. In larger companies this person is often a member of the pilot's association e.g. the British Airline Pilots Association (BALPA) or other pilots' representatives. In smaller companies this role may be carried out by the Flight Safety Officer or another trusted individual. All cases demand someone with good people skills and a positive attitude towards safety education. It is essential that the post holder has the trust of both crew and managers for their integrity and good judgement.

Engineering Technical Support

- 6.27 This will be an individual who is knowledgeable about the FDM and associated systems needed to run the programme. An avionics specialist, normally is also involved in the supervision of mandatory FDR system serviceability.

Air Safety Co-ordinator

- 6.28 This person will be involved with the follow-up of safety reports and will be able to put the FDM data into the context of the reports and vice versa. This function ensures read-across between the two systems and should reduce duplication of investigations.

Replay Operative and Administrator

- 6.29 Responsible for the day to day running of the system, producing reports and analysis. Methodical, with some knowledge of the general operating environment, this person is the 'engine room' of the system. The role of the individual should not be underestimated, as FDM systems are complex and require a variety of external sources of information to be kept up to date such as flight logs, flight plans, navigation data, pilot records, software upgrades and adjustments in event thresholds associated with SOP changes etc. Likewise an administrator may be involved (with the support of appropriate expertise) in the adaptation and creation of new events to ensure the operator has a robust set of events to adequately cover relevant aspects related to aviation safety that can be monitored through FDM.

Analysis Program Specification

- 6.30 An analysis program specification document has to be constructed to fulfil two principal requirements. Firstly, to set down the complete process by which flight data can be turned into useful information and secondly, to provide the system programmer with sufficient detail to code the data conversion and analysis software. This requires a detailed technical specification of the aircraft data systems that will involve considerable research to ensure valid data extraction. This document is likely to form an integral part of any contracts placed for the supply of a system but will continue to develop as the system matures and is refined.

Process Definition from Aircraft to Archive

- 6.31 This will detail the download and data transfer methodology, serviceability and replay statistics, the analysis modules, exceedence workflow (allocation of responsibility, investigation results, and actions taken...), archiving and historical records.

Complete Documentation Including Reasoning and all Changes

6.32 It is critical that the system is fully documented so that not only the construction of the system is transparent but also the reasoning behind the code is clear to future users. Changes, updates and fixes should be detailed and the implementation date recorded. Where a historical event record is being maintained then previous standards of event logic and limits should be available and referenced to past event trends.

Thorough Testing Procedures - Both Initial and Ongoing

6.33 The testing of the program should encompass the following aspects and on an ongoing basis may be done in the form of a FDM system audit involving the aforementioned FDM Team:

- **Testing basic data replay and conversion to engineering units** - this can be relatively simple for the principal variable parameters but very difficult for many discretises that are never seen during normal operations. Guidance in this area can be obtained from the processes involved in the verification of the crash-protected flight recorder, details of which may be found in the UK CAA's CAP 731 - 'The Approval, Operational Serviceability and Readout of Flight Data Recorder Systems'
- **Testing exceedence detection** - This can be tested either by realistically manipulating normal data to simulate an event, by reducing the event limits such that normal flying will trigger events, or more acceptably, replaying historical data known to contain incidents that should trigger events. It is also important to identify issues such as 'false events' generated by the program.
- **Ongoing tests** - It is important to have a means of ensuring that the quality of the system does not change after any significant program modification. This should include the review of data capture rates to support this. Additionally, a routine, say annual, 'health check' to pick up and resolve any unforeseen problems would be advisable and could be usefully incorporated with the routine DFDR serviceability checks.

Exceedence Detection

- 6.34 This is the traditional approach to FDM that looks 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. See **Appendix B section 1**.
- 6.35 **Example:** High lift-off rotation rate, stall warning, GPWS warning, flap limit speed exceedence, fast approach, high/low on glideslope, hard landing.
- 6.36 There will be additional safety related events that will produce useful information to supplement pilot safety reports.
- 6.37 **Example:** Reduced flap landing, emergency descent, engine failures, rejected take-offs, go-arounds, TCAS warning, handling problems, system malfunctions, pilot marked event.
- 6.38 Given the wide range of risk levels covered, it would be useful if an informed estimate of the risk, even if subjective, could be included. This will help focus attention on the higher risk events rather than just numbers.
- 6.39 **Example:** Equate the risk levels of other circumstances relative to a major warning such as a stall or GPWS warning that require direct crew intervention to prevent a catastrophe. Deduce a rule of thumb that may give, for example, a 50 degree bank angle at 400 ft as an equivalent risk to the GPWS and 30 degrees at 5000 ft a 10% risk.

Modified Standard Event Limits to Reflect Operator's SOPs and Requirements

- 6.40 A basic set of events provided by suppliers will need to be modified to tie in with the operator's SOPs. A direct read across will make interpretation of the results much easier and will need to be updated if SOPs change over time.
- 6.41 **Example:** If SOPs require the aircraft to be in landing configuration by 1000 ft AAL then setting three trigger levels at 1000, 800 and 600 ft give a range of significance covering the normal to the exceptional.

- 6.42 If there is a problem with SIDs at a particular airfield producing nuisance events, build a location condition into the event rather than lose the benefit of the event at all other locations. This way a known 'non-standard' SOP does not swamp the system and yet can still be monitored. However, the fact that an SOP produces an event may mean that its safety implications need reconsidering.

New Events For Specific Problem Areas

- 6.43 Where there are known areas of interest that are not covered by the standard set of events then it should be possible to add a new event. This gives additional value to an FDM programme as specific areas concerning other departments can be addressed in addition to the general monitoring of safety issues. See **Appendix B section 2**.
- 6.44 **Example:** Restrictions on the use of certain flap settings to increase component life. Detect and record number of uses.

All Flights Measurement

- 6.45 In addition to exceedences, most programs today retain various snapshots of information from every flight. This data is most useful in determining trends before there are statistically significant movements in event levels. Given data from most flights, the possibilities for substantial analysis breakdowns by time, location, aircraft weight etc. become more feasible than when using the, hopefully, small number of events. This approach to FDM data has proven very useful in determining what is normal as opposed to the event method that gives what is abnormal. See **Appendix B section 3**.
- 6.46 **Example:** Rotation rate at lift-off and its correlation with take-off weight and location can point to inaccuracy in the training simulator's model, an airfield problem or a new pilot intake.

Onboard 'Eventing' and Measurement

6.47 Some operators have experimented with in-flight exceedence and measurement software to reduce the amount of data transferred. While this has been reasonably successful there still remains the requirement to store flight data for ad hoc enquiries and incident analysis. In addition the software standards required for airborne software are more rigorous than that on the ground. This, combined with the initial costs of system programming and the practical difficulties in implementing changes across a large fleet, has limited the spread of such systems. However, a number of aircraft manufacturers have implemented on-board systems that can be used along with QARs or maintenance recorders giving 'snapshots'. These are often used for engine, ETOPS and autoland reporting.

CHAPTER 7

Organisation and Control of FDM Information

Introduction

- 7.1 As with all information systems, it is critical that the data flows are tightly controlled by clear procedures. Careful thought has to be given to the practicalities and possible disruptions involved in getting data from the aircraft and translated to useful information for safety managers. Additionally, much of the data has to be treated confidentially with access carefully restricted to those authorised to view it.
- 7.2 This section deals primarily with enabling the efficient handling of exceedences (or events) produced by an FDM programme. Any exceptions to normal operating practice, good airmanship and flight manual limitations should be highlighted ready for evaluation and, if necessary, action.

Rationalised Data Stream

Regular Replay Schedule

- 7.3 Downloaded data should be replayed to a regular schedule to avoid build ups. Batch processing of a number of files may be a practical method of initial replay and analysis if the system is suitably automated.

Initial Verification of Data

- 7.4 The first step in the investigation process is to ensure the information is realistic and presents a consistent picture. **VALIDATION IS CRITICAL.** Before any action is instigated the basic FDR information must be thoroughly checked. Well written FDM software should automate as much of this process as practical.

Identification of Urgent Actions

- 7.5 There are a number of circumstances where FDM data will indicate that immediate safety action is required and a fast procedure to ensure safety critical remedial action should be defined. In general, the urgent actions are associated with Continued Airworthiness checks, rather than operational situations. For example, a very hard landing with potential damage that has not been reported by other means should trigger relevant structural checks as soon as possible, whereas crew remedial investigations are not so urgent. Therefore, replays ideally should be completed and a basic initial examination of the results should be carried out before the next flight. When this is not practicable then a reasonable period of time after the flight should be specified.
- 7.6 Note that in an effective open safety culture the crew reporting of likely problems should be expected to alert the operator to the majority of these situations.

Allocation of Follow-up Co-ordinator

- 7.7 Once a basic assessment has been carried out and has revealed a significant risk, or aspect requiring further investigation, then one particular person or department should be allocated follow-up responsibility. This responsibility is normally fairly clearly defined by the type of incident. However, on occasions there may be a need to involve several departments or even organisations and in this case the follow-up co-ordinator will act as a focal point for the investigation.

Database all Results

- 7.8 The results of all analysis should be placed on a database ready for interpretation and further analysis. Generally it is best to automatically database all events detected and then mark as invalid those that are in error due to program or data anomalies. Experience has shown that a manual data entry of the event details is both time consuming and prone to error. Recording all erroneous events will assist in the later refinement and improvement of the program.

Record all Actions Taken

- 7.9 An important part of the assessment of a new FDM system and an integral part of a fully functioning system within an SMS is the careful recording of all actions arising from the data. This can be used to help demonstrate the benefits accrued and also ensure an audit path to confirm remedial actions have taken place.
- 7.10 The example below illustrates the series of actions pertaining to, in this case, a hard landing event:
- **Initial analysis action** - validate and set event in context of previous hard landings
 - **Action informee - structures:** action taken - checks, result - no damage,
 - **Action informee - operations:** action taken - flying assessed - crew interviewed, result - revised crew briefing for airfield
 - **Ongoing analysis action** - monitor airfield and runway events for recurrence or changes.

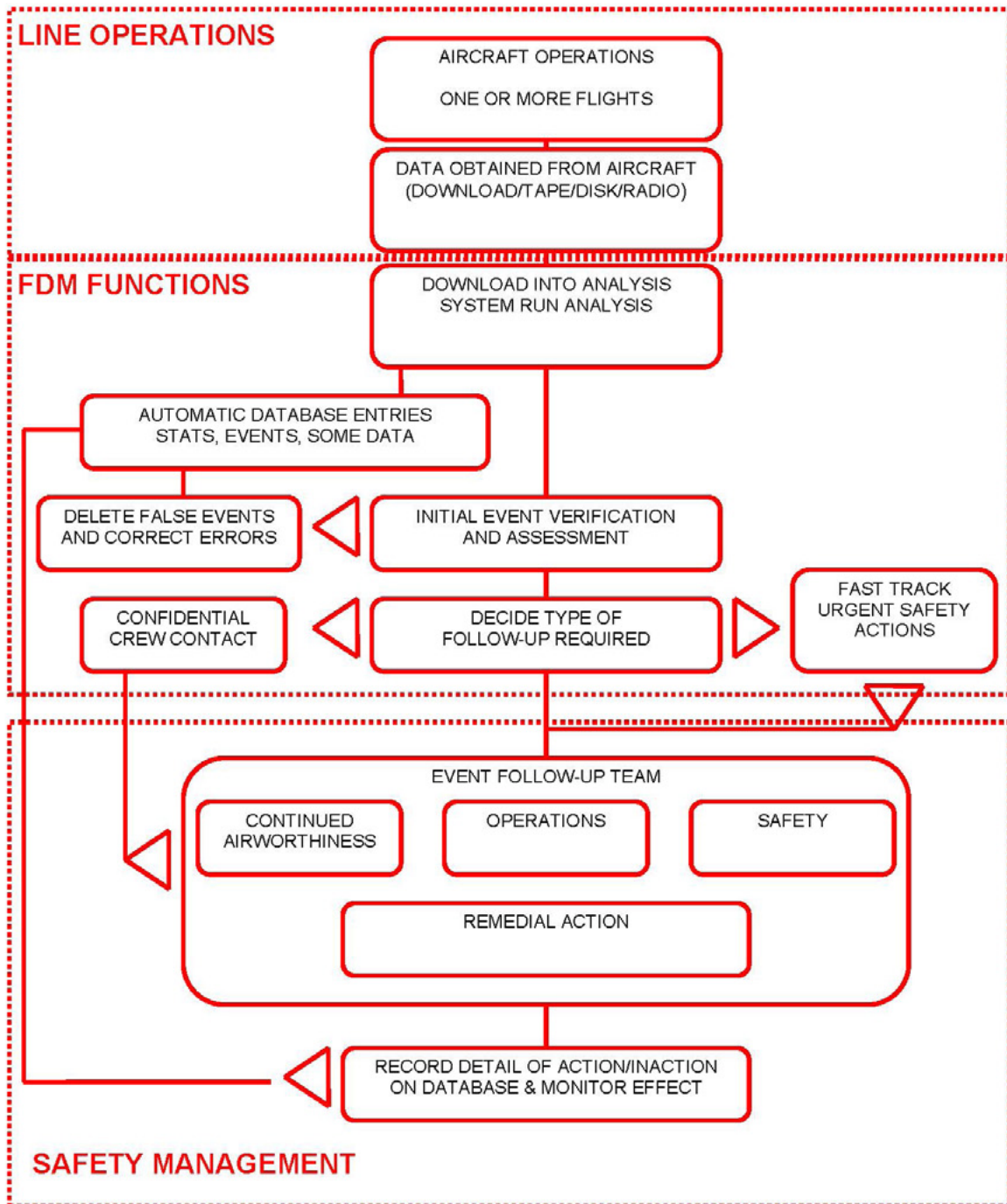
Replay Statistics

- 7.11 Part of the replay process should be the recording of statistics on replay coverage, individual aircraft reliability, general data quality measurements. Differences in replay success/errors between aircraft can help indicate where remedial engineering action is required. These statistics are required to allow the derivation of overall and specific event rates; airfield and aircraft specific rates etc.
- 7.12 Examples: Number of sectors and hours flown, replayed and analysed to give hard landing events per 1000 landings or turbulence encounters per 1000 hours. Proportion of bad data by aircraft/recorder/medium to identify problem areas.

Data Flow

- 7.13 The data flow should be optimised to minimise the delay between the flight and data analysis. This will ensure timely recognition of serious incidents that may need prompt action - for example a structural inspection - and increase the likelihood of the crew remembering the surrounding circumstances.

Figure 1 FDM Data Flow



Data Security and Control

Defined Policy on Retention of Data

- 7.14 Because of the large volumes of data involved, it is important that a strategy for data access, both on and off line, is carefully developed to meet the needs of the system users.
- 7.15 The most recent flight and event data is normally kept online to allow fast access during the initial analysis and interpretation stages. When this process is completed it is less likely that additional data from the flights will be required so the flight data can be archived. Event data is usually kept online for a much longer period to allow trending and comparison with previous events.
- 7.16 There are many hardware and software solutions to long-term data storage available off the shelf but the one selected must be compatible with the analysis software to allow practical access to historical data.
- 7.17 In most systems, data compression and the removal of non-essential parameters can reduce the capacity required. Also at this time removal of identification data can be completed.

Link with the Safety Reporting Process

- 7.18 This is required to allow relevant safety reports to be automatically added to FDM information. Low significance incidents/events that are not subject to mandatory occurrence reporting would not normally be identified (see 'Crew Identification in Mandatory Occurrences' below). Care has to be taken where there has been no safety report submitted for an apparently reportable incident detected by the FDM programme. The crew should be encouraged to submit a safety report without prejudice via a confidential contact method.

Engineering use of FDM Data

- 7.19 It must be recognised that the use of FDM and associated data sources for Continued Airworthiness purposes is an important component of the system. For investigation of say potential hard landing damage, there will be a need to identify the aircraft concerned and in the case of a technical defect report, the data associated with that particular flight may prove invaluable in fixing the fault. However, secure procedures must be in place to control access to the identified data and how the data is used. Identification of and contact with crews for operational rather than technical follow-up of FDM data should not be permitted through this path, without prior agreement.

Defined De-identification Policy and Procedures

- 7.20 This is an absolutely critical area that should be carefully written down and agreed before needed in extreme circumstances. Management assurance on the non-disclosure of individuals must be very clear and binding. The one exception is when the operator/crew team believe that there is a continuing unacceptable safety risk if crew specific action is not taken. In this case an identification and follow-up action procedure, previously agreed before the heat of the moment, can be brought into play.
- 7.21 Experience has shown that this is very, very rarely required. Most often a crew responds to advice from the crew representative to submit a safety report and they are then covered by protection assured under that programme.
- 7.22 There must be an initial stage during which the data can be identified to allow confidential follow up by the crew representative or agreed, trusted individual. Strict rules of access must be enforced during this period.

Crew Identification in Mandatory Occurrences

- 7.23 In the case of a UK mandatory occurrence or accident, any data retained by the programme may not be de-identified or removed from the system prior to the investigation or confirmation that it is not required. This will allow the air safety investigators access to all relevant information.
- 7.24 CAA CAP 382 (The Mandatory Occurrence Reporting Scheme) stresses that a safety rather than disciplinary approach should be taken in those cases that do not involve gross negligence or criminal acts.

Set Authorised Access Levels

7.25 The FDM system must have the ability to restrict access to sensitive data and also control the ability to edit data. The System Administrator should have full access, while operations management may only have oversight of de-identified data and the ability to add their views and recommendations. Similarly the replay technician will be able to feed in new data, check identification etc. but will not be able to change program specifications and event limits. Continued Airworthiness and operations would have particular views of the data, perhaps with the former being airframe identified, while the latter would by say, pilot group.

Crew Participation

Agree Joint Aim - to Improve Safety and Non-punitive

7.26 It is fundamental that all involved in FDM agree the aims and objectives of the work and the self-imposed restrictions which operate. The improvement of safety standards is accepted as a worthy goal by all aviation professionals but the method of achieving it is more difficult to agree. By fully sharing the objectives and concerns of all parties, the possibility of misunderstanding is reduced.

Flexible Agreement

7.27 It has been found that agreements of principles, with plain English definitions of the areas covered, exclusions and conditions of use, are far more workable than a rigid set of rules that impede progress. Based on trust and mutual consent, all parties should view the data access as privileged and handle it carefully.

Defined Procedure for Restricted Contact with Flight Crew

7.28 A step by step description of the restricted method by which crews are contacted and the safeguards in place should be publicised to gain crew confidence. The aims of the contact along with the approach to debriefing and raising actions should be clear. Flight crews should be encouraged to talk through difficult situations and learn from experience, even to ask for data about their flying. As with safety reporting, a willingness to communicate and learn is a good indicator of a successful safety culture. It is suggested that debrief tools including traces and visualisations/ animations would, in some cases, be useful during this process.

Discrete Retraining of Individuals where Required

- 7.29 Where it is agreed that retraining is appropriate then this should be scheduled into the training programme in a discrete manner to avoid highlighting the person. It must be stressed that additional training is not to be considered disciplinary action but merely a safety improvement action.
- 7.30 Note that while an individual co-pilot may be placed into a programme of continuation training fairly easily, a captain may be more difficult to schedule in unobtrusively.

Confidentiality

- 7.31 A statement of agreement outlining the protection of the identity of the individual should be clearly written, along with any provisos necessary. An example of such wording as used by the Chief Executive of the UK CAA in respect of the UK Mandatory Occurrence Reporting Scheme follows:
- 7.32 'It is fundamental to the purpose of the reporting of incidents and accidents, that the knowledge gained from the investigation of these occurrences is disseminated so that we may all learn from them.
- 7.33 Without prejudice to the proper discharge of its responsibilities, the CAA will not disclose the name of the person submitting the report or of a person to whom it relates unless required to do so by law; or the person concerned authorises disclosure.
- 7.34 Should any safety follow-up action arising from a report be necessary, the CAA will take all reasonable steps to avoid disclosing the identity of the reporter or of those individuals involved in any reportable occurrence.' (CAP 382)

Define Confidentiality Exceptions

- 7.35 It would be irresponsible to guarantee total confidentiality in a situation where there would be significant ongoing risk to safety. In the case of grossly negligent behaviour, where the crew have 'failed to exercise such care, skill or foresight as a reasonable man in his situation would exercise', then action to prevent repetition should be agreed by a pre-defined group that would usually include crew representatives. Formal action may be required by law.

Inform Crew

- 7.36 At all times keep the crew informed of areas of concern and remedial actions contemplated. Their involvement and ideas will usually ensure a workable solution to operational problems that they have experienced and ensure future buy-in to the programme.

Feedback on Good Airmanship

- 7.37 Where examples of good flying have been found then these should be highlighted and commented upon. They also make useful reference material when analysing or debriefing less well executed flights.
- 7.38 **Example:** A well flown go-around or procedurally correct TCAS resolution advisory action, with a safety report should be commended. Similarly, exceptional handling of technical problems may be singled out with data from the programme and used in training material.

CHAPTER 8

Interpretation and Use of FDM Information

Interpretation of Results - The Raw Data

- 8.1 Interpretation and verification of the basic flight data is a critical, if somewhat laborious, operation. The well known adage of 'rubbish in - rubbish out' very much applies here.

Validation Checking Strategy

- 8.2 Most parameters required for the FDM programme are seen on every flight and their validity should be primarily assured by the FDM software program and then confirmed visually while assessing the event trace. However, a number of parameters are rarely used except in more detailed analysis of incidents and these should be validated whenever the opportunity arises. There are also a number of rarely triggered warnings, operating modes etc. that can only be tested by complex procedures in the maintenance workshop. Reference to the validation and re-certification of the crash-protected flight recorder may assist in this process. A strategy outlining the frequency of checks and documenting 'opportunity' checks during analysis should be laid down as part of the basic system maintenance procedures.
- 8.3 **Examples of commonly used parameters:** airspeed, altitude, attitudes, air/ground switches, accelerations, flight controls, main auto-flight modes.
- 8.4 **Examples of infrequently used parameters:** alternate flap, less common auto-flight modes, GPWS, TCAS and other warnings.
- 8.5 **Examples of difficult to check parameters:** hydraulic pressure warning; fire warnings, N1 overspeed.

Watch for Bad Data, Datum Errors etc.

- 8.6 There are a range of basic data faults which can be either established - demanding changes in equipment or software, or transient such as a faulty transducer or processing unit.

- 8.7 **Example of a Transducer Error:** accelerometers occasionally stick and have an offset datum, say of 1.3g rather than 1.0g when at rest, or lose damping so they are over sensitive and hence reading too high.
- 8.8 **Examples of Data Acquisition faults:** One pitch angle sample each second does not follow the trend of the rest of the data. This can be caused by the system picking a sample from the previous second's data stream. Normal acceleration data can be filtered by passing through a system unit that removed high frequency data. Hence no hard landing g peaks!

Establish Characteristics of 'Normal' Data

- 8.9 The essence of good interpretation is an ability to detect what is different or unusual. To do this the analyst must have knowledge of what 'normal' data looks like and the variations that fall within a reasonable range.
- 8.10 **Example of Parameter Characteristics:** normal acceleration has a higher frequency content on the ground than in the air, has no stunted peaks, a 30 degree co-ordinated level turn should produce 1.15g and 45 degrees 1.4g.
- 8.11 **Examples of a Normal Range of Parameters:** pitch attitude should vary between say -10 and +25 degrees, speed on the approach should be between the stall speed and the flap limit speed +10 knots.

Cross-check Significant and Related Parameters

- 8.12 Where possible establish the technique of cross-checking between related parameters. For example, at rotation confirm pitch up is accompanied by an increase in normal acceleration, an elevator up control movement and is followed by the air/ ground switch moving to AIR.
- 8.13 Other Examples of Related Parameters: EPRs on engines normally are similar; heading changes with bank angle; opposing aileron deflections at turn initiation but the same sign during load relief or drooping with flap selection; positive longitudinal acceleration as ground speed increases.

Relate Data to SOPs

- 8.14 Data and events should always be placed in the context of the operator's Standard Operating Procedures. It would be useful to annotate a typical flight with the SOP action points.
- 8.15 **Examples of SOP Points Relevant to an Exceedence Program:** the following speeds are used for configuration changes after take-off - at positive climb retract gear; above 35 ft AGL - autopilot on, speed not less than V_2+10 or max pitch 18 degrees; at 1000 ft AGL select flaps up and set climb thrust.

Keep Examples for Future Training

- 8.16 Examples of good and bad data should be retained for use as training and familiarisation material. Annotated 'normal' traces can also be used as a yardstick against which to compare an incident/exceedence trace.
- 8.17 **Examples of retained data:** Significant incidents and unusual scenarios, Rejected Take-offs, GPWS reactions, exemplary cases where SOPs have been accurately followed, demonstrations of both good and bad techniques highlight the potential problems to crews.

Interpretation of Results - The Operational Assessment

- 8.18 During this part of the process the validated FDM data is assessed using a knowledge of the operating environment and standards. It is here where the safety lessons will emerge and action decided upon.

Further Validity Checks

- 8.19 While most basic data errors should have been eliminated by this stage, more subtle data problems may still exist. In addition, where incidents seem inexplicable, it may be that errors in the data or in the program are found to be present.
- 8.20 **Examples of subtle errors:** aircraft weight, parameter offsets, radio altimeter faults, airbrake lever arm position.
- 8.21 **Examples of program errors:** incorrect source of weight data taken, schedule speed reference table error, wrong event limits/specification.

Set Events in Context

- 8.22 Take-off and Approach events should be taken in the context of the physical and procedural characteristics of the particular airfield. During periods of bad weather, this also has to be taken into account.
- 8.23 **Examples of airfield related context:** location/local geography, altitude, runways, procedures including noise abatement, approach aids, ATC standards.

Correlation with Relevant Safety Reports

- 8.24 By this stage all events should have been correlated with relevant safety reports to give the best possible picture of these, normally more significant incidents. This will also prevent two separate investigations taking place into the same incident, each using only partial data. Normally, an interpreted summary of the FDM data should be added to the investigation file and the follow-up controlled by the normal flight safety process within the operator's safety management system. A lack of an FDM event that is expected to have been flagged may be due to problems with the trigger logic of the FDM event algorithm, or erroneous data. A safety report e.g. from a pilot, clearly describing a particular event occurring and a lack of an expected corresponding FDM event to support this may be an indicator of this and should be followed up accordingly.
- 8.25 **Examples of events normally covered by internal safety reports:** GPWS, stick shakes, loss of control, hard landings etc. See CAA CAP 382 for details of the requirements laid down in the Air Navigation (General) Regulations (2009) Article 226.

The Need for Crew Debrief for Background Information

- 8.26 At an early stage in the assessment, a decision should be made if more information on the circumstances of the event should be obtained. In this case the confidential crew contact procedures should be initiated and the sooner they are contacted after the event the better their recollection will be. The timely correlation with any relevant safety reports will prevent wasted effort and duplication.

- 8.27 The information gathering objectives of such a debrief include learning of: ATC involvement, Weather, Technical problems, Procedural difficulties, Operational lapses, other traffic....
- 8.28 The training objectives may include: re-enforcement of SOPs, reminders of safety reporting requirements, congratulations for well handled emergencies such as a well flown windshear recovery.
- 8.29 **Examples of cases benefiting from a confidential crew debrief:** hurried approaches at busy airports, take-off rotation technique, unreported hard landing, inappropriate autopilot mode use, SID technique, altitude busts...

Degree of Direct or Indirect Hazard

- 8.30 It is best if the degree of hazard is estimated to enable resources to be targeted at the most beneficial reduction in hazard. This may be to prevent a large number of relatively low risk events or to eliminate a low number of high risk events. In assessing the level of risk, the analyst must take into account both the direct risks and those that may be a consequence of those circumstances.
- 8.31 **Examples of direct and indirect risks:** a hard GPWS warning indicates a direct risk while an indirect one would be a plethora of false warnings - of little risk in themselves but which may result in pilots becoming too accustomed to hearing them; thus reducing the effectiveness of standard recovery from a real warning which could be catastrophic if not addressed.

Assessment of Potential Accident Factors

- 8.32 It is useful if a list of precursors of and causal factors in previous accidents are drawn up to further highlight potential hazards. These again may be relatively low risk events in their own right but good indications of the probability of further, more significant incidents.
- 8.33 **Examples of accident precursors:**
Controlled Flight into Terrain (CFIT) - positional errors or unstable approaches,
Loss of Control (LOC) - auto vs manual flight conflicts, speed and configuration errors,
Runway Excursions (REX) - landing technique, unstable approaches, directional control during take-off and landing runs.
Airborne Conflict (AC) - TCAS warnings, altitude excursions.

Assessment of Frequency - Single Event Or Systematic Problem

- 8.34 The events should be assessed in the context of previous experience. One of a series showing a trend or a one-off incident in exceptional circumstances. Clusters of events may occur at a particular airfield, on one aircraft or during a period of bad weather. Placing all events on a database will enable the analyst to decide an informed course of action.

Taking Action -The Decision Process

- 8.35 As with any safety report, the responsible person (e.g. FDM Manager) must decide if it is appropriate to take action to prevent repetition. Action could be required due to safety severity (through individual risk or high frequency), financial or operational implications. Actions, the underlying reasons and data used should be recorded to provide an audit path.

Continuous Monitoring of Result of Actions

- 8.36 After taking action, the issue that is to be addressed and any potential knock-on effects should be carefully monitored to ensure no risks are transferred elsewhere. A general monitoring process of all available data should be applied to identify any other changes which were not anticipated. That is to cover the possibility of unintended consequences.

CHAPTER 9

Statistics in FDM

Introduction

- 9.1 The intent of this chapter is to emphasise the importance of having an understanding of statistics when dealing with aviation safety matters. From the initial design concept through to end of service, statistics are entwined into: - the aircraft's structural design; performance estimation; Safety cases (especially where fail-safe is not possible); Continued Airworthiness/fatigue life etc.
- 9.2 When looking at FDM or any other safety data it is important to take account of the chance of drawing the wrong conclusions by misreading random variations or by taking biased samples of data. There are inherent dangers in taking no action where a risk exists or taking inappropriate action where no risk actually existed.
- 9.3 Statistical techniques have a range of practical applications in an FDM programme such as detecting abnormalities, both in terms of user-defined limits and statistical significance versus randomness. This information can then feed the process of determining the actual severity of an event and, together with other relevant information, help identify actual and potential risk. In turn this can lead to a better overall understanding of an event. When such techniques are employed in conjunction with IT systems and common software packages, it is practical to use these for day-to-day monitoring for FDM on larger quantities of data. The identification of trends, clusters, exceptions and correlations between different variables will greatly assist the analyst's work. Brief descriptions of some of the more common statistical tests and techniques are outlined in this chapter to assist the reader as well as information on ways of presenting data.

Collecting, Summarising and Presenting Data (Descriptive Statistics)

- 9.4 Depending on the type of feature being measured different types of data presentation will be appropriate. A random variable is a feature that can vary from one value to another; the following table shows examples of different types of random variable:

Example of Random Variable (r.v)	Example values that r.v can take	Name of the type of variable
Departure runway	27L , 27R, 09R, 09L	Nominal Variable
Auto brake selection	0, 1, 2, 3, RTO	Ordinal Variable
Number of TCAS warnings per week	0,1,2,3,4,5,6,7,8,9,10,	Discrete Variable
g load at touchdown	..0.1, 0.15, 0.2, 0.5, 0.55, 1, 2,...	Continuous Variable

9.5 Numerical data can be presented in a number of ways such as in time series bar charts or line graphs, pie charts and box plots:

Figure 1: Time series bar chart

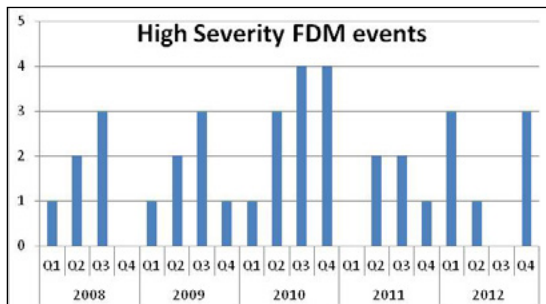


Figure 2: Time series line graph

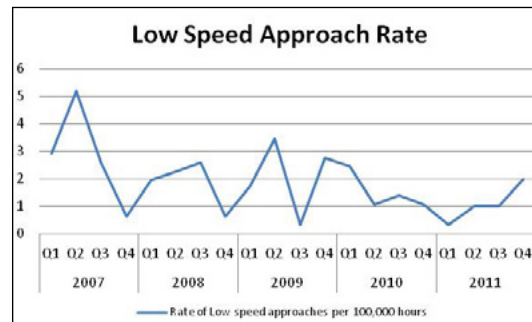


Figure 3: Pie chart

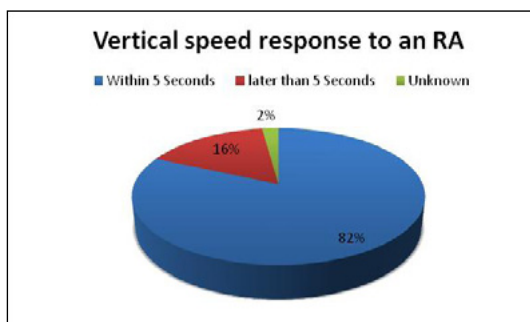
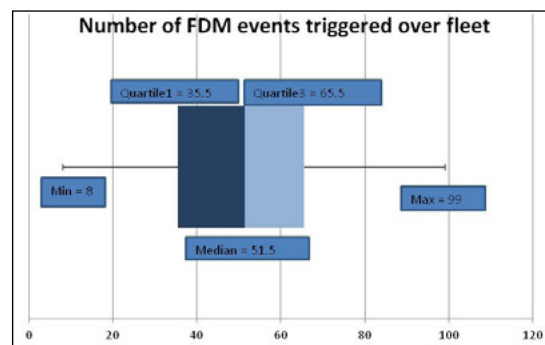


Figure 4: Box plot



9.6 It is often helpful to explain features visually identified in the data by presenting basic **sample** statistics. These statistics can be used to describe the **distribution** and pattern of data over a range. For further information see the definitions of **mean**, **median**, **interquartile range** and **standard deviation** in the glossary. The box plot in figure 4 shows how data is distributed across a range by plotting these various statistics across the distribution.

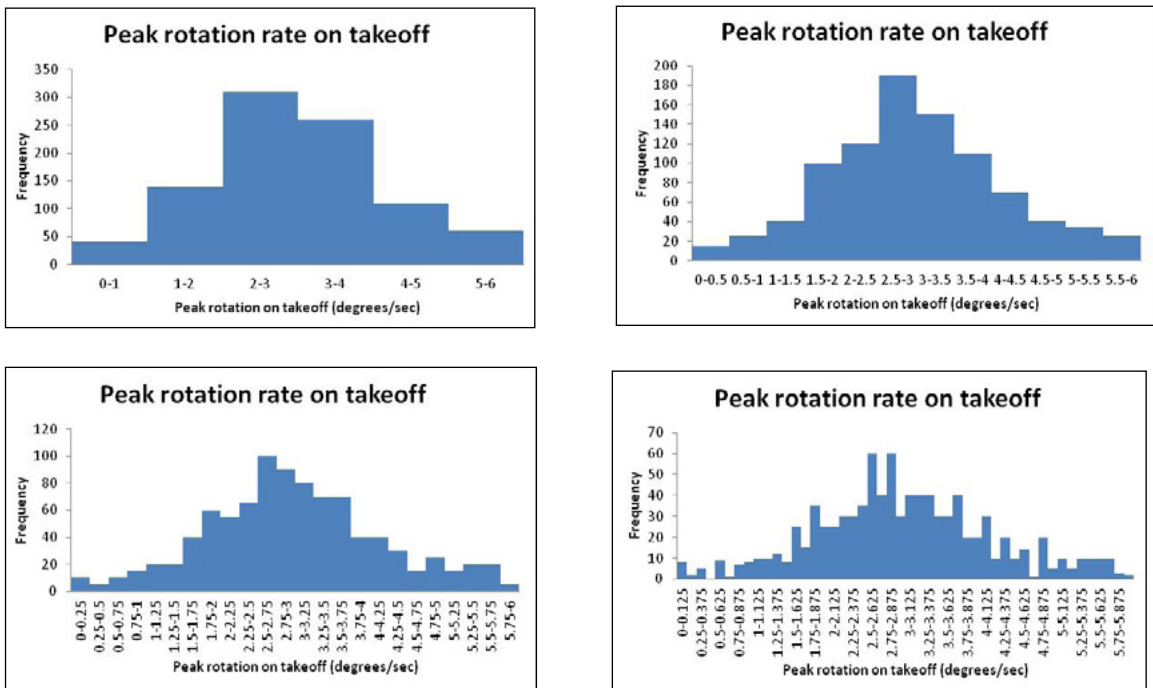
Histograms

9.7 Drawing a histogram is also a good starting point to identify how the data is distributed over a range and will often show up any unusual characteristics that should be investigated further. Consider asking the following questions:

- Does the distribution have a bell shape, in which case can it be approximated to what is called a Normal Distribution?
- Are there multiple peaks in the data? What could this represent?
- Is the data pushed up to one side of the range? This is said to be **Skewed** in some way.
- Are there noticeable outliers? That is data points or groups of data points that do not seem to fit with the rest of the distribution. These are of particular interest in FDM analysis as these may represent a different set of circumstances e.g. one particular airfield.

9.8 Answering these questions will often guide what statistical methods, such as those introduced in the rest of this document, could be used to describe or explain these features.

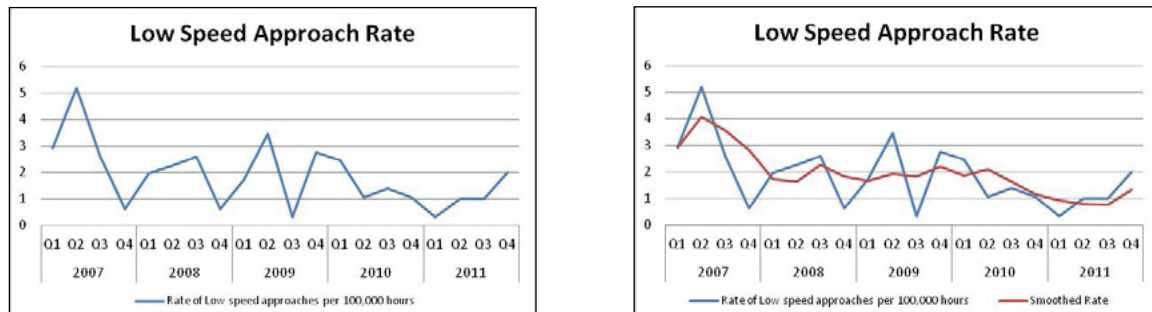
Figure 5: Example of histograms based on the same data set



- 9.9 An additional consideration when plotting a histogram is the width of the class groups, or in other words how many bars to choose within the graph. Too few will mask characteristics, too many will distort the picture, particularly with smaller data sets. This is illustrated in the increasing number of bars in figure 5 all of which are based on the same data set.

Time Series graphs

Figure 6: Example of Time Series line graph and the same example with a moving average (in red)



- 9.10 Typically time series graphs can be used to identify:
- Trends over time
 - Fluctuations over a fixed period: e.g. a year (seasonal effects)
 - Extreme fluctuations: for example exceptionally high rates in one month due to extreme weather
- 9.11 Reasons for fluctuations or extreme events will need further investigation however, as can be seen in the above, spiking, or noise in variable data can potentially mask underlying patterns. Applying a moving average to this data can help reduce this effect without removing the underlying trend. The second graph above shows an example of how this can be achieved. There is an additional smoothed line representing the average of the current quarter and the two previous quarters.

- 9.12 The more periods an average is taken over the smoother the line becomes, too many and the trend may disappear altogether. A centred moving average takes the number of events over a period of time, and averages it over a number of periods symmetrically around each data point. The moving average method used will be based on an analyst's judgment and considered on a case by case basis.

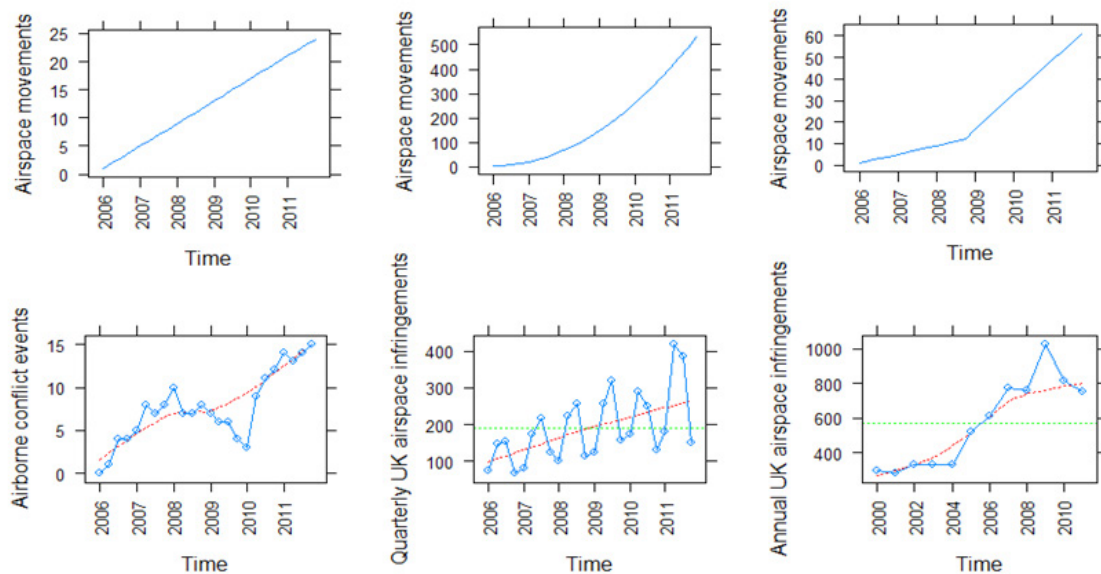
Trend Analysis

- 9.13 A general course or prevailing tendency, known as a trend can be estimated by either:
- Visually identifying a pattern;
 - Fitting a moving average as described above; or
 - Using a statistical method called **regression**, using techniques such as **ordinary least squares**¹ to fit a trend line (**Line of best fit**)
- 9.14 There are two different kinds of trend in a time series – **additive** and **multiplicative**. An additive trend assumes that the trend grows in a **linear** fashion with the level of variability in the time series remaining a constant size irrespective of the time of year; for example increasing by five events a month. A multiplicative trend assumes that the variations about the trend are the same proportionate size of the trend irrespective of the time of year; for example increasing by 5% each month. Examples of this are shown below in figure 7.
- 9.15 There is no specific reason to select a particular time period over which to estimate a trend, time periods should be selected on a case by case basis and left up to each analyst's best judgment. In the context of aviation safety monitoring, in most cases the trend should be present for at least 8 quarters (or selected time periods) to improve the reliability of the estimation of the trend. (i.e. the estimate did not arise due to chance).

¹ Ordinary least squares is a method that fits a line to data by minimising the distance between the fitted line and every data point in the sample. Further details are beyond the scope of this document.

- 9.16 Some examples of trends are presented below in Figure 7. These can be summarized as follows:
- **Top left:** is an example of an additive trend;
 - **Top middle:** is an example of a multiplicative trend;
 - **Top right:** is an example of trend with a structural break occurring in the year 2009;
 - **Bottom left:** is an example of a trend fitted using a locally weighted regression²;
 - **Bottom middle:** is an example of a seasonal time series with a linear trend fitted;
 - **Bottom right:** is a further example of a trend fitted using a locally weighted regression.

Figure 7: Fitted trends to time series data



² Locally weighted regression is a technique which is less sensitive to outlying data points as it only considers data over a limited range in the vicinity of the chosen value.

Other trend analysis considerations

9.17 Other issues which can influence trend analysis when fitting a line of best fit include the influence of outliers on the calculation of the trend and fitting a straight line to data that is not linear in nature. This is illustrated in the following scatter plots:

Figure 8: Valid trend fitted

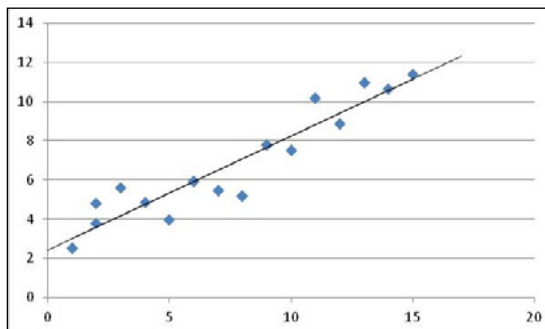


Figure 9: Linear trend line fitted to data which is not linear

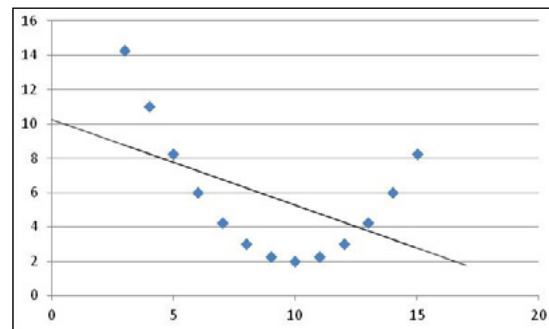


Figure 10: Fitted line is heavily fitted influenced by single outlier

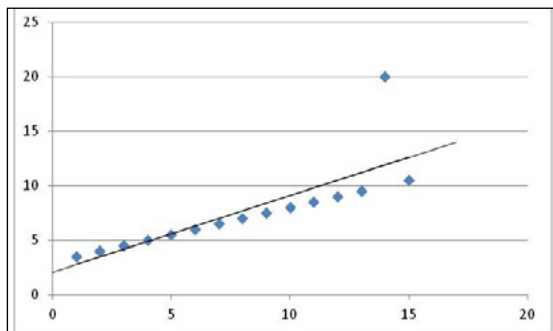
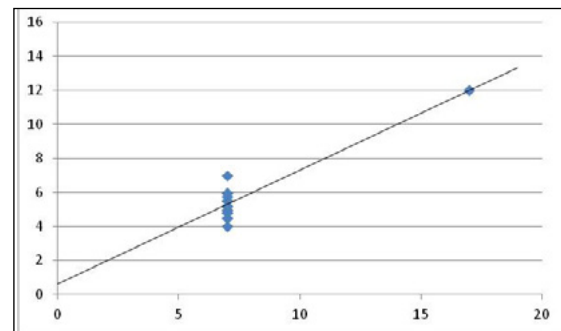


Figure 11: Upward slope of line only exists because of the presence of single outlier



9.18 Detecting outliers is therefore an important task before undertaking trend analysis. This can be done by a visual check for unusual observations or through the use of box-plots or scatter-plots.

9.19 Methods for testing whether fitted lines are statistically significant by means of analysis, rather than just visually, are available but are beyond the scope of this document.

Probability

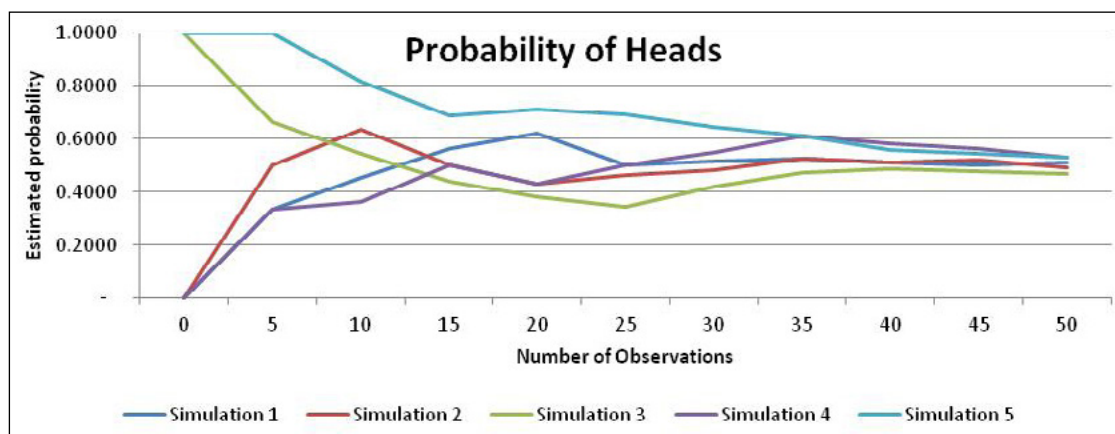
9.20 The probability of an event is a measure of how likely that the event will occur. An estimate of the probability can be obtained from a sample of data collected, for example:

$$\text{Probability of an individual pilot making a hard landing} \\ = \frac{\text{Number of observed hard landings made by Individual}}{\text{Total number of observed landings made by Individual}}$$

9.21 As the sample size increases, intuitively the accuracy of the estimate of the probability of the event for the whole population will improve and converge on the true **population** probability. This is called the **law of large numbers**. In practice this relates the sensitivity of the estimates of a **parameter** (in this case the probability of an individual making a hard landing) to the **sample size** used to estimate that parameter (in this case the total number of observed landings made by an individual). Smaller sample sizes will not give a reliable accurate estimate of the parameter under investigation. So for the example above, increasing the number of total observed landings made by an individual will achieve a better estimate of the probability of a hard landing for the entire population.

9.22 Figure 12 illustrates the law of large numbers by showing how an increasing sample size (number of observations) used to estimate a probability will converge to a single population probability, in this case the probability of getting a 'heads' from flipping a coin:

Figure 12: Shows how the observed probability of achieving a 'heads' converges to the true population probability (approximately 0.5) by increasing the number of observations within a simulation.



Quantity of data versus correct grouping of data

- 9.23 The term **Homogeneous** in statistics refers to the assumption that the properties of one part of a data set are the same as another part of the same data set. For example assuming the probability of a serious incident is the same across an entire fleet, entire pilot workforce or at all destinations. Making this assumption about data which in reality is not homogeneous can lead an analyst to make incorrect inferences from such data.
- 9.24 For example observing that there has been a slight increase in hard landings across all FDM data collected could lead to the interpretation that pilot skills are deteriorating; whereas in fact the actual explanation could be this is only the case on one type of aircraft or one particular group of pilots; perhaps those that have just converted onto the type.
- 9.25 However there is a payoff to be considered. Splitting the data into too many groups could reduce the data in each **bucket** to such an amount that render the statistics calculated from that data not reflective of the population of each group.

Distributions

- 9.26 A probability distribution is a table or an equation that links each outcome of a statistical experiment with its probability of occurrence. It can be useful to fit data output from an FDM project to a specific type of statistical distribution to help make predictions about the entire population, in particular at the extremes. Some of the commonly used distributions are the **Binomial Distribution**, the **Poisson Distribution** and the **Normal Distribution**. These are described in the table below:

Type of Distribution	Brief Description	Distribution Function Formula/Probability Density Function	Applications of fitting specified distribution
Binomial	<p>The Binomial distribution is a discrete distribution with two possible outcomes, often referred to as success or failure over n independent trials. Where the probability of success = p and the probability of failure is = $1-p$</p>	<p>$P(X = k) = \binom{n}{k} p^k (1 - p)^{n-k}$</p> <p>$k$ – is a whole number value random variable X can take between 0 and n</p> <p>$P(X=k)$ – is the probability that random variable $X = k$</p>	<p>1. Estimating the number of successes that will occur in a given number of trials. For example estimating the number of sectors a first officer will fly in a given number of trips</p>
Poisson	<p>A Poisson distribution is another type of discrete probability distribution that expresses the probability of a given number of events occurring in a fixed unit of time/ space.</p> <p>These events occur with a known average rate and independently of each other, in other words they occur at random</p>	<p>$P(X = k) = \frac{\lambda^k e^{-\lambda}}{k!}$</p> <p>$k$ – is a whole number value random variable X can take between 0 and n</p> <p>$P(X=k)$ – is the probability that random variable $X = k$</p> <p>e - A constant equal to approximately 2.71828 (e is the base of the natural logarithm system).</p>	<p>1. Estimating the number of events that will occur in a given space or time. For example estimating the number of TCAS events likely to occur a week</p> <p>2. Checking whether an event is occurring at random. (Either across time period, a fleet, a group of pilots etc.)</p>

Type of Distribution	Brief Description	Distribution Function Formula/Probability Density Function	Applications of fitting specified distribution
Normal	A normal distribution is a continuous probability distribution that is completely defined by the mean and variance of the distribution, and is symmetrical around its peak value; the mean.	$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$ <p>x – Any value that random variable can take</p> <p>μ – mean of the distribution</p> <p>σ – variance of the distribution</p>	<p>1. Estimating the probability that an unknown future value of the random variable lies between 2 values.</p> <p>(More examples given in next section)</p>

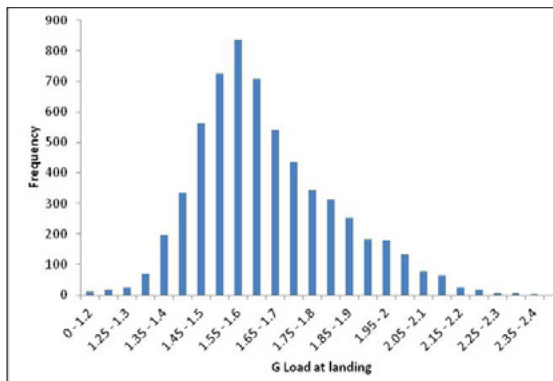
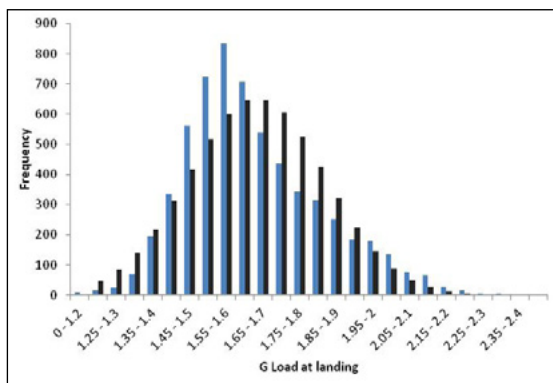
9.27 Further discussion of the Binomial and Poisson distribution is beyond the scope of this document.

Normal Distribution

9.28 The normal distribution is a very important distribution in statistics. It is often used to describe the probability shape for **continuous random variables**.

9.29 The way to recognise whether data can be approximated to the normal distribution is by identifying a 'bell shape' when plotting the histogram. This feature is more common than you might expect, and even if it is not instantly identifiable it may still be able to be treated as approximately normal.

9.30 After plotting a histogram for a set of data you may consider fitting a normal distribution. Consider the following example: Data for g load at touchdown is taken for around 3000 Captains and 3000 First Officers. The following graph shows a histogram of this data:

Figure 13: Histogram containing all sample data**Figure 14: Histogram containing all sample data and expected distribution (in black) values from fitted normal**

- 9.31 The blue bars in the histograms above show the actual observed data. By calculating and using the sample mean and the sample variance, we can fit a normal curve to the data. The histogram on the right shows the expected values in black for each group from the fitted normal. After fitting the normal distribution one should verify that the fit is appropriate. This can either be achieved visually or by using a statistical test as described below.
- 9.32 Visually we can see that that the data isn't quite symmetrical about the mean and the differences are significant between the observed values (blue) and the expected values (black), and this should lead the analyst to question the appropriateness of fitting a normal distribution to this particular data set. There are a number of statistical tests that you can use to test normality. A simple test is the Pearson's chi squared goodness of fit. Although this test is not without its limitations it can provide additional evidence to a visual interpretation. Other tests, which are mathematically intensive and beyond the scope of this document include the Anderson-Darling, and Shapiro-Wilk tests.

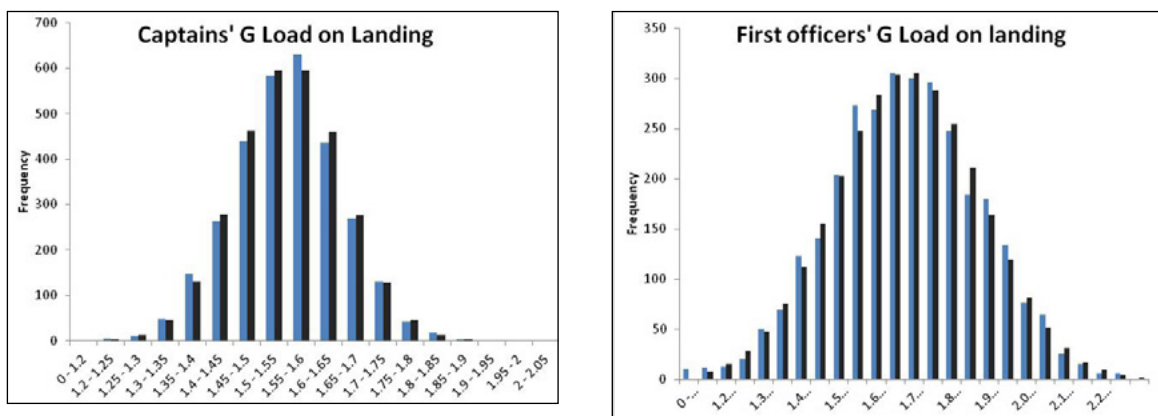
9.33 In general the chi square goodness of fit test compares the expected values from the fitted distribution with actual observed values, and tests whether the differences are statistically significant. If these differences are found to be significant the fitted distribution should be rejected. In the G-load and Landing example above, running the test determined that fitting a normal to this data set was indeed inappropriate, confirming the visual assessment.

9.34 We should now consider why this data is not normally distributed. It may just be that landing g is not normally distributed, or maybe it is because the distribution seen is made up of more than one normally distributed variable. In the latter case we should consider splitting the data into more homogenous groups. Given, say, we have data already split for captains and first officers this seems like a suitable place to start. Splitting the data in this way also leaves enough data in each group (around 3000 samples in each) to obtain the following sample statistics from this data:

	Sample mean	Sample variance
Captains' Landings	1.55	0.010
First Officers' Landings	1.75	0.039

9.35 This allows us to fit normal curves to the data, again the blue bars are the actual data and the black bars are those expected from the fitted normal distributions:

Figure 15: Histograms and expected respective values from normal, for captains and first officers.



- 9.36 On visual inspection the expected values from the fitted normal appear to fit the data in the histograms much better than they did in the histogram that combined both captains and first officers; indeed by using the chi square goodness of fit test this can be verified for both.
- 9.37 Once a normal curve has been fitted and accepted this distribution can then be used to make predictions about either:
- The rest of the population which has not been measured, or
 - Future events

Calculating data that will fall between certain values

- 9.38 Probabilities for any normal distribution can be calculated by transforming the normal distribution into the standard normal distribution for which there are published probability tables. The **standard normal distribution** is one with a mean of 0 and a variance of 1. Given the characteristic shape of the normal distribution, only a simple transformation is required to achieve standard normal values (or **z values**) from the values obtained from any normal distribution. The transformation is:

$$Z = \frac{X - \mu}{\sigma}$$

Where:

X is the random variable for which a normal has been fitted

μ is the population mean of the random variable

σ is the standard deviation of the random variable

Z is the standard normal random variable

Once z values have been calculated, the standard normal lookup tables can be used to find their associated probabilities.

Assigning values to trigger low probability events

9.39 Another use of the fitted normal distribution is to calculate trigger points for extreme events. This can help identify safety issues from FDM as they arise. Again probabilities corresponding to extreme events can be looked up in the standard normal tables and then z values can be transformed into values from the normal distribution concerned. For example having fit the normal distribution to g load at landing for first officers above, we could find the g load for a heavy landing corresponding to a 1 in 2000 event:

1. A 1 in 2000 event corresponds to a probability of 0.05%
2. In a standard normal table 0.05% corresponds to a z value of 3.291
3. Using the sample mean and sample variance of 1.75 and 0.039, and using the transformation formula above, this equates into 2.38 g
4. Therefore in this case an alert level could be set up at 2.38g

Hypothesis testing

Introduction

9.40 A **statistical hypothesis** is an assumption about a population parameter. This assumption may or may not be true. **Hypothesis testing** refers to the formal procedures used by statisticians to accept or reject statistical hypotheses based on whether they are statistically **significant**.

Examples of FDM Statistical hypotheses (for illustration purposes only)

- There is a significant upward trend in the number of low speed approaches experienced
- Ex-military pilots are performing significantly better than direct entry pilots
- Aircraft type A is significantly more likely to be involved in an incident than Aircraft type B
- TCAS events over time are not random

Step 1: State the hypothesis & set up the hypothesis test

9.41 The initial part of a hypothesis test is to decide, or state the statistical hypothesis. This should be done in a very prescriptive way by defining your theory, which is known as the **Null hypothesis (H0)** and the opposite theory, or **Alternative hypothesis (H1)**. Consider the following two samples:

Sample A: Existing 737 pilots performing over rotations

Sample B: Converted 757 pilots performing over rotations

An example of a corresponding hypothesis could be:

H0: Sample A and Sample B are from the same underlying population:

H1: Sample A and Sample B come from different underlying populations:

9.42 If your theory (H1) says the test statistics of one sample is less than the other or that it is greater than the other, we are only checking one side of distribution of the test statistic and this said to be a one tailed test. However, if H1 merely says that the test statistics are different then we need to check both sides of the distribution and it would therefore be two tailed. The above example should therefore be a two tailed test.

9.43 The next step is to decide with what level of certainty you wish to know the answer and this is known as the significance level. You will often see a level of 5% chosen however, this can be as high as 10% or as low as 1% and beyond. This is the level to which you are going to test your hypothesis and is the probability that you could reject a null hypothesis when it is in fact true (therefore we want it to be small).

9.44 As well as the error of rejecting a null hypothesis when it is in fact true (known as a **Type I error**) there is also the risk that you will accept a hypothesis when it is in fact false (known as a **Type II error**). The probability of the latter is based on a number of factors, including the test statistics chosen, and is called the power of the test.

9.45 These two types of errors should be understood before commencing a hypothesis test. Further details are beyond the scope of this document however this may be looked up under the terms of Type I and Type II errors of hypothesis testing.

- 9.46 Finally, as part of the set up we need to ensure that the test statistic chosen is appropriate for the type of hypothesis test. Whether it be a:
- z statistic** – Example: Can be used when testing for a difference between the means of two populations. This should only be used when sample size (n) is large - specifically when $n \geq 30$
- t statistic** – Example: Again this can be used when testing for a difference between the means of two populations, this can be used when n is small
- chi square statistic** – Example: Can be used for a goodness of fit test see previous section
- F test** – Example: Can be used to test if a regression model fits data well – this is beyond scope of this document.

Step 2: Analyse sample data and calculate test statistics

- 9.47 Once the relevant data has been collected, calculate the chosen test statistic value based on the sample data.
- 9.48 Calculate the probability of the test statistics taking this extreme value (p values) using the relevant published tables for that test statistic and compare the p value to significance level α . Remember if it is a two tailed test the p values need to be added together for both tails (both extremities).

Step 3: Interpret the result

- 9.49 Reject Null hypothesis H_0 if p -value is less than significance level α .
- 9.50 Do not reject Null Hypothesis H_0 if p value is greater than or equal to significance level α .
- 9.51 State clearly the conclusion you make from the above statistical test and then consider how this is relevant from an FDM point of view.

Hypothesis Test Example

Testing for a difference between two populations Z test

- 9.52 A hypothesis test can be used to see whether two populations have the same statistical characteristics. Consider the following scenario: "A company has recently consolidated its fleet by retiring its 757s, a group of pilots have moved from the 757 to the 737. There has been a slight increase in the number of high pitch take off events." The FDM question here would be: Is this related to the crew change or is this just a general change in rotation technique?
- 9.53 The following shows how we test this FDM question using hypothesis testing.
- Sample A – Sample of existing 737 pilots performing over rotations
- Sample B – Sample of converted 737 pilots performing over rotations
- 9.54 In this example we are testing to see whether the populations have different characteristics by comparing their mean values:

Set Up

Null hypothesis: The population means of both groups of pilots are the same

$$H_0: \mu_A = \mu_B$$

Alternative hypothesis: The population means of both groups are different

$$H_1: \mu_A \neq \mu_B$$

Chosen significance level (α): 5%

- 9.55 **This is a two tailed test** as we have a large sample (300 each in sample A and B) we have opted to use the **z statistic**. (For small samples where we do not have confidence that the sample standard deviation of a group of data is very close to the true population standard deviation we would use a **t statistic**)

Analysis and Calculations

	Sample A	Sample B
Sample Mean: \bar{x}	2.8	3.1
Sample Standard Deviation: sd	1.5	1.5
Number in sample: n	300	300

$$z \text{ statistic} = \frac{\bar{x}_A - \bar{x}_B}{\sqrt{\frac{sd_A^2}{n_A} + \frac{sd_B^2}{n_B}}} \quad \text{giving } z = 2.4495$$

Where:

\bar{x} - is the sample mean for each sample

sd - is the sample standard deviation of each sample

n - is the number in each sample

Now to calculate the probabilities based on this p value for both of the two tails:

$$P(z < -2.4495) + P(z > 2.4495) = 0.014 < \text{chosen significance level } \alpha \text{ of } 5\%$$

Interpretation

- 9.56 As the p value (0.014) is less than significance level α (0.05) we cannot accept the null hypothesis. We can say with confidence that group A and group B are drawn from different populations. This is because the recently converted pilots have a statistically **significant** higher rate of rotation than the existing 737 pilots. On average the rate of rotation is 0.3 degrees per second higher for the converted pilots.
- 9.57 The test has shown that this 0.3 degrees per second is statistically significant, however ignoring the results of the statistical test, judgement needs to be applied to work out whether this is practically significant. Does this make a difference in reality with respect to safety or operationally?

Other applications of this example of hypothesis testing

- 9.58 Another application of this test would be to consider whether the mean is changing over time, and therefore whether using a historic mean is valid to draw conclusions about the statistical significance of an event. This could be achieved by splitting data by time period and then testing the difference between the means of the different time periods. However, as discussed previously one must be careful that there remains enough data in each time period to ensure that tests remain valid.

Glossary

Alternative hypothesis (H1): The hypothesis that observation occurred due to a non random phenomenon

Central limit theorem: The central limit theorem states that as a sample size gets large enough the sampling distribution of sample statistics can be approximated by a normal distribution.

Continuous Random Variables: If the variable can take any value between its minimum and maximum value than it is continuous, otherwise it is a Discrete Random Variable.

Degrees of Freedom: The number of degrees of freedom refers to the number of observations in a sample minus the number of parameters that have been estimated from the sample data.

Discrete random variable: See Continuous Random Variable

Interquartile range: Shows the range of the middle 50% of the data. It can be used to identify outliers and show how the data is shaped about the mean. This can be particularly useful when used in conjunction with a box plot which can show the range, interquartile range, median and mean as one simple visual representation. The interquartile range is defined as $Q3 - Q1$. Where $Q1$ and $Q3$ are Quartile 1 and 3 respectively.

Linear: When something has the form of a straight line

Mean: The mean is the average score of a defined group (population mean) or a sample (sample mean). Sample mean is often denoted by \bar{x} and defined as:

$$\bar{x} = \frac{\sum_{i=0}^n x_i}{n}$$

Where: x_i is each data point in the sample

n is the total number in the sample

Median: The median is the middle value or the 50th percentile. If one were to line up all the observed data in a row according to size, the middle value is the median. This measure can be useful to determine when data is skewed. This can be identified particularly when the median value is significantly different to the mean value.

Nominal Variable: Categorical with no discernible order

Null hypothesis (H0): The hypothesis that the observation made within a sample occurred due to a purely random chance.

Ordinal Variable: Categorical but can be ordered in some way

Parameter: Is a measurable characteristic of a population. For example the mean or standard deviation

Population: Refers to the total set of observations that can be made. For example all the flights made in the UK every year.

Probability Distribution: A probability distribution assigns a probability to each possible outcome of a random experiment.

Quartiles: Quartiles divide the data into four equal amounts of observations. When arranging the data in order of increasing size the value at the first quarter is the first quartile Q1, the value at the second quarter is the second quartile Q2 (also known as the Median), and the value at the third quarter is the third quartile Q3.

Range: The difference between the highest and the lowest value observed. This has an obvious drawback when used to measure the spread of data because it is sensitive to outliers and therefore nothing can really be said about the data between the two most extreme points.

Regression: Is a statistical technique used to estimate the relationships between variables and in turn allow us to make predictions about one variable from values of another.

Sample: The part of the population that is selected for analysis. For example the proportion of the aircraft in the A320 series equipped with FDM

Significant: Significant in statistics means something cannot reasonably be explained as being due to chance alone.

Skewness: Skewness of data refers to the shape of data about the mean when it is not symmetrical. When there are more observations to the left/right of the range the distribution is said to be skewed left/right.

Standard deviation: Standard deviation measures the variability of a group of data – The higher the standard deviation the more variable the data is about the mean. Sample standard deviation is defined by the following formula:

$$s.d. = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (x_i - \bar{x})^2}$$

Where:

\bar{x} - is the sample mean

x_i - is each data point in the sample

n - is the total number in the sample

Standard Normal distribution: A standard normal is a special case of the normal distribution with a mean of 0 and standard deviation of 1. There are published probability tables available for the standard normal distribution. Every normal distribution can be transformed into the standard normal distribution via the following equation:

$$Z \text{ Value} = Z = \frac{X - \mu}{\sigma}$$

Statistic: A numerical measure that describes a characteristic of the sample. For example the proportion of landings which were hard

Variable: A characteristic of an item that can vary from one item to another.

Variance: Variance is a measure of how widely data observations in a group vary. If observations vary greatly from the mean then the variance is big. The sample variance is equal to the standard deviation squared.

Z Value: A z value indicates how many standard deviations an element is from the mean. A value greater than 0 represents that the element is above the mean and a value less than 0 represents that it is below the mean.

CHAPTER 10

FDM in Small Fleets and Business Aviation

Introduction

- 10.1 This chapter deals with the use of FDM in small operators with fleets of say less than ten aircraft and also business aviation companies who generally have a small fleet, although some do have large and varied fleets.

FDM in a Small Fleet

- 10.2 As with other aspects of Operational Safety there are issues with the applicability of large Operator type systems into a smaller company with, say, only a few aircraft or a mixed fleet of different types. The FDM requirements relate to aircraft MTOW and must be implemented in all companies with AOCs irrespective of the scale of their Operation.

Small Operators will need to consider:-

Obtaining sufficient technical expertise to implement an FDM data system.

- 10.3 A smaller Operator may not have access to technical expertise to implement an FDM data system. FDM system suppliers are normally experienced in a wide range of applications and so, bearing in mind their commercial interest, their advice could be sought. However, a basic knowledge of the principles and application of FDM is essential to ensure an appropriate system is implemented. This may be obtained by relevant training or through contacts with established FDM Operators. It is important to understand that the operator retains ultimate responsibility for their FDM programme.

Dealing with a mixed fleet of “one-off” aircraft rather than a standardised fleet.

- 10.4 Many smaller Operators have a mixed fleet obtained from various sources. As such their FDR, data acquisition and hence FDM specifications may be very airframe specific. Obtaining data frame specifications from aircraft manufactures can be very difficult and costly.

Getting the most from a limited number of flights.

- 10.5 In terms of data analysis it is recommended that Operators with a small number of flights should consider pooling FDM with other similar Operators to assess their flying against that of their peer group and also to obtain a more representative picture. This may be accomplished through an FDM replay and analysis service provider or by an independent organisation set up by a group of Operators.

Contracting out the routine acquisition and initial analysis of FDM data.

- 10.6 A smaller scale operation, of say less than ten aircraft, may find that it is commercially more appropriate to contract out analysis to a third party service provider rather than provide resources within the company. However, in this case the Operator must acquire sufficient skills and resources to fully understand the information produced by the service provider. This expertise must be able to formulate, direct and review actions taken to address issues presented by the FDM data. It is important to understand and fully document how responsibilities are split between contractor and Operator rather than assuming all aspects are covered. This is especially important to know as the Operator's accountable manager is responsible for ensuring their company is fully compliant.

Ensuring the confidentiality/protection of crew related data from a small, often non-unionised workforce.

- 10.7 Whereas large Operators are able to maintain confidentiality and anonymity through appropriate information security and control this is difficult for small Operators having few, or even just one, aircraft with a limited number of crews. With a small number of flights, identification is relatively easy, even with dates and other information removed. Hence, in this situation it is more critical than ever that there are formal agreements in place on the conditions of use and sensitivity of FDM information.

FDM in Business Aviation

- 10.8 Most Business Aviation Operators have smaller fleets and so the advice given previously for small operators will apply. Business Aviation includes many complex, high performance aircraft some of which are above the 27 tonnes MTOW threshold which requires FDM for those Business Aviation Operators who have an AOC.

- 10.9 Additionally, the UK CAA actively encourages the Operations of smaller business aircraft to be monitored by an FDM programme, not only to meet the ICAO Recommendation for aircraft over 20 tonnes MTOW but also for smaller aircraft equipped with flight data recorders. This approach is strongly supported by industry as a means to improve safety by detecting and investigating unsafe practices or situations leading to more effective training programmes and standardised operating procedures. By constructive and positive FDM based monitoring of compliance, flight crew performance will be improved and assured.

Challenges of Business Aviation

- 10.10 Such operations are often more challenging than normal Airline operations because of:-

Many “one off” sectors/airfields including positioning flights.

- 10.11 Business aviation has to deal with the unfamiliarity aspects through a proactive risk assessment and planning process that larger operators only have to go through upon the introduction of a new route or at the change from summer to winter schedules. By clustering FDM data from similar airfields, a generic assessment of the issues to be considered at a particular site may be built into planning and crew briefs. Although it should be noted that because of the very unpredictable nature of these operations, crews may become very skilled at handling the variability, this aspect still needs to be carefully monitored.
- 10.12 Statistically, positioning flights have proved to be of the order of 6 to 7 times more likely to result in an airline accident than a passenger flight. The airline industry has responded by declaring that these operations must be flown to the same SOPs as those with passengers aboard. This can be assured through FDM monitoring.

More operations into non-ILS equipped, remote, secondary airfields.

- 10.13 Again, issues arising from flying into non-ILS equipped airfields have traditionally been more likely than at standard, ILS equipped major airfields. FDM data has shown that approaches are more likely to be unstable when flying non-precision approaches than precision ones and so this aspect needs to be monitored and taken into account in training.

- 10.14 The business aviation operator can learn from hundreds of operations from a particular airfield but should also be able to compare the performance at one airfield with a “standard” operation to an airfield of that type. This is particularly important when flights to certain airfields may be infrequent. As a general rule each operation should be measured using a standard operator event set, unless totally inappropriate, so that a relative risk rating can be generated for each airfield.

Distributed small bases encouraging “local practices”.

- 10.15 Where a small group of crews and aircraft are located at an independent base there is a tendency for local practices to develop over time. Where these affect parameters monitored by FDM, for example unstabilised approaches, hard landing or altitude busts, then these instances can be followed up to correct the “operational drift” back to SOPs. In general, FDM provides the operator with greater intelligence and oversight capability on the adherence to SOPs as well as rationalisation of existing practices.

Lack of standardisation of SOPs across types.

- 10.16 Large public transport operators are increasingly standardising SOPs across their whole operation. This should be encouraged, as far as practicable, within a mixed business aviation fleet, especially when crews may be qualified on more than one type. The aspect of using FDM to provide assurance on standardisation also follows on to oversight of practices and performance during training flights.
- 10.17 Similarly the FDM event triggers should be standardised wherever possible so as to facilitate like with like comparisons. For example bank angle events, rates of descent on the approach and approach stabilisation criteria. These criteria need to account for the high performance and sometimes complex characteristics of certain business jet types, which are not always accounted for in the operational environment.

Extended tours away from the normal base of operations.

- 10.18 Typically during such tours, there are difficulties in returning data to the analysis base. Use of modern wireless and data transfer technologies facilitate the access to FDM data from more remote destinations and provide the operator with insight in a timelier manner. Due to limited facilities at such destinations, there are more responsibilities on crews than a typical airline crew. Therefore the likely higher workloads on pilots when away from base and sometimes unusual scheduling need to be considered in operators' SMS. As such FDM data provides insight into pilot performance, which other traditional information sources cannot provide, during these more challenging circumstances and evidence for any changes that may need to be made.

CHAPTER 11

Helicopter Flight Data Monitoring (HFDM)

Introduction

- 11.1 This chapter deals with the use of FDM in helicopter operations. This has proved to be especially useful on large public transport helicopters in the challenging offshore oil and gas support environment. Development has been actively promoted by the UK CAA and the Industry, as is briefly described below. For a fuller description of the work please refer to the two CAA Papers dealing with the Helicopter Operations Monitoring Programme (HOMP) trial. The reports provide a full account of the trials and also a comprehensive overview of the application of FDM to Helicopter Operations.
- CAA PAPER 2002/02: Final Report on the Helicopter Operations Monitoring Programme (HOMP) Trial
 - CAA PAPER 2004/12: Final Report on the Follow-on Activities to the HOMP Trial
- 11.2 It is important to note that the principles of FDM described elsewhere in this document are fully applicable to helicopter operations. However, the technical and operating environments offer a number of challenges that would need to be addressed to produce an effective FDM programme. These are also discussed in the CAA Papers.

UK Helicopter FDM Research and Development

- 11.3 Two trials, both jointly funded by the UK CAA and Industry, have demonstrated the routine downloading and pro-active analysis of helicopter flight data. The first trial focused on five FDR equipped Eurocopter AS332L Super Puma helicopters from one North Sea operator. Comprehensive sets of flight data events and measurements were developed and implemented to monitor the operation and an effective safety capability was demonstrated. The second trial applied the scheme to Super Puma helicopters at a second North Sea operator, and also extended coverage at the original operator to a different helicopter type, the Sikorsky S76.

- 11.4 During the first trial, significant safety issues were identified and the operator was able to take action to address them. The operator successfully implemented a closed-loop process for following up significant events, taking appropriate actions, and then monitoring the effectiveness of these actions. Aircrew responded positively to the programme and were receptive to the feedback provided. The large amount of new information produced by the trial enabled operational risks to be more accurately assessed and monitored.
- 11.5 The results obtained clearly demonstrated that HFDM can bring about improvements in flying practice, training, operating procedures and coping with the operational environment. The CAA considers that the trial successfully demonstrated real safety benefits. A measure of its success is that the UK Industry voluntarily elected to fully implement HFDM across all its North Sea helicopter operations in advance of any regulatory action.
- 11.6 In the second trial, the S76 HFDM system identified some different operational issues on the S76 to those found on the Super Puma. It illustrated how HFDM capabilities can be negatively impacted by the lack of some key FDR parameters, most notably GPS data and, to a lesser extent, tri-axial accelerometer data (i.e. lateral and longitudinal accelerations in addition to the existing normal acceleration). On this helicopter type it was a relatively straightforward task to add the missing parameters and the programme benefited significantly from the addition of the GPS data.
- 11.7 New events were developed for the Super Puma as a result of pilot-reported occurrences. Analysis of the measurements obtained from every flight showed how these can be used for the investigation of particular operational issues. Development work on 'mapping of the helideck environment' illustrated how HFDM measurements can be used to characterise problems of both structure-induced turbulence and hot turbine exhaust plumes on offshore platforms, providing data to support existing processes.
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International Requirements

- 11.8 Unlike the fixed wing ICAO Standard for FDM or Flight Data Analysis (FDA), the helicopter FDM specification is covered by a Recommendation. This is shown below and this covers all helicopters with “a certified take-off mass in excess of 7,000kg or having a passenger seating configuration of more than 9 and fitted with a flight data recorder”.

ICAO ANNEX 6 – Operation of Aircraft, Part III- International Operations Helicopters SECTION II. INTERNATIONAL COMMERCIAL AIR TRANSPORT

1.3 Safety management

1.3.5 Recommendation.— An operator of a helicopter of a certified take-off mass in excess of 7 000kg or having a passenger seating configuration of more than 9 and fitted with a flight data recorder should establish and maintain a flight data analysis programme as part of its safety management system.

Note.— An operator may contract the operation of a flight data analysis programme to another party while retaining overall responsibility for the maintenance of such a programme.

1.3.6 A flight data analysis programme shall be non-punitive and contain adequate safeguards to protect the source(s) of the data.

Note 1.— Guidance on flight data analysis programmes is contained in the Safety Management Manual (SMM) (Doc 9859).

Note 2.— Legal guidance for the protection of information from safety data collection and processing systems is contained in Annex 13, Attachment E.

Helicopter FDM Events and Measurements

- 11.9 Due to the characteristics of helicopter flight dynamics and operating techniques, helicopter FDM events are generally more complex than fixed wing equivalents. This is combined with an often limited number of available parameters and needs care in the development of events and measures based upon a sound knowledge of the helicopter environment.
- 11.10 As a result of the greater operational flexibility of helicopters and the greater variability in the nature of helicopter operations, 'normality' is harder to define. In order to ensure that notable events are not missed, however, it was found during the HOMP trials to be necessary to resist the temptation to relax event limits. This resulted in a relatively large number of 'nuisance' events (approximately 90%), but this did not cause a workload problem as the overall number of events was small and it was found that 'nuisance' events could be quickly and easily identified.
- 11.11 Typical lists of HFDM events and all flight measurements are shown in **Appendix C**. These are reproduced from CAA Paper 2002/02 and were constructed from first principles starting with an analysis of helicopter fatal and serious accidents/incidents (see CAA Paper 97005).
- 11.12 A similar event and measurement set may also be found in the Global HFDM Steering Group's Helicopter Flight Data Monitoring Industry Best Practice document (see www.hfdm.org).

Helicopter FDM Technology

- 11.13 The HOMP trial used a PCMCIA Card QAR system which proved to be very reliable despite the high vibration environment. Helicopter operators are accustomed to performing regular (daily) downloads for Health & Usage Monitoring System (HUMS) purposes and, during the trial, the HOMP and HUMS data were combined on a single PCMCIA Card recording device to improve efficiency.
- 11.14 On some helicopter types additional parameters may be needed to supplement the crash-protected flight recorder's limited dataframe. For example, in the case of the S76 used in the second HOMP trial, the non-mandatory GPS data (position, groundspeed and drift angle) and lateral and longitudinal accelerations were needed to enable the desired event set to be implemented. Without them, some 20% of the original event set would have been lost.

- 11.15 **Important Note:** In all the above technologies care should be taken to avoid excessive temporary memory buffering. There have been at least two cases where UK accident investigations have found that important QAR parameters were lost due to recording buffers of up to 120 seconds. The UK AAIB report states: "Although its primary purpose is not for accident investigation, data from HFDM and FDM programmes has frequently been used in accident investigations. Use of memory buffers in these systems is not unusual but can present limitations when data is recovered. There are currently no requirements for these systems to minimise the use of memory buffers, and advisory material for HFDM does not currently exist." **Therefore, the UK CAA recommends that "buffering of QAR data should be minimised, ideally to 10 seconds or less".**

CHAPTER 12

National FDM Forums

Introduction

12.1 The UK CAA's National FDM Forum, known as the UK FDM Operators Meeting, and hosted by the CAA, has been an active partnership with industry for over a decade. Although not directly prescribed in regulatory requirements, the presence of a National FDM Forum, if run properly, will provide a platform for open discussion between an NAA and its operators. For the past few years, this has enabled an exchange of 'lessons learnt' between operators and the CAA, with a mind to facilitate the improvement of aviation safety. However, in order to recreate this success, a number of aspects should be considered:-

Objectives

- 12.2 As with any meeting or working group, it is important for there to be objectives (updated as required), to define its purpose and drive the overall direction of the group. The UK FDM Operators Group has a number of safety related objectives that may directly involve either CAA or industry participants:
- Promote the use of FDM within the UK – The CAA directly engages with operators to promote best practice. The group was also used for consultation in publishing CAA guidance (CAP 739) on FDM.
 - Disseminate the lessons learnt by individual Operators – regular updates are given at meetings by operators on their experiences obtained through FDM. These often serve as valuable lessons to the other operators attending the meeting.
 - Provide Operators with a confidential online forum to raise any issues that concern them – the group gives operators the chance to liaise with the CAA and to raise and discuss any relevant issues with other operators.
 - The discovery of new issues – information provided by members of the group can highlight emerging issues.

- Feedback significant issues to the relevant specialists within the CAA – where appropriate the CAA representatives will take forward actions from the meeting to bring issues of significance to the attention of specialists who are in a position to give guidance or if necessary escalate the matter.
- Developing a practicable approach for the implementation of FDM Requirements in the light of UK experience – CAP 739 has been particularly useful in providing guidance on the implementation of an FDM programme and on ICAO standards and recommendations and regulations from EASA.

12.3 A wide variety of topics have been discussed over the past few years in line with these high level objectives. A lot of these are driven by the group's needs and current areas of interest. Some of the topics discussed include:

- Discussions on draft advisory material (initially)
- Operator FDM programmes
- Operator Statistical Analysis
- FDM equipment: FDRs, QARs, MMELs.....
- Regulatory processes/regulations (CAA)
- FDM software
- Outsourced FDM services
- Use of FDM with different aircraft manufacturers
- Use of FDM in foreign countries
- Data Protection and Confidentiality
- Union views on FDM (BALPA)

Meeting Operation

Frequency

- 12.4 To enable consistent discussion, feedback and follow-up, meetings should be held on a regular basis. In the UK's case, meetings are held every six months. This allows sufficient time to pass for operators to report on any developments or changes from meeting to meeting and facilitates the regular attendance of busy industry representatives and CAA staff.

Attendance

- 12.5 The primary audience for FDM based safety related discussions are operators. Thus the meeting is attended mainly by UK AOCs who are required to have FDM programmes. In addition, the CAA has also invited interested non-UK operators, who have large UK bases or operations, and third parties such as representatives from the RAF. The main reason for the inclusion of non-UK operators, aside from the lack of such groups in other countries, is that their presence facilitates greater learning and a wider perspective on the UK aviation environment.
- 12.6 The group has also greatly benefited from the membership and regular presence of representatives from the Air Accidents Investigation Branch (AAIB) and the British Airline Pilots Association (BALPA). The AAIB have been able to directly feed back their own findings through FDM from their investigatory work to CAA and industry; the attendance of BALPA representatives has been beneficial to both BALPA and operators since it has allowed both parties to interact and better understand each side's interests in an often complex and sensitive area.
- 12.7 On occasion the group have also included specially invited observers from other national authorities, industry (e.g. National Air Traffic Services - NATS) or international bodies such as IATA. Although not necessarily experts in FDM, all of these parties provide valuable insight into aviation safety from their individual perspectives. In turn both CAA and the operators have the chance to assist them in better understanding the strengths and potential of FDM.

Confidentiality

- 12.8 To build an atmosphere of trust among a large group and foster a good safety culture, there needs to be total confidence in the appropriate use of the sometimes sensitive information revealed by individuals. To this end, all new attendees of the FDM Operators' Group are required to sign a confidentiality agreement as shown below:

"We the undersigned agree to hold this meeting according to the Chatham House Rule as described below. That is:

This meeting is held under the Chatham House Rule, participants are free to use the information received, but neither the identity nor the affiliation of the speaker(s), nor that of any other participant may be revealed; nor may it be mentioned that the information was received at this meeting.

Where information is required to be passed outside the meeting this must be agreed, in advance, by a majority of those present and with the agreement of the information provider."

- 12.9 It is important to note that the CAA does not take ownership of an operator's risk or their responsibility to react appropriately to any safety issues discovered. The principles of a just culture still apply, therefore in the very rare event of a significant safety concern which is not being adequately addressed by an operator, the Authority retains its right to react and ensure safety standards. In practice the Authority would expect the operator's proactive Safety Management System to be covering the issue and standard oversight practices should ensure this.

Other Guidance on FDM Forums

- 12.10 The European Authorities coordination group on Flight Data Monitoring (EAFDM), of which the UK CAA is an active member, has produced a detailed guidance document on this topic called 'Guidance for National Aviation Authorities, Setting up a national Flight Data Monitoring forum'. It can be found on the EAFDM website, at the following link: <http://www.easa.europa.eu/safety-and-research/european-authorities-coordination-group-on-flight-data-monitoring-EAFDM.php>

CHAPTER 13

FDM use in Alternative Training & Qualification Programmes (ATQP)

Introduction

- 13.1 This chapter describes some of the considerations for FDM as an important component of an Alternative Training & Qualification Programme (ATQP). ATQP allows an operator to provide a more effective and more operator-specific recurrent training and checking package for its crews by utilising knowledge of their operation. For further detailed information about ATQP in the UK refer to CAA's Standards Doc 80 "Alternative Training and Qualification Programme Guidance to Industry".
- 13.2 For many years safety proactive operators have run additional training programmes over and above those legally specified in the requirements. It has been a feature of good safety programmes that real world experience has been used to develop training scenarios and initiatives to mitigate the risks to operators. FDM is one source of safety information that drives such programmes. For example a number of operators have learnt from FDM events that their crews have found visual approaches more challenging than the precision approaches that they had trained for in the simulator. Another example is the handling of go-arounds early in the approach when the aircraft are at low weight and there is an increased risk of an altitude bust due to the high rate of climb.

Comparing a Traditional Training Programme with an ATQP

- 13.3 A traditional programme contains fixed training and check items that are identical for all aircraft types and operators whereas in an ATQP training programme the syllabus is adjusted by the findings of a training needs analysis and is specific to each operator and fleet.

- 13.4 If properly justified, under an ATQP, the CAA may approve significant departures from traditional requirements. An ATQP may employ innovative training and qualification concepts, provided the applicant can demonstrate to the Authority that the resulting aircrew proficiency will meet or exceed the proficiency obtainable through a traditional programme. The Operator has to establish a safety case to provide justification and a rationale for the programme's structure and content.
- 13.5 An approved ATQP is a company and type specific alternative to traditional training. Ongoing data collection, including FDM, should be developed into a responsive programme that will adapt to an operator's changing requirements such as new equipment, new technology or a differing route structure. Focusing on specific needs of fleets and groups of pilots, targeted training can enhance performance while reducing costs in the long term.

European Guidance Material on FDM in ATQP

- 13.6 The following extract is taken from EASA's Acceptable Means of Compliance and Guidance Material which is at present being implemented throughout Europe through the COMMISSION REGULATION (EU) No 965/2012 of 5 October 2012. This Regulation will be in place by 28th October 2014.

European Aviation Safety Agency Acceptable Means of Compliance (AMC) and Guidance Material (GM) to Part-ORO.

AMC1 ORO.FC.A.245 Alternative training and qualification programme

(7) A data monitoring/analysis programme consisting of the following:

- (i) A flight data monitoring (FDM) programme as described in AMC1 ORO.AOC.130. Data collection should reach a minimum of 60 % of all relevant flights conducted by the operator before ATQP approval is granted. This proportion may be increased as determined by the competent authority.

(ii) An advanced FDM when an extension to the ATQP is requested: an advanced FDM programme is determined by the level of integration with other safety initiatives implemented by the operator, such as the operator's safety management system. The programme should include both systematic evaluations of data from an FDM programme and flight crew training events for the relevant crews. Data collection should reach a minimum of 80 % of all relevant flights and training conducted by the operator. This proportion may be varied as determined by the competent authority.

The purpose of an FDM or advanced FDM programme for ATQP is to enable the operator to:

- (A) provide data to support the programme's implementation and justify any changes to the ATQP;
- (B) establish operational and training objectives based upon an analysis of the operational environment; and
- (C) monitor the effectiveness of flight crew training and qualification.

(iii) Data gathering: the data analysis should be made available to the person responsible for ATQP within the organisation. The data gathered should:

- (A) include all fleets that are planned to be operated under the ATQP;
- (B) include all crews trained and qualified under the ATQP;
- (C) be established during the implementation phase of ATQP; and
- (D) continue throughout the life of the ATQP.

(iv) Data handling: the operator should establish a procedure to ensure the confidentiality of individual flight crew members, as described by AMC1 ORO.AOC.130.

(v) The operator that has a flight data monitoring programme prior to the proposed introduction of ATQP may use relevant data from other fleets not part of the proposed ATQP.

Maximising the Use of FDM in the Training Environment.

- 13.7 In the past the emphasis of FDM has been on the individual event or small groups of events rather than the wider ranging, statistical approach that ATQP uses. A combination of the statistical and individual approaches would maximise the training benefits available to the proactive Operator.
- 13.8 Generally events have not been attributable to individual pilots so a broad education campaign has had to be taken across the pilot workforce. However, a number of Operators have, with full non-punitive safeguards, been able to offer crews remedial briefing or training.
- 13.9 One operator has, for many years, been able to provide pilots with a summary of their own flights and events prior to their regular simulator visits. This gives the pilot the opportunity to ask for additional refresher training to address their weaknesses.
- 13.10 Another Operator also uses a statistical technique (Poisson distribution) to identify those individuals who “have more than their fair share of events” in a six month period. After analysis of an individual’s events an assessment is made about any potential remedial action – either de-briefing or training. The crew member is contacted by the crew union representative, who has the ability to decode their unique identity code, for a briefing. Note that these codes are not available to any airline managers. Finally, any training actions are recorded on the FDM follow-up file rather than on the individual’s training file, hence retaining confidentiality.

FDM to Support ATQP Implementation

- 13.11 The Operator is required to conduct a training needs study which requires the analysis of specific tasks to the aircraft type. These are subsequently validated by data and allow the identification of event-based assessment and skill-based training frequency of training events to be established. FDM data from a minimum of 60% of all relevant flights must be collected. While many traditional FDM events can help populate this analysis additional events may need to be developed to cover all identified risk areas. The analysis also requires the severity of these training events to be established and these, combined with FDM event rates and severity rates form the basis of the FDM input to ATQP.

FDM to Establish Training Objectives and Monitor Effectiveness

- 13.12 A baseline operational standard should be established prior to the start of ATQP by using a core set of relevant FDM events as a measure of pilot proficiency. Normally this is the result of an initial two year data collection period before ATQP training changes are approved by a competent authority.
- 13.13 The real world data provided by FDM is used to supplement the syllabus derived from the training needs analysis which takes a more theoretical approach to risk exposure. By establishing the normal range for FDM events numbers/rates the operator should set limits beyond which review or action is required. This provides training objectives and a monitoring process for maintaining and improving operational standards.

Develop a Skill-based Training Programme

- 13.14 The data monitoring / analysis programme should identify tasks where crew training is required. Training items should be prioritised and may subsequently form part of a Line Oriented Evaluation (LOE) event-based assessment to validate the training given.

Scope of FDM within ATQP

- 13.15 When, after the initial period of data collection from at least 60% of all relevant flights, an extension to the ATQP is requested, an "Advanced" FDM programme (defined by the degree of integration with other safety initiatives) is required to collect data from at least 80% of relevant flights and training.

The Role of FDM in ATQP

- 13.16 FDM, along with other sources of information, such as safety reports, MOR's, LOQE, electronic training records, global marking system and SMS, is used throughout the life of an ATQP. Initially it provides data to support the implementation by establishing operational and training objectives which lead to measures of the effectiveness of the crew training provided. This can then be used to further refine and adjust the training programme. It provides a classic SMS closed loop risk management system as discussed in Chapter 4.

Review the Training at Least every 6 Months

- 13.17 The operator should set up a regular meeting with key personnel to look at information from the data monitoring / analysis programme for each aircraft type including feedback data and amend the training programme as appropriate.

CHAPTER 14

Legislation and Requirements Related to FDM

Introduction

- 14.1 This chapter summarises some of the legislation and requirements that surround the area of FDM cascading down from the ICAO recommendation and standard for Flight Data Analysis (FDA) into the European and then UK requirements.
- 14.2 The current regulations will be subject to significant change from late 2014 with the adoption of the European Air Operations Regulation - Commission Regulation (EU) 965/2012. This regulation will initially affect all European CAT aeroplanes and helicopters with commercial and non-commercial operations following later. Aircraft covered by (EC) Regulation 216/2008 (Basic Regulation), Annex II, will remain under the regulation of the Air Navigation Order. However the basic requirements for FDM are very similar and further to this, acceptable means of compliance and guidance material have also been produced.

NOTE: The selected text from such requirements is shown below, boxed for clarity.

Safety Management and Accident Prevention and Flight Safety Programmes

ICAO Annex 6 Part 1 – Flight Data Analysis

- 14.3 ICAO Annex 6, Part 1, International Commercial Air Transport – Aeroplanes 3.3.3 requires that 'an operator implements a safety management system acceptable to the State of the Operator (note it is anticipated that ICAO SMS provisions will be moved to Annex 19 later this year). Part of this system requires the establishment of a flight data analysis programme.

ICAO Annex 6 Part 1 - CHAPTER 3. GENERAL

3.3.5 Recommendation. – An operator of an aeroplane of a certificated take-off mass in excess of 20,000kg should establish and maintain a flight data analysis programme as part of its safety management system.

3.3.6 An operator of an aeroplane of a certificated take-off mass in excess of 27,000kg shall establish and maintain a flight data analysis programme as part of its safety management system.

Note.- An operator may contract the operation of a flight data analysis programme to another party while retaining the overall responsibility for the maintenance of such a programme.

3.3.7 A flight data analysis programme shall be non-punitive and contain safeguards to protect the source(s) of the data.

- 14.5 Since 2005 FDA has been mandatory on aeroplanes over 27,000kg whilst since 2002 it has been a recommendation for aeroplanes over 20,000 kg.

EU-OPS 1.037 Accident Prevention and Flight Safety Programme

- 14.6 The ICAO Standards are given effect in European (and therefore UK law) in Regulation (EEC) 3922/1991 (EU-OPS) OPS 1.037 as set out below. EU-OPS applies to all European aeroplanes flown for the purpose of commercial air transport (CAT):

EU-OPS 1.037 Accident Prevention and Flight Safety Programme

(a) An operator shall establish an accident prevention and flight safety programme, which may be integrated with the Quality System, including:

(1) Programmes to achieve and maintain risk awareness by all persons involved in operations; and

(2) An occurrence reporting scheme to enable the collation and assessment of relevant incident and accident reports in order to identify adverse trends or to address deficiencies in the interests of flight safety. The scheme shall protect the identity of the reporter and include the possibility that reports may be submitted anonymously; and

(3) Evaluation of relevant information relating to accidents and incidents and the promulgation of related information, but not the attribution of blame; and

(4) a flight data monitoring programme for those aeroplanes in excess of 27 000 kg MCTOM. Flight data monitoring (FDM) is the pro-active use of digital flight data from routine operations to improve aviation safety. The flight data monitoring programme shall be non-punitive and contain adequate safeguards to protect the source(s) of the data; and

(5) The appointment of a person accountable for managing the programme.

(b) Proposals for corrective action resulting from the accident prevention and flight safety programme shall be the responsibility of the person accountable for managing the programme.

(c) The effectiveness of changes resulting from proposals for corrective action identified by the accident and flight safety programme shall be monitored by the Quality Manager.

- 14.8 Guidance on complying with OPS 1.037 is set out in JAA Administrative & Guidance Material, Section Four: Operations, Part Three: Temporary Guidance Leaflet (TGL) No 44 Interpretive and Explanatory Material (IEM) to OPS 1.037. These Guiding Principles are shown in **Appendix E** and form the basis of the building blocks of all FDM systems. It is presented here in the form of an audit questionnaire check list that may be used by both an Operator and also an Agency overseeing that operation.

ANO 2009 Article 94 Flight Data Monitoring, Accident Prevention and Flight Safety Programme

- 14.9 EU-OPS does not apply to aircraft flying for the purpose of public transport (as defined in UK law) that fall outside the definition of commercial air transport under European law. For those operators, the UK Air Navigation Order 2009 (ANO 2009) Article 94 requires the establishment and maintenance of an accident prevention and flight safety programme (AP&FSP) and includes the requirement for FDM for aeroplanes of more than 27,000 kg MTOW. The content of safety programmes, including FDM, will need to be confirmed as acceptable by the CAA's Flight Operations Inspectors against the guiding principles shown in **Appendix E**.

ANO 2009 Article 94 Flight Data Monitoring, Accident Prevention and Flight Safety Programme

- (1) The operator of an aircraft registered in the United Kingdom flying for the purpose of public transport must establish and maintain an accident prevention and flight safety programme.
- (2) The operator of an aeroplane registered in the United Kingdom with a maximum total weight authorised of more than 27,000kg flying for the purpose of public transport must include a flight data monitoring programme as part of its accident prevention and flight safety programme.
- (3) The sole objective of an accident prevention and flight safety programme is the prevention of accidents and incidents and each programme must be designed and managed to meet that objective.
- (4) It is not the purpose of an accident prevention and flight safety programme to apportion blame or liability.

Requirements - EU-OPS Rules for Retention of Data for Accidents and Reported Occurrences

- 14.10 This section describes the requirement to retain flight recorder data following an accident, or more commonly, an incident that is subject to mandatory reporting. Considerable planning has to go into workable procedures to ensure the retention of such data. Prompt action is required to prevent overwriting of the crash-protected flight recorder data (normally a 25 hour overwrite cycle) and possibly to quarantine the QAR data if this has been deemed an acceptable substitute/backup.

EU-OPS 1.160 Preservation, production and use of flight recorder recording**(a) Preservation of recordings**

(1) Following an accident, the operator of an aeroplane on which a flight recorder is carried shall, to the extent possible, preserve the original recorded data pertaining to that accident, as retained by the recorder for a period of 60 days unless otherwise directed by the investigating authority.

(2) Unless prior permission has been granted by the Authority, following an incident that is subject to mandatory reporting, the operator of an aeroplane on which a flight recorder is carried shall, to the extent possible, preserve the original recorded data pertaining to that incident, as retained by the recorder for a period of 60 days unless otherwise directed by the investigating authority.

Paragraph (c) then describes the limitations placed on the use of such data:

(c) Use of recordings

(1) The cockpit voice recorder recordings may not be used for purposes other than for the investigation of an accident or incident subject to mandatory reporting except with the consent of all crew members concerned.

(2) The flight data recorder recordings may not be used for purposes other than for the investigation of an accident or incident subject to mandatory reporting except when such records are:

(i) Used by the operator for airworthiness or maintenance purposes only; or

(ii) De-identified; or

(iii) Disclosed under secure procedures.

Requirements – Mandatory Occurrence Reporting Scheme

- 14.12 Mandatory Occurrence Reporting is required by EU Directive 2003/42/EC of 13 June 2003 on occurrence reporting in civil aviation. This is given effect in UK law via Article 226 of the ANO 2009, which imposes a duty on a number of specified persons, including the operator and commander of public transport aircraft, CAT aircraft and maintenance organisations, to report to CAA. Full details of the scheme are contained in CAP 382 -The Mandatory Occurrence Reporting Scheme.

CAP 382

2 Applicability

2.1 What Should be Reported?

2.1.1 In deciding whether or not to report an occurrence it must be decided whether the event meets the definition as specified in the ANO. A reportable occurrence in relation to an aircraft means:

Any incident which endangers or which, if not corrected, would endanger an aircraft, its occupants or any other person.

A list of examples of these occurrences appears in Appendix B to this publication. This Appendix provides more detailed guidance on the types of occurrences that are required to be reported. However, reporters are left to determine whether endangerment is a factor and thus determine whether the incident should be reported.

Requirements - DFDR Carriage Requirements

- 14.13 The operational performance requirements for Flight Recorders are laid down in ICAO Annex 6 (Operation of Aircraft) Parts 1, 2 and 3.
- 14.14 EU-OPS 1.715, 1.720, 1.725 Flight data recorders – describes the flight recorder carriage requirements for aeroplanes first issued with an individual Certificate of Airworthiness (C of A) on various dates and the latest standards applying to those with C of A's issued on or after 1 April 1998. Because of the numerous requirements dependent upon the certification date and aircraft weight, a summary of United Kingdom Flight Data Recorder Requirements is given in **Appendix G**. The reader should note that this table is a guide only and EU-OPS should be consulted for a definitive view.
- 14.15 The parameters to meet EU-OPS 1.715, 1.720, 1.725 are defined in the appendices to the Operational Rules.

- 14.16 The requirements for UK aircraft, other than those under EU-OPS, are contained in Schedule 4 the ANO and for public transport helicopters in JAR-OPS 3.
- 14.17 From late 2014, the regulations for European aircraft will start to become effective with those affecting CAT aeroplanes and helicopters first. DFDR requirements must be checked against the appropriate equipment requirements of the new regulations.

Requirements - DFDR Engineering Data Decoding Specification

- 14.18 The need for retaining information for the decoding of the crash-protected flight recorder data is outlined in ED 55, 112 or 155's general standards, naming conventions etc. and this is also highlighted in EU-OPS 1.160 (a)4(ii). International efforts are being made to ensure that the information required for reliable decoding for accident investigation is properly retained by all operators.
- 14.19 The Canadian Transportation Development Centre developed a useful tool to assist in this task. The Flight Recorder Configuration Standard (FRCS) and FRCS Editor were designed to solve the difficulties by providing a standardised format for maintaining FDR information.
- 14.20 FRCS has now been superseded by FRED (Flight Recorder Electronic Documentation) which is detailed in ARINC 647A.

Requirements - QAR Installation

- 14.21 Quick Access Recorders are normally fitted on a 'no hazard-no credit' basis. They should satisfy the environmental test requirements for equipment specified in EUROCAE ED-14 or RTCA DO160.

Requirements - QAR Serviceability and MELs

- 14.22 While there are no specific requirements for these non-mandatory recorders, if, after CAA approval, the data is to be used to replace DFDR downloads for incidents then a similar standard is required. However, in the event of a QAR being unserviceable then the DFDR would of course be available provided a timely data download is made. The confirmation of acceptable data on the QAR must always take place within the DFDR overwriting time-scale.
- 14.23 Current policy accepted by the UK CAA on aircraft dispatch with an unserviceable QAR is contained within JAA Administrative and Guidance Material, Section 4, Operations, Part Three, Temporary

Guidance Leaflet No 26 (Guidance Document for Minimum Equipment List Policy).

- 14.24 Upon the introduction of EASA Master Minimum Equipment List requirements (CS-MMEL), currently expected in late 2013, the applicable policy will be that contained within CS-MMEL.

Figure 1 MMEL - QAR

ATA 31 – INDICATING / RECORDING

Insert this page facing page 31-1 of the MMEL.

1.	Quick Access Recorders (QAR)	A	-	-	<p>May be inoperative subject to arrangements approved by the Authority.</p> <p><u>Note:</u> Any alleviation and corresponding rectification interval will be dependent on the usage requirements of the QAR for individual operators, and will be subject to approval by the Authority.</p>
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- 14.25 Essentially this means that the status of the QAR or equivalent data system is dependent on the criticality of the uses to which the data is put.

- 14.26 **See also Chapter 17 – Maintaining Aircraft FDM Systems.**

CHAPTER 15

Legislation Related to FDM Information

Introduction

- 15.1 This chapter explores the relationships between underlying European and UK law and FDM processes or actions undertaken by the operator. The information given here is only a discussion of the possible interactions and should be regarded only as a guide to the subject area. **For definitive information specialist legal advice should be sought.**
- 15.2 As with all safety related information, but more particularly the automatically generated FDM exceedence events, secure and confidential processing and a 'just' approach are important. However, any protection or identification of individuals and companies has to remain within the current legal framework. The primary purpose of FDM data collection and analysis is to maintain and improve safety. Therefore it is essential that operators properly review, analyse and act upon this information. Otherwise an operator would be legally exposed should an incident occur after warning signs had not been acted upon.
- 15.3 When FDM was first mandated some air crew and operators were concerned they would face increasing claims for damages in the civil courts or even criminal prosecutions. UK experience shows these concerns appear to have been unfounded in practice. Whilst data collected from FDM programmes can be used in both civil and criminal courts, there has been no recognisable increase in UK litigation since data has been routinely collected in this way. Indeed it is important to remember that data obtained from FDM is far more likely to reveal that action taken by pilots was reasonable in the great majority of occasions rather than reveal that the pilot acted negligently or was wilfully reckless.
- 15.4 The International aviation industry and the general public that use public aviation transport, benefit from the application of a 'Just Culture'. The Just Culture is discussed in more detail in CAP 382 - The Mandatory Occurrence Reporting Scheme. These same principles underpin the way FDM data is used to improve safety.

- 15.5 Given the above it is useful to set out some of the legal concepts that are relevant when considering the collection, retention and use of information collected from FDM programmes.

Legal Responsibility for Conduct

- 15.6 It is important to recognise the responsibilities placed on aviation professionals by the law, in particular, the obligation not to endanger people or aircraft by **reckless** or **negligent** behaviour. Such responsibilities need to be understood when constructing the protective agreements in FDM programmes – referred to in Chapter 16 and **Appendix D**. These should take into account the potential implications of these very rare situations.
- 15.7 A high percentage of accidents or incidents are said to be due to pilot error. Accidents are however rarely caused by a single factor; usually many things have 'gone wrong'. Although it may be that the pilot's reaction to the final event is found wanting, it may not be accurate to ascribe the accident or incident solely to this.
- 15.8 Aviation professionals, such as pilots, operations or certification managers are not expected to be superhuman beings. It must therefore be accepted that they will make mistakes. Accidents do happen even when the professional has acted entirely properly. If however it can be proved that the professional has made an error that amounts to gross negligence, they may be liable to criminal prosecution action. If they have displayed a lack of competence, the regulator may take licensing action. They may also be subject to disciplinary action by the employer. Finally, they may be liable to a civil claim for damages from, for example, a passenger injured in a resulting accident.

Legal Terms - Criminal responsibility

- 15.9 The relevant provisions are set out in the Air Navigation Order 2009. A pilot can be punished in the criminal courts for negligently or recklessly endangering persons on the aircraft and/or persons on the ground. Depending on the seriousness of the offence they may be fined or very exceptionally imprisoned.

Legal Terms - Reckless Endangerment

- 15.10 Endangering means putting in danger. Endangering means there was a real likelihood that someone or something would suffer harm (even if they didn't), but it is more than only a possibility of suffering harm.

Legal Terms - Negligent

- 15.11 A person is negligent if they fail to exercise such care, skill or foresight as a reasonable person in their situation would exercise. In other words based on the relevant pilots experience and qualifications they did not take the amount of care they should have done.

Legal Terms - Reckless

- 15.12 A person is reckless if they should have known the consequences of the action they took (or failed to take) and either gave no thought to those consequences or having considered them went on to take the risk anyway. Courts punish recklessness more severely than negligence.
- 15.13 In the UK the CAA is generally the prosecuting authority in respect of aviation offence (although the Crown Prosecution Service does sometimes bring charges against pilots for endangering aircraft or persons, often when they are also bringing charges for manslaughter). As regards prosecutions brought by the CAA, the Statement from the CAA's Chief Executive office in March 2011 (which can be found in CAP 382 - The Mandatory Occurrence Reporting ("MOR") Scheme) clarifies that pilots will not face prosecution from the CAA unless they are found to have been grossly negligent (that is to say so very negligent that their conduct is bordering on recklessness)¹. This statement relates to unpremeditated or inadvertent breaches of the law which come to the CAA's attention only because such breaches have been reported under the MOR Scheme.

¹ See also Air Navigation Order 2009 Article 227(17) which implements Article 4 of the Occurrence Reporting Directive 2003/42/EC

Legal Terms - Manslaughter

15.14 If a person or persons have died as a result of an accident the criminal law provides for offences of manslaughter and corporate manslaughter.

Manslaughter can be committed in one of three ways:

1. Killing with the intent to kill.
2. Conduct that was grossly negligent given the risk of death, and did kill, ("gross negligence manslaughter"); and
3. Conduct taking the form of an unlawful act involving a danger of some harm, that resulted in death, ("unlawful and dangerous act manslaughter").

15.15 It is possible that actions taken by a pilot, that result in death, can be considered to be manslaughter under test 2 and 3 above. Very occasionally a pilot has been charged and convicted of manslaughter in the UK.

15.16 Corporate manslaughter is committed by an organisation if the way in which its activities are managed or organised, by senior management, causes a person's death; and amounts to a gross breach of a relevant duty of care owed by the organisation to the deceased.

15.17 (Up to October 2012) there have been only three convictions for corporate manslaughter in the UK and none has been against the operators of commercial air transport operations.

Legal Terms - Civil Liability

15.18 Where an accident or incident has occurred a victim or a victim's family may consider whether they have cause to claim civil damages from the pilot or operator concerned. To successfully do so they will have to prove that the pilot or the operator was negligent. This means that the pilot or operator owed them a duty of care, which that pilot or operator breached and that breach caused the loss that the victim or victim's family has experienced. This is to be expected after every major aviation accident involving loss of life or serious injury.

Actions by the Regulator (CAA)

- 15.19 Licensing action may be taken in the interest of safety. CAA may well use FDR/FDM data to reach a conclusion that a pilot's licence be suspended for safety reasons (for example whilst that pilot undertakes some further training). This is no different to taking action based on information gleaned from an MOR. See the statement from the CAA's Chief Executive Officer in March 2011 (which can be found in CAP 382 - The Mandatory Occurrence Reporting Scheme) for further information.

Possible Action by Employers

- 15.20 In the interests of continually improving safety the CAA has made it known to employers that, upon identifying a breach of procedure by aircrew or other employees when analysing FDM data, that had an impact on safety and except in the cases of flagrant gross negligence, employers should refrain from disciplinary or punitive action but focus instead e.g. on training. Again see the statement from the CAA's Chief Executive Officer in March 2011 (which can be found in CAP 382 - The Mandatory Occurrence Reporting Scheme) for further information.

Data Protection Act, Human Rights Acts and Legal Discovery

- 15.21 This section examines some of the legal issues surrounding the retention of FDM data. The aviation professional may be concerned that FDM data is being collected and analysed and may result in action being taken against them. Several decades of UK experience in fact shows it is relatively unlikely pilots face disciplinary action as the result of FDM. In practice, with well-devised organisation and control of the FDM process, the aviation professional should be reassured.

Is data confidential or can it be used in legal proceedings?

- 15.22 This section discusses the various, albeit not frequent, circumstances under which data may be used during legal proceedings. The basic premise is that operators that obtain and retain flight data must keep it confidential. However, both the CAA and the Air Accident Investigations Branch will have occasion to require access to both FDR and FDM information. Neither of these organisations voluntarily disclose the information to a third party but a court may well order they do so.

- 15.23 When requested, data must be disclosed to the CAA. CAP 382 - The Mandatory Occurrence Reporting Scheme states "The CAA expects to use flight recorder data only when this is necessary for the proper investigation of the more significant occurrences." Further it states "The more comprehensive recorders fitted to some aircraft are capable of providing valuable data on a wider range of occurrences and the CAA would expect to make judicious use of such information in relation to appropriate occurrences".
- 15.24 If a person commences civil litigation against an operator as a result of an accident, in due course, the operator will have to disclose relevant FDR/FDM data to the litigant (as part of the normal court rules). This could be FDR/FDM data collected on flights other than that which was involved in the accident or incident that is the subject of the case. If facing such a court order for disclosure operators should not seek to de-identify the flight crew concerned and, if relevant to the case, may be ordered to identify any that have been de-identified.
- 15.25 In some limited cases the court will order disclosure by the operator to a person who is conducting litigation against a third party totally unconnected with the operator (known as Third Party disclosure).
- 15.26 In other cases the court will issue an order for pre-action disclosure against the operator where a court is persuaded by a victim or a victim's family that the operator's FDR/FDM data is relevant to a case that the victim (or family) will bring in due course.
- 15.27 Another possible scenario is that the police may obtain court orders requiring FDR/FDM data be provided to them for their investigation.

Does collecting and storing this data infringe the pilot's rights?

- 15.28 The aviation professional may be concerned FDM data that is being collected and analysed may result in action being taken against them. Several decades of UK experience in fact shows that pilots are more likely to be supported by such data than face disciplinary action as the result of FDM. In practice, with well-devised organisation and control of the FDM process, the aviation professional should be reassured. This section examines some of the legal issues surrounding the retention of FDM data that help minimise the potential for unwarranted intrusion on the individual.

Data Protection Act (DPA)

15.29 This applies to personal data held on computer or stored on paper. The data collected by FDM systems will be 'personal data' whether or not it is de-identified as the operator will always have the ability to trace it back to the flight and therefore to the pilot concerned. For example, if a crew roster database can be linked with the FDM database to identify individuals then the DPA will apply. The Acts impose an obligation on the retainer of the information to process it fairly, retain it for lawful purposes only, retain only relevant and not excessive data and to keep it accurate and up to date. This should not present any problems if the FDM process has been constructed so as to ensure valid and secure data is used following good working practices and for carefully defined purposes. Accordingly the operator has the obligation to inform the pilot how the data will be retained, when it will be destroyed and to whom and in what circumstances it will be given to another person (e.g. to the CAA). It also means that pilots may request to see the data that is stored about them which the operator will have to consider properly within their FDM processes under the provisions of the Act. See guidance available here http://www.ico.gov.uk/for_organisations/data_protection/the_guide.aspx.

Human Rights Act 1998

15.30 After the HRA came into force the human rights enshrined in the European Convention on Human Rights over 50 years ago became enforceable in the UK courts. One such right is the right to a private life and some years ago there was discussion whether cockpit voice recording could be said to breach that right. The Human Rights Act makes clear that an individual's human rights must be balanced against the needs and rights of the wider community. In the case of cockpit voice recorders the benefit to aviation safety of access to recordings of pilots' voices before and at the time of accidents and incidents has been considered by legislators to justify the intrusion into the flight crews' personal conversations. It is open to a pilot in any particular case before a UK court to argue that the public benefit should not justify that intrusion but to date we know of no case where this has been attempted or been successful. **Note:** FDM does not include any cockpit voice recorder data.

Destruction Policies

- 15.31 Operators must have destruction policies, not least to comply with Data Protection Act obligations. In some cases there are statutory limitations as to how long data should be retained [Chapter 14 sets out the law on retention of FDR data]. Otherwise it is a question of what is reasonable.
- 15.32 As previously described, the CAA's MOR scheme sets out when it might expect to require production of and use data from FDRs to facilitate investigations. Based on that guidance operators should consider whether the FDR/QAR data they hold may fall into a category that the CAA may request to investigate. If so, they should retain the data for 14 days.
- 15.33 As well as ensuring compliance with the legal requirements for retention, operators should consider whether they want to retain data to defend themselves against actions from the public, employees or others in the aviation industry. In the UK contractual claims can be brought up to 6 years after the date the breach of contract occurred and personal injury claims can be brought 3 years after the accident or 3 years after the victim first became aware they had a claim (whichever is the later).

Retaining and Preserving Documents/Records for Court Proceedings

- 15.34 Operators should have procedures in place to ensure that they do not destroy data that is likely to be the subject of either criminal or civil litigation, even if to do so would be in compliance with the operator's normal retention/destruction policies. To fail to do so may be a contempt of court or an attempt to pervert the course of justice (punishable by a fine or exceptionally by a prison sentence).
- 15.35 Disclosure requires one party to a court action to allow the other parties in the litigation access to all those documents and computer records in its control that are relevant to the issues in the action (unless the documents/ records are privileged). De-identified documents need not be made identifiable. However, if the identity of, for example, the flight crew-member concerned is relevant, the court may order disclosure of those documents/records which enable identification to be made.

- 15.36 It is also possible for the Police to obtain court orders requiring access to FDM data when investigating a suspected criminal offence. If the case did not proceed then this data should be considered confidential and not disclosed. A potential civil litigant can sometimes persuade a court to order disclosure of apparently relevant information prior to commencing legal proceedings. 'Fishing expeditions' to try and discover if a case exists rather than to support a particular case are not permitted.
- 15.37 Once litigation is contemplated no-one may 'amend' documents by de-identifying them. Again this would be contempt of court. Relevant material must not be destroyed, even if to do so would otherwise be in accordance with a normal, say for example, 3 month destruction period.
- 15.38 However, recipients of a party's documents/records i.e. other parties to proceedings, can only use that information in those particular proceedings. A party is entitled to ask for copies back at the end of proceedings and seek an injunction if information is used for any other purposes. Nevertheless, in cases where information is commercially sensitive and the other parties to the proceedings are competitors, the 'damage' may already have been done.
- 15.39 Destroying evidence of a criminal offence can be an attempt to pervert the course of justice. However, unless a person is aware that a criminal offence has occurred or an investigation is, or will likely be carried out, it might be considered unreasonable to expect retention of information that will be needed for evidence.
- 15.40 In criminal proceedings there is no disclosure by the Defendant as set out in relation to the civil proceedings discussed above. However, the Police have certain powers to seize documentation/records when investigating an offence. If the CAA is conducting a prosecution, in theory it can also ask the court to order that certain information be presented to the CAA. However, the court would have to have strong evidence, from other sources, that an offence had been committed before it is likely that a court would exercise its discretion to make an order in this way.

The Need to Take Reasonable Action on Information Held

- 15.41 Industry should make use of data that it collects. If it became apparent that the analysis of data, which had been collected and held, would have alerted an operator to a problem before an incident/accident occurred, it could be argued the operator is liable for the result of failing to conduct that analysis and act upon the results. It is important that it is recognised that 'doing the right thing' is the best defence in the event of legal action as it demonstrates 'best endeavours'.

CHAPTER 16

Mandatory Occurrence Reporting and FDM

Introduction

- 16.1 This chapter deals with the practical issues arising when FDM information is used in the follow-up process. The European regulations for Mandatory Occurrence Reporting are given in Chapter 14 paragraph 2.8 [Mandatory Occurrence Reporting is covered by EU Directive 2003/42/EC of 13 June 2003 on occurrence reporting in civil aviation].
- 16.2 Once it has been ascertained that there is significant actual or potential risk associated with an issue raised by any safety monitoring process then it is widely accepted that there is an obligation to (a) act upon it to prevent a repetition and (b) spread the safety message both within the company and to industry to prevent 'someone else's accident'. After recording and acting upon such information as an internal safety report within the company then the principal medium for broadcast to UK industry is the Mandatory Occurrence Reporting Scheme (MORS). It is logical to feed the lessons obtained from FDM into this existing and trusted system.

Safety Reports and Mandatory Occurrence Reporting

Safety Reports

- 16.3 This section refers to the incident reports initially submitted to the operator's flight safety officer. The processing, assessment and actions arising from each safety report will form part of the operator's Safety Management System. Safety reports are raised by a wide range of methods and triggers. A flight crew or air traffic controller's assessment of a risk, the result of an engineer's inspection, cabin crew reports, security staff etc. all contribute to an overall awareness of the safety risk to the operation. Be aware that an incident may be reported in one or more reporting systems e.g. ground report, maintenance, human factors, cabin crew etc. and that an integrated system will bring together all the relevant information. Issues reported could indicate failure of the defensive measures you have put in place to prevent a hazard.

Mandatory Occurrence Reports (MORs)

- 16.4 The more significant safety reports (along with maintenance and other reports) will be noted, either by the person submitting the report or the safety officer, as requiring submission to the CAA's MOR Scheme. These reports are evaluated and where necessary, further investigated and summaries are provided to industry for their awareness.

Retention of FDR data for MORs

- 16.5 CAP 382, Mandatory Occurrence Reporting Scheme, gives the following advice:

6.5.1 The CAA expects to use flight recorder data only when this is necessary for the proper investigation of the more significant occurrences. It is not intended to use such data to check on information contained in a written report, but to supplement and extend the written information. Examples of the types of occurrence for which flight data records would be most useful are: significant excursion from the intended flight parameters; significant loss of control or control difficulties; unexpected loss of performance or a genuine GPWS warning.

6.5.2 The more comprehensive recorders fitted to some aircraft are capable of providing valuable data on a wider range of occurrences and the CAA would expect to make judicious use of such information in relation to appropriate occurrences. For this purpose, the CAA requests that operators retain the data from an FDR which is relevant to a reportable occurrence for a period of 14 days from the date of the occurrence being reported to the CAA, or a longer period if the CAA so requests.

6.5.3 The CAA depends upon the judgement of those responsible for submitting reports to establish which occurrences require the retention of FDR data. It is equally incumbent upon the CAA to advise the reporting organisation, as quickly as possible, when it requires such data.

CAP 382 March 2011

- 16.7 After an incident, a timely and considered judgement has to be made as to whether FDR data is likely to be useful in an investigation. The short recycling/overwriting time of most DFDRs makes it critical that a decision to quarantine the data is taken very rapidly. Experience shows that this is a very difficult requirement to fulfil. Where QAR data is available it is suggested that operators may wish to approach the CAA with a proposal to substitute QAR data for that from the DFDR.

Confidentiality Issues

- 16.8 An open safety reporting culture relies on the knowledge that the identification of individuals is restricted to a need-to-know basis and that it is definitely non-punitive. This is highlighted in the MOR guidance material (CAP 382).
- 16.9 It should be noted that there is a difference between anonymity and confidentiality with the former being less desirable in an integrated safety system. While the reports generated automatically from FDM programmes should be treated confidentially, the greatest benefit will be gained by correlating this information with other relevant safety and technical reports especially in the case of the most hazardous or significant events. Where a safety report has already been submitted then (only) relevant FDM events can be used to add to the understanding of the circumstances of the incident. It is important to emphasise that it is not the purpose of the process to check out the reporter's recollection and accuracy.

Withdrawal of Protection of Identity

- 16.10 UK experience has shown that very rarely there will be cases where an important issue has been raised by FDM and for some reason no report has been submitted. In such cases the persons involved have been encouraged, through a confidential contact by a crew representative or other trusted person, to submit, 'without prejudice', a report. This method of contact has proved to be very effective in soliciting reports and a good means of imparting constructive safety advice to those involved. Almost invariably any advice or remedial action, i.e. training, is well received by the crews – on the understanding that this has been carried out purely in the interests of safety.

- 16.11 In the **extremely** rare case where **there is a definite ongoing safety risk** and no report is forthcoming despite requests, making remedial action impossible, then agreed procedures are followed to allow essential safety action to be taken. It should be emphasised that at no stage in this process is non-safety related disciplinary action considered, unless it is warranted due to gross negligence or wilful violation. A judgement may have to be made on the probability of recurrence against a potential reduction in the openness of the overall safety culture resulting from a loss of confidence. However, experience has shown that the vast majority of issues discovered from FDM information are concerned with lower levels of hazard where no identification is needed.

FDM and Mandatory Occurrence Reporting

- 16.12 Within a good safety culture the vast majority of significant Individual FDM events/ exceedences will be the subject of crew air safety or occurrence reports and investigations. This section considers the interaction of FDM information and the MOR system.

Reporting Standards and Audit Events

- 16.13 FDM systems have proven to be very effective in reminding crews to submit reports during the early stages of a programme and are then a useful audit tool, confirming reporting standards in an established programme. Issues covered may include the following:
- Various warnings: Stall, Hard GPWS, high speed or major systems warning
 - Hard landing
 - Tailscrape
 - Rejected take-off at high speed and go-arounds
 - Engine failure
 - Severe turbulence and vortex wake encounters
 - Altitude deviation
 - Flight control difficulties indicated by excessive/untypical control deflections

- It should be remembered that in the case of significant incidents found as the result of FDM analysis, the crews should be encouraged to submit retrospective reports - without prejudice or penalty to the crew concerned, if they have not already done so.

Reporting of Issues raised by FDM Events

- 16.14 In cases of general underlying trends and wider issues, then FDM data alone would be used to raise internal safety reports or MORs. In such cases it is expected that the reporter will submit a single occurrence report together with the supporting evidence of high frequency and/or rate when it is considered that such a situation has been reached. Further reports should be submitted if the situation remains unchanged. CAP 382 specifically mentions:

Repetitive instances of a specific type of occurrence which in isolation would not be considered "reportable" but which due to the frequency with which they arise, form a potential hazard.

- 16.16 Multiple FDM events may come together to indicate a potential issue for wider consideration or action. Examples of the type of issue that would be appropriate for such a submission include:
- Unacceptable number of unstabilised/rushed approaches at a particular airfield.
 - False/nuisance GPWS warnings at a particular location or with certain equipment.
 - Rough Runway – permanent problem area or out of Specification temporary ramps.
 - Repeated near tailscrapes due to pilot rotation technique indicating revised guidance required.
 - Repeated events considered unacceptable elsewhere produced by a particular SID.
 - Reduced fuel reserves on certain sectors.

CHAPTER 17

Maintaining Aircraft FDM Systems

Introduction

- 17.1 This chapter deals with the requirements for the maintenance of FDM systems subsequent to the introduction of the FDM requirements. Requirements for FDM apply an additional mandate to the carriage and intended usage of the Flight Data Recorder system that the original design and certification assumptions may not have taken into account.
- 17.2 When operators make operational and maintenance decisions based on data additional to that mandated for accident investigation purposes, it is important that the validity of the data on which the decisions are based and the reliability of the recording devices are assured by applicable and effective scheduled maintenance instructions and procedures.

Equipment Specification

- 17.3 For operators working under EU-OPS - the EUROCAE Documents ED-55 and ED-112² give the Minimum Operational Performance Specification (MOPS) that 'define the requirements to be met in all aircraft required to carry a flight data recorder system **for the purposes of accident investigation**.' While the environmental conditions would not apply in the case of a Quick Access Recorder the other standards relating to the data and other general performance characteristics provide worthy guidance.
- 17.4 For operators working under the UK's ANO – Airworthiness Specifications 10 and 10A apply.
- 17.5 The equipment that operators propose to use for FDM should be acceptable to the CAA. The justification submitted may be based on ED-55, ED-112. This equipment should be maintained to an agreed schedule that will meet these requirements.
- 17.6 Clarification of what are mandatory DFDR parameters is in CAP 731 as are the maintenance practices to assure recorder serviceability.

² ED-55 has been superseded by ED-112 and in turn ED-112 is due to be superseded by ED-112A.

Maintaining Equipment Performance

- 17.7 In regard to crash-protected flight recorders, ED-55 states - 'The maintenance tasks required to ensure the continued serviceability of the installed flight recorder system will depend on the extent of monitoring built into the recorder and its sensors. The system installer will need to perform an analysis of the system to identify those parts of the system which, if defective would not be readily apparent to the flight crew or maintenance personnel. Appropriate inspections and functional checks, together with the intervals at which these would need to be performed, will need to be established as indicated by the analysis.' This philosophy should be applied to recoding systems used for FDM.
- 17.8 CAP 731 states – 'Articles 153, 154 and 155 of the Air Navigation Order 2009 require that operators preserve a record of one representative flight made within the last 12 months. The purpose of this is to ensure that, in the event of an accident/incident, air accident investigators have access to a readout from the flight data recording system that is representative of the actual aircraft condition prior to the accident/incident. It follows that the data originating from the selected representative flight will need to be evaluated to determine that it comprises a valid record.'
- 17.9 While it is not mandatory to use this data for the evaluation of FDR serviceability, CAP 731 recommends that operators do this as it is an effective method of confirming compliance. Valid recorded data can provide evidence of the FDR system performance in a flight dynamic situation that cannot be achieved during ground testing alone. CAP 731 goes on to give guidance on utilising this data, or FDR readouts in general, to evaluate FDR serviceability. It is recommended that when the crash-protected flight recorder calibration checks are carried out, a parallel check is made to confirm the validity of any other recording equipment such as QARs.

QAR Serviceability and MELs

- 17.10 When considering an inoperative QAR or equivalent data system, the associated MEL conditions are dependent upon the criticality of the uses to which the data is put. The CAA MMEL Policy on QARs is shown in Chapter 14 paragraph 2.18 and 2.19.

CHAPTER 18

Regulatory Oversight of FDM

Introduction

- 18.1 FDM is primarily a tool for gathering intelligence from flight operations in order to monitor, maintain and improve safety. As FDM data becomes increasingly important in Safety Management Systems (SMS) and Alternative Training and Qualification Programmes (ATQP), National Aviation Authorities need to be (a) assured of the effectiveness of FDM programmes and (b) its compliance with requirements. Under Part ORO.AOC.130 FDM must be integrated as part of an operator's management system and hence SMS. A more detailed description of a management system can be found under AMC1 ORO.GEN.200
- 18.2 The underlying principles set out in **Appendix E** and in the forthcoming new European air operation rules acceptable means of compliance and guidance material (AMC1 ORO.AOC.130 and GM1 ORO.AOC.130) should form the basis of the audit methodology. Each applicable operator should be assessed on how effectively they have implemented FDM against each of the principles. This chapter describes some of the considerations pertinent to such oversight.

Method of FDM Oversight

- 18.3 The competent Authority's audit schedule for an operator should include an assessment of how effectively it has implemented its FDM programme measured against the underlying principles referred to above. Each of the principles in **Appendix E** is accompanied by processes which illustrate the type of supporting mechanisms and procedures needed for a satisfactory FDM programme.
- 18.4 For audit purposes, and to ensure compliance, these processes have been expanded into questions for specific information. For example:
- Under the principle of Education and Publication - "Give examples of how training utilises FDM data, including its use to construct relevant simulator scenarios." Or 'Which means of distribution of safety messages, to crews or other relevant personnel, do you use? Newsletter or flight safety magazine; Simulator/training feedback; Other means?'

Under Accident and Incident Data Requirements: - "What are the FDM data processes when an incident or accident has occurred?"

- 18.5 A pre-audit questionnaire enables an operator to provide a useful overview of their programme for the audit. Furthermore, experience has shown that the completion has helped operators review and in some cases improve their FDM programme by clarifying critical components.
- 18.6 After reviewing the completed questionnaire the physical audit can focus on any perceived deficiencies and the integration and use of FDM within the operator's Safety Management System.
- 18.7 Additionally, there is potential, through this process, to have a measure of the implementation and effectiveness of FDM as a national safety performance indicator. For example scales of the maturity, effectiveness and innovation of each operator's programme.
- 18.8 It is recommended that an FDM data summary is included with the questionnaire to provide information relating to the ability of the operator to analyse output from the FDM programme. As de-identified information this can form a useful overview of national safety performance.

The Role of the Flight Operations Auditor

- 18.9 An important feature of the competent Authority's safety assurance process is the auditor's expertise and judgement, based partly on professional aviation experience and also through training, when assessing an operator. The use of a pre-audit questionnaire would further aid their understanding of a particular operation and of the operator's competence in this area.
- 18.10 Due to the importance of FDM the UK CAA has ensured their Flight Operations Inspectors and Inspecting Officers receive training on FDM implementation and oversight.
- 18.11 FDM programmes, when run properly and fully integrated with the other information sources, provide rational evidence of the level of risk and how much control an operator has over its risks. Understanding FDM will provide a key indication of the status of an SMS.

APPENDIX A

Terms, Definitions and Abbreviations

Definitions

Accident - An unintended event or sequence of events that cause death injury, environmental or material damage.

FDM Event/Exceedence - Circumstances detected by an algorithm looking at FDR/QAR data.

FDM Parameter Analysis - Measurements taken from every flight e.g. maximum g at landing.

Hazard - A physical situation, often following from some initiating event, that can lead to an accident.

Incident - An occurrence, other than an accident, associated with the operation of an aircraft that affects or could affect the safety of operation.

Level of Safety - A level of how far safety is to be pursued in a given context, assessed with reference to an acceptable risk, based on the current values of society.

Qualitative - Those analytical processes that assess system and aeroplane safety in a subjective, non-numerical manner.

Quantitative - Those analytical processes that apply mathematical methods to assess system and aeroplane safety.

Risk - Is the combination of the probability, or frequency of occurrence of a defined hazard and the magnitude of the consequences of the occurrence.

Risk Assessment - Assessment of the system or component to establish that the achieved risk level is lower than or equal to the tolerable risk level.

Safety Assessment - A systematic, comprehensive evaluation of an implemented system to show that the safety requirements are met.

Safety Objective - A safety objective is a planned and considered goal that has been set by a design or project authority.

Safety Policy - Defines the fundamental approach to managing safety and that is to be adopted within an organisation and its commitment to achieving safety.

Serious Incident - An incident involving circumstances indicating that an accident nearly occurred.

Severity - The potential consequences of a hazard.

System - A combination of physical components, procedures and human resources organised to achieve a function.

Validation - The process of determining that the requirements are the correct requirements and that they are complete.

Verification - The evaluation of the results of a process to ensure correctness and consistency with respect to the inputs and standards provided to that process.

Abbreviations

ACARS: Aircraft Communication Addressing Reporting System

ADS: Air Data System - computer interface between aircraft systems and instrumentation/FDR

AGL: Above Ground Level - measured by aircraft's radio altimeter

ANO (2009): Air Navigation Order 2009 - Primary UK aviation legislation

APMS: Aviation Performance Measuring System - NASA's advanced FDR analysis tool set

AQP: Advanced Qualification Programme – relates training to operational experience

ARMS: Aviation Risk Management Solutions - Methodology for Operational Risk Assessment developed by an Industry working group.

ASR: Air Safety Report - (normally) aircrew report on a safety incident

ATQP: Alternative Training & Qualification Programme

BALPA: British Airline Pilots Association

BCAR: British Civil Airworthiness Requirements - civil code replaced by Part -145

CAADRP: Civil Airworthiness Data Recording Programme - CAA-SRG's flight recorder analysis research programme

C of A: Certificate of Airworthiness

DFDAU: Digital Flight Data Acquisition Unit

DFDR: Digital Flight Data Recorder - normally the crash-protected flight recorder

DMU: Data Management Unit

DPA: Data Protection Act (UK)

EASA: European Aviation Safety Agency

EFIS: Electronic Flight Instrument System

EGT: Exhaust Gas Temperature

ERC: Event Risk Classification

EU-OPS: European Operations requirements

FDR: Flight Data Recorder - normally the crash-protected flight recorder

FMC: Flight Management Computer - aircraft system control computer

FMS: Flight Management System - aircraft control system

FODCOM: CAA Safety Regulation Group's Flight Operations Department Communications. (Information to Industry.)

FOQA: Flight Operational Quality Assurance - FAA's term for flight data monitoring and its systematic use as a quality and safety monitor.

FSO: Flight Safety Officer - investigates incident reports and promotes safety

JAR-OPS: Joint Aviation Requirements - Flight operations codes

MEL: Minimum Equipment List

MO: Magneto-Optical

MORS: Mandatory Occurrence Reporting Scheme (UK)

OQAR: Optical Quick Access Recorder

PCMCIA: Personal Computer Miniature Computer Interface Adaptor - credit card size PC interfaces - Disk storage versions used for QAR recording mediums

QA: Quality Assurance

QAR: Quick Access Recorder - secondary recorder with a removable recording medium - traditionally tape, now moving towards Optical Disk or solid state

SDD: Safety Data Department - UK CAA Department responsible for Mandatory Occurrence Reporting System

SFB: Specific Fuel Burn

SID: Standard Instrument Departure

SIRA: Safety Issue Risk Assessment

SOP: Standard Operating Procedure

SRG: Safety Regulation Group - part of UK CAA responsible for all safety matters

SSFDR: Solid State Flight Data Recorder

TCAS: Traffic Alert and Collision Avoidance System

UNS: User Needs Study - Research study into the application of FDR/QAR data within an operator

WQAR: Wireless Quick Access Recorder

APPENDIX B

Typical FDM Exceedence Detection and Routine Parameter Analysis

Traditional Basic Operational Event Set

- B1 These operational events are typical of those found in most current FDM programs. There have been minor developments over the past 20 years but are basically the same as developed by the CAA's programme with British operators during the late 1970s. However, they still form an excellent starting point for any monitoring programme. (Refer to Chapter 6 'Exceedence Detection')

Event Group	Description
Flight Manual Speed Limits	Vmo exceedence
	Mmo exceedence
	Flap placard speed exceedence
	Gear down speed exceedence
	Gear up/down selected speed exceedence
Flight Manual Altitude Limits	Exceedence of flap/slat altitude
	Exceedence of maximum operating altitude
High Approach Speeds	Approach speed high within 90 sec of touchdown
	Approach speed high below 500 ft AAL
	Approach speed high below 50 ft AGL
Low Approach Speed	Approach speed low within 2 minutes of touchdown
High Climb-out Speeds	Climb out speed high below 400 ft AAL
	Climb out speed high 400 ft AAL to 1000 ft AAL
Low Climb-out Speeds	Climb out speed low 35 ft AGL to 400 ft AAL
	Climb out speed low 400 ft AAL to 1500 ft AAL
Take-off Pitch	Pitch rate high on take-off
Unstick Speeds	Unstick speed high

Event Group	Description
	Unstick speed low
Pitch	Pitch attitude high during take-off
	Abnormal pitch landing (high)
	Abnormal pitch landing (low)
Bank Angles	Excessive bank below 100 ft AGL
	Excessive bank 100 ft AGL to 500 ft AAL
	Excessive bank above 500 ft AGL
	Excessive bank near ground (below 20 ft AGL)
Height Loss in Climb-out	Initial climb height loss 20 ft AGL to 400 ft AAL
	Initial climb height loss 400 ft to 1500 ft AAL
Slow Climb-out	Excessive time to 1000 ft AAL after take-off
High Rate of Descent	High rate of descent below 2000 ft AGL
Normal Acceleration	High normal acceleration on ground
	High normal acceleration in flight flaps up/down
	High normal acceleration at landing
	Normal acceleration; hard bounced landing
Low go-around	Go-around below 1000 ft AAL
High go-around	Go-around above 1000 ft AAL
RTO	High Speed Rejected take-off
Configuration	Abnormal configuration; speed brake with flap
Low Approach	Low on approach
Configuration	Speedbrake on approach below 800 ft AAL
	Speedbrake not armed below 800 ft AAL (any flap)
	Early configuration change after take-off (flap)
Ground Proximity Warning	GPWS operation - hard warning
	GPWS operation - soft warning
	GPWS operation - false warning
	GPWS operation - windshear warning
Margin to Stall	Reduced lift margin except near ground

Event Group	Description
	Reduced lift margin at take-off
	Stickshake
	False stickshake
TCAS warning	TCAS warning details
Landing Flap	Late land flap (not in position below 500 ft AAL)
	Reduced flap landing
	Flap load relief system operation
Glideslope	Deviation under glideslope
	Deviation above glideslope (below 600 ft AGL)
Localiser	Excessive Localiser Deviation
Buffet Margin	Low buffet margin (above 20,000 ft)
Approach Power	Low power on approach

Extended Operational Event Set

- B2 In addition to the basic events detailed above, there are a number of new events that could be used to detect other situations that an operator may be interested in. Some of the new triggers are relatively simple to implement while others would need careful coding and research to avoid false events while still activating against good data. (refer to Chapter 6 'New Events For Specific Problem Areas')

Description	Notes
Engine parameter exceedence (e.g. TGT etc.)	One of a range of engine monitors.
Full and free control checks not carried out	Essential pilot actions and a measure of control transducers.
Taxi out to take-off time - more than (x) minutes	Can be measured against a standard time for that airfield and runway.
High Normal Acceleration - Rough taxi-way	Record an estimate of position derived from groundspeed and heading.
High Longitudinal Acceleration - Heavy braking	as above

Description	Notes
Excessive Taxi Speed	as above
Take-off configuration warning	
Landing gear in transit longer than (x) seconds	To be used as an indicator of system problems and wear.
Flap/slats in transit longer than (x) seconds	as above
Master Warning	All master warnings, even if false, heard by the crew are a useful indicator of distractions and "mundane/known problems".
Engine failure	To confirm efficacy of crew training and assist any technical investigation.
Autopilot vertical speed mode selected below (x) ft	One of a range of auto flight system usage monitors.
Fuel Remaining at landing below minimums	
Airborne holding - more than (x) minutes	Pin-points large holding delays.
Excessive control movement - airborne (especially rudder)	This will indicate control problems that other events might not identify.
Reverse thrust not used on landing	Dependant on operator SOPs.
Auto ground-spoiler not selected for landing	
Landing to shutdown time - more than (x) minutes	Indicates taxiway or stand allocation problems.
Altitude deviation	Level busts, premature descents etc.

Operational Parameter Analysis Variables

B3 The following list suggests additional parameters that could be extracted from each flight and logged into a database. The concept is to log a sufficiently wide range of data points from each flight so as to enable the analyst to deduce and compare performance and safety measures. Airfield, runway, weight, time of year and many other combinations of circumstances may be correlated. This approach to FDM has proved very useful in determining what is normal as opposed to the event method that gives what is abnormal.

Subject Area	Description
General	Arrival and Departure time, airfield and runway *note the identification of date is normally limited to month to restrict identification
	Temperature, pressure altitude, weight, take-off/landing configuration
	Estimated wind speed - headwind and crosswind components
	Aircraft Routing - reporting points and airways
	Cruise levels
	Elapsed times - taxi-out, holding, climb, cruise, descent and approach, taxi in.
Powerplant	Start up EGT etc.
	Max power during take-off
	Cruise performance measure
	Reverse thrust usage, time, max-min speeds, thrust setting
Structures	Flap/slat configuration vs time usage
	Flap/slat configuration vs max normal acceleration
	Flap/slat configuration vs normal acceleration max/min counter
	Flap/slat - Asymmetric deployment
	Airbrake extension - time, max and min speeds
	Gear extension/retraction cycle times
	Aircraft weight at all loading event times

Subject Area	Description
	Landing assessment - pitch and roll angles and rates (plus other parameters)
	Normal acceleration at touchdown
	Normal acceleration - Airborne - Count of g crossings
	Normal acceleration - Ground - Count of g crossings
Flight Operations	Take-off and landing weight
	Thrust setting at take-off
	Rotation speed
	Lift-off speed and attitude
	Climbout speeds
	Climb height profile
	Noise abatement power reduction - height, time etc.
	Flap speeds - selection, max, min
	Gear speeds - selection, max, min
	Top of Descent point - time to landing
	Holding time
	Autopilot mode usage vs altitude
	Approach flap selection - time, speed, height
	Glideslope capture point - time, speed, height
	Localiser capture point - time, speed, height
	Maximum control deflection - airborne
	Maximum control deflection - ground
	Maximum control deflection - take-off or landing roll
	Landing speeds, attitudes and rates
	Turbulence indication - climb, cruise, descent and approach
Flight Data Quality	Periods of bad/poor data
	Percentage of airborne data not analysed
	Take-off or landing not analysed
	Bad/non-existent FDR parameters

Subject Area	Description
Fuel Usage	Take-off fuel and Landing fuel
	Taxi-out fuel burn
	Taxi-in fuel burn
	Total fuel burn
	Reserve fuel
	Specific fuel burn
	Cruise fuel burn measurement

APPENDIX C

Typical Helicopter FDM Exceedence Detection and Routine Parameter Analysis

Helicopter FDM Event Set

C1 These operational events are taken from CAA Paper 2002/02 and were developed for the AS332L Super Puma as part of the HOMP trials. The parameters required for this event set may also be found in the CAA Paper.

	On Ground before Take-off	Take-off/Climb	Cruise	Descent/Approach/Landing	On Ground after Landing
F L T P R O F I L E		<ul style="list-style-type: none"> • Press alt at t/o • Max pitch attitude at rotation (for rig t/o) • Max pitch rate at rotation (for rig t/o) • Radio alt at rotation (for rig t/o) • Radio alt at gear up 	<ul style="list-style-type: none"> • Max Press alt • Max airspeed at low height 	<ul style="list-style-type: none"> • Press alt at landing • Radio alt at gear down 	
S P E E D	<ul style="list-style-type: none"> • Max taxi speed 	<ul style="list-style-type: none"> • Max rate of descent • Max rate of descent at low airspeed • Min airspeed 	<ul style="list-style-type: none"> • Max rate of descent • Max rate of descent at low airspeed • Max/Min airspeed 	<ul style="list-style-type: none"> • Max rate of descent • Max rate of descent at low airspeed • Max/Min airspeed • Groundspeed on approach 	<ul style="list-style-type: none"> • Max taxi speed
A T T I T U D E	<ul style="list-style-type: none"> • Max/Min pitch attitude • Max roll attitude 	<ul style="list-style-type: none"> • Max/Min pitch attitude • Max pitch rate • Max roll attitude • Max roll rate • Max yaw rate 	<ul style="list-style-type: none"> • Max/Min pitch attitude • Max pitch rate • Max roll attitude • Max roll rate • Max yaw rate 	<ul style="list-style-type: none"> • Max/Min pitch attitude • Max pitch rate • Max roll attitude • Max roll rate • Max yaw rate 	<ul style="list-style-type: none"> • Max/Min pitch attitude • Max roll attitude
C O N T R O L S	<ul style="list-style-type: none"> • Max cyclic longitudinal pitch • Max cyclic lateral rate • Max cyclic longitudinal rate 	<ul style="list-style-type: none"> • Max collective pitch • Max cyclic longitudinal pitch • Max cyclic lateral pitch • Min airspeeds for autopilot modes 	<ul style="list-style-type: none"> • Max collective pitch • Max cyclic longitudinal pitch • Max cyclic lateral pitch • Min airspeeds for autopilot modes 	<ul style="list-style-type: none"> • Max collective pitch • Max cyclic longitudinal pitch • Max cyclic lateral pitch • Min airspeeds for autopilot modes 	<ul style="list-style-type: none"> • Max cyclic longitudinal pitch • Max cyclic lateral rate • Max cyclic longitudinal rate
A C C E L S	<ul style="list-style-type: none"> • Max Deck Motion Severity Index • Max lateral acceleration • Max longitudinal acceleration 	<ul style="list-style-type: none"> • Max lateral acceleration • Max longitudinal acceleration • Max normal acceleration 	<ul style="list-style-type: none"> • Max lateral acceleration • Max longitudinal acceleration • Max normal acceleration 	<ul style="list-style-type: none"> • Max lateral acceleration • Max longitudinal acceleration • Max normal acceleration • Peak normal acceleration on landing 	<ul style="list-style-type: none"> • Max Deck Motion Severity Index • Max lateral acceleration • Max longitudinal acceleration
P O W E R T R A I N	<ul style="list-style-type: none"> • Max main rotor speed • Max EGT at engine start 	<ul style="list-style-type: none"> • Max/Min main rotor speed power on • Max/Min main rotor speed power off • Max torque • Max EGT • Max engine gas generator speed • Max MGB/IGB/TGB oil temp • Max/Min MGB oil press 	<ul style="list-style-type: none"> • Max/Min main rotor speed power on • Max/Min main rotor speed power off • Max torque • Max EGT • Max engine gas generator speed • Max MGB/IGB/TGB oil temp • Max/Min MGB oil press 	<ul style="list-style-type: none"> • Max/Min main rotor speed power on • Max/Min main rotor speed power off • Max torque • Max EGT • Max engine gas generator speed • Max MGB/IGB/TGB oil temp • Max/Min MGB oil press 	<ul style="list-style-type: none"> • Max main rotor speed • Main rotor speed at rotor brake application • Max EGT at engine start
O T H E R		<ul style="list-style-type: none"> • OAT at take-off • Take off weight • Fuel contents at t/o • Wind speed/direction • Max increase in OAT 		<ul style="list-style-type: none"> • OAT at landing • Landing weight • Fuel contents at landing • Max pilot workload/turbulonce • Wind speed/direction • Max increase in OAT 	

Helicopter FDM Routine Parameter Analysis

C2 These routine measurements of all flights are taken from CAA Paper 2002/02 and were developed for the AS332L Super Puma as part of the HOMP trials.

	On Ground before Take-off	Take-off/Climb	Cruise	Descent/Approach/Landing	On Ground after Landing
F L T P R O F I L E		<ul style="list-style-type: none"> High/Low pitch attitude at rotation point (for rig t/o) High/Low pitch rate at rotation point (for rig t/o) Early turn at night Gear up early Downwind flight 	<ul style="list-style-type: none"> Low height in cruise 	<ul style="list-style-type: none"> Go around Low height on go around Gear down late Downwind flight 	
S P E E D	<ul style="list-style-type: none"> High taxi speed 	<ul style="list-style-type: none"> High rate of descent High rate of descent at low airspeed Low airspeed 	<ul style="list-style-type: none"> VNO/VNF exceedance High rate of descent High rate of descent at low airspeed Low airspeed 	<ul style="list-style-type: none"> VNO/VNF exceedance High rate of descent High rate of descent at low airspeed High groundspeed on approach 	<ul style="list-style-type: none"> High taxi speed
A T T I T U D E	<ul style="list-style-type: none"> High pitch attitude (up/down) High roll attitude 	<ul style="list-style-type: none"> High pitch attitude (up/down) High pitch rate High roll attitude High roll rate 	<ul style="list-style-type: none"> High pitch attitude (up/down) High pitch rate High roll attitude High roll rate 	<ul style="list-style-type: none"> High pitch attitude (up/down) High pitch rate High roll attitude High roll rate 	<ul style="list-style-type: none"> High pitch attitude (up/down) High roll attitude
C O N T R O L S	<ul style="list-style-type: none"> Rollover limits Autopilot engagement Excessive cyclic longitudinal pitch High cyclic lateral rate High cyclic longitudinal rate 	<ul style="list-style-type: none"> Excessive collective pitch Excessive cyclic longitudinal pitch Excessive cyclic lateral pitch Inappropriate autopilot modes 	<ul style="list-style-type: none"> Excessive collective pitch Excessive cyclic longitudinal pitch Excessive cyclic lateral pitch Inappropriate autopilot modes 	<ul style="list-style-type: none"> Excessive collective pitch Excessive cyclic longitudinal pitch Excessive cyclic lateral pitch Inappropriate autopilot modes 	<ul style="list-style-type: none"> Rollover limits Autopilot engagement Excessive cyclic longitudinal pitch High cyclic lateral rate High cyclic longitudinal rate
A C C E L S	<ul style="list-style-type: none"> High Dock Motion Severity Index High lateral acceleration High longitudinal acceleration 	<ul style="list-style-type: none"> High lateral acceleration High longitudinal acceleration High normal acceleration 	<ul style="list-style-type: none"> High lateral acceleration High longitudinal acceleration High normal acceleration 	<ul style="list-style-type: none"> High lateral acceleration High longitudinal acceleration High normal acceleration High normal acceleration on landing 	<ul style="list-style-type: none"> High Dock Motion Severity Index High lateral acceleration High longitudinal acceleration
P O W E R T R A I N	<ul style="list-style-type: none"> High main rotor speed 	<ul style="list-style-type: none"> Heater on during take-off High/Low main rotor speed power on High/Low main rotor speed power off High torque Single engine flight 	<ul style="list-style-type: none"> High/Low main rotor speed power on High/Low main rotor speed power off High torque Torque split Single engine flight 	<ul style="list-style-type: none"> Heater on during landing High/Low main rotor speed power on High/Low main rotor speed power off High torque Single engine flight 	<ul style="list-style-type: none"> High main rotor speed Rotor brake application
O T H E R		<ul style="list-style-type: none"> Flight through hot gas 	<ul style="list-style-type: none"> Low fuel contents 	<ul style="list-style-type: none"> Pilot workload/turbulence Flight through hot gas Low fuel contents 	

APPENDIX D**Sample FDM Procedural and Confidentiality Agreement**

D1 This sample agreement is based on a generalised version of a UK operator's agreement that has stood the test of time. It should be understood that there are many different ways of organising FDM programmes and hence many different arrangements. This agreement assumes that an aircrew representative organisation is in place and is taking a pivotal role in communications.

Flight Data Monitoring Agreement**Statement of Understanding between Operator and Aircrew Organisation (AO) or Staff Representative**

Dated 1 January 2005

1 Preamble

These notes are intended as guidance to new members of the operator's FDM programme, either operator or AO staff.

It is important to be aware that FDM is but a part, albeit an important one, of the operator's total use of Flight Recorder data. These notes refer specifically to the FDM use of the data.

2 Introduction

It is accepted by both the operator and the AO that the greatest benefit will be derived from FDM by working in a spirit of mutual co-operation towards improving flight safety. A rigid set of rules can, on occasions, be obstructive, limiting or counter-productive, and it is preferred that those involved in FDM should be free to explore new avenues by mutual consent, always bearing in mind that FDM is a safety programme, not a disciplinary one. The absence of rigid rules means that the continued success of FDM depends on mutual trust.

3 Statement of Purpose

3.1 The primary purpose of monitoring operational flight data by the FDM program is to enhance flight safety. The actions to be taken to reverse an adverse trend, or to prevent the repetition of an event, may include raising pilot awareness, changing procedures and/or manuals, and seeking to change pilot behaviour (individually or collectively), amongst others.

3.2 Interested third parties (Manufacturer, Regulator or Research body) may seek access to FDM data for safety purposes.

3.3 If the request is for de-identified data (i.e. the data does not contain any information that would enable the data to be identified as originating from a particular flight), then the operator may supply this information, and will notify the AO representatives on each occasion.

3.4 If, on the other hand, the requested data only has value when it can be linked to specific flights, then the operator will agree with the AO representatives the terms under which the data can be provided.

3.5 Where FDM data is to be used for Continued Airworthiness or other engineering purposes within the company, then secure procedures must be in place to control access to the data. Identification of and contact with crews will not be permitted through this path.

4 Constitution

4.1 The constitution and responsibilities of the Flight Data Monitoring Group are defined in Flight Crew Orders (Detailing working practices and methods). The Group meets once a month. Membership consists of:

Flight Data Monitoring Manager (Meeting Chairman)

A representative from each Fleet's training section

A representative from Flight Data Recording Engineering

A representative from Flight Operations

AO Representatives

4.2 The constitution and responsibilities of the Operational Flight Data Recording Working Group is defined in Flight Crew Orders (Policy, management and longer term matters). The Group meets bimonthly. Membership consists of:

Flight Data Monitoring Manager (Meeting Chairman) Manager Flight Data Recording Engineering

Aircraft Performance and Operational Representatives

A representative from the Flight Safety Office

AO Representatives

5 Confidentiality

5.1 The operator will not identify flight crew involved in FDM events, except as in 5.1.1, 5.1.2 and 5.1.3 below.

Exceptions:

5.1.1 If the event is reported to the operator in an Air Safety Report. (In which case the FDM group will not investigate the event, provided the ASR relates directly to the FDM event.)

5.1.2 In the case of repeated events by the same pilot in which the FDM group feel extra training would be appropriate.

The AO Representative will invite the pilot to undertake such extra training as may be deemed necessary after consultation with the Fleet manager concerned. The operator will arrange the training.

5.1.3 In other cases of repeated events by the same pilot; or a single pilot-induced event of such severity that the aircraft was seriously hazarded, or another flight would be if the pilot repeated the event.

The AO recognises that, in the interests of flight safety, it cannot condone unreasonable, negligent or dangerous pilot behaviour and, at the operator's request, will normally consider withdrawing the protection of anonymity.

This consideration by the AO will be undertaken by:

The relevant AO FDM Representative and previously agreed senior members of the AO (e.g. the operator's council chairman).

6 Contact with Pilots

6.1 It is accepted that an FDR trace may give an incomplete picture of what happened, and that it may not be able to explain “why” it happened. The AO Representatives may be asked to contact the pilot(s) involved to elicit further information as to “how” and “why” an event occurred. The AO Representatives may also be asked to contact a pilot to issue a reminder of Fleet or Company policy and/or procedures. In this case the relevant AO Representative will identify and contact the staff concerned.

6.2 In the case of a single event, or series of events, that is judged sufficiently serious to warrant more than a telephone call, but not sufficiently serious to make an immediate application for the withdrawal of anonymity under paragraph 5.1.3, then the AO Representatives will be asked to present the operator’s Management view to the crew member(s) concerned, in accordance with the procedure described in **Appendix I**.

6.3 Contact will initially be with the Captain of the flight, but where Human Factors are thought to be involved it may also be necessary to contact the co-pilot or other flight- deck crewmembers.

6.4 It is recognised that the value of the “AO Rep’ call” could be demeaned by over-use. Therefore the number of calls, and the value of each, will be monitored by the FDM Group.

6.5 If a pilot fails to co-operate with the AO Representative with regard to the provisions of this agreement, then the operator will receive the AO Representative’s approval to assume responsibility for contact with that pilot, and any subsequent action.

Signed on behalf of the Operator

Signed on behalf of the AO Representatives

Appendix I

Procedure to be used when paragraph 6.2 is invoked

- The operator will call upon the AO to arrange for the crew members involved to discuss the event(s) with senior AO personnel.
- The selected AO personnel will possess the following qualifications: a current or recent Base Training appointment with this OPERATOR and a senior elected position within the AO. The operator will be notified of the interviewers before any such interview to confirm their acceptability.
- The AO will provide a written report of each interview to the operator.
- If either the operator or the AO are convinced that, after the interview, the concerns have not been satisfactorily resolved, then the provisions of paragraph 5.1.3. will be invoked.

APPENDIX E

Operators Checklist on FDM Guiding Principles

Audit of UK Operator’s Systems Application of Flight Data Monitoring (FDM) Principles:

To enable the Authority to discharge its responsibility to ensure that operators’ FDM programme is compliant with the requirements of EU-OPS, please use this document to review and record your FDM process and practice against the requirements laid down in EU-OPS 1.037 ACJ as contained in TGL 44. Similar principles are also outlined as acceptable means of compliance (AMC1 ORO.AOC.130) and guidance material (GM1 ORO.AOC.130) for FDM in the forthcoming new European air operation rules (see ORO.AOC.130).

This information will then ensure a less intrusive audit of the FDM programme during the next subsequent annual audit.

Filling in this form:

Please complete this form by entering information in the dark grey data entry boxes. These will expand to include all the information you wish to insert. You can skip to the next box by either pressing <enter> after completing the entry to that box or by pressing <tab>.

When completed – save the file and return a copy to your Flight Operations Inspector by e-mail.

Explanation of layout:

Each section starts with each main paragraph heading originally described in the first edition of CAP 739 and also 1.037 ACJ. The questions are then set out as below:

1) The “**process illustration**” entries are based upon those given in the first edition of [CAP 739](#).

Please describe your process with reference to applicable documentation (attach documents where possible).

2) Answers to the “**specific evidence**” entries should give evidence to support the system description.

3) The “**comments**” entry may be used to clarify the above and to highlight issues, future plans etc.

4) Finally, we would like you to produce a top level **FDM data summary** in the spreadsheet provided.

<p>Please detail your organisation’s processes against each principle and add any further comments that may be needed for clarification.</p> <p>Enter sufficient information such that a high-level audit approach will be able to verify the effectiveness of the FDM process.</p> <p>Questions about this document should be passed to:</p>	<p>Operator’s Details:</p> <p>Operator Name:</p> <p>Operator AOC No:</p> <p>Primary FDM Contact Person:</p> <p>Aircraft Types Covered:</p>
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Information received will not be passed outside CAA except in a de-identified and aggregated format. It is intended that a high-level report on the effectiveness of FDM programmes within the industry will be generated.

1 Definition:	
Flight Data Monitoring (FDM) is the pro-active and non-punitive use of digital flight data from routine operations to improve aviation safety.	
Process illustration	Describe your process with reference to applicable documentation:
1. Provide a high-level statement of your FDM system's safety objectives.	1.
2. What is your formal policy to address the risk management and conditions of use of FDM data?	2.
Specific evidence	Answers
1. Provide evidence of a commitment to a non-punitive/just safety culture.	1.
2. <ul style="list-style-type: none"> a. Demonstrate the provision of resources for the capture, transcription, replay and analysis of FDM data. b. What are the manning levels/provision for your FDM programme? e.g. man days per month. 	2a.
	2b.
3. Estimate for a typical month: <ul style="list-style-type: none"> a. the approximate time spent on the review and assessment of events (in man days); b. the number of events; and c. the number of events individually reviewed per month. 	3a.
	3b.
	3c.
Comments:	

2 Accountability:	
<p>The manager responsible for the accident prevention and flight safety programme, which includes the FDM programme, is accountable for the discovery of issues and the transmission of these to the relevant manager(s) responsible for the process(es) concerned. The latter are accountable for taking appropriate and practicable safety action within a reasonable period of time that reflects the severity of the issue.</p> <p>Note: While an operator may contract the operation of a flight data analysis programme to another party the overall responsibility remains with the operator's accountable manager.</p>	
Process illustration	Describe your process with reference to applicable documentation:
1. Is FDM included in an appropriate manager's responsibilities? If not, who is responsible?	1.
2. Who has responsibility for the discovery and transmission of FDM issues?	2.
3. Who is responsible for taking action on FDM discovered issues?	3.
4. If a third party organisation analyses your FDM data, is there an agreement that sets out the demarcation between the FDM service provider's output and the Operator's responsibility for taking action?	4.
Specific Evidence	Answers
1. Who is responsible for taking action upon Operational and Airworthiness issues raised by FDM?	1.
2. Demonstrate the training and background of your staff that enables them to fully understand the FDM process.	2.
Comments:	

3 Objectives:	
An FDM Programme will allow an operator to:	
3.1. Identify areas of operational risk and quantify current safety margins.	
3.2. Identify and quantify operational risks by highlighting when non-standard, unusual or unsafe circumstances occur.	
3.3. Use the FDM information on the frequency of occurrence, combined with an estimation of the level of severity, to assess the safety risks and to determine which may become unacceptable if the discovered trend continues.	
3.4. Put in place appropriate procedures for remedial action once an unacceptable risk, either actually present or predicted by trending, has been identified.	
3.5. Confirm the effectiveness of any remedial action by continued monitoring.	
Process illustration	Describe your process with reference to applicable documentation:
Policy Statement and Procedures on:	
1. How are risks identified by FDM fed into your risk management or Safety Management System?	1.
2. How do you decide if there are changing, especially increasing, levels of risk? Give an example.	2.
3. How would you describe your criteria for acceptance of a particular risk or initiating remedial action?	3.
4. Do you have a procedure for putting in place remedial action and ensuring it is carried out? (Note – this may fall outside FDM area.)	4.
5. Describe your process for deciding the success/failure criteria of follow-up actions.	5.
Specific Evidence	Answers
1. FDM and other safety measures and indicators make up a closed loop risk monitoring system. Give an example of the identification, assessment, action and then monitoring of results.	1. .
2. How do you set an acceptable event rate to determine when action is needed?	2.
3. Give examples of effective remedial action taken because of FDM insight.	3.
Comments:	

4 Flight Recorder Analysis Techniques:	
<p>1. Exceedence Detection: This looks for deviations from flight manual limits, and standard operating procedures. A set of core events should be selected to cover the main areas of interest to the operator. The event detection limits should be continuously reviewed to reflect the operator's current operating procedures.</p> <p>2. All Flights Measurement: A system that defines what is normal practice. This may be accomplished by retaining various snapshots of information from each flight.</p> <p>3. Statistics: A series of measures collected to support the analysis process. These would be expected to include the numbers of flights flown and analysed, aircraft and sector details sufficient to generate rate and trend information.</p>	
Process illustration	Describe your process with reference to applicable documentation:
1. Are your FDM events tailored to your particular operation or set to standard FDM supplier's defaults? Have you added additional events to cover known issues and if so what is your review process to keep the program up to date?	1.
2. Do you have a set of basic measures taken from every flight and if so how do you use them?	2.
3. What supporting statistics are used (e.g. flights/hours scanned, airfield movements etc.)?	3.
Specific Evidence	Answers
1. Give details of the FDM system used, e.g. supplier, recorder hardware used etc.	1.
2. Do you have access to full details of recorded parameters for all aircraft covered by the FDM program?	2.
3. Do you have access to a complete list of current events, their logic and trigger levels?	3.
4. <ul style="list-style-type: none"> a. Does the program allow you to identify which sector all events occur on? b. Does the program allow you to use important discrettes (stall warning, GPWS-modes, TCAS, autopilot/throttle etc.)? c. Please note any significant omissions. 	4a.
	4b.
	4c.
5. How many flights and hours were flown and scanned by the program in the last year?	5.

<p>6. Which airfield has the highest overall event rate per 1000 arrivals/departures? Please give details.</p>	<p>6.</p>
<p>Comments:</p>	

5 Flight Recorder Analysis, Assessment and Process Control Tools:

The effective assessment of information obtained from digital flight data is dependent on the provision of appropriate information technology tool sets. A program suite may include: Annotated data trace displays, engineering unit listings, visualisation for the most significant incidents, access to interpretative material, links to other safety information, and statistical presentations.

Process illustration	Describe your process with reference to applicable documentation:
1. Describe your data verification and validation process.	1.
2. Does your system provide data traces, listings and visualisations? Describe how these tools are regularly used.	2.
3. Do you have full access to interpretive material? (Flight manuals, operating manuals, etc.)	3.
4. What links do you have with other safety systems (Tech Logs, ASRs etc.) and how often are these used?	4.
Specific Evidence	Answers
1. Describe the basic bad data detection and validation routines which are built into your FDM program to increase the quality of the analysed data.	1.
2. What percentage of the events produced are validated/examined in detail/individually?	2.
3. What proportion of your 'raw' events are invalid?	3.
4. FDM events should be tied in with relevant air safety reports or technical logs. Give examples that: <ol style="list-style-type: none"> a. indicate the number of times per month this is carried out; and b. show how this process is achieved by either a manual or automatic link. 	4a.
	4b.
Comments:	

6 Education and Publication:	
<p>Sharing safety information is a fundamental principle of aviation safety in helping to reduce accident rates. The operator should pass on the lessons learnt to all relevant personnel and, where appropriate, industry. Similar media to air safety systems may be used. These may include: Newsletters, flight safety magazines, highlighting examples in training and simulator exercises, periodic reports to industry and the regulatory authority.</p>	
Process illustration	Describe your process with reference to applicable documentation:
1. What FDM reports are produced to a regular timescale?	1.
2. Which means of distribution of safety messages, to crews or other relevant personnel, do you use? a. Newsletter or flight safety magazine. b. Simulator/training feedback. c. Other means – please specify.	2a.
	2b.
	2c.
3. By what means do you inform the industry and the Authority of issues discovered through FDM?	3.
Specific Evidence	Answers
1. List the FDM trend and analysis reports given to management in the last year.	1.
2. List any other routine publications that contain FDM information circulated in the last year.	2.
3. Give details of both routine and one-off flight crew updates/FCNs using FDM information.	3.
4. Give examples of how training utilises FDM data, including its use to construct relevant simulator scenarios.	4.
5. Give examples of how any other Departments use your FDM data.	5.
6. In which industry safety information exchange groups do you participate regularly? e.g. UK FDM Operators meetings, UKFSC, PODs etc.	6.
Comments:	

7 Accident and Incident Data Requirements:	
Those specified in EU-OPS 1.160 take precedence over the requirements of an FDM system. In these cases the FDR data shall be retained as part of the investigation data and may fall outside the de-identification agreements.	
Process illustration	Describe your process with reference to applicable documentation:
1. Describe your procedures to retain and protect data if an accident or reportable incident takes place.	1.
Specific Evidence	Answers
1. Show how mandatory FDR data for serious incidents or accidents is handled.	1.
2. What are the FDM data processes when an incident or accident has occurred?	2.
3. Is FDM data substituted for the mandatory FDR data and if so on what authority?	3.
4. The use of FDM data may, on occasions, be appropriate background material to an investigation. Give details of any process in place to facilitate this under secure conditions. Has it been used?	4.
Comments:	

8 Significant Risk-Bearing Incidents Detected by FDM:

Every crew member has a responsibility to report events described in EU-OPS 1.085(b) using the company occurrence reporting scheme detailed in EU-OPS 1.037(a)(2). Mandatory Occurrence Reporting is a requirement under EU-OPS 1.420.

Significant risk-bearing incidents detected by FDM will therefore normally be the subject of mandatory occurrence report by the crew. If this is not the case then they should submit a retrospective report that will be included under the normal accident prevention and flight safety process without prejudice.

Process illustration	Describe your process with reference to applicable documentation:
1. How do you confirm if an FDM exceedence has been the subject of a crew safety report?	1.
2. Describe how you estimate the severity of each FDM event or ASR and if it should be a mandatory report.	2.
3. If an ASR has not been submitted on a serious FDM detected event how do you follow this up with the crew?	3.
4. What is your management approach to retrospective reporting?	4.
Specific Evidence	Answers
1. Do you know how many ASRs have related FDM events?	1.
2. The correct functioning of both the FDM and ASR/MOR processes can be confirmed by cross-checking and associating FDM and relevant crew reports. <ol style="list-style-type: none"> a. Do you attempt this? b. If so please give specific examples such as hard GPWS warnings, heavy landings, turbulence, tailscrapes etc. 	2a.
	2b.
3. FDM can be used to encourage and seek confirmation of crew compliance with ASR/MOR requirements. <ol style="list-style-type: none"> a. Is this done? If so please give an example of crews being requested to submit ASRs and their non-punitive treatment. 	3.
Comments:	

9 Data Recovery Strategy:	
The data recovery strategy should ensure a sufficiently representative capture of flight information to maintain an overview of operations. Data analysis should be performed sufficiently frequently to enable action to be taken on significant safety issues and to enable an operational investigation before crew members memories of the event can fade.	
Process illustration	Describe your process with reference to applicable documentation:
1. What are your data recovery objectives and targets?	1.
2. If not 100% recovery and analysis how did you determine what constituted a representative sample?	2.
3. What is your target for achieving timely processing and targets?	3.
Specific Evidence	Answers
1. If not 100% describe how a representative capture covering all aspects of operations is ensured. (Types, bases, routes etc.)	1.
2. Give details of your systems recovery performance over the last year (as a percentage of flown flights/hours). a. What is the average for each fleet? b. What were the best and worst monthly figures for each fleet?	2a.
	2b.
3. Explain any gaps in FDM coverage (e.g. technical issues, short term disposal plans) and provide evidence of CAA dispensation.	3.
4. How is FDM data used for ATQP (if applicable)? If not applicable, is ATQP being considered?	4.
Comments:	

10 Data Retention Strategy:

The data retention strategy should aim to provide the greatest safety benefits practicable from the available data. A full data set should be retained until the action and review processes are complete; thereafter, a reduced data set relating to closed issues can be maintained for longer term trend analysis. Programme managers may wish to retain samples of de-identified full-flight data for various safety purposes (detailed analysis, training, benchmarking etc.).

Process illustration	Describe your process with reference to applicable documentation:
1. What is your data retention policy?	1.
2. What is your identification and subsequent de-identification policy and timescales?	2.
3. What is your data destruction policy?	3.
4. What is your FDM data retention policy on ASRs/MORs?	4.
Specific Evidence	Answers
1. What are the target and normal timescales for investigation and assessment?	1.
2. How is the data from flights subject to MORs protected, retained and finally cleared for release?	2.
Comments:	

11 Data Access and Security:

Data Access and Security policy should restrict information access to authorised persons. When data access is required for airworthiness and maintenance purposes, a procedure should be in place to prevent disclosure of crew or flight identity.

Process illustration	Describe your process with reference to applicable documentation:
1. What is your policy on access to FDM data?	1.
2. Provide a list of persons/posts with access, data views, and typical use of FDM data.	2.
3. Do you have a procedure for the secure Continued Airworthiness use of FDM data?	3. _____
Specific Evidence	Answers
1. Have you an audit trail for all access history? If so give details of how this is accomplished.	1.

Comments:

12 Procedure Document:

The conditions of use and protection given to participants should be defined in a procedure document acknowledged by all parties. This document, signed by all parties (airline management, flight crew member representatives nominated either by the union or the flight crew themselves), will, as a minimum, define:

- a) The aim of the FDM programme.
- b) A data access and security policy that should restrict access to information to specifically authorised persons identified by their position.
- c) The method to obtain de-identified crew feedback on those occasions that require specific flight follow-up for contextual information; where such crew contact is required the authorised person(s) need not necessarily be the programme manager, or safety manager, but could be a third party (broker) mutually acceptable to unions or staff and management.
- d) The data retention policy and accountability including the measures taken to ensure the security of the data.
- e) The conditions under which, on rare occasions, advisory briefing or remedial training should take place; this should always be carried out in a constructive and non-punitive manner.
- f) The conditions under which the confidentiality may be withdrawn for reasons of gross negligence or significant continuing safety concern.
- g) The participation of flight crew member representative(s) in the assessment of the data, the action and review process and the consideration of recommendations.
- h) The policy for publishing the findings resulting from FDM.

Process illustration**A single document containing:****Describe your process with reference to applicable documentation:**

Refer to the document itself – if possible please attach a copy.

1. Do you have such a document? If so please indicate the items below that are included. If not give the reference to other documents which contain equivalent sections.	1. (Yes/No)
2. Aims and objectives of FDM programme.	2.
3. Detailed data access and security policy.	3.
4. The method to obtain de-identified crew feedback.	4.
5. The data retention policy.	5.
6. The conditions under which advisory briefing or remedial training should take place.	6.
7. The conditions under which the confidentiality may be withdrawn for reasons of gross negligence.	7.
8. The participation of flight crew representatives in the FDM process.	8.

9. The policy for publishing the findings resulting from FDM.	9.
Specific Evidence	Answers
1. If your organisation does not recognise flight crew unions what alternative safeguards have been put in place?	1.
Comments:	

13 Airborne Systems and Equipment:

Airborne systems and equipment used to obtain FDM data will range from an already installed full Quick Access Recorder, in a modern aircraft with digital systems, to a basic crash protected recorder in an older or less sophisticated aircraft. The analysis potential of the reduced data set available in the latter case may reduce the safety benefits obtainable. The operator shall ensure that FDM use does not adversely affect the serviceability of equipment required for accident investigation.

Process illustration	Describe your process with reference to applicable documentation:
1. Describe your means of FDM data storage and recovery including outlines of your installation, test and maintenance procedures.	1.
2. If mandatory recorders are used for FDM what procedures are in place to minimise the effect on their serviceability?	2.
3. What entry for QAR has been added to the Minimum Equipment List.	3.

Specific Measures	Answers
1. What technology is used to obtain FDM data? e.g. WQAR, PQAR, OQAR, MQAR, Mandatory FDR.	1.
2. If a crash recorder is used: <ol style="list-style-type: none"> a. Is it solid state or tape? b. How is full data recovery ensured (25/50hr recycle time)? 	2a.
	2b.
3. Describe processes, other than basic FDM, that are dependent upon FDM data.	3.
4. What are your MEL procedures for departure with an unserviceable QAR device?	4.

Comments:

The following is given as just an example of the data that Operators ought to be able to produce from their FDM programmes and with agreement share – there are potentially many other areas beyond these that could be considered to gain a further understanding of safety risks.

FDM Data Summary

Finally, we would like you to produce a top level FDM data summary of one year's experience. [A spreadsheet set out for you to enter the information needed is attached.](#)

There are three objectives for this request:

- (1) To ascertain if your FDM programme has the capability to produce basic overviews and subsets from the data.
- (2) To pool information about some of the most significant events (e.g. GPWS pull up warnings, stall warnings, TCAS RAs etc.).
- (3) To provide an insight into the potential for FDM as an industry-wide safety measure.

Information received will not be passed outside CAA except in a de-identified and aggregated format. It is intended that a high-level report on the effectiveness of FDM programmes within the UK industry will be produced.

Required Information to be entered into spreadsheet:

System Overview of your FDM Programme

Aircraft Type or Fleet	Number of Flights Scanned	Number of Events Produced			Number of Crew Contacts*	Number of Events with ASR	Number of Retrospective ASRs
		Level 1	Level 2 (or Detect)	Level 3 (or Alert)			
* as a result of an FDM event							

Information for Specific Types of Events

Aircraft Type or Fleet	Number of events:					Comments
	Go arounds below 1,000 ft AAL	Genuine Hard GPWS Warnings	Genuine Stall Warnings	TCAS RAs	Land flap selected below 500 ft AAL	

Information on the Location of Specific Events

Event Location (Airfield or in case of TCAS RAs an approximate area)	Number of events at each location:				Comments
	Go arounds below 1,000 ft AAL	Genuine Hard GPWS Warnings	TCAS RAs	Land flap selected below 500 ft AAL	

Information on Hard/Heavy Landing events

Aircraft Type	For each Hard Landing Event			Comments
	Airfield	Maximum Normal Acceleration	Event trigger level	

Flights Scanned by your FDM Programme by Airfield of Departure

Airfield Name	Airfield IATA Code	Airfield ICAO Code	Number of Departures Scanned for each Fleet				Comments
			Aircraft Fleets				

APPENDIX F**FDM Programme Costs and Benefits**

F1 The following information is intended as only an indication of the possible costs of a modern FDM programme.

An FDM programme, when part of an operator's Accident Prevention and Flight Safety programme, enables an operator to identify, quantify, assess and address operational risks that are present in normal operations. As well as this being an enhancement to flight safety, current operators of FDM programmes have reported substantial cost savings being achieved. These cost saving areas include engines, fuel, maintenance, inspection and hull insurance.

The basic costs of establishing and running such a programme can be broken down into the following areas:

i) Quick Access Recorder (QAR) - Costs vary between vendors, but also specifically relate to the type of QAR technology involved. Wireless Quick Access Recorders (WQAR) tend to be marginally more expensive than traditional PC card and Optical QARs. However, the cost of these may be justified due to the improved data recovery rates and their full-automated functionality. Potential benefits with WQARs include them supporting automated QAR data delivery plus a range of other additional functions such as ACMS data download.

ii) QAR Installation - Costs can be dependent on aircraft and type of QAR being installed

iii) Ground-based data replay and analysis system software - Such costs will vary depending on the number of different fleets that an Operator uses as well as the costs associated with the number of different data frames required.

The ongoing annual cost per aircraft provided by these operators varies greatly, and generally appears to be inversely proportional to the fleet size. Thus the annual running cost quoted will vary for example, between a small 10 aeroplane UK operator and a large UK operator.

- F2 **NOTE:** Where an existing DFDR crash-protected flight recorder is used there may be an equipment cost for download devices. This would be considerably less than the cost of a QAR and its installation. However, the time taken to download the DFDR may possibly make this process untenable during turnarounds.
- F3 Listed below are some of the cost and benefit aspects that should be taken into account during a cost benefit exercise:

Cost of an Accident

- F4 Various approaches to the cost savings through the prevention of a catastrophic accident have been attempted. The following costs could be estimated and compared with FDM system costs and benefits spread over a period of time.
- Life costs per life lost can be obtained from recent claim trends.
 - Hull replacement cost.
 - Third party damage costs.
 - Loss of revenue due to loss of use of aircraft.
 - Loss of revenue likely through lowering of public confidence.
 - Reduction in company value due to stock market loss of confidence.
 - Increase in insurance premium.
 - Offsetting this is the insurance payment for the loss.
- F5 There would be additional industry costs that would not fall upon the individual Operator resulting from a general loss of confidence in aviation and increased overall risk levels.
- F6 Perhaps more relevant to these preventive programmes is the cost of “minor” damage accidents such as tailscrapes, hard landings, turbulence upsets etc. The costs associated with these more common events are easier to estimate. These are often easily addressed by FDM and hence there could be a more quantifiable cost saving.

Non-Recurring Costs

- F7 If new equipment is to be installed on the aircraft:
- Aircraft equipment - Quick Access Recorders or other data storage devices.
 - Aircraft installation hardware - cables, mountings, etc.
 - Modification - design and approval of modifications.
 - Installation labour costs.
 - Ground replay installation - hardware and software.
 - Loss of revenue due to aircraft downtime.

Recurring Costs

- F8 These costs may be internal or external if the processing is contracted out. Note that in this case there are still unavoidable staff costs associated with assessment and decision making.
- FDM administration and processing staff costs.
 - FDM analysis, interpretation and assessment staff costs.
 - Continued Airworthiness and maintenance.
 - Staff training.
 - Media logistic costs - collecting and transporting.
 - Consumables - recording media, paper, etc.
 - If used wireless system running costs replace the previous two items.

Potential Benefits

- F9 The following examples of where FDM data has produced savings have been taken from a wide range of operators.
- Engine savings - ECM - Postponed/reduced removals, manufacturer supported extended servicing.
 - Fuel savings - revised operating practices, trim analysis, airframe differences.
 - Fuel tankering - more accurate burn calculations.
 - Brake savings - better crew awareness and highlighting heavy use.
 - Flap maintenance savings - fewer overspeeds and use as a 'drag flap'.
 - Inspections savings - reduced number required due to availability of maximum values for hard landings, engine over temp', flap placard, etc.
 - Safety savings - improved safety estimated from probable hull loss rates.
 - Insurance savings - based on experience of long term FDM operators.
 - Increased aircraft availability - better/faster fault diagnosis.
 - Repair savings - reduced numbers of tailstrikes, hard landings, etc.
 - Reduced ACARS costs - ECMS and other data collection from QAR.
 - Increased simulator effectiveness - better targeted.
 - ETOPS monitoring - automatic rather than manual.
 - Warranty support - definitive usage evidence.
 - Autoland support - record keeping and system health/accuracy.

APPENDIX G

Summary of United Kingdom Mandatory Flight Data Recorder Requirements

- G1 The following tables provide simple guidance on how to interpret the operational requirements relating to the installation of Mandatory Flight Data Recorders. This will be especially useful when developing FDM on an older airframe. They specify when a flight recorder has to be carried, how long its recording duration should be and provide reference data for the required FDR parameters.
- G2 It should be noted that this information is for guidance purposes only, and that reference should be made to the appropriate operational rules as these are the definitive source of the requirement.
- G3 The following tables are current at the time of publication of this document only and should not be used in preference to the actual operational rules.
- G4 The tables are provided in the following order:
1. Tables relating to the Air Navigation Order
 2. Tables relating to EU-OPS 1
 3. Tables relating to JAR-OPS 3
- G5 The tables do not attempt to list the sets of mandatory parameters as these are explicitly detailed in the operational requirements.

List of Tables Included

- G.1 Air Navigation Order 2009 – Scale P. Type Certificate issued anywhere before 1st April 1971
- G.2 Air Navigation Order 2009 – Scale S.
- G.3 Air Navigation Order 2009 – Scale SS. Rotorcraft Type Certificate issued anywhere on or after 1st April 1971
- G.4 EU-OPS 1
- G.5 JAR OPS-3

Table G.1 Air Navigation Order 2009 – Scale P: Type Certificate issued anywhere before 1st April 1971

Weight in Kilogrammes	Turbine Engine		Piston Engine	
	Transport Cat. Passenger/ Cargo	Special Cat. or 'A' conditions if applied for Transport Cat.	Transport Cat. Passenger/ Cargo	Special Cat. or 'A' conditions if applied for Transport Cat.
5,700 < X ≤ 11,400	Operated by Air Transport undertaking FDR or CVR	FDR or CVR		
11,400 < X ≤ 230,000	Operated by Air Transport undertaking FDR and CVR	FDR and CVR		
27,000 < X ≤ 230,000			Operated by Air Transport undertaking FDR	FDR

NOTES:

1. All CVRs are required to be 4 Channel CVRs.
2. For the list of parameters to be recorded refer to ANO 2009 Schedule 4 Scale P.
3. 'X' refers to the weight of the aircraft in question.

Table G.2 Air Navigation Order 2009 – Scale S.

Type Cert. Issued Anywhere	Individual C of A Issued Anywhere	Weight in Kilogrammes	Specific Conditions	ANO Scale	Turbine Engine	Piston Engine
on/after 1/4/71		5,700 < X ≤ 11,400	-	S(1)	FDR or CVR	FDR or CVR
on/after 1/4/71		11,400 < X ≤ 27,000	-	S(2)	FDR and CVR	FDR and CVR
on/after 1/4/71		27,000 < X ≤ 230,000	-	S(3)	FDR and CVR	FDR and CVR
on/after 1/1/70 in UK		X > 230,000	-	S(3)	FDR and CVR	FDR and CVR
	on/after 1/6/90	X ≤ 5,700	2+ Engines and 9+ Pax	S(4)	FDR and CVR or Combined FDR/CVR	
	on/after 1/6/90	5,700 < X ≤ 27,000	-	S(5)	FDR and CVR	FDR and CVR
	on/after 1/6/90	X > 27,000	-	S(6)	FDR and CVR	FDR and CVR
	on/after 1/6/90 for aerial work and Private Cat.	X > 27,000	-	S(6)	FDR and CVR	FDR and CVR

NOTES:

1. All CVRs are required to be 4 Channel CVRs.
2. For the list of parameters to be recorded refer to ANO 2009 Schedule 4 Scale S.
3. 'X' refers to the weight of the aircraft in question.

Table G.3 Air Navigation Order 2009 – Scale SS. Rotorcraft Type Certificate issued anywhere on or after 1st April 1971

Type Cert. Issued	Weight (kg)	Specific Conditions	Scale	Helicopters/Gyroplanes	
				Transport Cat. Passenger/ Cargo	Special Cat. or 'A' conditions if applied for Transport Cat.
Applies to all Rotorcraft	2,730 < X ≤ 7,000	9+ Pax or The Specified Weight	SS(1) or SS(3)	½hr CVR + 8hr FDR or Combined 1hr CVR */8hr FDR or 5hr FDR + 3 hrs Non-Protect FDR Data.	½hr CVR + 8hr FDR or Combined 1hr CVR */8hr FDR or 5hr FDR + 3 hrs Non-Protect FDR Data.
Applies to all Rotorcraft	X > 7,000	-	SS(2) or SS(3)	½hr CVR + 8hr FDR or Combined 1hr CVR */8hr FDR or 5hr FDR + 3 hrs Non-Protect FDR Data.	½hr CVR + 8hr FDR or Combined 1hr CVR */8hr FDR or 5hr FDR + 3 hrs Non-Protect FDR Data.

* 3 Channel CVR Minimum.

NOTES:

1. All CVRs, except those marked Q, are required to be 4 Channel CVRs.
2. For the list of parameters to be recorded refer to ANO 2009 Schedule 4 Scale SS.
3. 'X' refers to the weight of the aircraft in question.

Table G.4 EU-OPS 1

EU-OPS 1 Section	Type Certificated After	Individual A/C Cert. Issued Anywhere	Weight in kg	No. T. Eng's	Approved PAX Seating Config	Turbine Powered	Recording Duration	Parameter Definition Table
715 a1 and a2	-	on/after 1/4/98	X > 5,700	2+	> 9	Digital FDR	25 Hrs	See Table A1 or A2 of Appendix 1 to JAR-OPS 1.715
715 b and 727	-	on/after 1/4/98	X ≤ 5,700	-	-	FDR or Combined FDR/CVR	10 Hrs	See Table A1 or A2 of Appendix 1 to JAR-OPS 1.715
720	-	1/6/90 to 31/3/98	5,700 < X ≤ 27,000	-	-	Digital FDR	25 Hrs	See Table A of Appendix 1 to JAR-OPS 1.720
720	-	1/6/90 to 31/3/98	X > 27,000	-	-	Digital FDR	25 Hrs	See Tables A and B of Appendix 1 to JAR-OPS 1.720

EU-OPS 1 Section	Type Certificated After	Individual A/C Cert. Issued Anywhere	Weight in kg	No. T. Eng's	Approved PAX Seating Config	Turbine Powered	Recording Duration	Parameter Definition Table
725		Before 1/6/90	X > 5,700	-	-	Digital FDR	25 Hrs	See Table A of Appendix 1 to JAR-OPS 1.725
725	30/6/69	Before 1/6/90	X > 27,000	-	-	Digital FDR	25 Hrs	See Table A + Parameters 6-15 of Table B of Appendix 1 to JAR-OPS 1.725

NOTES:

1. For details of the variations related to required parameters refer to the latest version of EU-OPS 1.
2. 'X' refers to the weight of the aircraft in question.

Table G.5 JAR OPS-3

JAR-OPS 3 Section	Applicable After	Individual A/C Cert. Issued Anywhere	Weight in kg	Approved PAX Seating Config	Recorder Requirement	Recording Duration	Parameter Definition Table
715	-	on/after 1/8/99	3,175 < X ≤ 7,000	-	Digital FDR or Combined FDR/CVR	8 Hrs	See Table A of Appendix 1 to JAR-OPS 3.715 + Table C of Appendix 1 to JAR- OPS 3.715 for rotorcraft with electronic display systems
715	-	on/after 1/8/99	X > 7,000	-	Digital FDR or Combined FDR/CVR	8 Hrs	See Table A of Appendix 1 to JAR-OPS 3.715 + Table C of Appendix 1 to JAR- OPS 3.715 for rotorcraft with electronic display systems
720	1/4/2000	1/1/89 to 31/7/98	X ≤ 7,000	or > 9	Digital FDR or Combined FDR/CVR	5 Hrs	See Table A of Appendix 1 to JAR-OPS 3.720 + Table C of Appendix 1 to JAR- OPS 3.715 for rotorcraft with electronic display systems
720	1/4/2000	1/1/89 to 31/7/98	X > 7,000	or > 9	Digital FDR or Combined FDR/CVR	5 Hrs	See Table B of Appendix 1 to JAR-OPS 3.720 + Table C of Appendix 1 to JAR- OPS 3.715 for rotorcraft with electronic display systems

NOTE: 'X' refers to the weight of the aircraft in question.