ITU-T

ITU-T Focus Group on Aviation Applications of Cloud Computing for Flight Data Monitoring

Use cases and requirements

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April 2016

Foreword

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The procedures for establishment of focus groups are defined in Recommendation ITU-T A.7. The ITU-T Focus Group on Aviation Applications of Cloud Computing for Flight Data Monitoring – FG AC – was established by the ITU-T Telecommunication Standardization Advisory Group (TSAG) in June 2014 and completed the work on its deliverables in December 2015. More information is available at http://itu.int/en/ITU-T/focusgroups/ac/.

Deliverables of focus groups can take the form of technical reports, specifications, etc. and aim to provide material for consideration by the parent group in its standardization activities. Deliverables of focus groups are not ITU-T Recommendations.

SERIES OF FG AC TECHNICAL REPORTS	
Deliverable 1	Existing and emerging technologies of cloud computing and data analytics
Deliverable 2/3	Use cases and requirements
Deliverable 4	Avionics and aviation communications systems
Deliverable 5	Key findings, recommendations for next steps and future work

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1 Introduction

This document describes the scenarios identified for – **Deliverable 2/3**: *This deliverable will identify and describe scenarios for cloud computing for flight data. It will use existing aviation terminology and definitions.*

Recorded flight data has been used as the basis for scrutinizing aircraft operations and system performance/ integrity for 50 years. This has been supplemented in more recent years by technologies such as central maintenance computer (CMC) functionality, aircraft condition monitoring system (ACMS) techniques, aircraft communications addressing and reporting system (ACARS) transmissions and the wireless offload of data to the airline back office.

ACMS functionality is responsible for powering the majority of flight data acquisition activities that generate data for airline operations and aircraft systems performance monitoring. Whilst older and smaller aircraft typically rely on mandatory flight data recordings as the basis for flight data gathering, ACMS provides greater flexibility for all airlines in terms of the selection of aircraft system parameters to be recorded. This activity is supplemented in recent years by aircraft original equipment manufacturers (OEMs) who, increasingly, are providing baseline ACMS functionality that allows performance-related parameters to be available, rather than having to work with flight data that is optimized for accident investigations.

The capabilities of ACMS and acquisition systems have advanced significantly over the last 30 years. Data management units that were supplied in the 1980s used to generate ACMS recordings typically of 100-200 parameters; as a measure of progress, Boeing 787 aircraft in 2016 will be recording approximately 4800 parameters that will have been acquired by the data acquisition system from a wide range of aircraft systems, allowing unprecedented levels of scrutiny of aircraft operations and systems and supporting a wider portfolio of ground-based data analytics.

The content of flight data recordings are, however, sensitive to the airline. The de-identification of these recordings is necessary for many airlines that subject their data to flight data analyses. As custodians of recorded flight data, flight safety departments are typically charged with the management of recorded flight data and the dissemination of airline flight data outside flight safety departments. Because of union cultural and other factors, the extent of the use of flight data beyond the ICAO-mandated accident prevention programs is variable. See ICAO Annex 6 part 3.3, Safety Management for the use of flight data analysis as part of an accident prevention program.

The value of ACMS recorded data is such that airlines are increasingly seeking to access these recordings as soon as possible after the aircraft has landed and the flight is ended. Wireless technologies and the Internet are increasingly being used to move this data rapidly to airline back offices such that flight data analyses can be effected without unnecessary delay.

There is frustration then that this sizeable and valuable data that has been generated by an acquisition system, or some of it, is not routinely made available via in-flight transmissions to the ground during abnormal situations, which would facilitate scrutiny and relevant analyses, including the determination of flight track and the prediction of flight track.

There is a balance to be struck over the use of recorded flight data. Airlines have established processes for the processing of recorded flight data; each will have access to a ground data replay and analysis system (GDRAS) from a small number of available GDRAS suppliers. These GDRAS systems will already possess a range of analytical tools, including operational monitoring/operational risk identification, maintenance analyses, performance analyses and more. Working Group 2 has agreed that there is no intent to recommend changes that affect these existing GDRAS systems or the flight data analysis (FDA) processes that exist at airlines.

Whilst Working Group 2 has identified many use cases for the analysis of flight data, the reality is that the prevalence of GDRAS systems, procedures and activities worldwide means that many of these use cases have been previously captured and GDRAS solutions are already providing valuable information from recorded flight data.

Cloud computing can provide some advantages over established GDRAS systems. Cloud computing offers a scalable and affordable environment in which a range of flight data analysis and visualization/reporting functions can be established, from which an array of benefits can be derived by airline flight safety, flight operations and maintenance departments and other user groups. When combined with the real-time transmission of flight data, this environment is also able to host functionality that meets the requirements for flight tracking, which is an element of the global aeronautical distress and safety system (GADSS) as described by the International Civil Aviation Organization (ICAO). It is the opinion of Working Group 2 that cloud computing has more potential than traditional GDRAS systems for the introduction and integration of datasets from additional data sources. Consequently, there is greater potential for cloud computing to generate additional value and benefit as a result of the processing and analysing of data from additional datasets along with traditional flight data and the visualization of new information derived from those analyses in new and useful ways.

2 Use cases overview and user groups

2.1 Use cases overview

Working Group 2 has identified use cases for flight data tracking. This section presents an overview of the uses cases, while section 4 describes them in detail. The use cases are categorized in terms of their relevance to flight data streaming and the potential for selected parameter data being used in real time for new and valuable purposes:

Category A – High priority for real-time transmission of relevant parameters within flight streaming.

Category B – Low priority for the transmission of relevant parameters within flight streaming.

Table 1 identifies the high and low categories of use cases.

Table 1 – List of use cases, with relevant importance

No.	Use case	Category	Comment	Section
1	Search and rescue	A- High	The task of tracking an aircraft for supporting search and rescue operations by providing the last known aircraft position and trajectories of likely aircraft movement after the last reported position.	4.1
2	Flight tracking	A- High	The task of tracking an aircraft for the purpose of determining its real-time spatial location or post-flight track flown.	4.1
3	Accident investigations	A- High	Analysis of flight data immediately after an accident, before the flight data recorder (FDR) is recovered and read out.	4.10
4	Mission support	A- High	Real-time situation awareness of aircraft condition for flight operations department.	4.21
5	Air traffic control (ATC)	A- High	Provide real-time instantaneous aircraft departure, arrival and en-route information to ATC.	4.3
6	Ground movement/handling	A- High	Provide real-time instantaneous aircraft departure, arrival and en-route information to airports.	4.4
7	Trouble-shooting	A- High	Collect, analyse and store aircraft systems, engines data for detection and analysis of failures.	4.5
8	Crew scheduling	A- High	Provide real-time instantaneous aircraft departure, arrival and en-route information to airline operational communication (AOC) and crew scheduling.	4.6

No.	Use case	Category	Comment	Section
9	Abnormal movement of passengers and crew	A- High	Collect video of people's movement along the aisle of the aircraft. Analyse and detect abnormal movement through the use of on the fly real-time video analytics.	4.22
10	Reliability	B- Low	Analysis of dispatch reliability, failure rates of systems, failure rates of components.	4.9
11	Flight planning	B- Low	Analysis of collected flight data to optimize ground processes, flight processes and passenger services.	4.23
12	Fuel optimization	B- Low	Collect, analyse and store fuel-related aircraft data to optimize flight procedures and flight routes.	4.7
13	Predictive maintenance	B- Low	Collect, analyse and store aircraft performance data for early detection of degradation. The reliability of an A/C can be significantly increased by detection and replacement of attired parts.	4.2
14	Route planning and optimization	B- Low	Analysis of collected flight data to optimize airline network, schedules and passenger services.	4.8
15	Flight crew techniques	B- Low	Analysis of quick access recorder (QAR) data to optimize flight procedures and practices.	4.11
16	Approach statistics	B- Low	Analysis of procedures, timing, performance indicators, etc., of importance for approach and landing.	4.12
	Maintenance reports for airframers, engines and equipment manufacturers	B- Low	Maintenance and monitoring of reports to be forwarded to manufacturers for condition monitoring.	4.13
17	Meteorological purposes	B- Low	Provide meteorological data of interest to weather service providers.	4.14
18	Cargo monitoring and tracking	B- Low	Information on cargo such as cargo hold temperature, load sheet, etc.	4.15
19	Airspace optimization	B- Low	Analysis and optimization of airspace, such as routes, based on aircraft positions over time and technical capabilities.	4.16
20	Flight information display system	B- Low	Arrival and departure information shown in airports, on websites, or other media.	4.17
21	Green aircraft/fuel, noise, carbon footprint	B- Low	Analysis of performance data with respect to fuel burn and noise to reduce carbon footprint and noise emissions.	4.18
22	Information for research and development (R&D)	B- Low	Provide access to the selected flight data to research facilities to support their work and increase the quality of their results.	4.19
23	Information for regulatory purposes	B- Low	Provision of collected flight data to support regulatory organizations in their work.	4.20
24	Passenger and crew health monitoring	B- Low	Monitoring of passengers and crew with biometric sensors to detect diseases.	4.24
25	Entertainment based on flight data	B- Low	Computer games based on real flight data to provide realistic scenarios and experiences.	4.25
26	Medical and health management on air travel	B- Low	Analysis of the impact on health due to noise, stress, pollution, etc.	4.26

No.	Use case	Category	Comment	Section
27	Anti-terrorism and national security	A- High	Provide access to selected flight data to government organizations for anti-terrorism and national security.	4.27
28	Military purposes	A- High	Provide access to selected flight data for military purposes.	4.28

2.2 User groups

In addition to the use cases, Working Group 2 has also identified the user groups that are interested in the use cases. Table 2 shows all user groups that Working Group 2 identified and the use cases that are applicable to each user group. Section 4, which describes the use cases in detail, only includes the use cases that are of importance to FG AC.

Table 2 – List of use cases, by user group

User group	Use case
Air traffic management	Flight tracking
	Airspace optimization
	ATC
	Meteorological purposes
	Search and rescue
	Flight planning
	National security
	Anti-terrorism
	Flight information display system (FIDS)
	Approach statistics
Airport operations	Cargo information
	Flight tracking
	FIDS
	Meteorological purposes
	Passenger information – including health status
	Ground movement/handling

User group	Use case
AOC/central dispatch	Flight tracking
	Meteorological purposes
	Search and rescue
	Mission support
	Flight planning
	Fuel optimization
	Route planning and optimization
	Crew scheduling
	Approach statistics
	Cargo information
	Cargo related hazard monitoring
	Abnormal movement of crew and passengers
Flight operations	Route optimization
	Search and rescue
	Flight planning
	Fuel optimization
	Route planning and optimization
	Crew scheduling
	Flight crew techniques
	Approach statistics
Flight safety	Search and rescue
	Accident investigations
	Flight crew techniques
	Approach statistics
Maintenance, repair and operations (MRO)	Trouble-shooting
	Predictive maintenance
	Reliability
	Fuel optimization

User group	Use case
Government/regulatory authorities	Airspace optimization
	Search and rescue
	Accident investigations
	Anti-terrorism and national security
	Information for regulatory purposes
	Passenger information – including health status
	Medical community
	Flight information display system (FIDS)
	Approach statistics
	Information for R&D
	Military purposes
	Green aircraft/fuel, noise, carbon footprint
Academia/R&D	Information for R&D
OEMs	Predictive maintenance
	Fuel optimization
	Maintenance Reports for airframers, engines and equipment manufacturers
	Information for R&D
General public	Flight information display system (FIDS)
	Entertainment based on flight data

3 Description of available data

This section provides an overview of available data that is of possible interest for cloud computing.

3.1 Digital flight data recorder (DFDR)

DFDR, or mandatory FDR, or accident recorder, records a large number of aircraft parameters in a highly robust unit. The primary use case for DFDRs is the investigation of aircraft loss or accidents.

Aircraft parameters that are recorded to DFDRs are a combination of the parameters that are identified by the appropriate regulatory authority (the Federal Aviation Administration (FAA), the European Aviation Safety Agency (EASA), the Civil Aviation Safety Authority (CASA), etc.) as being mandatory parameters to record on DFDR, plus a series of other parameters as selected by the aircraft OEM. The quantity of aircraft parameters that are recorded is variable and is typically related to the size and age of the aircraft (see EUROCAE ED-112A and FAR 121.344 for current regulations; also see Appendix A).

As an example, a Boeing 737NG will record approximately 1000 different parameters, amongst which are navigational position data, control surface position, engine parameter data, environmental control system data, switch and lever position data in the cockpit such as thrust lever position, fuel flow and many more. The frequency in which individual parameters varies in the range of 0.25 Hz to 20 Hz.

3.2 Quick access recorder (QAR)

QAR, or digital ACMS recorder (DAR), can be any flight data recording device where a removable media can be easily removed by a technician for subsequent processing and flight data monitoring (FDM) analysis. This can include acquisition units with built-in personal computer (PC) card slots, or supplementary 4MCU-sized recording devices/small-sized solid state devices that record data transmitted to it by an acquisition unit. The nature of QAR recordings is very similar to DFDR recordings, except that there is a variety of proprietary QAR recording styles, plus QARs can record data that is supplied by ACMS functionality (see ACMS below). The unit is not designed to withstand a crash.

DFDR and QAR data can both be used for FDM, but QAR data is the predominant source of flight data for FDM because the removable media is a much more efficient means of flight data removal from the aircraft. QARs have media, such as magneto-optical disks and Type II Personal Computer Memory Card International Association (PCMCIA) cards or compact flash cards. In more recent years, devices have been introduced that automatically transmit recorded flight data at the end of a flight via second/third/fourth generation mobile network (2G/3G/4G) cellular connections or wireless fidelity (Wi-Fi) to transfer data to the airline back office. In addition, aircraft such as Boeing 737 MAX and Airbus A350 have no option to fit QAR and virtual QAR applications within network file servers' record QAR data.

The image below is an example of a view of recorded flight data as generated by GDRAS and could be DFDR or QAR data. The recorded flight data has previously been transcribed from the DFDR/QAR recording medium and a selection of recorded parameters are being decoded into engineering units and displayed for scrutiny by the GDRAS user.

	A	C	L	P	Q	AJ	AK	AL	AM	AO	AP	
1	9X-XXX 14/04/xxxx Parameter Map: xxxxxxxx-x-x (v1.12) Format: ALL PARAMETERS (v1.17) **Parameters: 1388**											
2	Flight: 00000000-0 KUL-KUL T/O Frm: 1223 12:19:22 AM Lnd Frm: 12305 12:38:11 PM											
3												
4	Frame-Sf	Time		Left Aileron Position	Right Aileron Position	Barometric Altitude	Captain Baro Settings	F/O Baro Settings	Altitude Settings	Altitude Radio Color	Selected altitude	Standar
5			_ACC_Z_EARTH	_AILERON_1	_AILERON_2	_ALT_BARO	_ALT_BARO_CPT	_ALT_BARO_FO	_ALT_MODE	_ALT_RADIO_COLOI	_ALT_SEL	_ALT_S
6			m.s²			ft					ft	ft
7	933-1	23:59:58	-0.23	6.71	6.71	72	1018	0	QNH	Amber	6000	
8	933-2	23:59:59	-0.19	6.71	6.71	72	1018	0	QNH	Amber	6000	
9	933-3	0:00:00	-0.19	6.71	6.71	72	1018	345	QNH	Amber	6000	
10	933-4	0:00:01	-0.23	6.71	6.71	72	1018	345	QNH	Amber	6000	
11	934-1	0:00:02	-0.23	6.71	6.71	72	1018	345	QNH	Amber	6000	
12	934-2	0:00:03	-0.23	6.71	6.71	72	1018	345	QNH	Amber	6000	
13	934-3	0:00:04	-0.19	6.71	6.71	72	1018	345	QNH	Amber	6000	
14	934-4	0:00:05	-0.15	6.71	6.71	72	1018	345	QNH	Amber	6000	
15	935-1	0:00:06	-0.19	6.71	6.71	72	1018	345	QNH	Amber	6000	
16	935-2	0:00:07	-0.19	6.71	6.71	72	1018	345	QNH	Amber	6000	
17	935-3	0:00:08	-0.19	6.71	6.71	72	1018	345	QNH	Amber	6000	
18	935-4	0:00:09	-0.19	6.71	6.71	72	1018	345	QNH	Amber	6000	
19	936-1	0:00:10	-0.19	6.71	6.71	72	1018	345	QNH	Amber	6000	
20	936-2	0:00:11	-0.19	6.71	6.71	72	1018	345	QNH	Amber	6000	
21	936-3	0:00:12	-0.19	6.71	6.71	72	1018	345	QNH	Amber	6000	
22	936-4	0:00:13	-0.12	6.71	6.71	72	1018	345	QNH	Amber	6000	
23	937-1	0:00:14	-0.23	6.71	6.71	72	1018	345	QNH	Amber	6000	
24	937-2	0:00:15	-0.19	6.71	6.71	72	1018	345	QNH	Amber	6000	
25	937-3	0:00:16	-0.19	6.71	6.71	72	1018	345	QNH	Amber	6000	
26	937-4	0:00:17	-0.19	6.71	6.71	72	1018	345	QNH	Amber	6000	
27	938-1	0:00:18	-0.19	6.71	6.71	72	1018	345	QNH	Amber	6000	
28	938-2	0:00:19	-0.15	6.71	6.71	72	1018	345	QNH	Amber	6000	
29	938-3	0:00:20	-0.19	6.71	6.71	72	1018	345	QNH	Amber	6000	
30	938-4	0:00:21	-0.12	6.71	6.71	72	1018	345	QNH	Amber	6000	
31	939-1	0:00:22	-0.15	6.71	6.71	72	1018	345	QNH	Amber	6000	
32	939-2	0:00:23	-0.19	6.71	6.71	72	1018	345	QNH	Amber	6000	
33	939-3	0:00:24	-0.15	6.71	6.71	72	1018	345	QNH	Amber	6000	
34	939-4	0:00:25	-0.15	6.71	6.71	72	1018	345	QNH	Amber	6000	
35	940-1	0:00:26	-0.19	6.71	6.71	72	1018	345	QNH	Amber	6000	
36	940-2	0:00:27	-0.19	6.71	6.71	72	1018	345	QNH	Amber	6000	

3.3 Aircraft condition monitoring system (ACMS)

In the 1980s, as recorded flight data became more useful to airlines, acquisition unit manufacturers developed a range of functions (separated from the mandatory flight data record functionality) that allowed airlines to develop their own airborne applications. The outcome was a suite of functionality that worked on aircraft parameters in real time on the aircraft, without any regulatory control, for the benefit of the airline.

This custom monitoring and reporting is referred to as aircraft integrated data system (AIDS), airplane information management system (AIMS), aviation data acquisition system (ADAS), ACMS or airplane condition monitoring function (ACMF), depending on the system manufacturer and age of the acquisition system. The outcome of this secondary process (hereafter generically called ACMS in this document) can be made available to any combination of the following: a flight deck printer, a flight deck display, a download unit, to ACARS, and to an auxiliary recorder.

ACMS functions are under the control of a dedicated microprocessor. Depending on where the second processor is located, it may be called a central processing unit (CPU) #2 or a data management processor (DMP). For some aircraft types, this processor exists within a dedicated line replaceable unit or in a single box that includes also the mandatory FDR functions.

ACMS functions involve uploaded application software to:

- manage acquisition of aircraft parameters;
- allow scripts to work on acquired data;
- derive recording modes and flight modes;
- perform triggering;
- perform reasonability testing;
- derive new parameters;
- generate a data stream that, when received by an auxiliary recorder, generates custom flight data recordings;
- in some cases, route a data stream that is a replica of the DFDR data to an auxiliary recorder;
- generate reports which:
  - can be interfaced with a flight deck display system for control and display purposes (examples of such equipment are interactive display units (IDUs), flight data entry panels (FDEPs), precision distance measuring equipment (PDME), control display units (CDUs) and more commonly multipurpose control display units (MCDUs));
  - can be interfaced with a data loader (for offload);
  - can be interfaced with the same auxiliary recorder that records ACMS-related flight data recordings.

Report and message data

Report generation within ACMS relies on other pre-occurring ACMS activities (parameter acquisition, scripts and triggering). Outputs from the ACMS reporting function, which always contains the American Standard Code for Information Interchange (ASCII) text, are in two styles:

- Formatted – The layout of information is arranged for human reading.
- Unformatted – The layout of information is arranged for machine reading and efficient transmission to the ground.

Examples of ACMS reports include take-off reports, engine stable cruise reports, performance reports and auxiliary power unit (APU) reports. Other reports may exist for environmental control system, brake temperature, tail strike, hard landing and more. These reports are typically transmitted via ACARS, but alternatives include cellular or Wi-Fi on the ground. ACMS reports are transmitted on defined criteria, depending on airline requirements (for instance after take-off, top of decent or at occurrence of a parameter threshold exceedance).

ACMS report example

```
 |0    0    1    1    2    2    3    3    4    4    5    5    6   6
 |1    5    0    5    0    5    0    5    0    5    0    5    0   4
-+---------------------------------------------------------------------
 |ACM210    AAAAAAAAAA TAKE OFF REPORT               NNN
 |
 |TAKEOFF ROLL SNAPSHOT
 | ACID        FLT      DPT    DST     DATE     FLCT FM   GMT      SFC
 |AAAAAAAA  AAAAAAAA  AAAA   AAAA  ZZ/ZZ/ZZ NNNN AA ZZ:ZZ:ZZ NNNNN
 |
 |     SWID        PKWD TMDRT DTMP DP1T DP2T DP1C DP2C   GWT
 |AAAA-AAA-AAA-AA HHHH   H     NN   NN   NN   NN   NN   NNNNNN
 |
 |  NAI WAI LTCC ICCC MW09 MW10  SER # TC BC CC        AVM HWS CIC
 |L AAA AAA AAAA AAAA HHHH HHHH NNNNNN HH  H  H         B   H   A
 |R AAA AAA AAAA AAAA HHHH HHHH NNNNNN HH  H  H         B   H   A
 |
 | ESS CW3
 |L H   HHHH
 |R H   HHHH
 |
 |      INITIAL IDLE SNAPSHOT           PRE-TAKEOFF IDLE SNAPSHOT
 |  BSVP  MSVP  T12    SFC     GMT         BSVP  MSVP  T12    SFC
 |L SNNN  SNNN  SNN  NNNNN  ZZ:ZZ:ZZ      SNNN  SNNN  SNN  NNNNN
 |R SNNN  SNNN  SNN  NNNNN  ZZ:ZZ:ZZ      SNNN  SNNN  SNN  NNNNN
```

3.4 Central maintenance computer (CMC)

The central maintenance computer (CMC) is used to facilitate maintenance tasks by directly indicating the fault messages in the cockpit, and allowing some specific tests. It includes the built-in test equipment (BITE) of all electronic systems and there are always two redundant CMCs, one for use and the other on standby in case of emergency/failure of the first one. The communications management unit (CMU) operates in two main modes: the normal or reporting mode (in-flight) and the interactive or menu mode (on ground). In the normal mode, CMS records and permanently displays the failure messages transmitted by each system of BITE. In the interactive mode, CMS allows the connection of any BITE system with MCDU, in order to initiate a test, or to display the maintenance data stored and formatted by the systems BITE. CMC messages are routed through ACARS for transmission to the ground for scrutiny and action.

Example of a CMC/fault detection and exclusion (FDE) message

QU xxxxxx

.xxxxxxx 160855

_CFD

FI xxxxx/AN xx-xxxx

DT xxx IOR2 160855 C03A

- PLF 1 16APR15 0852 xxxxxxx xxxxx SZBAP/WMKK 3110-BCG-00W-12 L 0133 16APR15

FDE 21507241 A 0133 16APR15

MSG 2124101 L 0133 16APR15 ES M PL

DB CABIN TEMPERATURE CONTROLLER (L CHAN2)

DB CABIN TEMPERATURE CONTROLLER (L CHAN1)

NCMM

POST LEG FAULTS

AIRCRAFT REG: XX-XXX

DATE: 16APR15

FLIGHT NO: XXXXX

ORGIN AIRPORT: NRT

DESTINATION AIRPORT: SZBAP

FDE FAULTS

FDE Fault: 21507241

FDE DESCRIPTION: 21507241

FDE ATA: 21

FDE Time / Date: 0133 16APR15

FDE Fault Mode: Active

FDE Correlated Faults

FDE CORRELATED Faults: 2124101

DESCRIPTION: Upper Flow Control And SOV (L Pack) torque motor is not in commanded position.

CMC ATA: 21

CMC Time / Date: 0133 16APR15

CMC Correlated Fault Type: EN-START MODE DEPENDENT

CMC Correlated Mode: Latched

NON-FDE FAULTS

CMC: 2229340

DESCRIPTION: FSEU 2 Control Channel signals are invalid.

NCMM ATA: 22

Time / Date: 0828 16APR15

FAULT TYPE: DESCENT INTERMITTEN

FAULT MODE: Inactive

CMC: 2229330

DESCRIPTION: FSEU 2 Monitor Channel signals are invalid.

NCMM ATA: 22

Time / Date: 0828 16APR15

FAULT TYPE: DESCENT INTERMITTEN

FAULT MODE: Inactive

CMC: 2229320

DESCRIPTION: FSEU 1 Control Channel signals are invalid.

NCMM ATA: 22

Time / Date: 0828 16APR15

FAULT TYPE: DESCENT INTERMITTEN

FAULT MODE: Inactive

CMC: 2229310

DESCRIPTION: FSEU 1 Monitor Channel signals are invalid.

NCMM ATA: 22

Time / Date: 0828 16APR15

FAULT TYPE: DESCENT INTERMITTEN

FAULT MODE: Inactive

CMC: 2229270

DESCRIPTION: Electronic Engine Control (L Eng

NCMM ATA: 22

Time / Date: 0828 16APR15

FAULT TYPE: DESCENT INTERMITTEN

FAULT MODE: Inactive

CMC: 2229148

DESCRIPTION: TMCF in Right AIMS has no input from Engine Data Interface Unit (R Eng

NCMM ATA: 22

Time / Date: 0828 16APR15

FAULT TYPE: DESCENT INTERMITTEN

FAULT MODE: Inactive

3.5 Flight management computer (FMC)

Flight management computer or flight management system (FMC/FMS) is a fundamental component of modern aircraft avionics. It is a specialized computer system that automates a wide variety of in-flight tasks, reducing the workload on the flight crew. All FMSs contain a navigation database. The navigation database contains the elements from which the flight plan is constructed for the aircraft, other in-flight tasks include: position determination, guidance and vertical navigation (VNAV) which includes control of the pitch axis and control of the throttle.

FMCs are usually connected to the ACARS communication unit. The flight crew can send requests or reports to the ground or receive reports from the ground. The uplinked data as reviewed by the pilot and if accepted it gets stored and activated in FMC. With the uplinks, paper documents and processes of manually entering data are eliminated in order to reduce pilot workload.

Each airline makes different use of the FMC messaging. This means not airlines use all features. Important factors for using the FMC messaging are airline ground and flight processes, available information technology (IT) systems and airline size.

Many FMC messages use the ARINC 702A standard.

Examples of downlinks:

- Flight plan data report downlink: Contains the list of waypoints, flight levels, etc.
- Position report downlink: Contains the position, current and next waypoint, time, altitude, wind data, speed, fuel data, air temperature, etc.

Examples of uplinks:

- Flight plans data uplink: Contains the list of waypoints, flight levels, etc.
- Performance data uplink: zero fuel weight, centre of gravity, cruise altitude, fuel data, etc.
- En-route wind data uplink: Wind direction speed for each requested waypoint on different flight levels.
- Take-off data uplink: Runway data, etc.

Example message

(position report; content only)

/PSN47261W122185,SEA,093118,350,ORTIN,093436,BARRO,M32,120015,0485,789,ECON

3.6 ADS-B and ADS-C

Automatic dependent surveillance-broadcast (ADS-B) is a cooperative surveillance technology in which an aircraft determines its position via satellite navigation and periodically broadcasts it, enabling it to be tracked. The information can be received by air traffic control ground stations as a replacement for a secondary radar. It can also be received by other aircraft to provide situational awareness and allow self-separation. Benefits include both safety and efficiency of flight: traffic, weather, terrain, flight information, and expenses. ADS-B is "automatic" in that it requires no pilot or external input. It is "dependent" in that it depends on data from the aircraft's navigation system. ADS-B equipment is currently mandatory in portions of Australian airspace, the United States requires some aircraft to be equipped by 2020 and the equipment will be mandatory for some aircraft in Europe from 2017; meanwhile Canada is already using ADS-B for air traffic control.

Automatic dependent surveillance-contract (ADS-C) uses a "contract" concept. A ground system, for instance the air traffic controller, can request ADS-C reports from the aircraft. Within this request, the frequency of the report transmissions can be defined. Pilots can see the active contracts and terminate them or initiate a contract on their own.

ADS-B and ADS-C messages exist in different versions and with different content.

Examples of ADS messages

1	Time	Position		Orientation		Groundspeed		Altitude	
2	EDT	Latitude	Longitude	Course	Direction	KTS	MPH	feet	Rate
3									
4	Wed 07:18:40 PM	51.4778	-0.424	76°	East	158	182	600	Level
5	Wed 07:18:42 PM	51.4773	-0.4216	93°	East	159	183	800	2,211 Climbing
6	Wed 07:18:59 PM	51.4735	-0.4032	119°	Southeast	159	183	1,300	1,688 Climbing
7	Wed 07:19:14 PM	51.4681	-0.389	121°	Southeast	157	181	1,700	973 Climbing
8	Wed 07:19:36 PM	51.4596	-0.3664	120°	Southeast	180	207	1,900	649 Climbing
9	Wed 07:19:51 PM	51.4524	-0.347	121°	Southeast	201	231	2,100	750 Climbing
10	Wed 07:20:08 PM	51.4437	-0.3242	122°	Southeast	224	258	2,300	1,000 Climbing
11	Wed 07:20:27 PM	51.4339	-0.2992	122°	Southeast	229	264	2,700	1,622 Climbing
12	Wed 07:20:45 PM	51.4254	-0.2698	103°	East	252	290	3,300	2,118 Climbing
13	Wed 07:21:01 PM	51.4211	-0.2372	102°	East	252	290	3,900	2,000 Climbing
14	Wed 07:21:18 PM	51.4171	-0.207	101°	East	264	304	4,400	1,543 Climbing
15	Wed 07:21:36 PM	51.4118	-0.1686	101°	East	282	325	4,800	1,765 Climbing
16	Wed 07:21:52 PM	51.4085	-0.1445	102°	East	284	327	5,400	2,250 Climbing
17	Wed 07:22:08 PM	51.4032	-0.1049	102°	East	288	331	6,000	2,323 Climbing
18	Wed 07:22:23 PM	51.3987	-0.0729	102°	East	291	335	6,600	2,200 Climbing
19	Wed 07:22:38 PM	51.3946	-0.0426	102°	East	299	344	7,100	1,800 Climbing
20	Wed 07:22:53 PM	51.3897	-0.0076	102°	East	307	353	7,500	1,355 Climbing
21	Wed 07:23:09 PM	51.3844	0.0305	102°	East	327	376	7,800	1,161 Climbing
22	Wed 07:23:24 PM	51.3794	0.0669	101°	East	340	391	8,100	977 Climbing
23	Wed 07:23:52 PM	51.3695	0.1381	102°	East	369	425	8,500	1,180 Climbing
24	Wed 07:24:25 PM	51.3579	0.2203	102°	East	381	438	9,300	1,837 Climbing

3.7 Air traffic control (ATC)

Air traffic control (ATC) is a service provided by ground-based controllers who direct aircraft on the ground and through controlled airspace, and can provide advisory services to aircraft in non-controlled airspace.

The primary purpose of ATC worldwide is to prevent collisions, organize and expedite the flow of traffic, and provide information and other support for pilots.

With the growing number of flights worldwide and congestion of the radio frequencies in areas with heavy aircraft activities, systems have been developed to replace voice communication with data communication. The controller can send new instructions, for example heading or altitude, via an ATC data message to the aircraft. The pilot can accept the message, which automatically transfers the data to the autopilot and sends a confirmation to the controller.

All the ATC messages can be collected and can provide an information source for reconstructing the moments before an accident.

3.8 Airline operational communication (AOC)

Airline operational communication (AOC) integrates the aircraft with the airlines/operators network, allowing monitoring of each aircraft's track, position and faults to pre-emptively plan for repair. Up-to-the-minute fleet information allows for better planning and significant cost savings.

The airlines have very different use cases for the AOC messaging. It can include fuelling processes, de-icing processes, weather and airport information, position reports, flight log, defect reporting, maintenance or station communication, load sheets, flight plans, etc. Some of these messages, for instance position reports or defect reports, can be of interest for a flight data cloud.

3.9 Dedicated data units

Besides the mentioned data above, operators can install additional units to monitor and/or stream data. These range from simple position reports to complete flight data streaming. Many of these systems are found in business jets or smaller. The format and data depend on the individual product and the purpose of the device. However, the data can be a valuable source of information.

3.10 Computer system log files

Modern aircraft produce a number of log files for various aircraft systems. These files need to be downloaded and analysed. They are different in format and size. Potentially they could also include helpful information for the cloud applications.

One example: modern aircraft have an integrated wireless fidelity (WiFi) system in the cabin. An on-board server stores log files for the WiFi performance and access point status. These log files of the WiFi system or other systems might become of interest in an accident investigation.

3.11 Technical logbook

Technical defects and problems are recorded in a technical logbook available to the flight crew. Typically this logbook is paper based. A current trend in aviation innovation is to move the paper based logbook to an electronic technical logbook (eTLB). This data can be sent during the flight and directly fed into the maintenance ground systems.

3.12 Custom modifications

There is always the possibility for an operator to install additional systems that can generate data, for instance custom A/C tracking systems or smoke and fire detection systems. In addition, video streaming systems could be developed and installed in aircraft to monitor activities in the cabin or cockpit.

3.13 Cockpit voice recorder (CVR)

Civil aviation airliners are required to have a cockpit voice recorder on board. These devices record the cockpit voice continuously. Latest models also store the datalink data. The data storage can hold the data of several hours. It is organized in a ring buffer, meaning that with new data to be stored, the oldest data gets overwritten. The voice recorder is one of the two black boxes that are recovered after an accident. The data is considered private data and usually not fed into databases. Only for accident investigation or maintenance activities the data gets downloaded from the device. Irrespective of the legal implications, the voice data could in the future be transmitted in real time from the aircraft and provide highly valuable data for accident investigation.

4 Use cases

4.1 Flight tracking and search and rescue

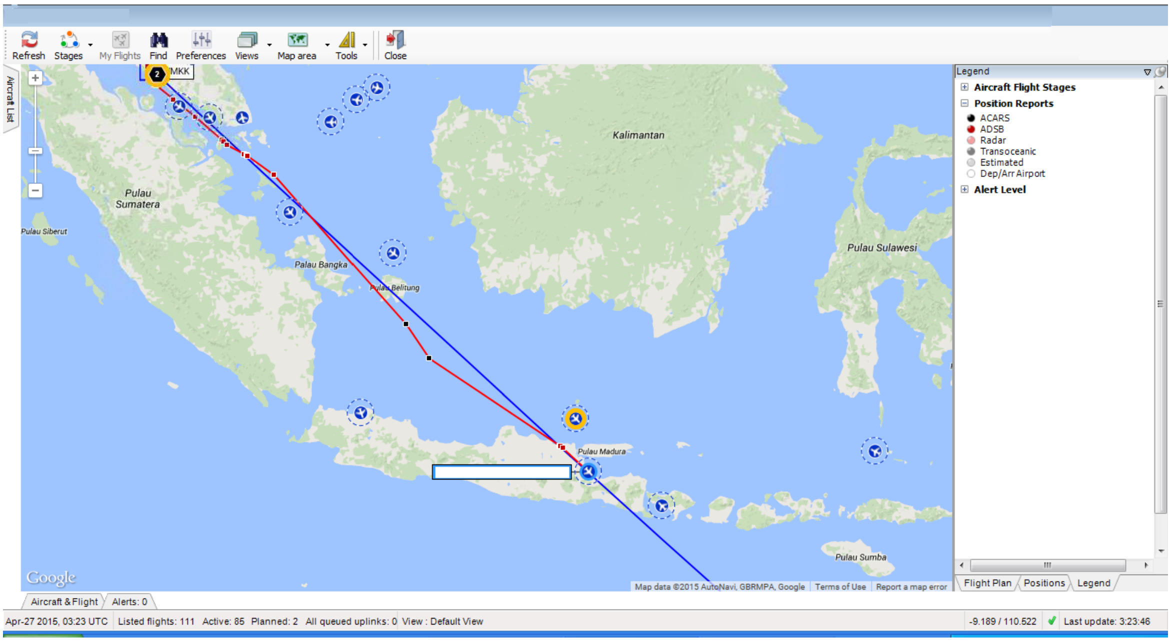
The use case flight tracking/flight following will utilize the same parameters from aircraft data and hence are grouped together here.

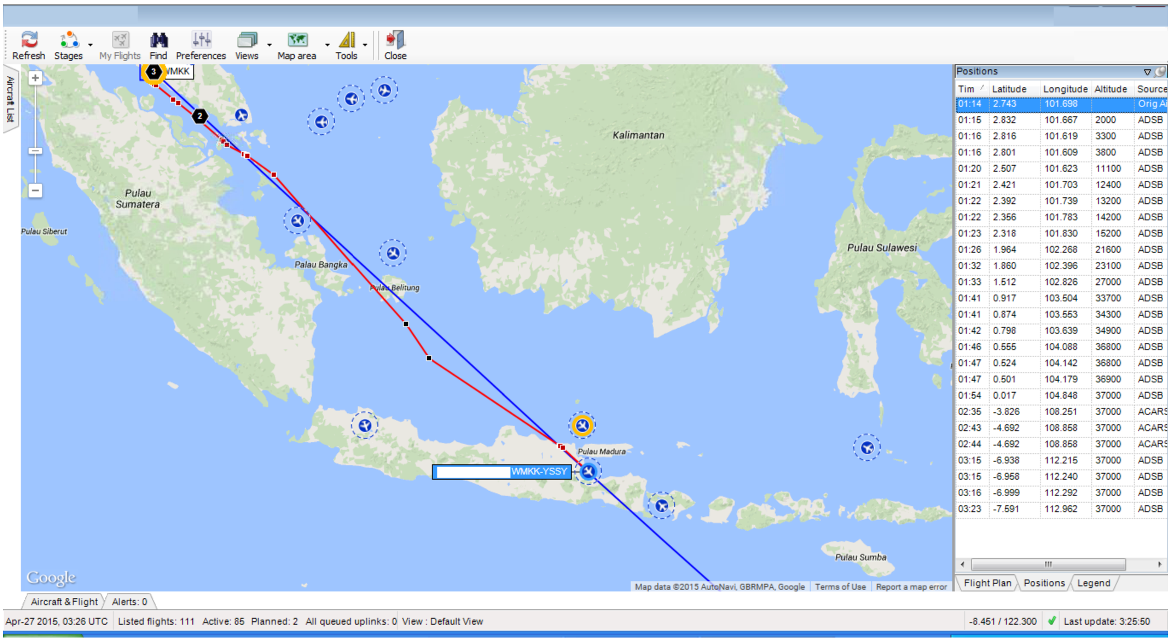
Description	Collect <u>(tamper-proof collection of flight data),</u> analyse and store the aircraft position (latitude/longitude) and possibly additional data such as altitude, speed, wind direction, wind speed, time and heading in real time. The task of tracking an aircraft for the purpose of determining its real-time spatial location or post-flight track flown.
Scenario	The aircraft either periodically transmits the tracking data to a server on the ground via a communication network or periodically records the tracking data onto an on-board recorder that can then be accessed in-flight or post-flight. The ground system stores the data to provide situational awareness.
User groups	Primary user groups: • Air traffic management; • Airline; • Airport ground operations; • Contracted maintenance organizations (line maintenance). • Secondary user groups: • Military; • Passengers.

Benefit	The timely and real-time availability of an asset location in relation to space and time. The tracking of an aircraft: • Improves determining the estimated time of arrival (ETA) of an aircraft. • Improves re-scheduling of aircraft if in-flight delays occur. • Makes it easier to locate an aircraft in case of an emergency. • Increases accurate search and rescue response that would significantly reduce the search and rescue efforts and costs in determining the location of an accident site. • Allows passengers to know in-flight and in real time their location in space and time. • May allow passengers awaiting their flight at an airfield to know of an aircraft's real-time location in space and time. • May allow airport ground personnel to know where their particular aircraft for service is in space and time so as to allow for adequate and efficient arrival and departure preparations and resource allocation. • May allow maintenance personnel to know where a particular aircraft is in space and time so as to allow for adequate and efficient preparations for aircraft servicing, resource allocation and aircraft scheduling and distribution. • Will allow governmental organizations to automatically track their contracted service provider's assets in real time allowing for efficient distribution of aerial resources. • Improves instrument flight rules (IFR) separation, especially in non-radar airspace. • Improves and increases the visual flight rules (VFR) following coverage. • Monitors ATC final approach and runway occupancy, reducing runway incursions on the ground. • Provides information to cockpit with regards to own ship position and that of other aircraft cockpit display of traffic information (CDTI) in real time. • Allows ATC to potentially guide aircraft into and out of crowded airspace/airports with smaller separation standards. This in turn reduces the amount of time the aircraft must spend waiting for clearances or in holding patterns. Furthermore, this could lead to benefits of reducing pollution and fuel consumption. Would benefit automatic devices such as: • airport lighting control automation and operation; • airport emergency vehicle situational attention provider; • aircraft spotter alerts; • noise abatement measurement devices.
Required data	Minimum: Aircraft registration, aircraft hardware unit serial identification, time, position (latitude/longitude), altitude. The cockpit voice data can also be used in determining the last position in case of an accident.
Data sources	• ADS-B (traditional and via satellite) or Mode-S transceiver. • ADS-C. • FMC messages. • High-integrity global positioning system (GPS) navigation source or from alternative aircraft navigational devices (e.g. GLONASS, Galileo, GNSS, IRNSS, QZSS, BeiDou-2, DORIS, etc.). • Inertial navigation system (INS) – via automated dead reckoning. • Routine radio position reports. • Automated celestial navigational systems (ANSs). (Additional source, but not from A/C data: primary radar.)

Special considerations	• Aircraft navigational capabilities – Many aircraft do not have modern navigational equipment. This may bring about the need to access traditional cockpit devices and calculate via dead-reckoning methods the aircraft position in time and space. Accuracy and precision will be affected. Alternatively a GPS (or other) antenna may need to be installed. • Some aircraft do not have communication equipment possible of transferring any data to the ground in real time. A communication device capable of transferring data to the ground needs to be installed. • Portable versus installed equipment and the supplemental type certificate (STC) considerations associated with it. • Satellite technologies for transmitting data in real time needs to be available globally (over poles, land and water). • Most authorities classify non-installed components as "transmitting portable electronic devices" (T-PEDs) and as such require them to be switched off during the critical phases of the flight. • Access control to data because it can reveal sensitive operational and economical details of the airlines. Security mechanisms to avoid and detect misuse of the system or false data injection. NOTE – Some aircraft acquisition systems may not read latitude and longitude coordinates.
Amount of data	Depends on interval and data set. Flight tracking data is usually very small and can be sent through short burst data (SBD) messages. It is dependent on the position interval and amount of data in the string. Flight tracking data file size is considered small and varies from approximately 10 bytes to 40 bytes and up, per single position report that can get sent.
Transmission interval	Best case real-time streaming data but maximum acceptable transmission interval is one minute. Depends on existing technologies on board aircraft. NOTE – As per IATA/ICAO ATTF recommendations of 15-minute normal tracking and one minute abnormal tracking triggered by an event.
Transmission technologies	Technologies are available as of today. Current technologies have sufficient capabilities for tracking, sending alerts, and a few parameters. Global transmission technologies are limited to satellite-based technologies with global coverage. However, current available market technologies have sufficient capabilities for retrieving position and time data and either recording it or sending it via communication network channels. Possible methods: • Satellite (Globalstar, Inmarsat, Iridium, Thuraya, ViaSat). • Terrestrial communication.

Flight tracking example





4.2 Predictive maintenance

Description	Collect, analyse and store aircraft performance data (tamper-proof collection of flight data) for early detection of degradation. The reliability of an A/C can be significantly increased by detection and replacement of attired parts.
Scenario	The performance and maintenance reports are collected in a database by MRO. This data is matched against computer models of the A/C systems, such as the engines, to detect deviations from nominal values.
User groups	• MRO; • OEMs.

Benefit	• Increase in A/C safety; • High reliability for A/C dispatch; • Reduced maintenance cost.
Required data	Any data that contains technical information of the aircraft. This is a wide range of parameters, e.g. engine data (gas temperatures at various stages in the engine, oil consumption, fuel burn, rotation, vibration, etc.), flight controls data (actuator activities, movement durations, etc.), fuel pumps data, environmental control system data, hydraulics, electrics, pneumatics, etc.
Data sources	• ACMS reports; • CMC reports; • QAR data; • Technical logbook.
Special considerations	The QAR data provides many aspects of the situation and performance. It may require access control to the data because it can reveal sensitive operational and economical details of the airlines. Assure data ownership, data privacy, data security and access control.
Amount of data	ACMS, CMC and technical logbook reports are typically between 40 bytes and 10 kilobytes. The number of reports depends on the events and A/C type; it can range from five reports up to 40 reports per flight. The QAR data today can be up to 100 MB per long distance flight.
Transmission interval	Today some data, for example ACMS reports, is sent in real time. QAR data is typically downloaded post-flight.
Transmission technologies	Very high technology (VHF), satellite, WiFi, 2G/3G. The protocols are typically ACARS and Internet protocol (IP) based.

4.3 ATC

Description	Provide real-time instantaneous aircraft departure, arrival and en-route information (tamper-proof collection of flight data) to ATC.
Scenario	The air traffic controller uses the data of aircraft position, type, heading, etc., to manage the airspace activities. The pertinent data from FMC can be routed to ATC using real-time systems.
User groups	• AOC; • ATC.
Benefit	• Increase in A/C safety; • High reliability for A/C dispatch; • Accurate aircraft information.
Required data	• Position reports; • Any data that contains aircraft out, off, on, in (OOOI) times.
Data sources	• FMC; • DFDR; • AOC reports; • ADS-B/ADS-C.
Special considerations	Data security, integrity and reliability.
Amount of data	Very nominal payload.

Transmission interval	Performance criteria.
Transmission technologies	VHF, satellite. The protocols are typically ACARS, satellite communication (SatCom) and IP based.

4.4 Ground movement/handling

Since the ATC functions include the separation of incoming and outgoing traffic from an aerodrome, there are almost the same parameters for ground movement/handling.

Description	Provide real-time instantaneous aircraft departure, arrival and en-route information (tamper-proof collection of flight data) to ATC.
Scenario	The ground controllers use the data from the aircraft to monitor and manage the activities and movements on the ground.
User groups	• AOC; • ATC.
Benefit	• Increase in A/C safety; • High reliability for A/C dispatch; • Accurate aircraft information.
Required data	• Position reports; • Any data that contains aircraft out, off, on, in (OOOI) times.
Data sources	• FMC; • DFDR; • AOC reports.
Special considerations	Data security, integrity and reliability.
Amount of data	Very nominal payload.
Transmission interval	Performance criteria.
Transmission technologies	VHF, satellite. The protocols are typically ACARS, SatCom and IP based.

4.5 Trouble-shooting

Description	Collect, analyse and store aircraft systems (tamper-proof collection of flight data), engines data for detection of degradation. The reliability of an A/C can be significantly increased by detection and replacement of attired parts.
Scenario	Trouble-shooting is an activity from the line maintenance to solve technical aircraft problems that are not directly covert in the aircraft mechanics procedures. The pertinent data from CMC, ACMS, maintenance panel and related avionics equipment that generate BITE can be acquired. The BITE status can be then transmitted for trouble-shooting. Obtaining the performance data and BITE data during the flight gives a time advantage. Spare parts and tools can be prepared before the aircraft is on ground. The time to fix the problem and release the aircraft back to service gets significantly shortened.
User groups	• Maintenance; • MRO.
Benefit	• Increase in A/C safety; • High reliability for A/C dispatch; • Accurate aircraft information.

Required data	Various aircraft systems, engine systems data.
Data sources	• CMC; • ACMS; • Maintenance panel; • QAR; • DFDR.
Special considerations	Data security, integrity and reliability.
Amount of data	Very nominal payload.
Transmission interval	In real time or during events such as top-of-descent or touch-down.
Transmission technologies	VHF, satellite. The protocols are typically ACARS, SatCom and IP based.

4.6 Crew scheduling

Description	Provide real-time instantaneous (tamper-proof collection of flight data) aircraft departure, arrival and en-route information to AOC, crew scheduling.
Scenario	The pertinent data from FMC can be routed to AOC, crew scheduling using real-time systems. The airline can use the available real-time data to detect deviation from the schedule. The aircraft assignments of the crews can be updated accordingly.
User groups	• AOC; • Crew scheduling; • Airline/operator finance department.
Benefit	• Improved flight operations; • High reliability for A/C dispatch; • Accurate aircraft information.
Required data	• Position reports. • Any data that contains aircraft out, off, on, in (OOOI) times.
Data sources	• FMC; • DFDR; • AOC reports; • ADS-B/ADS-C.
Special considerations	Data security, integrity and reliability.
Amount of data	Very nominal payload.
Transmission interval	Performance criteria.
Transmission technologies	VHF, satellite. The protocols are typically ACARS, SatCom and IP based.

4.7 Fuel optimization

Description	Collect, analyse and store (tamper-proof collection of flight data) fuel-related aircraft data.
Scenario	The pertinent data from the aircraft can be obtained for analysis to optimize fuel consumption, pilot techniques, and maintenance practices.

User groups	• AOC; • Crew training; • Maintenance/MRO; • Airline/operator finance department.
Benefit	• Improved flight operations; • High reliability for A/C dispatch; • Accurate aircraft information; • Fuel savings.
Required data	All fuel-related data, APU-related data, engines-related data – fuel consumption, OOOI times, slat/flap data, etc.
Data sources	• QAR; • DFDR; • AOC reports.
Special considerations	Data security, integrity and reliability.
Amount of data	Very nominal payload.
Transmission interval	Performance criteria.
Transmission technologies	VHF, satellite, WiFi, wireless groundlink (WGL), and global system for mobile communications (GSM). The protocols are typically ACARS, SatCom and IP based.

4.8 Route planning and optimization

Description	Collect (tamper-proof collection of flight data), analyse and store the aircraft position and possibly additional data such as altitude, speed and heading. The route planning department can analyse the data to improve the airline network, minimize costs, and increase passenger satisfaction.
Scenario	The aircraft periodically transmits the own ship position to the ground. This happens without interaction of the crew. The ground system stores the data for later analysis. The route planning department uses this data for optimization. Possible results can be changes in the destinations, number of connections per week to a destination, used airways, used aircraft model, etc. This is a continuous process, but the updates usually take place a couple of times per year.
User groups	• Air traffic management (ATM); • Airport operations; • Airline: AOC/central dispatch/flight control.
Benefit	Timely and instant availability of A/C situational awareness. Real-time information of flight status.
Required data	• Minimum: Position, altitude. • Additional: Speed, heading.

Data sources	• ADS-B (traditional and via satellite) or Mode-S transceiver. • ADS-C. • FMC messages including the required data. • Airline operational communication (AOC) position reports. • Dedicated positioning system. • Flight data streaming/flight operational quality assurance (FOQA) streaming. (Additional source, but not from A/C data: primary radar).
Special considerations	Access control to the data because it can reveal sensitive operational and economical details of the airlines. Security mechanisms to avoid and detect misuse of the system or false data injection.
Amount of data	Depends on interval and data set. Flight tracking data is usually very small and can be sent through short burst data (SBD) messages.
Transmission interval	Performance criteria.
Transmission technologies	Technologies are available as of today. Current technologies have sufficient capabilities for tracking, sending alerts, and a few parameters.

Flight/route plan example


```
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<ISETP>Y</ISETP>

4.9 Reliability

Description	Collect, analyse and store (tamper-proof collection of flight data) aircraft data for technical reliability of the aircraft.
Scenario	The pertinent data from the aircraft can be obtained for analysis to predict systems and mechanical failures proactively. The airlines and maintenance organizations continuously monitor the dispatch reliability of the aircraft. Secondly, aircraft system engineers regularly compile reliability reports of all aircraft systems to detect low performance of components or maintenance processes.
User groups	• Maintenance/MRO.
Benefit	• Improved flight operations; • High reliability for A/C dispatch; • Accurate aircraft information; • Fuel savings.
Required data	All fuel-related data, APU-related data, engines-related data – fuel consumption, OOOI times, slat/flap data, etc.
Data sources	• QAR; • DFDR; • ACMS reports; • CMC reports.
Special considerations	Data security, integrity and reliability.
Amount of data	Nominal payload.
Transmission interval	When required.
Transmission technologies	VHF, satellite, WiFi, WGL, GSM. The protocols are typically ACARS, SatCom and IP based.

4.10 Accident investigation

Description	Collect, analyse and store (tamper-proof collection of flight data) aircraft data to assist accident investigation.
Scenario	After an accident, the cause must be identified to prevent additional accidents. Depending of the magnitude of the accident, the investigation can be done by the airline, maintenance organization or authorities.
User groups	• Flight safety; • Safety boards; • Flight operations; • Maintenance/MRO.
Benefit	• Post-accident analysis on a timely fashion. No need to find the black boxes.
Required data	All fuel-related data, APU-related data, engines-related data – fuel consumption, OOOI times, flight controls, slat/flap data, etc.
Data sources	• QAR; • DFDR; • Voice data.
Special considerations	Data security, integrity and reliability.

Amount of data	Nominal payload.
Transmission interval	When required – based on triggered events and transmissions.
Transmission technologies	VHF, satellite, WiFi, WGL, GSM. The protocols are typically ACARS, SatCom and IP based.

4.11 Flight crew techniques

Description	Collect, analyse and store (tamper-proof collection of flight data) aircraft data to improve flight crew processes.
Scenario	Data from real flights can be used to develop and enhance flight procedures.
User groups	• Flight safety; • Flight operations and re-training; • Maintenance/MRO.
Benefit	Flying techniques optimization – better practices adoption, fuel savings, and maintenance savings.
Required data	All fuel-related data, APU-related data, engines-related data – fuel consumption, OOOI times, flight controls, slat/flap data, etc.
Data sources	• QAR; • DFDR.
Special considerations	Data security, integrity and reliability.
Amount of data	Nominal payload.
Transmission interval	When required – based on triggered events and transmissions.
Transmission technologies	VHF, satellite, WiFi, WGL, GSM. The protocols are typically ACARS, SatCom and IP based.

4.12 Approach statistics

Description	Collect, analyse and store (tamper-proof collection of flight data) aircraft data for approach statistics.
Scenario	Creating and evaluating approach statistics is an essential activity in an airline to optimize the operation costs. These are mainly defined by fuel costs, maintenance costs, and landing fees.
User groups	• Flight operations; • Maintenance/MRO; • Finance.
Benefit	• Data can be used to optimize approaches on every airport. Traffic management, fuel management, and traffic separation, etc.
Required data	All fuel-related data, APU-related data, engines-related data – fuel consumption, OOOI times, flight controls, slat/flap data, etc.
Data sources	• QAR; • DFDR.
Special considerations	Data security, integrity and reliability.
Amount of data	Nominal payload.
Transmission interval	When required – based on triggered events and transmissions.

Transmission technologies	VHF, satellite, WiFi, WGL, GSM. The protocols are typically ACARS, SatCom and IP based.

4.13 Maintenance reports for airframers, engines and equipment manufacturers

Description	Collect, analyse and store (tamper-proof collection of flight data) aircraft data for analysis by the airframers and component manufacturers.
Scenario	The pertinent data from the aircraft can be obtained for analysis to provide aircraft pertinent information to airframe manufacturers, engine manufacturers, leasing and insurance companies. Today many performance reports of the engines and aircraft are sent to the manufacturers, such as Airbus, Boeing, GE, Rolls Royce, etc. The daily operation of an aircraft or components gets analysed to improve the products.
User groups	• OEMs; • Leasing and insurance companies; • Flight operations; • Maintenance/MRO.
Benefit	• Data analysis in a timely fashion. No need to download the black box or QAR data.
Required data	All fuel-related data, APU-related data, engines-related data – fuel consumption, OOOI times, flight controls, slat/flap data, etc.
Data sources	• QAR; • DFDR; • ACMS reports; • CMC reports.
Special considerations	Data security, integrity and reliability.
Amount of data	Nominal payload.
Transmission interval	When required – based on triggered events and transmissions.
Transmission technologies	VHF, satellite, WiFi, WGL, GSM. The protocols are typically ACARS, SatCom and IP based.

4.14 Meteorological purposes

Description	Collect, analyse and store (tamper-proof collection of flight data) aircraft data for meteorological purposes.
Scenario	Aircraft can be used as weather sensors providing temperature, wind data, humidity, etc. Meteorological organizations and companies use this data to provide weather information at different flight levels.
User groups	• ATC; • Flight dispatch; • Flight operations.
Benefit	• Weather data in a timely fashion on a particular route for better flight planning purposes.
Required data	ADC data.
Data sources	• QAR; • DFDR; • AOC weather reports.

Special considerations	Data security, integrity and reliability.
Amount of data	Nominal payload.
Transmission interval	When required.
Transmission technologies	VHF, satellite, WiFi, WGL, GSM. The protocols are typically ACARS, SatCom and IP based.

4.15 Cargo monitoring and tracking

Description	Some cargo requires special treatment, such as temperature control, vibration monitoring, humidity control, etc. The cargo hold and individual cargo containers are monitored during the flight and the monitoring data is streamed of the aircraft.
Scenario	The cargo hold and cargo container gets equipped with sensors. The data that is being collected and transmitted during the flight is monitored and analysed on the ground. Alerts can be automatically generated. Corrective actions can be planned in advance.
User groups	• Airlines; • Cargo owners; • Cargo forwarders.
Benefit	• Flight safety, by closely monitoring the cargo; • Ensure the quality of the delivery service.
Required data	• Aircraft position; • Cargo sensor data (to be defined).
Data sources	• Monitoring devices installed in the cargo hold and containers.
Special considerations	None.
Amount of data	Depends on the selected sensors.
Transmission interval	Depends on the cargo.
Transmission technologies	In the cargo hold: radio frequency identification (RFID), near field communication (NFC), WiFi, Bluetooth, etc. Off aircraft: VHF, satellite, 3G/4G, WiFi.

4.16 Airspace optimization

Description	Collection of aircraft movement data to analyse and optimize the airspace.
Scenario	The detailed aircraft position data can be used to optimize the airspace for en-route traffic and approach/departure traffic. Air routes can be modified, as well as the departure and arrival vectors. ATC processes can be enhanced.
User groups	• AOC; • ATC.
Benefit	• Increase in A/C safety; • High reliability for A/C dispatch; • Accurate aircraft information.
Required data	• Position reports; • Any data that contains aircraft out, off, on, in (OOOI) times.
Data sources	• FMC; • DFDR; • AOC reports; • ADS-B/ADS-C.
Special considerations	Data security, integrity and reliability.
Amount of data	Very nominal payload.
Transmission interval	Performance criteria.
Transmission technologies	VHF, satellite. The protocols are typically ACARS, SatCom and IP based.

4.17 Flight information display system

Description	Collect and store (tamper-proof collection of flight data) arrival/departure timings.
Scenario	To be used for passengers and other authorities for aircraft arrivals and departures.
User groups	• ATC; • Airport authorities; • Passengers; • Flight operations – planning, crew scheduling; • Maintenance/MRO.
Benefit	• Accurate reporting of aircraft arrivals and departures for various operational uses.
Required data	• All OOOI times.
Data sources	• QAR; • DFDR; • AOC reports.
Special considerations	Data security, integrity and reliability.
Amount of data	Nominal payload.
Transmission interval	When required – based on triggered events and transmissions – like take-off and landing times.
Transmission technologies	VHF, satellite, WiFi, WGL, GSM. The protocols are typically ACARS, SatCom and IP based.

4.18 Green aircraft/fuel, noise, carbon footprint

Description	Collect, analyse and store (tamper-proof collection of flight data) fuel-related aircraft data.
Scenario	The pertinent data from the aircraft can be obtained for analysis to optimize fuel consumption, pilot techniques, and maintenance practices.
User groups	• AOC; • Crew training; • Maintenance/MRO; • Airline/operator finance department.
Benefit	• Improved flight operations; • High reliability for A/C dispatch; • Accurate aircraft information; • Fuel savings.
Required data	• All fuel-related data, APU-related data, engines-related data – fuel consumption, OOOI times, slat/flap data, etc.
Data sources	• QAR; • DFDR.
Special considerations	Data security, integrity and reliability.
Amount of data	Very nominal payload.
Transmission interval	Performance criteria.
Transmission technologies	VHF, satellite, WiFi, WGL, GSM. The protocols are typically ACARS, SatCom and IP based.

4.19 Information for R&D

Description	Collect, analyse and store (tamper-proof collection of flight data) aircraft data.
Scenario	The pertinent data from the aircraft can be obtained for analysis to R&D purposes.
User groups	• OEMs; • Safety boards; • Civil aviation authorities (CAAs), FAAs, EASA; • Maintenance/MRO.
Benefit	• Better practices, systems optimization through data analysis and data mining.
Required data	• All fuel-related data, APU-related data, engines-related data – fuel consumption, OOOI times, flight controls, slat/flap data, etc.
Data sources	• Any data from the aircraft.
Special considerations	Data security, integrity and reliability.
Amount of data	Nominal payload.
Transmission interval	Post flight.
Transmission technologies	VHF, satellite, WiFi, WGL, GSM. The protocols are typically ACARS, SatCom and IP based.

4.20 Information for regulatory purposes

Description	Collect, analyse and store (tamper-proof collection of flight data) systems-related aircraft data.
Scenario	The pertinent data from the aircraft can be obtained for analysis for regulatory reporting purposes.
User groups	• CAA, FAA, EASA; • Crew training; • Maintenance/MRO.
Benefit	• Improved flight operations; • High reliability for A/C dispatch; • Accurate aircraft information for mandatory reporting to regulatory authorities.
Required data	• All fuel-related data, APU-related data, engines-related data – fuel consumption, OOOI times, slat/flap data, etc.
Data sources	• QAR; • DFDR.
Special considerations	Data security, integrity and reliability.
Amount of data	Very nominal payload.
Transmission interval	Post-flight.
Transmission technologies	VHF, satellite, WiFi, WGL, GSM. The protocols are typically ACARS, SatCom and IP based.

4.21 Mission support

Description	In-flight support for the flight crew from ground. The mission support team is usually part of the flight operations centre. They assist by tracking the flight, monitoring bad weather areas, awareness of special airport information, etc. With flight data being available in real time, the mission support team can know the technical status of the aircraft. Technical problems can be detected early and support from ground will be available. The members of the mission support team itself are typically not technical experts. The analysis will be done by the trouble-shooting team from the maintenance department.
Scenario	A flight is being monitored from the mission support team. An in-flight engine shutdown occurs. This is automatically reported to the ground system, together with monitoring and flight data. The incident is being reported to trouble-shooting for technical analysis and the mission support team evaluates diversion airports, fuel quantity, etc.
User groups	• AOC/central dispatch.
Benefit	• Real-time awareness of aircraft situation; • Quick reaction times; • Information on aircraft and flight status without pilot communication.
Required data	• Flight data, monitoring data.
Data sources	• FDR/QAR; • ACMS/CMC system; • Systems for passenger/crew or cargo monitoring.
Special considerations	Data security, integrity and reliability.

Amount of data	Depends on attached systems. If the flight data from the FDR/QAR are streamed, it is about 50 MB per long-range flight. Custom systems for cargo or passenger/crew monitoring might require even more data to be transmitted.
Transmission interval	Continuous streaming.
Transmission technologies	Depends on the aircraft model and used system. Basically it can be anything: VHF, satellite, WiFi, WGL, and GSM.

4.22 Abnormal movement of passengers and crew

Description	State-of-the-art research works on aircraft systems that monitor the cabin areas. Abnormal movement, such as fights, groups, running people, etc., can be detected by the system. A report and possibly a video clip will be downlinked to the ground for further analysis.
Scenario	During a flight, terrorists capture the flight. The terrorists carry weapons and overwhelm one or two flight attendants. The situation is being detected and a report is sent to the ground. The ground has an early notification of the situation and can continue to monitor the situation or assist the flight crew in their decisions.
User groups	• AOC/central dispatch.
Benefit	• Early notifications of assaults.
Required data	• Video data, audio data, pre-processed reports.
Data sources	• Custom video systems.
Special considerations	Video streaming of the aircraft is something new in aviation.
Amount of data	Unknown.
Transmission interval	None for no abnormal detection.
Transmission technologies	Satellite, cellular networks.

4.23 Flight planning

Description	Collect (tamper-proof collection of flight data), analyse and store the aircraft position and additional data such as altitude, speed and heading. This also includes the data while the aircraft is on the ground. Other data of interest are door open/close time, boarding time or catering, cleaning and fuelling times. All this data can be used to optimize the events on the ground and in the air. For instance, the passenger service routines can be updated or additional time on the ground can be foreseen to avoid delays based on experience on that route.
Scenario	The aircraft periodically transmits the own ship position to the ground. This happens without interaction of the crew. The ground system stores the data for later analysis. On demand or on continuous improvement programs, this data gets analysed to update the processes during flight for cabin and cockpit or the processes during pre-flight and post-flight.
User groups	• Airline: AOC/central dispatch/flight control.
Benefit	• Timely and instant availability of A/C situational awareness. • Real-time information of flight status.
Required data	• Minimum: Position, altitude. • Additional: Speed, heading.

Data sources	• ADS-B (traditional and via satellite) or Mode-S transceiver; • ADS-C; • FMC messages; • Controller-pilot data link communication (CPDLC)/automatic dependent surveillance (ADS); • ARINC 623 messaging (D-ATIS, OCL, DCL); • Airline operational communication (AOC) position reports; • Dedicated positioning system; • Flight data streaming/FOQA streaming. (Additional source, but not from A/C data: primary radar).
Special considerations	Access control to the data because it can reveal sensitive operational and economical details of the airlines. Security mechanisms to avoid and detect misuse of the system or false data injection.
Amount of data	Depends on interval and dataset. Flight tracking data is usually very small and can be sent through short burst data (SBD) messages.
Transmission interval	Performance criteria.
Transmission technologies	Technologies are available as of today. Current technologies have sufficient capabilities for tracking, sending alerts, and a few parameters.

4.24 Passenger and crew health monitoring

Description	The global system to prevent or mitigate the expansion of infectious diseases by means of real-time health status monitoring of those who move globally, and detecting symptoms of infectious diseases for the purpose of taking appropriate action as instructed by healthcare authorities as early as possible. This system can also be used for fatigue risk management (FRM) of crews by studying crew health parameters to optimize the duty times and to increase flight safety.
Scenario	For flights departing from an infected area, it is mandated for each passenger and crewmember to wear health status monitors (sensors) for body temperature, oxygen saturation rate, blood pressure, etc., for the entire flight duration. The collected health data are analysed during the transportation time to detect any person who might be infected and an appropriate action, such as seclusion, is taken as early as possible. The collected health data is also transferred to the health authority to double-check the possibility of the infectious disease. The health monitoring should be continued after the arrival of a person suspected of infection at their destination under the mandated healthcare regulations of the destination. The said person(s) will need to keep wearing the health status monitor provided at the departing location, since there might be infected people who have not yet developed symptoms of the disease during their transportation time. The monitoring could be continued by the administration of the transportation facility under the control of their healthcare regulator. The health status monitoring task is then transferred to the next transportation service provider under the control of the next healthcare regulator for those who proceed to another international transportation service, and to a local telecom service operator under the control of the healthcare regulator of the country/area of arrival for those who stay there. With the mandate to continue wearing the health status monitor provided at in-flight precautionary continuous monitoring, the monitoring is accomplished with the assistance of a mobile telecom operator until the risk of infection is cleared.
User groups	• Healthcare authorities; • Airline carrier; • Airport administrators.
Benefit	Detecting symptoms of infectious diseases as early as possible for the purpose of taking appropriate action as instructed by healthcare authorities and contribute to prevent or mitigate the expansion of infectious diseases.

Required data	• Details to be decided by the instructions of the World Health Organization (WHO) depending on the targeted infectious disease. • Reports from flight crews on situations and activities in the aircraft, such as medical reports through ACARS.
Data sources	• Wearable health status monitor (sensors); • In-seat sensors; • AOC messages.
Special considerations	The framework is studied at Q28/16 as F.MCDC [1], and close collaboration of related organizations such as WHO and civil aviation industries is expected.
Amount of data	Depending on the targeted infectious disease but expected not to be large.
Transmission interval	To be decided by the instructions of WHO depending on the targeted infectious disease.
Transmission technologies	Short-range wireless communications such as body area network (BAN) to collect health data from monitoring devices. VHF, satellite, WiFi, WGL, GSM to transfer the collected health data to healthcare authorities on the ground for analysis and appropriate action.

4.25 Entertainment based on flight data

Video games, especially flight simulators, can use real flight data, including the exact trajectory, to simulate other traffic in the game or to re-enact real technical problems.

This use case is not further developed in this document.

4.26 Medical and health management on air travel

Description	Collection and analysis of air travel activities for medical studies. For example, study the impact on the crew and passengers of cabin humidity, noise levels, etc., in the cabin and also noise and emission pollution on the ground due to air travel.
Scenario	The data on the aircraft gets collected and transmitted to the ground systems for analysis. Depending on the sensors available on the aircraft model, different parameters will be available. Airlines and medical research groups process and evaluate the data.
User groups	• Medical researchers; • Airlines; • Regulatory authorities; • Airports.
Benefit	• Improving the working and living conditions.
Required data	• Traditional flight data (position, altitude, speed, thrust settings, etc.). • Cabin sensors (humidity, temperature, noise).
Data sources	• FDR; • Cabin environmental systems. Additional sources: primary radar and ground sensor stations.
Special considerations	None.
Amount of data	Depends on the available sensors.
Transmission interval	Post-flight transmission.

Transmission technologies	Not applicable because of post-flight transmission.

4.27 Anti-terrorism and national security

Flight data and any data transmitted to and from an aircraft could be of interest for anti-terrorism and national security organizations. Their focus is not only on situation awareness but also on training and counter-measure development.

This use case is not further developed in this document.

4.28 Military purposes

The military may also have interest in in-flight aircraft data for instantaneous situation awareness, as well as strategic and tactical planning.

This use case is not further developed in this document.

5 Key findings

Working Group 2 has identified 28 use cases that utilize data aggregated from an aircraft and transmitted wirelessly in-flight to the ground for further processing and correlation.

The use cases can be categorized into two groups.

The first group contains those use cases that require that data be transmitted virtually in real time; this means that data has to be transmitted during the flight and as quickly as possible after it has been generated. Examples for this category are flight tracking/following, search and rescue operations or mission support with in-flight aircraft condition monitoring.

The second category deals with use cases that do not require a real-time transmission of data and where post-flight availability is sufficient. Two out of many examples are: approach statistics and predictive maintenance. In this category, the potential for innovation is limited. The use cases already exist in the aviation industry, by using post-flight downloads of the data. On some aircraft, the data is downloaded to rewritable compact discs (CDs) or universal serial bus (USB) sticks. Other aircraft use cellular network data streaming on the ground. However, if a central data repository is being developed, because of the real-time use cases, then also the post-flight use cases can benefit from the repository. The airlines and MROs can use and process the data more efficiently, compared to today's many individual companies and manufacturers specific solutions. In addition, new applications might evolve if auto-correlation and automatic pattern recognition algorithms are applied to the collection of all data available from an aircraft and reveal previously unseen information.

6 Recommendations

FG AC Working Group 2 recommends:

- Regulatory authorities to mandate real-time flight data streaming. The requirements for the airlines should be identical worldwide to provide the same service levels in all airlines. Without a unified approach, the implementations can vary significantly and the advantages of real-time flight data might not be achieved for all airlines.

- Regulatory authorities shall establish the appropriate detailed definition of real-time FDM in terms of data types and data volume (parameters and recording intervals).
- Once the required datasets are defined, then streaming technologies described in Deliverable 4 can be selected and applied to the flight data for optimum use.
- Airlines, operators, MROs, OEMs, etc., shall continuously be involved in due course , so that they also understand what ITU/ICAO are doing in that regard and what is coming their way.
- The list of use cases should be enhanced to meet the future requirements of stakeholders.

7 Conclusion

The deliverable of Working Group 2 describes use cases that make use of in-flight transmission of flight data. Known data sources that currently transmit or might transmit in the near future from an aircraft have been described. Most important is the data of the digital flight data recorder, also known as black-box. In addition, other data, such as aircraft condition monitoring system reports, often sent via VHF datalink is of high interest. Future systems can include video streaming for surveillance and analysis or health sensor data for health monitoring.

Twenty-eight use cases have been identified for the aviation cloud. These use cases are categorized in two groups: real-time data streaming, and on-demand or post-flight data collection.

The real-time aspect is a new quality that has never been available for ground flight data processing. It is an enabler for new techniques and processes in aviation. The use cases of this category contain high potential for innovation. Real-time processing of flight data will increase flight safety, dispatch reliability, efficiency and on-time performance. The processes, algorithms and IT-systems for real-time flight data monitoring are currently not available and need to be developed.

8 Acronyms and abbreviations

This document uses the following acronyms and abbreviations:

2G	Second Generation mobile network
3G	Third Generation mobile network
4G	Fourth Generation mobile network
4MCU	Air data Inertial Reference Unit
AC	Alternating Current
A/C	Aircraft
ACARS	Aircraft Communications Addressing and Reporting System
ACMF	Airplane Condition Monitoring Function
ACMS	Aircraft Condition Monitoring System
ADAS	Aviation Data Acquisition System
ADC	Air Data Computer
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance-Broadcast
ADS-C	Automatic Dependent Surveillance-Contract
AFCS	Automatic Flight Control System
AIDS	Aircraft Integrated Data System
AIMS	Airplane Information Management System
ANS	Automated celestial Navigational System
AOC	Airline Operational Communication
APU	Auxiliary Power Unit
ASCII	American Standard Code for Information Interchange
ATC	Air Traffic Control
ATM	Air Traffic Management
ATTF	Aircraft Tracking Task Force
BAN	Body Area Network
BITE	Built-In Test Equipment
CAA	Civil Aviation Authority
CASA	Civil Aviation Safety Authority
CD	Compact Disc
CDTI	Cockpit Display of Traffic Information
CDU	Control Display Unit

CG	Centre of Gravity
CMC	Central Maintenance Computer
CMU	Communications Management Unit
CPDLC	Controller-Pilot Data Link Communication
CPU	Central Processor Unit
CVR	Cockpit Voice Recorder
D-ATIS	Digital Automatic terminal Information Service
DAR	Digital ACMS Recorder
DC	Direct Current
DCL	Data Link Clearance
DFDR	Digital Flight Data Recorder
DME	Distance Measuring Equipment
DMP	Data Management Processor
EASA	European Aviation Safety Agency
EFIS	Electronic Flight Instrument System
ETA	Estimated Time of Arrival
eTLB	Electronic Technical Logbook
FAA	Federal Aviation Administration
FDA	Flight Data Analysis
FDE	Fault Detection and Exclusion
FDEP	Flight Data Entry Panel
FDM	Flight Data Monitoring
FDR	Flight Data Recorder
FIDS	Flight Information Display System
FMC	Flight Management Computer
FMS	Flight Management System
FOQA	Flight Operational Quality Assurance
FRM	Fatigue Risk Management
GADSS	Global Aeronautical Distress and Safety System
GDRAS	Ground Data Replay and Analysis System
GPS	Global Positioning System
GSM	Global System for Mobile communications
IATA	International Air Transport Association

ICAO	International Civil Aviation Organization
IDU	Interactive Display Unit
IFR	Instrument Flight Rules
INS	Inertial Navigation System
IP	Internet Protocol
IT	Information Technology
MCDU	Multipurpose Control Display Unit
MLS	Microwave Landing System
MRO	Maintenance, Repair and Operations
NFC	Near Field Communication
OCL	Oceanic Clearances
OEM	Original Equipment Manufacturer
OOOI	Out, Off, On, In
PC	Personal Computer
PCMCIA	Personal Computer Memory Card International Association
PDME	Precision Distance Measuring Equipment
Q	Question
QAR	Quick Access Recorder
R&D	Research and Development
RFID	Radio Frequency Identification
SatCom	Satellite Communication
SBD	Short Burst Data
STC	Supplemental Type Certificate
T-PED	Transmitting Portable Electronic Device
USB	Universal Serial Bus
VFR	Visual Flight Rules
VHF	Very High Frequency
VNAV	Vertical Navigation
WGL	Wireless Groundlink
WHO	World Health Organization
WiFi	Wireless Fidelity

9 References

[1] F.MCDC: Framework for in-flight and post-flight precautionary continuous monitoring for communicable disease control, ITU-T Study Group 16 (Under Study)

[2] Annex 6 to the Convention on International Civil Aviation.

[3] Annex 9 to the Convention on International Civil Aviation.

10 Acknowledgements

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Appendix A

Mandatory operational parameters for DFDR

(1) Time;

(2) Pressure altitude;

(3) Indicated airspeed;

(4) Heading-primary flight crew reference (if selectable, record discrete, true or magnetic);

(5) Normal acceleration (vertical);

(6) Pitch attitude;

(7) Roll attitude;

(8) Manual radio transmitter keying, or CVR/DFDR synchronization reference;

(9) Thrust/power of each engine-primary flight crew reference;

(10) Autopilot engagement status;

(11) Longitudinal acceleration;

(12) Pitch control input;

(13) Lateral control input;

(14) Rudder pedal input;

(15) Primary pitch control surface position;

(16) Primary lateral control surface position;

(17) Primary yaw control surface position;

(18) Lateral acceleration;

(19) Pitch trim surface position or parameters of paragraph (h) (82) of this section if currently recorded;

(20) Trailing edge flap or cockpit flap control selection (except when parameters of paragraph (h) (85) of this section apply);

(21) Leading edge flap or cockpit flap control selection (except when parameters of paragraph (h) (86) of this section apply);

(22) Each thrust reverser position (or equivalent for propeller airplane);

(23) Ground spoiler position or speed brake selection (except when parameters of paragraph (h) (87) of this section apply);

(24) Outside or total air temperature;

(25) Automatic flight control system (AFCS) modes and engagement status, including autothrottle;

(26) Radio altitude (when an information source is installed);

(27) Localizer deviation, microwave landing system (MLS) Azimuth;

(28) Glideslope deviation, MLS elevation;

(29) Marker beacon passage;

(30) Master warning;

(31) Air/ground sensor (primary airplane system reference nose or main gear);

(32) Angle of attack (when information source is installed);

(33) Hydraulic pressure low (each system);

(34) Ground speed (when an information source is installed);

(35) Ground proximity warning system;

(36) Landing gear position or landing gear cockpit control selection;

(37) Drift angle (when an information source is installed);

(38) Wind speed and direction (when an information source is installed);

(39) Latitude and longitude (when an information source is installed);

(40) Stick shaker/pusher (when an information source is installed);

(41) Wind shear (when an information source is installed);

(42) Throttle/power lever position;

(43) Additional engine parameters (as designated in appendix F of this part);

(44) Traffic alert and collision avoidance system;

(45) DME 1 and 2 distances;

(46) Navigation 1 and 2 selected frequency;

(47) Selected barometric setting (when an information source is installed);

(48) Selected altitude (when an information source is installed);

(49) Selected speed (when an information source is installed);

(50) Selected mach (when an information source is installed);

(51) Selected vertical speed (when an information source is installed);

(52) Selected heading (when an information source is installed);

(53) Selected flight path (when an information source is installed);

(54) Selected decision height (when an information source is installed);

(55) Electronic flight instrument system (EFIS) display format;

(56) Multi-function/engine/alerts display format;

(57) Thrust command (when an information source is installed);

(58) Thrust target (when an information source is installed);

(59) Fuel quantity in (the centre of gravity(CG)) trim tank (when an information source is installed);

(60) Primary navigation system reference;

(61) Icing (when an information source is installed);

(62) Engine warning each engine vibration (when an information source is installed);

(63) Engine warning each engine over temperature (when an information source is installed);

(64) Engine warning each engine oil pressure low (when an information source is installed);

(65) Engine warning each engine over speed (when an information source is installed;

(66) Yaw trim surface position;

(67) Roll trim surface position;

(68) Brake pressure (selected system);

(69) Brake pedal application (left and right);

(70) Yaw or sideslip angle (when an information source is installed);

(71) Engine bleed valve position (when an information source is installed);

(72) De-icing or anti-icing system selection (when an information source is installed);

(73) Computed centre of gravity (when an information source is installed);

(74) Alternating current (AC) electrical bus status;

(75) Direct current (DC) electrical bus status;

(76) APU bleed valve position (when an information source is installed);

(77) Hydraulic pressure (each system);

(78) Loss of cabin pressure;

(79) Computer failure;

(80) Heads-up display (when an information source is installed);

(81) Para-visual display (when an information source is installed);

(82) Cockpit trim control input position-pitch;

(83) Cockpit trim control input position-roll;

(84) Cockpit trim control input position-yaw;

(85) Trailing edge flap and cockpit flap control position;

(86) Leading edge flap and cockpit flap control position;

(87) Ground spoiler position and speed brake selection; and

(88) All cockpit flight control input forces (control wheel, control column, rudder pedal).

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