



# *Flight Data Recorder Read-Out*

## *Technical and Regulatory Aspects*



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# Glossary

AMC	Acceptable Means of Conformity
ARINC	Aeronautical Radio Incorporated
BCD	Binary Coded Decimal
CAA	Civil Aviation Authority (United Kingdom)
CASA	Civil Aviation Safety Authority (Australia)
CVR	Cockpit Voice Recorder
DAC	Direction de l'Aviation Civile (France)
DAR	Direct Access Recorder
DFL	Data Frame Layout
DGAC	Direction Générale de l'Aviation Civile (France)
DMU	Data Management Unit
EASA	European Aviation Safety Agency
ED	EUROCAE Document
EGT	Exhaust Gas Temperature
EUROCAE	European Organization for Civil Aviation Equipment
FAA	Federal Aviation Administration (USA)
FAR	Federal Aviation Regulations
FDAU	Flight Data Acquisition Unit
FDR	Flight Data Recorder
GPWS	Ground Proximity Warning System
IRS	Inertial Reference System
JAA	Joint Aviation Authorities
JAR	Joint Airworthiness Requirements
kt	Knot
QAR	Quick Access Recorder
ICAO	International Civil Aviation Organization
MOPS	Minimum Operational Performance Specifications
NTSB	National Transportation Safety Board (USA)
SFACT	Service de la Formation Aéronautique et du Contrôle Technique (France)
SSCVR	Solid State Cockpit Voice Recorder
SSFDR	Solid State Flight Data Recorder

## SCOPE

The readout of Flight Data Recorders (FDR), whether performed in France or elsewhere, often brings to light a variety of problems such as aircraft operators having incomplete, outdated or inappropriate documents or not having the relevant documentation at all. Sometimes this significantly delays the validation of the readout work.

However, rapidly obtaining complete and accurate data after an accident or an incident is often critical for the technical investigation and, in a broader way, to air transport safety. Data extracted from FDRs help to determine causes and to develop appropriate preventive measures.

There are no single guideline document relating to FDR regulations. Several international and French texts touch on these aspects, though not always in a coherent fashion.

In order to get a complete picture of the problems encountered, the BEA has produced this study, based on the analysis of known issues and on consultations with French aircraft operators. Its objective is to increase awareness among the various actors of the importance of FDRs for accident prevention and to recommend improvements.

# 1 - TECHNICAL ASPECTS

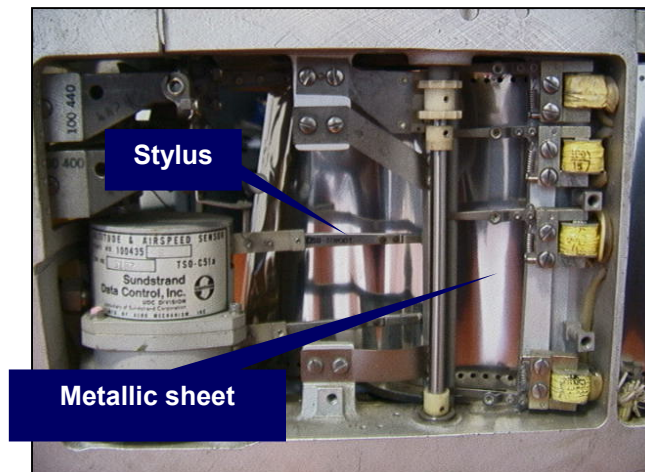
Flight recorders, often called “black boxes” by the media are two devices designed to record data about flights. Flight Data Recorders (FDR) record various flight parameters, whereas Cockpit Voice Recorders (CVR) record the acoustic environment of cockpits. This study will be limited to FDRs.

## 1.1 Technical Evolution of FDRs

The aeronautical industry’s efforts to design recording devices that could sustain accidental damage, such as impact and fire, date to the beginning of commercial aviation. It was only in 1958 that aviation authorities began imposing minimum specifications for flight recorders to aid technical investigations.

### 1.1.1 Metal foil and photographic film recorders

Boeing 707’s, DC8’s and Caravelles were the first jet engine aircraft to be equipped with FDRs in the early sixties. These recorders consisted of a mechanical stylus engraving a metal foil. For metal foil FDRs, the parameters are processed internally with data coming in directly from basic aircraft sensors, such as accelerometers and pitot tubes. At about the same time, a similar technology consisted of replacing the sheet of metal with a photographic film and the mechanical stylus with light beams. That was the photographic film FDR. Both types of FDRs could only monitor a limited number of important parameters, usually 5 or 6, such as magnetic heading and airspeed.



### 1.1.2 Magnetic Tape Recorders

Metal foil and photographic film FDRs started to fall behind in relation to investigation needs in 1965. With the introduction of magnetic tape-based recorders, it became possible to not only record conversations but also to progressively increase the number of parameters monitored by FDRs.

With the new magnetic FDRs, parameters were no longer recorded in a single stream. Instead, they were first sampled, digitalized and multiplexed inside a 1-second long frame. Then, this digital frame was recorded on a magnetic tape using simple signals to code 0's and 1's. Hence the name Digital Flight Data Recorder (DFDR).



**Inside a magnetic tape recorder**

### **1.1.3 Acquisition unit**

As the need for more parameters grew and as new digital technology appeared, it became inadequate to have FDRs compute parameters internally based on data received from sensors.

Flight data acquisition devices began to be designed to collect all parameters before being recorded. These devices include the Flight Data Acquisition Unit (FDAU), Flight Data Interface Unit (FDIU) or Flight Data Acquisition Card (FDAC). They order data and then send it to FDRs, whose function is then limited to data recording.

Note: Aircraft operators can modify FDAU programming.

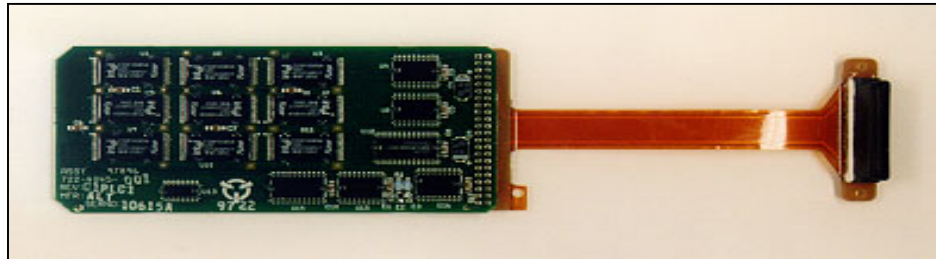
It is important to note that mainly large aircraft in the public transport category are equipped with data acquisition units. For smaller aircraft, the data acquisition function is still often performed by FDRs.

### **1.1.4 Solid state recorders**

With the evolution of digital technologies, solid-state memory cards replaced magnetic tapes in FDRs around 1985. Recordings on these new Solid State Flight Data Recorders (SSFDR) have far better restitution reliability than on the magnetic FDRs.

As memory cards got smaller, the number of recorded parameters went up to several hundred, sampling frequencies increased and recording times of some models rose to 50 hours or more.

Sound recorders also benefited from this technological evolution, with not only the possibility of recording sound digitally, but also with a recording time that was extended to 2 hours as opposed to half an hour for magnetic tape-based CVRs.



**Memory Card on an SSFDR**

### **1.1.5 Non-protected recorders**

The introduction of data acquisition units has also benefited what is commonly called “flight data monitoring”. FDRs were the only devices recording data and that data was only used after an accident. Now, with data acquisition units, data is also directed to other types of recorders.

These recorders are not protected. The recording media can be a tape, an optical magnetic disc or a PCMCIA card. The recording media is designed to be removed and replaced quickly. The access to the recording media is located either in the cockpit or in the electronics bay.

Quick Access Recorders (QAR’s) usually record exactly the same data as FDRs. Onboard an aircraft, the data acquisition unit feeds both the FDR and the QAR. The most recent QARs also have input ports compatible with the standard aircraft buses (ARINC 429) and can therefore receive additional data.

Direct Access Recorders (DARs) receive data from Data Management Units (DMUs) and can be programmed not only to select which parameters to record and with which sampling frequency, but also to select the recording mode: periodic recording or recording triggered by events such as a parameter passing over a pre-determined threshold.

These recorders are used for maintenance, research or flight data monitoring purposes.



## **1.2 Data Acquisition System**

### **1.2.1 Data acquisition computer operational concept**

Data acquisition computers centralize and format data coming from sensors, onboard computers and other instruments and then transfer it to FDRs via a dedicated digital link (serial link ARINC 573 or 717). There are four types of input data:

- Discrete (logical status detection, indicators, switches, relays);
- Analog (potentiometer);
- Synchronization transmitters;
- Digital bus (ARINC 429).

Data acquisition units are programmed to produce a continual flow of data towards FDRs. They deal with the time sampling of parameters and of their digital encoding from the actual physical value to the recorded value.

### **1.2.2 Data Frame Layout**

FDR Data Frame Layout (DFL) documents depend on the type of recording systems. They describe:

- the programming method used by the data acquisition system (location of parameters, number of bits used to encode parameters, type and method of encoding);
- the functions used to convert the recorded value into the actual physical value. For each parameter, the conversion function is checked with the calibration of the measuring and processing channel, as mentioned later in this document.

These documents are completed by calibration control reports on the mandatory parameters.

### **1.2.3 Parameter decoding**

Data acquisition systems output a binary file sequenced in four-second frames. Each frame is divided into four one-second-subframes.

Each subframe is divided into 64, 128, 256 or 512 “words” of 12 bits each, depending on the FDR’s technology. The bit is the basic binary unit whose value is either 0 or 1.



### **1.3.1.2 Method**

In order to be efficient, the check must only deal with recordings on FDRs and not on other devices like QARs or DARs. The entire set of recorded data can be copied for analysis and be converted into engineering units <sup>(1)</sup> using decoding software that has to be programmed according to data frame layout documents.

The check on recorded parameters may include:

- location of regulatory parameters in accordance with data frame layouts;
- validity of conversion functions for each regulatory parameter, taking into account their operational value range;
- coherence of parameters' patterns for several phases of flight;
- check for long or cyclical areas of unreadable data;
- chronological integrity of recordings.

Examples of procedures are available in the Flight Data Recorder Maintenance document published by Australian authorities <sup>(2)</sup>.

## **1.3.2 Calibration of measuring and processing channels**

### **1.3.2.1 Objective**

Data recording quality is evaluated by comparing a parameter's value, as measured by instruments, with the recorded value. It is therefore essential to calibrate the measuring and processing channels of each parameter.

Calibration is also necessary because conversion functions provided by manufacturers are only theoretical since they are the results of tests performed on prototypes, and can therefore differ from the ones of the actual aircraft.

In addition, several factors can alter the quality of the measurements. These factors include:

- Sensor aging. Sensors are subject to environmental constraints like water or high temperature and pressure variations that can cause the system to drift from the initial calibration.
- Connecting an additional device to an analog input, like a potentiometer or a synchronized transmitter. These additions can modify the electrical characteristics of the transmitted signal in terms of amplitude and/or phase.
- The disassembly and reassembly of mechanical elements. This can cause some sensors to go out of adjustment and can happen during major overhauls or during an FDR systems retrofit.

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<sup>(1)</sup> An engineering unit is a unit measuring a physical value. For instance, for pressure altitude, the engineering unit is the foot.

<sup>(2)</sup> Civil Aviation Safety Authority Australia, October 2002, Flight Data Recorder Maintenance CAAP 42L-4(0), appendix 1, pp 14-18.

Finally, sensors used for recorders can be different from the ones feeding data to flight instruments and other aircraft systems. Consequently, a recorded value can differ from the value actually used by aircraft systems.

Note: These problems primarily affect older aircraft. For more recent ones, parameters are usually digitized and used by several systems, including flight data acquisition systems, which makes anomaly detection easier.

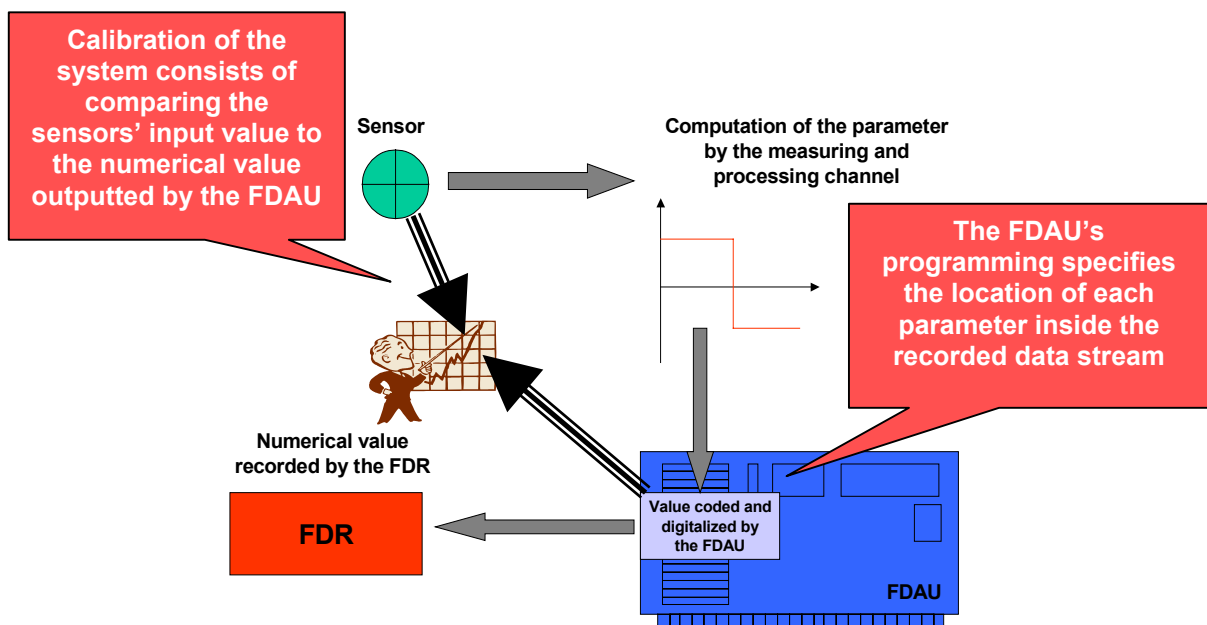
When allowable deviations between nominal values and recorded values are exceeded, two types of actions can be taken, depending on the nature of the issue:

- replacement or repair of malfunctioning elements, or
- modification of conversion functions in data frame layout documents, through a calibration procedure.

Discrete parameters which are used to warn of unusual situations, such as GPWS Warning, Stick Shaker, Mach Warning, and/or Engine Fire, are not activated during normal flights and do not appear on FDR recordings. Examining these recordings is therefore not adequate to ensure that the recording of these alarm parameters is performed properly. The following procedure suits this need better.

### 1.3.2.2 Calibration procedure

Calibration of the parameters' measuring and processing channels consists of generating baseline values, entering them into sensors and noting the output values of acquisition devices, or, in the case where the acquisition is performed by the recorders, retrieving the corresponding recorded value.



Calibration process diagram

### 1.3.2.2.1 Generation of baseline values

Baseline values can be generated using one of the following methods:

- Sensor activation. This includes:
  - Sensor “stimulation” which consists of applying physical inputs to it, such as a calibrated pressure on a static port;
  - Sensor “simulation” which consists of reproducing the sensor’s electrical signal output. This is done when sensor stimulation is too complex to perform, as for instance for engine temperature or alarms.
- Activation of auto-test functions of systems such as Inertial Reference Systems (IRS). These functions internally adjust parameters with reference to baselines.
- Read-out of instrument indications when no internal test exists or when sensors feeding the recording system also feed cockpit indicators.

### 1.3.2.2.2 Check on output values

In order to check the output values of the data acquisition system, a compatible read-out system can be connected to it. This read-out system computes the parameters’ real-time values using conversion functions identical to those given by the data frame layout document.

### 1.3.2.2.3 Example

Calibration of the “aileron position” parameter

Actual position measured with a clinometer (degrees)	Raw output value from the acquisition system	Converted value using conversion functions (degrees)	Deviation of the acquisition system (degrees)
+ 25.5 (right stop)	2,880	+ 25.2	- 0.3
+ 15	2,545	+ 15.1	+ 0.1
0	2,065	0.5	+ 0.5
- 15	1,603	- 13.4	+ 1.6
- 25 (left stop)	1,246	- 24.3	+ 0.7
Maximum allowable deviation: +/- 2° Source: AMC OPS 1.720 1.725 Appendix 1 – Table A			Result: precision OK

As of today, the calibration of all measuring and processing channels is only performed by aircraft manufacturers prior to delivery.

## **2 - OPERATIONAL AND REGULATORY ASPECTS**

### **2.1 Overview of Regulations**

#### **2.1.1 Introduction**

Regulations pertaining to flight data recorders and data frame layouts are covered by several different texts. At the ICAO level, Annex 6 (eighth Edition, July 2001) and Annex 13 are the principal documents relating to these subjects. At the European level, information can be found in the JAR OPS1 document, which, at the French level, was transposed into a regulation dated 12 May 1997 (called OPS1).

EUROCAE also produces documents regarding recorders. These documents are referred to by a variety of other regulations. See Appendices for extracts from EUROCAE 55 (ED55) and EUROCAE 112 (ED112).

#### **2.1.2 Annex 6, Part I**

Annex 6 to the Convention on International Civil Aviation contains standards and recommended practices for the technical operation of aircraft. It is divided into 3 parts. Part I contains standards and recommended practices applicable to the operation of aircraft by operators authorized to conduct international commercial air transport operations. Provisions relating to flight recorders are included in attachment D.

##### ***2.1.2.1 FDR equipment regulations***

Annex 6, Part I, paragraphs 6.3.3 and 6.3.4 indicate that all aircraft with a maximum certificated take-off weight over 5,700 kg are required to be equipped with an FDR, regardless of the date of the individual certificate of airworthiness.

Paragraph 6.3.6 indicates that the list of parameters <sup>(3)</sup> to be recorded for aircraft with a maximum certificated take-off weight of over 27,000 kg also applies to aircraft with a maximum certificated take-off weight of over 5,700 kg and for which the individual certificate of airworthiness was first issued after 1 January 2005.

France has pointed out that the list of parameters required by ICAO Annex 6 has not been incorporated into French regulations. Consequently, the standard described in paragraph 6.3.6 has not yet been applied by France.

See Appendix III for compulsory parameter requirements.

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<sup>(3)</sup> See paragraph 6.3.1.8 for this list

### **2.1.2.2 Installation of FDRs**

Attachment D to ICAO Annex 6, paragraph 1.3 lists the rules relative to the installation of FDRs. It includes:

- Recording requirements on installed equipment must be verified by methods approved by the appropriate certifying authority.
- The manufacturer must provide the national certifying authority with the following information concerning the FDR:
  - manufacturer's operating instructions and installation procedures,
  - parameter origin or source and equations which relate to conversions to units of measurement,
  - Manufacturer's test reports.

Operators must archive all documents concerning FDRs <sup>(4)</sup> in case they need to be read out. Annex 6, Attachment D, paragraph 1.3.4 states:

*"Documentation concerning parameter allocation, conversion equations, periodic calibration and other serviceability/maintenance information should be sufficient to ensure that accident investigation authorities have the necessary information to read out the data in engineering units."*

### **2.1.2.3 Flight data analysis programme**

Paragraph 3.2.3 states that:

*"From 1 January 2005, an operator of an aeroplane of a maximum certificated take-off mass in excess of 27,000 kg shall establish and maintain a flight data analysis programme as part of its prevention and flight safety programme."*

*Note: an operator may sub-contract performance of a flight data analysis programme to another party while retaining overall responsibility for the programme".*

A note in paragraph 3.2.4 states that:

*"Guidance on flight data analysis is contained in the Accident Prevention Manual (Doc 9422)".*

France has specified that such an analysis programme is required by French regulations for aircraft with a certificated take-off weight in excess of 10,000 kg or with a number of seats in maximum configuration in excess of 20.

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<sup>(4)</sup> This information is usually listed in documents called "data frame layout documents" in this study.

#### **2.1.2.4 Inspection of FDR systems**

ICAO Annex 6, Part I, Attachment D, paragraph 3.2 states that annual inspection of FDRs should be carried out by operators as follows:

- *“the read-out of the recorded data from the FDR (...) should ensure that the recorder operates correctly for the nominal duration of the recording;”*
- *“the analysis of the FDR should evaluate the quality of the recorded data to (...) determine the nature and distribution of the errors;”*
- *“the FDR data from a complete flight should be examined in engineering units to evaluate the validity of all recorded parameters (...).”* Thus, the engineered parameters processed from raw data must be examined.
- *“Particular attention should be given to parameters from sensors dedicated to the FDR”,* because failures of these sensors cannot be detected by other onboard systems.
- *“the read-out facility should have the necessary software to accurately convert the recorded values to engineering units and to determine the status of discrete signals”.* The use of software for these tasks is necessary in order to process all the compulsory parameters of a flight in a timely manner.
- *“A report of the annual inspection should be made available on request to the State’s regulatory authority for monitoring purposes”.*

#### **2.1.2.5 Criteria for serviceability of flight recorder systems**

Attachment D, paragraph 3.3 states that:

*“Flight recorder systems should be considered unserviceable if there is a significant period of poor quality data (...), or if one or more of the mandatory parameters is not recorded correctly.”*

Corrective actions must be taken on the flight recorder system as soon as a mandatory parameter is not recorded in the manner specified by quality requirements.

#### **2.1.2.6 Calibration of measuring and processing channels**

Attachment D, paragraph 3.5 indicates the frequency at which the recorder system and the measuring and processing channel should be re-calibrated:

- *“the FDR system should be re-calibrated at least every five years [...] for the mandatory parameters”*
- *when the parameters of altitude and airspeed are provided by sensors that are dedicated to the FDR system, there should be a re-calibration performed as recommended by the sensor manufacturer, at least every two years.*



## **2.1.3 JAR OPS 1 and OPS 1**

### **2.1.3.1 FDR regulations and nature of data to be recorded**

JAR OPS 1 application depends on the date of the individual certificate of airworthiness <sup>(5)</sup>. Paragraphs 1.715, 1.720 and 1.725 for FDRs and paragraph 1.727 for Combination Recorders describe how recorders have to be installed, the parameters to record and the length of recordings.

It is specified that aircraft with a maximum certified take-off weight over 5,700 kg are required to be equipped with an FDR. This requirement is extended to multi-engine turbine powered aircraft, which have a maximum approved passenger seating configuration of more than 9, when the individual certificate of airworthiness was issued after 1 April 1998.

Parameters to be recorded are listed in JAR OPS 1 (see Appendix III of this study) which stipulates that a method to extract data from the memory support must be available. However, not all parameters are required to be recorded, depending on the maximum certificated take-off weight and on the date of issue of the individual certificate of airworthiness.

Operators must comply, when possible, with operational calibration, precision and resolution specifications defined in ED55. See Appendix I for an extract from these specifications.

### **2.1.3.2 Flight safety programme**

Paragraphs 1.037 of JAR OPS 1 and the French regulation of 12 May 1997 have the same title, "*Accident Prevention and Flight Safety Programme*", but their contents slightly differ.

Paragraph 1.037 of the French regulation states, "*an operator shall establish an accident prevention and flight safety programme which includes an analysis of flight safety or flight parameter recording reports.*" This requirement was put in place in response to recommendations after the accident that occurred on 20 January 1992 near Mont Sainte-Odile <sup>(6)</sup>.

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<sup>(5)</sup> Effective dates :

- OPS 1.715: aircraft for which the individual certificate of airworthiness was issued after 1 April 1998
- OPS 1.720: aircraft for which the individual certificate of airworthiness was issued between 1 June 1990 and 31 March 1998
- OPS 1.725: aircraft for which the individual certificate of airworthiness was issued before 1 June 1990

<sup>(6)</sup> In the accident report involving an Airbus A320 registered F-GGED that crashed on 20 January 1992 near Mont Sainte-Odile in Alsace, France, domestic and international civil aviation authorities were recommended to take measures to encourage aircraft operators:

- to expand their systematic analysis of recorded flight parameters,
- to perform a detailed analysis, including on an operational level, of the major detected anomalies by a specialized department at the operator,
- to communicate, using appropriate means, the results of analyses to the appropriate authorities, manufacturers and other operators, while complying with confidentiality and anonymity constraints.

Since 1 January 2000, flight safety reports and flight parameter recordings must be analyzed for turbine-engine-powered aircraft with a maximum certificated take-off weight in excess of 10,000 kg or with a number of seats, in maximum configuration, in excess of 20.

In contrast, JAR OPS 1, paragraph 1.037 requires since 1 January 2005 a flight data monitoring programme for those aeroplanes with a maximum certificated take-off weight in excess of 27,000 kg.

Note: In the United States, flight data monitoring is not mandatory, but simply recommended by the FAA through Flight Operational Quality Assurance (FOQA) activities.

### **2.1.3.3 Data frame layout documents**

Paragraph 1.160 of JAR is about “*preservation, production and use of flight recorder recordings*”. Sub-paragraph (a)-(4)-(ii) states that aircraft operators shall “*keep a document which presents the information necessary to retrieve and convert the stored data into engineering units.*”

### **2.1.4 French texts**

#### **2.1.4.1 SFACT letter of 13 February 1998**

Letter #98159 of the SFACT (a department of the French Civil Aviation Authority specialized in airworthiness oversight), dated 13 February 1998, defines how frequently parameter checks must be performed, depending on the following:

- FDR technology: the presence of a magnetic tape and rotating parts cause magnetic tape FDRs to age quicker, which imposes more frequent inspections than for the newer generation solid state FDRs;
- Existence of a flight data analysis programme that takes into account all required parameters. Such a programme allows for more time between inspections, provided that “*the data source used for analysis is the same as for the DFDR*”.

Note: see appendix III for a table summarizing these requirements.

#### **2.1.4.2 SFACT letter of 4 August 1989**

In the SFACT letter dated 4 August 1989 concerning the readout of FDRs, regional services of the Civil Aviation authority are requested to issue registration numbers to aircraft operators only if the following items are provided:

- type of FDR installed;
- data frame layout and FDR calibration documents.

The letter also mentions that FDRs cannot be read-out without these documents.

### **2.1.4.3 Civil Aviation Code – Part VII**

Article R.711-2 of the French Civil Aviation Code stems from order #2001-1043 of 8 November 2001 and stipulates that the Director of the BEA may offer guidance to the Minister regarding “*regulations related to the protection of technical investigation elements as well as the general use of FDRs*”. In other words, the BEA is associated with the regulatory branch regulating FDR installation and usage.

### **2.1.5 Information on US regulations**

Regulations concerning FDRs in the United States are prescribed in FAR (Federal Aviation Regulations), Part 125 – “Certification and Operations of airplanes which have a seating capacity of 20 or more passengers or a maximum payload capacity of 6,000 pounds or more,” section 125.226. Aircraft operators are required to establish a method of readily retrieving data and to maintain documentation sufficient to convert recorded data into engineering units (in data frame layout documents). However, a single document may be established for any group of aircraft that are of the same type and on which the flight recorder system and its installation are the same.

In addition, the FAA’s HBAW (Handbook Bulletin for Airworthiness) 97-13B of 15 December 1997 provides *Principal Avionics Inspectors (PAI)* with guidance needed to evaluate FDR maintenance programmes. In particular, PAI’s should check if the data frame layout documents are kept up to date and any modifications/retrofits to DFDR systems are documented and accounted for. Furthermore, it is stated that, “*PAI action should include air carrier operator readout of each airplane’s DFDR to determine that all required parameters are being recorded, and to verify that each parameter is working properly.*”

Finally, the FAA’s Advisory Circular AC 20-141 regarding Airworthiness and Operational Approval of Digital Flight Data Recorder Systems gives explanations about regulations, including information about maintenance operations on FDRs.

## 2.2 Comparison of regulatory requirements

### 2.2.1 Programme for analysis of recorded parameters

Document	Requirement or important recommendation
SFACT letter #98159	None
JAR-OPS 1	From 1 January 2005, an operator shall establish a flight data monitoring programme for those aeroplanes with a maximum certificated take-off weight in excess of 27,000 kg <sup>(7)</sup> .
ICAO Annex 6, Part I	An operator of an aeroplane with a maximum certificated take-off weight in excess of 27,000 kg shall establish and maintain a flight data analysis programme.
ED55	None
ED112	None

None of the texts mentioned above specify what documentation should be produced or archived.

### 2.2.2 Inspection of FDR systems

Document	Required or recommended maintenance interval	Requirement or important recommendation	Documentation to be produced or archived
SFACT letter #98159	SSFDR: 4,000 hours or 2 years (8,000 hours or 4 years in the case of flight data analysis allowing a check of all FDR parameters.)  DFDR: 2,000 hours or 12 months (4,000 hours or 2 years in the case of flight data analysis allowing a check of all FDR parameters.)	Read-out of a meaningful phase of flight during which all parameters' values vary.  The data source used for analysis must be the same as for the DFDR.	None
JAR-OPS 1	None	None <sup>(8)</sup>	None
ICAO Annex 6, Part I	1 year	A complete flight from the FDR should be examined in engineering units to evaluate the validity of all recorded parameters. (The read-out facility should have the necessary software to accurately convert the recorded values to engineering units.)  FDRs should be considered inoperative if one or more mandatory parameters are not recorded correctly.  Particular attention should be given to parameters from sensors dedicated to the FDR.	A report on the annual inspection should be made available on request to the State's regulatory authority.
ED55	2,000 hours or 12 months	Read-out of the last 15 recorded minutes of flight.	None

<sup>(7)</sup> French regulations require that flight safety reports and flight parameter recordings must be analyzed for turbine-engine-powered aircraft with a maximum certificated take-off weight in excess of 10,000 kg or with a number of seats, in maximum configuration, in excess of 20.

<sup>(8)</sup> French regulations (OPS 1.715, 1.720 and 1.725) require that a recorder be considered inoperative if more than 5% of mandatory parameters are not properly recorded.

ED112	3,000 hours or 12 months	<p>Read-out of an entire flight and evaluation of parameters in engineering units. The quality of some parameters must be checked for various phases of flight.</p> <p>FDRs should be considered inoperative when signals are unintelligible for a significant period of time or when one or more mandatory parameters are not recorded correctly.</p> <p>Particular attention should be paid to parameters not monitored by any on-board system.</p>	Archive the most recent recording copy.
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Annex 6 and ED112 have two additional requirements:

- A complete flight should be analyzed, as opposed to just a phase of flight or a pre-determined interval of time, since some parameters have to be examined during several phases of flight to check for consistency;
- The analysis must be carried out with decoded parameters to be meaningful. That is to say after raw data is converted into engineering units using conversion functions.

In addition, Annex 6 and ED112 recommend paying particular attention to parameters whose data source supplies only the FDR and no other aircraft systems that could evaluate the quality of the measurements. In such a case, a defect in the measuring and processing channel could only be detected through a check on the FDR recording.

It is interesting to note that Annex 6, eighth Edition has higher standards than the French or European regulations, since it requires annual inspections.

### 2.2.3 Calibration of measuring and processing channels

Document	Required or recommended maintenance interval	Requirement or important recommendation	Documentation to be produced or archived
SFACT letter #98159	None	None	None
JAR-OPS 1	None	None	None
ICAO Annex 6, Part I	Every 5 years (2 years when the altitude and airspeed parameters are provided by sensors dedicated to the FDR)	All mandatory parameters.	Keep an up-to-date documentation related to the calibration
ED55	Determined by the installer	All mandatory parameters  Special device necessary to simulate physical values measured by sensors.	For each tested parameter, check if measured values fit into the allowable range of values  Documents to archive and to be made available to the State's investigative body
ED112	Determined by the	Tests shall be performed on the	Documents to be

	installer	entire measuring and processing channel (from the sensors to the FDR)	archived and made available to the State's investigative body
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JAR-OPS1 does not require the testing of the measuring and processing channels, even though ICAO Annex 6, eighth Edition states that this should be done.

It should be pointed out that no calibration procedure is described in detail in Annex 6 and that ED112 must instead be used for guidance.

Annex 6 suggests a 5-year minimum maintenance interval for this task, whereas ED112 does not mention any time period.

It would be useful to systematically perform this task at the beginning of an aircraft's operation (except immediately after delivery from the manufacturer) and after each major overhaul, since some of the maintenance actions might inadvertently degrade the sensors' accuracy.

ICAO and EUROCAE recommend archiving calibration test reports. These reports are useful since they consist of tables comparing, for each parameter, the value computed by the acquisition unit to the simulated value at the sensor level. Such documents help determine the actual physical value of recorded parameters in a more accurate way than having to convert values using generic conversion functions from data frame layout documents.

#### 2.2.4 Documentation within operators area of responsibility

Document	Documentation to be produced or archived by operators
SFACT letter #98159	None
JAR-OPS 1	Archive the document related to <i>"data extraction and conversion into engineering units"</i> .
ICAO Annex 6, Part I	<i>"Documentation concerning parameter allocation, conversion equations, periodic calibration (...) should be maintained by the operator. The documentation must be adequate to ensure that accident investigation authorities have the necessary information to read-out the data in engineering units"</i> A report on the FDR recording test should be made available on request to the State's regulatory authority.
ED55	After every measuring and processing channel calibration test, fill out a table comparing, for each tested parameter and each measuring point, the value measured before it enters the FDR relative to the allowable range of values. Documents to be archived and made available to the State's investigative body.
ED112	During installation tests, the installer and the operator fill out a report on their calibration tests and all information necessary to decode and convert parameters into engineering units. This report is to be archived by the operator. Keep only the most recent copy.  Archive results after every calibration test and make them available, upon request, to the State's investigative body..

JAR-OPS1 dictates that data frame layout documents be archived by operators. However, as mentioned above, data frame layout documents provided by aircraft manufacturers contain only generic information. This information should be updated by operators.

This is why ICAO Annex 6, eighth Edition and ED112 also recommend that

operators document and archive:

- periodic test reports on the parameters recorded by the FDR,
- periodic calibration check of acquisition units.

Details on these tasks are provided in ED112.

## **2.3 Problems encountered during FDR operations**

Problems encountered by the BEA and other investigative bodies have been separated into three categories for purposes of clarity:

1. missing or incomplete data,
2. incomplete or unavailable data frame layout documents,
3. calibration issues.

Nevertheless, it is important to remember that an investigation can generate problems that fall into several categories at the same time. The following examples illustrate many of the problems that can be encountered, but is by no means exhaustive.

### **2.3.1 Missing or incomplete data**

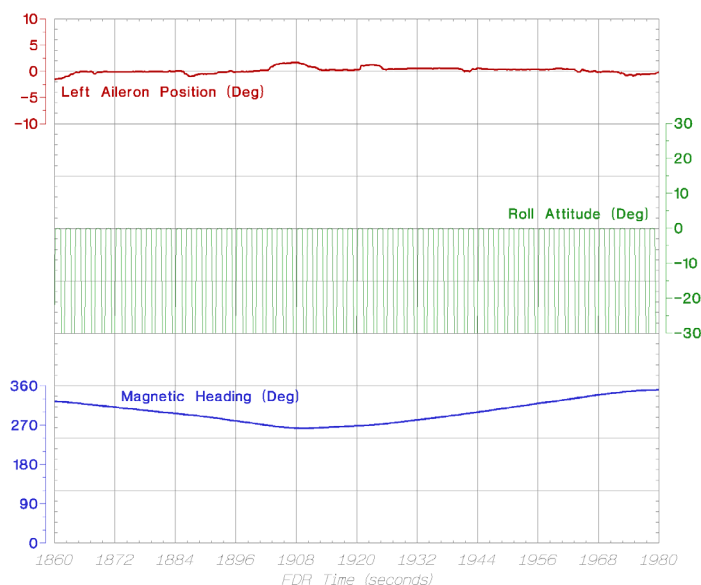
Without any recorder or any recorded data, there can be no analysis. Having no data at all is much more of a handicap to an investigation than not having any data frame layout document.

#### ***2.3.1.1 Event that occurred outside of France in 2002 and was investigated by the BEA***

The following parameters were not valid: longitudinal and lateral accelerations, elevator control position, aileron control position, trim control position and rudder control position. In addition, data from recent flights overlapped with data from previous flights on the FDR recording, due to a chronology issue. A sub-contractor had performed tests on the FDR system on behalf of the airline two days prior to the event, but the invalid parameters listed above were not part of the list of checked parameters. Furthermore, the FDR test was performed on about one hour's worth of flight data, which was insufficient to detect the issue of overlapping data.

#### ***2.3.1.2 Event that occurred outside of France in 2001 involving an aircraft manufactured in France***

The bank angle parameter was not recorded correctly, as shown on the graph below. Since this parameter was essential to the event's analysis, it was impossible to reach a conclusion.



### ***2.3.1.3 Event that occurred outside of France in 2001 involving an aircraft manufactured in France***

The FDR system was modified by the operator, who could not provide a reliable document listing the modifications. Some parameters mentioned in that document were either not recorded or recorded with an erroneous coding. The validation of the parameters essential to the understanding of the event took several months. This involved tests on similar aircraft from the fleet that had the same modification as well as on test benches.

### ***2.3.1.4 Event that occurred outside of France in 2000 involving an aircraft manufactured in France***

Series of 0's and 1's were written but did not correspond to any flight data. Tests performed on the FDR showed that a warning light should light up in the cockpit in the event of an FDR failure. That light could have been defective, but if that was the case, it should have been detected by the pre-flight check. This failure lasted at least 25 flight hours, and the FDR could not be used to find the causes of the event.

## **2.3.2 Incomplete or unavailable data frame layout documents**

### ***2.3.2.1 Event that occurred in France in 2000 involving an aircraft operated by a non-French airline***

The operator was not able to provide the BEA with any data frame layout documents. A list of recorded parameters and their allocation in the data frame was obtained, but the conversion equations and the calibration reports were missing. The FDR data could not be analyzed.



### ***2.3.2.2 Event that occurred in France in 1999 involving an aircraft operated by a non-French airline and chartered by a French operator***

The operator was not able to provide any data frame layout documents. A data frame layout document was obtained from the aircraft manufacturer based on the aircraft's serial number. The document contained information about the aircraft's original configuration and therefore did not integrate modifications performed after delivery. The information ended up being enough to investigate the event, but had the accident been more complex, the lack of information would have been more detrimental.

### ***2.3.2.3 Event that occurred in France in 2000 involving an aircraft operated by a non-French airline***

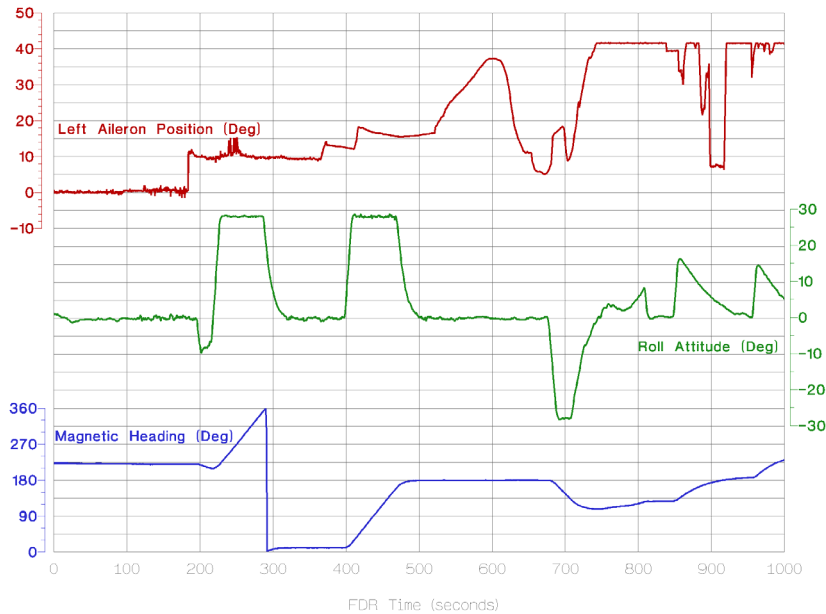
The operator was not able to provide the BEA with the requested information and redirected the request to another company responsible for the maintenance of their aircraft. Documents provided by the latter contained errors, including sign convention mistakes. The analysis of the FDR was delayed because of the poor quality of the documents provided and because of the multiple parties involved. These additional parties did not always make the availability and quality of the documents a top priority since they did not see it as their responsibility.

### ***2.3.2.4 Event that occurred in France in 2000 involving an aircraft manufactured in France and operated by a French airline***

The documents provided by the operator following this accident contained incoherent information, such as inconsistent numbers of bits for some parameters. Furthermore, two parameters were recorded even though they were not listed in the documentation. These issues significantly delayed the validation of the recorded data because a longer study of the recording was necessary.

### ***2.3.2.5 Event that occurred outside of France in 2001 but was investigated by the BEA***

The documentation provided by the operator after the accident contained errors. The following graph shows the evolution of the left aileron position, bank angle, and heading during an uneventful phase of flight. It can be deduced that the left aileron parameter was incorrect, but it was not possible to determine if another parameter was recorded in its place or if a recording problem occurred relating to that aileron position.



### **2.3.2.6 Event that occurred outside of France in 2001 involving an aircraft operated by a French airline**

Initially, the operator was not able to provide the requested documentation, because the only person who had access to it was on vacation. The regional services of the Civil Aviation Authority were able to provide the BEA with a document that had been filed by the operator when the aircraft was registered, but this document did not contain the parameter conversion equations. Ten days after the FDR was received, the person in question, back from vacation, provided the BEA with the same document received previously from the regional services of the Civil Aviation Authority. The person indicated that flight data analysis was performed by an outside company, which should be able to provide the appropriate documentation. The company in question replied that, since no documentation was ever provided by the airline, they were using a standard data frame layout document for similar aircraft, which was giving “*good-enough results for most parameters*”

In this case, no regulation was technically broken. However, the problem of documentation was never brought to light because of the lack of real flight data analysis and the lack of involvement of all parties.

### **2.3.2.7 Event that occurred in France in 1999 involving an aircraft operated by a French airline**

According to the documentation, the “terrain warning” parameter was recorded. In fact, this parameter instead corresponded to all GPWS warnings (except “glideslope warning”), and not just “terrain warning”.

### ***2.3.2.8 Event that occurred in France in 1999 involving an aircraft operated by a French airline***

The operator had a document that did not contain information related to the conversion functions of the recorded parameters. Contacting the manufacturer did not prove successful. In the end, the company that performed the installation and calibration of the FDR system was the one that was able to provide this information.

### ***2.3.2.9 Event that occurred outside of France in 2002 but was investigated by the BEA***

The operator did not provide any information. The FDR analysis was therefore only partially performed with only 4 parameters that were identified. Among them, the vertical acceleration had values that were not physically possible, which indicated that calibration problems with accelerometers or erroneous conversion functions were likely.

## **2.3.3 Calibration issues**

### ***2.3.3.1 Event that occurred outside of France in 2001 involving a French-manufactured aircraft***

The operator gave an acquisition unit serial number that did not correspond to the one installed on the aircraft. The work performed with a data frame layout document provided by the aircraft manufacturer did not lead to satisfactory results. The operator later provided another data frame layout document, but it contained errors. In particular, the evolution of a discrete parameter's value at the moment of the accident first raised concerns before it was determined that it was erroneous. Further, the investigation brought to light calibration issues due to a malfunctioning synchronization signal acquisition card on the acquisition unit. This generated errors on the aircraft attitude and flight controls parameters, with deviations ranging from 2 to 3 degrees <sup>(9)</sup>. A regular check of the measuring and processing channel's calibration could have helped detect this problem.

### ***2.3.3.2 Events involving a French operator***

Over one summer, the EGT (Exhaust Gas Temperature) values of one type of engine from the fleet exceeded the maximum allowable value on numerous occasions. However, during the same period, the operator was performing systematic flight recorder analysis and no such excessive values were ever identified. One day, while reading out parameters, inconsistent values of recorded EGT were noticed by chance: values around 700 °C were recorded, while nominal values for take-off should have been around 950 °C. This anomaly led to a check on the data frame layout document for EGT. A comparative study of the values displayed in the cockpit and the recorded values help detect an error in the conversion equation.

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<sup>(9)</sup> As a reminder, OPS 1 requires a deviation of 2 degrees or less.

## 2.4 Survey of 20 French Airlines

### 2.4.1 Airline participation

Twenty airlines carrying out public transport of passengers with aircraft equipped with FDRs participated in this study (see Appendix IV for the list of participating airlines).

The primary areas analyzed include the following:

- equipment,
- read-out equipment used,
- origin and update of data frame layout documents,
- FDR maintenance programme,
- calibration, if any, of measuring and processing channels,
- additional questions about CVRs.

### 2.4.2 FDR maintenance

Eighteen operators used sub-contractors for their FDR maintenance. Two maintained them themselves.

### 2.4.3 Lessons Learned programme and flight data analysis

Nineteen operators had a “Lessons Learned” programme, through, for instance, flight safety bulletins. Nine performed systematic analysis of recorded parameters and eight also did it regularly, though not systematically (see Figure 1). An analysis is considered as non-systematic when the analysis is limited to only a part of the fleet (for a fleet composed of several aircraft types for instance) or to only some categories of events. Numerous problems, such as the absence of recording or inconsistent values, can be detected and corrected when the analysis of recorded parameters is performed.

About 30 percent of operators entrusted their analysis of flight parameters to a third party.

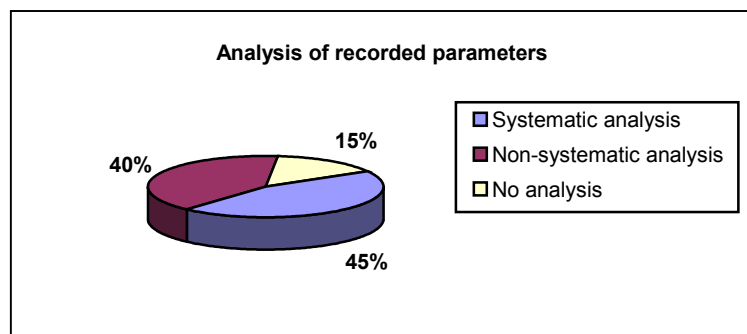


Figure 1

Small airlines (less than 100 employees) have difficulty in setting up an analysis programme, whereas larger airlines (more than 100 employees) all perform some kind of analysis. Systematic analysis is performed mainly by airlines having more than 500 employees.

Figure 2 illustrates what kind of analysis is performed based on the size of the airline (number of employees):

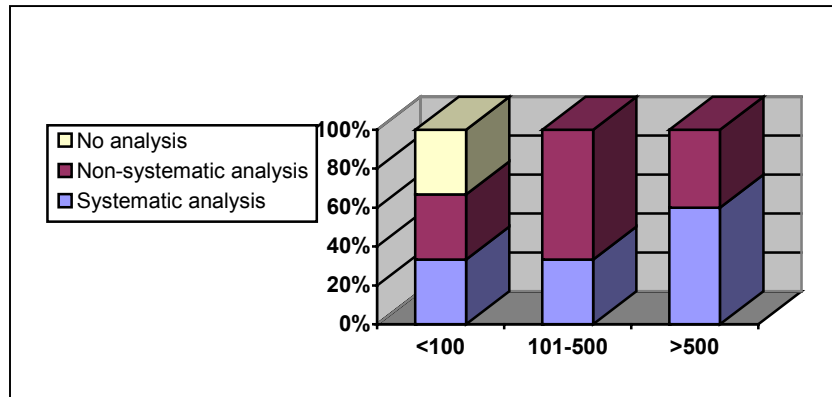


Figure 2

#### 2.4.4 Data frame layout documents

Eleven operators had a comprehensive set of data frame layout documents for their entire fleet. Ten of them performed flight parameter analyses, including six who did it systematically.

Four operators had incomplete or partially outdated documents. Five did not store any documents (they were stored by a sub-contractor instead) or did not even know if the documents existed.

Note: one sub-contractor, who typed in data frame layout documents into a computer system, confirmed these problems, stating that: *“hardcopy of these documents are not always readable, (...) and often incomplete. Customers provide the data frame layout document but often forget the conversion functions that go with parameters and the calibration reports”*.

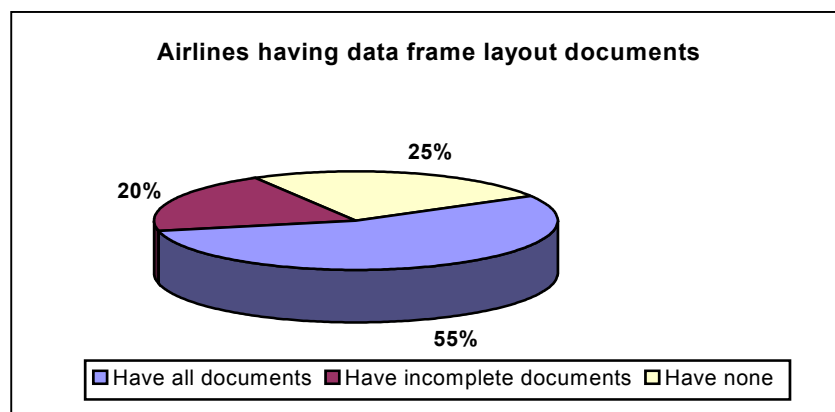


Figure 3

Only seven out of 20 airlines (or 35%) using FDRs filed their data frame layout documents with the regional services of the Civil Aviation Authority. It is interesting to note that these documents were not necessarily complete, or up to date.

Just as for the analysis of recorded parameters, it was mainly small and medium airlines that had incomplete data frame layout documents.

This problem was especially true for aircraft that had been operated by a variety of operators over the years and on which systems had been modified without actually updating data frame layout documents accordingly.

Note: The problem of having obsolete data frame layout documents is also evident in cases outside of France. The NTSB produced a similar study in 1997.

#### 2.4.5 Measuring and processing channel calibration

None of the surveyed airlines calibrated their aircraft's measuring and processing channels.

Fifty-five percent of the surveyed airlines checked each of the elements of the measuring and processing channel independently during maintenance operations. For other airlines, checks were only partial or were not performed at all.

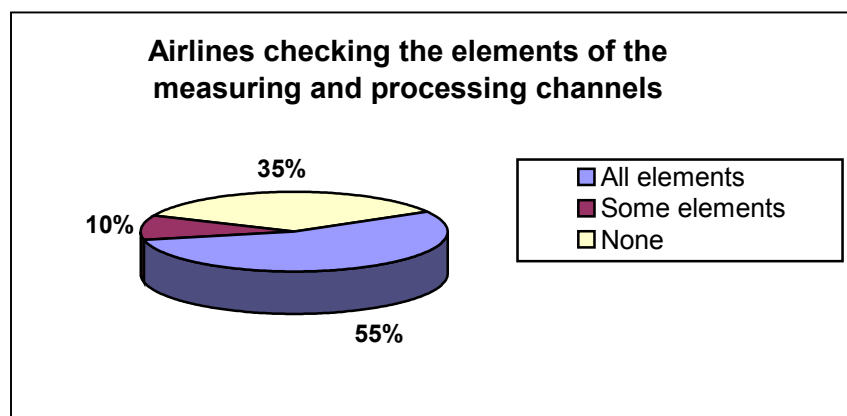


Figure 4

#### 2.4.6 Summary

Of the 20 French airlines surveyed:

- 55 percent had a comprehensive set of data frame layout documents for their fleet;
- 35 percent had filed their data frame layout documents with the local Civil Aviation Authority;

- None calibrated the measuring and processing channels;
- 55 percent checked the various elements of the measuring and processing channels of mandatory parameters;
- 85 percent performed an analysis of the parameters, including 45 percent systematically and 40 percent not systematically.

Of the 11 airlines that had data frame layout documents, 90 percent performed parameter analyses.

### **3 - CONCLUSIONS**

Investigative bodies often encounter problems with the quality of recorded data and data frame layout documents.

These FDR read-out and analysis issues are detrimental to air safety by slowing down or restricting technical investigations aimed at preventing future accidents.

Poor data quality is due to several factors, including:

- inadequate FDR maintenance;
- data frame layout documents not being archived or updated, especially following a reprogrammed FDAU or a change of operator;
- incomplete check of recorded parameters;
- partial checking of the measuring and processing channels elements, which does not guarantee a satisfactory operation of the channel as a whole.

These issues are often linked to poor specific knowledge about FDRs, especially for airlines with less than 100 employees. This may be due to the complexity of the regulations.



## 4 - SAFETY RECOMMENDATIONS

Note: In accordance with Directive 94/56, Article 10 of the European Union concerning accident investigations, a safety recommendation does not, under any circumstances, constitute a presumption of blame or responsibility related to an accident or incident.

### 4.1 Installation of FDRs on Aircraft

On 24 March 2001, a DHC 6 registered F-OGES crashed in Saint Barthélemy (French West Indies) but was not equipped with an FDR <sup>(10)</sup>, which significantly delayed the determination of the causes of the accident.

In the light of these difficulties, the BEA recommended that:

- **the DGAC and the JAA urgently take into account, for safety reasons, the need for flight recorders for the rapid determination of the causes and circumstances of accidents which occur in public air transport and that, to this end, these organizations:**
  - **impose as soon as possible, without any possible exemptions, the carriage of at least one flight recorder on aircraft operating for public transport with a maximum certificated takeoff weight less than 5,700 kg and whose maximum approved passenger seating configuration is ten seats or more, whatever the date of certification may be;**
  - **extend these provisions to airplanes of the same type transporting cargo;**
  - **study the extension of these provisions to helicopters operated for public transport.**

The SFACT responded in 2004 by stating that the JAA's Equipment Subcommittee (EGSC) and Flight Recorder Subgroup (FRSG) had proposed a new wording of the relevant JAR OPS 1 paragraph: *"to extend the mandatory installation aircraft of a CVR to aircraft weighing less than 5.7 tons and more than 9 passengers, regardless of the date of issue of the individual Certificate of Airworthiness and of the engine type"*.

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<sup>(10)</sup> This aircraft was not required by French regulations to be equipped with an FDR since the individual certificate of airworthiness was issued before 1 April 1998

## 4.2 Data Frame Layout Documents

The availability of data frame layout documents, which have to be obtained prior to any read-out, is one of the main problems facing FDR analysis. ICAO Annex 6, Part I, Attachment D stipulates that operators have to keep such documents up to date.

The French regulation of 12 May 1997 requires that operators retain data frame layout documents. However, these documents are often missing or incomplete, and seldom filed with the regional services of the French Civil Aviation authorities.

Consequently, the BEA recommends that:

- **the DGAC ensure that all operators and regional services of the French Civil Aviation authorities possess identical, up to date and comprehensive data frame layout documents.**

And that:

- **the ICAO ensure, through its audit procedures, that Contracting States ensure that their operators can rapidly provide comprehensive and up-to-date data frame layout documents.**

In addition, the use of electronic memory cards in FDRs can generate the need for new technical specifications

Consequently, the BEA recommends that:

- **the EASA define the regulatory requirements to have data frame layout information recorded on FDRs themselves, in a format that is readable by investigative bodies.**

## 4.3 Recording Quality

ICAO Annex 6, Part I, eighth Edition and ED112 both stipulate that corrective actions must be taken as soon as a mandatory parameter is incorrectly recorded. European and French regulations have no such requirements.

Annex 6 and ED112 mention the problem of “*significant period of poor quality data*”, but European texts do not. This type of problem may indeed seriously hinder any kind of analysis.

Finally, some recordings do not match with the chronology of the flights. This can be seen through time period overlaps, anachronisms and significant loss of data.

Consequently, the BEA recommends that:

- **the DGAC ensure, in cooperation with the JAA, that European regulations be updated to meet the standards of ICAO Annex 6 in terms of necessary corrective actions when a mandatory parameter is not correctly recorded or the chronological recording structure does not match the history of the flights performed.**

## 4.4 Verification of Recorded Parameters

Numerous mid-size operators lack adequate resources to periodically verify the recorded parameters on FDRs themselves. This task is therefore sub-contracted, but the reports provided by sub-contractors are often informal and are difficult to interpret for non-specialists.

Defining a guideline for parameters' check reports is desirable so as to make them more readable and understandable by operators' flight safety departments and, if necessary, by investigative bodies.

Consequently, the BEA recommends that:

- **the DGAC study, in cooperation with the BEA, a formalized report template for the verification of mandatory parameter recordings**

Note: detailed verification reports could contain the following items:

1. A comprehensive list of each parameter to be checked, and for each of them:
  - the allocation in the data frame (frame, sub-frame, word, least significant bit, most significant bit)
  - the equations used to convert recorded values into corresponding physical values expressed in engineering units.
2. Graphs of the checked parameters to show their evolution during cruise, take-off and landing phases of a same flight. Each graph should:
  - display a time period of 3 to 5 minutes,
  - have a time axis that is readable and graduated every 10 or 20 seconds,
  - clearly list the date, time, phase of flight (take-off, climb, stabilized cruise, descent, approach or landing), departure and arrival airports,
  - legibly list on the vertical axis the values of parameters in engineering units,
  - have each graphed parameter legibly labeled,
  - have a table showing the values in engineering units using the same time interval as the corresponding graph.
3. An analysis of the validity of parameters based on graphs and corresponding tables.
  - This analysis should indicate parameter validity by showing samples of recorded values in engineering units.
  - This analysis could be based on some characteristic points in a flight <sup>(11)</sup>, on manufacturer-specified performances, or on the history of procedures actually performed during the analyzed flight.
4. A check on the chronological structure of the complete recording, based on the aircraft flight history
  - This check could be based on the evolution of some basic parameters, such as airspeed or pressure altitude, for a particular phase of flight.
  - A check based on graphs for the entire length of the recording would be sufficient.

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<sup>(11)</sup> Such as lift-off, straight and level flight, stabilized turn, flare

## 4.5 Calibration of measuring and processing channels

This study has illustrated the need to systematically calibrate measuring and processing channels when any of the following occur:

- a new operator puts an aircraft in service,
- after a modification of the FDR system,
- after each major overhaul.

However, the calibration of measuring and processing channels is not required by European regulations.

Consequently, the BEA recommends that:

- **the DGAC, in cooperation with the JAA, study a comprehensive calibration programme for mandatory parameters' measuring and processing channels.**

# *List of Appendices*

## **Appendix I**

EUROCAE Document 55, May 1990

## **Appendix II**

Extracts from EUROCAE Document 112, March 2003

## **Appendix III**

Extracts from regulatory texts

## **Appendix IV**

List of airlines that participated in this study

## **EUROCAE Document 55, May 1990**

ED55 <sup>(12)</sup>, published in May 1990, defines the “*Minimum Operational Performance Specifications for Flight Data Recorder Systems*”. Current European regulations references to this document may be replaced by references to ED112, which is meant to supersede ED55.

The following annexes to ED55 relate to certification and monitoring of recorders:

- Annex 3: Flight testing
- Annex 4: Maintenance practices

### **FDR system installation check**

Annex 3 (A3) defines a combination of ground and flight tests to demonstrate correct operation of the installed system and include the following:

- tests on prototype installation for the certification of newly-installed FDR systems
- tests for series installations.

During these tests, the installer must demonstrate correct correlation between instrument values and recorded values.

Paragraph A3.3 requires that the following documentation be produced as a result of the tests:

- a report
- flight test recording in “*graphical and tabular format*”

ED55, Chapter 2, paragraph 2.17 lists the recommended documents for the certification of newly-installed FDR systems, including: “*Conversion and logic for translation of the recorded data stream into parameters expressed in engineering units*”.

### **FDR system maintenance**

Annex 4 (A4) defines all the maintenance tasks recommended by the EUROCAE.

It stipulates that the maintenance programme should be defined by the installer: “*The system installer will need to perform an analysis of the system to identify those parts of system (...) which would not be readily apparent to (...) the 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* <sup>(13)</sup>.”

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<sup>(12)</sup> EUROCAE Documents (ED's) are currently used as a reference by regulatory authorities.

<sup>(13)</sup> ED55, Annex 4, paragraph A4.1.1

This maintenance programme must include the following maintenance tasks related to recording quality:

#### **A/ Parameter recording check**

Paragraph A4.1.3 states that *“a copy recording of a record made in flight should be made”* in order to *“reveal defective or noisy sensors”*.

The installer determines the intervals between checks, though table A4-2 suggests 2,000 hours or 12 months. This table contains the following additional recommendations:

- *“copy and replay at least the last 15 minutes of flight recording”*;
- *“check all mandatory parameters are active and are of acceptable quality”*.

#### **B/ Test procedure for measuring and processing channels calibration**

Calibration checks demonstrate if conversion equations provided by operators are appropriate. These equations should convert recorded binary words into parameters expressed in engineering units. If conversions are shown to be inappropriate, acquisition channel elements or conversion equations should be adjusted.

The fact that this task should be performed on the entire FDR system and therefore should be done onboard aircraft should here be underlined. It should not be mistaken for bench tests performed for FDR or acquisition units.

Paragraph A4.2 describes the test procedure in detail.

- tests must be performed for *“a newly installed flight recorder system and at intervals thereafter”*. They apply to the acquisition of all parameters and discretets (paragraph A4.2.2);
- the operator should fill out a *“tabulated (...) calibration record sheet”* that shows the correlation between simulated inputs (at the sensor level), acceptable output value ranges (at the FDR level) and the values indicated on the test set. Table A4-1 gives an example of such a sheet;
- sensor outputs may be simulated by suitable test equipment (paragraph A4.2.5). Measuring devices may be used when a sensor output does not provide any indication in the cockpit (paragraph A4.2.7).

#### **C/ Calibration documents**

Paragraph A4.1.4 recommends that the operator document sensor calibration data that should be *“made available when required to the accident investigation authorities”*.

## **Extracts from EUROCAE Document 112, March 2003**

ED112<sup>(14)</sup>, published in March 2003 and titled “*Minimum Operational Performance Specification (MOPS) for Crash Protected Airborne Recorder Systems*”, gives requirements for all airborne recorders. Part II relates to FDRs.

The following sections of ED112 contain information concerning certification and monitoring of recorders.

- chapter II-6, titled “*Equipment Installation and Installed Performance*”, defines the tests for the certification of newly-installed equipment and follow-on series installation of a certified FDR system, as well as the related documents
- Annex II-B, titled “*Maintenance practices*”, makes maintenance recommendations to operators.

### **Tests for initial FDR system installation**

Paragraph II-6.3.4 lists the ground and flight tests for the initial FDR system installation, including:

#### **A/ Ground tests: paragraph II-6.3.4.1**

The installer should run sensor calibration tests (paragraph II-6.3.4.1.b) and “*each calibration point should be predetermined and tabulated on a record sheet*” (paragraph II-6.3.4.1.d). Table II-6.1 gives an example of a parameter calibration record.

#### **B/ Flight tests: paragraph II-6.3.4.2**

Flight tests are performed to reproduce the operational environmental conditions of FDR systems and to confirm the results of ground tests

### **Test for follow-on installation of FDR systems**

Paragraph II-6.3.5 lists the required tests for follow-on installation of FDR systems. Ground tests include sensor calibration that has to be performed for each parameter (paragraph II-6.3.5.b). Flight testing is not required for follow-on FDR installations.

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<sup>(14)</sup> ED112 replaced ED55 (May 1990) and ED 56A (December 1993) in March 2003



## **FDR installation documentation**

Paragraph II-6.3.7 lists all recommended documents.

In particular, during tests on prototypes, *“a report (...) shall describe the FDR system installation (...) and shall contain the results of all ground and flight tests, including calibrations and correlations. A copy of the actual ground and flight test data shall be retained by the installer and operator”*.

In addition, *“for each follow-on installation, a copy of all ground calibration and correlation data shall be retained by the installer and operator.”* (paragraph II-6.3.7.b).

Paragraph II-6.3.7.d describes the information that should also be documented and made available to authorities, mainly in terms of data frame layout:

- parameter location in the data stream (subframe, word, first bit, number of bits...),
- information necessary to convert binary values into engineering units, such as polynomial coefficients, conversion table, pre-determined equation, discrete interpretation (e.g. 0=“Engaged”, 1=“Disengaged”),
- units, sign conventions, etc.

## **Modification to the list of recorded parameters**

Paragraph II-6.3.6 states :

*“If new parameters or discrete signals are added (...) re-certification testing is required”*

Evaluation tests can be one of two kinds, depending on the type of modification:

- *“If the existing system can accommodate the change(s) without modification to FDR system components (...), confirmation of satisfactory performance should be established by means of ground and flight testing of the additional FDR system inputs only”* (paragraph II-6.3.6.a). However a note states: *“an assessment should be conducted to determine the need for re-testing of existing FDR parameters to confirm continued acceptability”*.
- *“Where significant (...) changes result from the requirement to augment the list of parameters (...), a re-certification of the system will be necessary with ground testing of all parameters”*.

## **Maintenance practices**

ED112, Annex II-B defines all EUROCAE-recommended maintenance practices. This Annex establishes the principle that the system installer is responsible for defining the maintenance programme:

*“The system installer shall 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 (...) shall be established as indicated by the analysis”*

Paragraph II-B.1.7 defines when FDR systems should be considered unserviceable: *“Flight recorder systems should be considered unserviceable if there is a significant period of (...) unintelligible signal or if one or more of the mandatory parameters is not recorded correctly”*.

In addition, Note 1 states:

*“In the analysis performed by the system installer the following causes of an incorrect parameter calibration should be taken into account:*

- *“The dismantling and reassembling of some part of an aircraft may affect the adjustment of a sensor”;*
- *“Any change to the interconnectivity between sensor and sampling equipment which may affect an analogue signal provided by the sensor (e.g. feeding the sensor output to an other equipment)”;*
- *“The characteristics of some sensors and transducers are susceptible to drift”.*

Note 2 states:

*“In the analysis performed by the system installer, particular attention should be paid to those parameter sources which are not monitored by any other airborne system and therefore are critical regarding undetected failure.”*

This is why paragraph II-B.1.2 states:

*“The checks will include a validation of the whole measuring and processing channel from the sensor input to the acquisition unit output”.*

Making sure that a FDR is functioning correctly is not enough. Maintenance programmes consist of two main types of tasks related to the recording quality:

### **A/ Parameter recording check**

Paragraph II-B.1.3 recommends a regular inspection of recordings, taking the following precautions:

- *“All mandatory parameters recorded should be expressed in engineering units”;*
- A copy and readout of a recording including a whole flight should be transcribed and played back. And *“when applicable, each mandatory parameter should be checked for different values of its operational range. For this purpose, some parameters should be inspected at different flight phases<sup>(15)</sup>”* (paragraph II-B.1.3).

Table II-B-1 suggests an interval between checks of 3,000 hours or 12 months.

In addition paragraph II-B.1.3 states:

*“The operator shall retain the most recent copy recording”*

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<sup>(15)</sup> take-off, climb, cruise, approach, landing

## **B/ Sensor calibration procedure**

Table II-B.1 describes the sensor calibration procedure. The check covers the entire measuring and processing calibration channel:

*“Check serviceability and calibration of the measuring and processing chain from sensors to recorders”*

No specific intervals between checks are suggested.

### **Calibration documents**

Paragraph II-B.1.4 states:

*“Sensor calibration data shall be retained by the aircraft operator and made available when required by the accident investigation authorities.”*

**Extracts from regulatory texts**

**Appendix to SFACT letter #98159/SFACT/E.EN**

**Time intervals between checks for DFDR and sensors**

(does not replace maintenance operations required by the manufacturer)

	<b>No flight data analysis or Flight data analysis taking into account only a portion of the mandatory parameters</b>		<b>Flight data analysis taking into account all the mandatory parameters<sup>i</sup></b>	
<b>DFDR Type</b>	Magnetic tape DFDR	SSFDR <sup>ii</sup>	Magnetic tape DFDR	SSFDR
<b>Interval between checks<sup>iii</sup></b>	2,000 hours or 12 months (unchanged)	4,000 hours or 2 years	4,000 hours or 2 years	8,000 hours or 4 years <sup>iv</sup>
<b>Type of check</b>	Removal, check on the recorder and read-out of a phase of flight during which every parameter varies.	Download of recorded parameters and read-out of a phase of flight during which every parameter varies.	Removal and check of the recorder	Download of recorded parameters and read-out of a phase of flight during which every parameter varies.

<sup>i</sup> Which implies that the parameters' data source used for the analysis is the same as the one used for the DFDR and as close as possible

<sup>ii</sup> Solid State Flight Data Recorder

<sup>iii</sup> Whichever comes first

<sup>iv</sup> Only if the installation can automatically indicate if no parameter enters the SSFDR. Otherwise, use the values for a SSFDR with no flight data analysis.

Extract from ICAO Annex 6, Part I: Parameters to record (page 1 of 2)

Annex 6 — Operation of Aircraft

Part I

Table D-1  
Parameters for Flight Data Recorders

Serial number	Parameter	Measurement range	Recording interval (seconds)	Accuracy limits (sensor input compared to FDR read-out)
1	Time (UTC when available, otherwise elapsed time)	24 hours	4	±0.125% per hour
2	Pressure-altitude	−300 m (−1 000 ft) to maximum certificated altitude of aircraft +1 500 m (+5 000 ft)	1	±30 m to ±200 m (±100 ft to ±700 ft)
3	Indicated airspeed	95 km/h (50 kt) to max $V_{S_0}$ (Note 1) $V_{S_0}$ to 1.2 $V_D$ (Note 2)	1	±5% ±3%
4	Heading	360°	1	±2°
5	Normal acceleration	−3 g to +6 g	0.125	±1% of maximum range excluding datum error of ±5%
6	Pitch attitude	±75°	1	±2°
7	Roll attitude	±180°	1	±2°
8	Radio transmission keying	On-off (one discrete)	1	
9	Power on each engine (Note 3)	Full range	1 (per engine)	±2%
10	Trailing edge flap or cockpit control selection	Full range or each discrete position	2	±5% or as pilot's indicator
11	Leading edge flap or cockpit control selection	Full range or each discrete position	2	±5% or as pilot's indicator
12	Thrust reverser position	Stowed, in transit, and reverse	1 (per engine)	
13	Ground spoiler/speed brake selection	Full range or each discrete position	1	±2% unless higher accuracy uniquely required
14	Outside air temperature	Sensor range	2	±2°C
15	Autopilot/auto throttle/AFCS mode and engagement status	A suitable combination of discrettes	1	

Note.— The preceding 15 parameters satisfy the requirements for a Type II FDR.

16	Longitudinal acceleration	±1 g	0.25	±1.5% max range excluding datum error of ±5%
17	Lateral acceleration	±1 g	0.25	±1.5% max range excluding datum error of ±5%
18	Pilot input and/or control surface position-primary controls (pitch, roll, yaw) (Note 4)	Full range	1	±2° unless higher accuracy uniquely required

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ATT D-4

## Extract from ICAO Annex 6, Part I: Parameters to record (page 2 of 2)

Attachment D

Annex 6 — Operation of Aircraft

Serial number	Parameter	Measurement range	Recording interval (seconds)	Accuracy limits (sensor input compared to FDR read-out)
19	Pitch trim position	Full range	1	±3% unless higher accuracy uniquely required
20	Radio altitude	−6 m to 750 m (−20 ft to 2 500 ft)	1	±0.6 m (±2 ft) or ±3% whichever is greater below 150 m (500 ft) and ±5% above 150 m (500 ft)
21	Glide path deviation	Signal range	1	±3%
22	Localizer deviation	Signal range	1	±3%
23	Marker beacon passage	Discrete	1	
24	Master warning	Discrete	1	
25	NAV 1 and 2 frequency selection (Note 5)	Full range	4	As installed
26	DME 1 and 2 distance (Notes 5 and 6)	0 – 370 km	4	As installed
27	Landing gear squat switch status	Discrete	1	
28	GPWS (ground proximity warning system)	Discrete	1	
29	Angle of attack	Full range	0.5	As installed
30	Hydraulics, each system (low pressure)	Discrete	2	
31	Navigation data (latitude/longitude, ground speed and drift angle) (Note 7)	As installed	1	As installed
32	Landing gear or gear selector position	Discrete	4	As installed

Note.— The preceding 32 parameters satisfy the requirements for a Type I FDR.

Notes.—

1.  $V_{S_0}$  stalling speed or minimum steady flight speed in the landing configuration.
2.  $V_D$  design diving speed.
3. Record sufficient inputs to determine power.
4. For aeroplanes with conventional control systems “or” applies. For aeroplanes with non-mechanical control systems “and” applies. In aeroplanes with split surfaces, a suitable combination of inputs is acceptable in lieu of recording each surface separately.
5. If signal available in digital form.
6. Recording of latitude and longitude from INS or other navigation system is a preferred alternative.
7. If signals readily available.

ATT D-5

1/11/01

Extract from JAR OPS 1: parameters to record (page 1 of 4)

Appendix 1 to JAR-OPS 1.715

Flight data recorders - 1 - List of parameters to be recorded

Table A1 - Aeroplanes with a maximum certificated take-off mass of over 5,700 kg

Note: The numbers in the left column reflect the Serial Numbers depicted in EUROCAE document ED55

No.	Parameter
1	Time or relative time count
2	Pressure altitude
3	Indicated airspeed
4	Heading
5	Normal acceleration
6	Pitch attitude
7	Roll attitude
8	Manual radio transmission keying
9	Propulsive thrust/power on each engine and cockpit thrust/power lever position if applicable
10	Trailing edge flap or cockpit control selection
11	Leading edge flap or cockpit control selection
12	Thrust reverse status
13	Ground spoiler position and/or speed brake selection
14	Total or outside air temperature
15	Autopilot, auto-throttle and AFCS mode and engagement status
16	Longitudinal acceleration (Body axis)
17	Lateral acceleration

Table A2 - Aeroplanes with a maximum certificated take-off mass of 5,700 kg or less

Note: The numbers in the left column reflect the Serial Numbers depicted in EUROCAE document ED55

No.	Parameter
1	Time or relative time count
2	Pressure altitude
3	Indicated airspeed
4	Heading
5	Normal acceleration
6	Pitch attitude
7	Roll attitude
8	Manual radio transmission keying
9	Propulsive thrust/power on each engine and cockpit thrust/power lever position if applicable
10	Trailing edge flap or cockpit control selection
11	Leading edge flap or cockpit control selection
12	Thrust reverse status
13	Ground spoiler position and/or speed brake selection
14	Total or outside air temperature.
15	Autopilot/auto-throttle engagement status
16	Angle of attack (if a suitable sensor is available)
17	Longitudinal acceleration (Body axis)

Extract from JAR OPS 1: parameters to record (page 2 of 4)

Appendix 1 to JAR-OPS 1.715

Flight data recorders - 1 - List of parameters to be recorded

Table B - Additional parameters for aeroplanes with a maximum certificated take-off mass of over 27,000 kg

Note: The numbers in the left column reflect the Serial Numbers depicted in EUROCAE document ED55

No.	Parameter
18	Primary flight controls - Control surface position and/or pilot input (pitch, roll, yaw)
19	Pitch trim position
20	Radio altitude
21	Vertical beam deviation (ILS Glide path or MLS Elevation)
22	Horizontal beam deviation (ILS Localizer or MLS Azimuth)
23	Marker Beacon Passage
24	Warnings
25	Reserved (navigation receiver frequency selection is recommended)
26	Reserved (DME distance is recommended)
27	Landing gear squat switch status or air/ground status
28	Ground Proximity Warning System
29	Angle of attack
30	Low pressure warning (hydraulic and pneumatic power)
31	Groundspeed
32	Landing gear or gear selector position

Table C - Aeroplanes equipped with electronic display systems

Note: The numbers in the centre column reflect the Serial Numbers depicted in EUROCAE document ED55 table A1.5

No	No.	Parameter
33	6	Selected barometric setting (Each pilot station )
34	7	Selected altitude
35	8	Selected speed
36	9	Selected mach
37	10	Selected vertical speed
38	11	Selected heading
39	12	Selected flight path
40	13	Selected decision height
41	14	EFIS display format
42	15	Multi function /Engine / Alerts display format



Extract from JAR OPS 1: parameters to record (page 3 of 4)

Appendix 1 to JAR-OPS 1.720

Flight data recorders - 2 - List of parameters to be recorded

Table A - Aeroplanes with a maximum certificated take-off mass of over 5,700 Kg

No	Parameter
1	Time or relative time count
2	Pressure altitude
3	Indicated Airspeed
4	Heading
5	Normal Acceleration
6	Pitch attitude
7	Roll attitude
8	Manual radio transmission keying unless an alternate means to synchronize FDR and CVR recordings is provided
9	Power on each engine
10	Trailing edge flap or cockpit control selection
11	Leading edge flap or cockpit control selection
12	Thrust reverse position (for turbojet aeroplanes only)
13	Ground spoiler position and/or speed brake selection
14	Outside air temperature or Total Air Temperature
15a	Autopilot engagement status
15b	Autopilot operating modes, autothrottle and AFCS systems engagement status and operating modes.

Table B - Additional parameters for aeroplanes with a maximum certificated take-off mass over 27,000 kg

No	Parameter
16	Longitudinal acceleration
17	Lateral acceleration
18	Primary flight controls - Control surface position and/or pilot input (pitch, roll and yaw)
19	Pitch trim position
20	Radio altitude
21	Glide path deviation
22	Localizer deviation
23	Marker beacon passage
24	Master warning
25	NAV 1 and NAV 2 frequency selection
26	DME 1 and DME 2 distance
27	Landing gear squat switch status
28	Ground proximity warning system
29	Angle of attack
30	Hydraulics, each system (low pressure)
31	Navigation data
32	Landing gear or gear selector position

Extract from JAR OPS 1: parameters to record (page 4 of 4)

Appendix 1 to JAR-OPS 1.725

Flight data recorders - 3 - List of parameters to be recorded

Table A - Aeroplanes with a maximum certificated take-off mass of over 5,700 Kg

No	Parameter
1	Time or relative time count
2	Pressure altitude
3	Indicated Airspeed
4	Heading
5	Normal Acceleration

Table B - Additional parameters for aeroplanes with a maximum certificated take-off mass of over 27,000 kg

No	Parameter
6	Pitch attitude
7	Roll attitude
8	Manual radio transmission keying unless an alternate means to synchronize the FDR and CVR recordings is provided
9	Power on each engine
10	Trailing edge flap or cockpit control selection
11	Leading edge flap or cockpit control selection
12	Thrust reverse position (for turbojet aeroplanes only)
13	Ground spoiler position and/or speed brake selection
14	Outside air temperature or Total air temperature
15a	Autopilot engagement status
15b	Autopilot operating modes, autothrottle and AFCS, systems engagement status and operating modes.
16	Longitudinal acceleration
17	Lateral acceleration
18	Primary flight controls - Control surface position and/or pilot input (pitch, roll and yaw)
19	Pitch trim position
20	Radio altitude
21	Glide path deviation
22	Localizer deviation
23	Marker beacon passage
24	Master warning
25	NAV 1 and NAV 2 frequency selection
26	DME 1 and DME 2 distance
27	Landing gear squat switch status
28	Ground proximity warning system
29	Angle of attack
30	Hydraulics, each system (low pressure)
31	Navigation data (latitude, longitude, ground speed and drift angle)
32	Landing gear or gear selector position

Extract from JAR-OPS 1: parameters to record (page 1 of 2)

This extract gives an example of criteria used to assess the quality of FDR recordings.

Appendix 1 to [ACJ] OPS 1.720[ ]/1.725[ ]  
See ACJ OPS 1.720[ ]/1.725[ ]

TABLE [1] – Parameters [Performance Specifications]

Serial No.	Parameter	Range	Sampling Interval in seconds	Accuracy limits (sensor input compared to FDR readout)	Recommended Resolution in readout	Remarks
1	Time [or relative time count]	24 hours	4	±0-125% per hour	1 second	UTC time preferred where available, otherwise elapsed time
2	Pressured altitude	-1 000 ft to maximum certificated altitude of aircraft +5000 ft	1	±100 ft to ±700 ft	5 ft	For altitude record error see JAR-JT50 C124 [ ]
3	Indicated airspeed	50 kt to max $V_{SO}$ Max $V_{SO}$ to 1.2 $V_S$	1	±5% ±3%	1kt	$V_{SO}$ stalling speed or minimum steady flight speed in the landing configuration $V_{DF}$ design diving speed
4	Heading	360°	1	±2°	0.6°	
5	Normal acceleration	-3 g to +8 g	0-125 ±	0-125 ±1% of maximum range excluding a datum error of ± 5%	0.004 g	
6	Pitch attitude	±75°	1	±2°	0.5°	
7	Roll attitude	±180°	1	±2°	0.5°	
8	Manual radio transmission keying	Discrete	1	-	-	On-off (one discrete). An FDR/CVR time synchronisation signal complying with EUROCAE Document ED65 dated May 1980 paragraph 4.2.1 is an acceptable alternative means of compliance
9	Power on each engine	Full range	Each engine each second	±2%	0.2% of full range	Sufficient parameters e.g. EPR/N <sub>1</sub> or Torque/N <sub>1</sub> as appropriate to the particular engine should be recorded to determine power
10	Trailing edge flap or cockpit control selection	Full range or each discrete position	2	±5% or as pilot's indicator	0.5% of full range	
11	Leading edge flap or cockpit control selection	Full range or each discrete position	2	-	0.5% of full range	
12	Thrust reverser position	Stowed, in transit, and reverse	Each reverser each second	±2% unless higher accuracy uniquely required	-	[ ]
13	Ground spoiler and/or speed brake selection	Full range or each discrete position	1	±2°	0.2% of full range	
14	Outside air temperatures [or Total air temperature]	Sensor range	2	-	0.3°	
15a	[Autopilot engagement status]					
15b	Autopilot [operating modes, autopilot and AFCS systems engagement status and operating modes]	A suitable combination of discretely	1		-	
16	Longitudinal acceleration	± 1 g	0-25	± 1.5% of maximum range excluding a datum error of ± 5%	0.004 g	

Extract from OPS 1 (French regulation of 12 May 1997): parameters to record  
(page 2 of 2)

Serial No.	Parameter	Range	Sampling Interval in seconds	Accuracy limits (sensor input compared to FDR readout)	Recommended Resolution in readout	Remarks
16	Longitudinal acceleration	± 1 g	0.25	± 1.5% of maximum range excluding a datum error of ± 5%	0.004 g	
17	Lateral acceleration	± 1 g	0.25	± 1.5% of maximum range excluding a datum error of ± 5%	0.004 g	
18	Primary flight controls. Control surface positions and/or pilot input (pitch, roll, yaw)	Full range	1	± 2° unless higher accuracy uniquely required	0.2% of full range	For aeroplanes with conventional control systems 'or' applies. For aeroplanes with non-mechanical control systems 'and' applies. For aeroplanes with split surfaces a suitable combination of inputs is acceptable in lieu of recording each surface separately.
19	Pitch trim position	Full range	1	± 3% unless higher accuracy uniquely required	0.3% of full range	
20	Radio altitude	-20 ft to +2500 ft	1	± 2 ft or ± 3% whichever is greater below 500 ft and ± 5% above 500 ft	1 ft below 500 ft, 1 ft +5% of full range above 500 ft	As installed. Accuracy limits are recommended
21	Glide path deviation	Signal range	1	± 3%	0.3% of full range	As installed. Accuracy limits are recommended
22	Localiser deviation	Signal range	1	± 3%	0.3% of full range	As installed. Accuracy limits are recommended
23	Marker beacon passage	Discrete	1	-	-	A single discrete is acceptable for all markers
24	Master warning	Discrete	1	-	-	
25	NAV 1 and 2 frequency selection	Full range	4	As installed	-	
26	DME 1 and 2 distance	0-200 nm	4	As installed	-	Recording of latitude and longitude from INS or other navigation system is a preferred alternative
27	Landing gear squat switch status	Discrete	1	-	-	
28	Ground proximity warning system (GPWS)	Discrete	1	-	-	
29	Angle of attack	Full range	0.5	As installed	0.3% of full range	
30	Hydraulics	Discrete(s)	2	-	-	
31	Navigation data	As installed	1	As installed	-	
32	Landing gear or gear selector position	Discrete	4	As installed	-	

### **List of airlines that participated in this study**

- Aero Service Corporate
- Aero Service Executive
- Aigle Azur
- Air Atlantique
- Air France
- Air Littoral
- Air Lib
- Air Méditerranée
- Alsair
- Brit Air
- CCM
- Chailair
- Champagne Airlines
- Corsair
- Dassault Falcon Services
- Europe Airpost
- Leadair Unijet
- Occitania
- Régional Airlines
- Star Airlines

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