A11L.UAS.101 – A55 Identify Flight Recorder Requirements for Unmanned Aircraft Systems (UAS) Integration into the National Airspace System (NAS)

Literature Review

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16. Abstract

Flight Data Recorders (FDRs) and Cockpit Voice Recorders (CVRs) have a long history within manned aviation. These systems have significantly contributed to safety by providing accurate and timely information to accident investigators to help understand what occurred. More recently, the industry has incorporated FDRs into voluntary safety programs and safety management systems. Although FDRs and CVRs have been well established within the manned aviation industry, their use with unmanned aircraft is still relatively new. The uniqueness and diversity of unmanned platforms also demonstrate that the requirements of FDRs and CVRs will be different than that of the manned requirements. Many Unmanned Aircraft Systems (UASs) can transmit real-time flight telemetry data from the platform to a Ground Control Station (GCS). This flight data is retrieved after a flight, much like a traditional FDR. Several federal regulations govern the use of FDRs and CVRs with manned aircraft. Even though the ultimate requirements for an unmanned FDR will likely be different from their manned counterparts, these regulations represent a good starting point to help build and design unmanned FDR and CVR requirements. The Federal Code also governs the requirements, standards, and use of recording devices. The international community has also recognized the value of FDRs and CVRs. The International Civil Aviation Organization (ICAO) has published several annexes that address recording standards. Similarly, the European Organization for Civil Aviation Equipment (EUROCAE) has issued several requirements and standards documents regarding these recording devices. Industry groups and private companies, including the American Society for Testing and Materials (ASTM), Radio Technical Commission for Aeronautics (RTCA), and Aeronautical Radio Inc. (ARINC), have also published and maintained recording standards. The Federal Aviation Administration (FAA) released guidance for FDRs and CVRs through the release of Technical Standard Orders (TSOs) and Advisory Circulars (ACs). Several regulators have issued requirements for the survivability of FDRs and CVRs in an aircraft accident. Researchers can utilize several different structural testing techniques to determine how these recording devices survive intact under impact force, fire, or underwater conditions. Modeling, or non-destructive techniques, can likely be used to verify the survivability of these devices when they are mounted on a UAS and experience these crash conditions. In some cases, destructive techniques will have to be utilized to determine post-accident survival, especially with fire and underwater conditions. Several examples of the types of data and parameters could be included in a requirements document for unmanned FDRs and CVRs. By examining contemporary telemetry streams of UASs, one can assess requirements germane to the unmanned operational environment. By analyzing all the above literature, there is little doubt that unmanned FDRs and CVRs can play a pivotable role in safety, similar to what is seen with the manned industry.

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AC	Advisory Circulars
ADRS	Aircraft Data Recording Systems
ADS-B	Automatic Dependent Surveillance-Broadcast
ARINC	Aeronautical Radio Inc
ATS	Air Traffic Services
ASTM	American Society for Testing and Materials
BAU	Deployable Beacon Airfoil Unit
CARS	Cockpit Audio Recording Systems
CVR	Cockpit Voice Recorder
CFR	Code of Federal Regulations
C2	Command and Control
COTS	Commercial Off-the-Shelf
DFDR	Digital Flight Data Recorder
EUROCAE	European Organization for Civil Aviation Equipment
FAA	Federal Aviation Administration
FDR	Flight Data Recorder
GCS	Ground Control Station
GOTS	Government Off-the-Shelf
IFR	Instrument Flight Rules
ICAO	International Civil Aviation Organization
ISR	Intelligence, Search and Rescue
LOS	Line of Sight
MHz	Megahertz
MOPS	Minimum Operational Performance Specifications
NAS	National Airspace System
NTSB	National Transport Safety Board
PANS	Procedures for Air Navigation Services
RF	Radio Frequency
RTCA	Radio Technical Commission for Aeronautics
RCC	Rescue Coordination Centre
SAR	Search and Rescue
SARP	Standards and Recommended Practices
TSO	Technical Standard Order
UHF	Ultrahigh Frequency
UAV	Unmanned Aerial Vehicle
UA	Unmanned Aircraft
UAS	Unmanned Aircraft Systems
USC	United States Code
VHF	Very High Frequency
VFR	Visual Flight Rules

EXECUTIVE SUMMARY

Flight Data Recorders (FDRs) and Cockpit Voice Recorders (CVRs) have a long history within manned aviation. These systems have significantly contributed to safety by providing accurate and timely information to accident investigators to help understand what occurred. More recently, the industry has incorporated FDRs into voluntary safety programs and safety management systems.

Although FDRs and CVRs have been well established within the manned aviation industry, their use with unmanned aircraft is still relatively new. The uniqueness and diversity of unmanned platforms also demonstrate that the requirements of FDRs and CVRs will be different than that of the manned requirements. Many Unmanned Aircraft Systems (UASs) can transmit real-time flight telemetry data from the platform to a Ground Control Station (GCS). This flight data is retrieved after a flight, much like a traditional FDR. Several federal regulations govern the use of FDRs and CVRs with manned aircraft. Even though the ultimate requirements for an unmanned FDR will likely be different from their manned counterparts, these regulations represent a good starting point to help build and design unmanned FDR and CVR requirements.

After an extensive review of the available literature, including Federal, international, and industry sources, the research team is confident in the current research plan and recommends no changes. The one area for which there might be some limiting factors is with the destructive testing techniques. Due to the expense of such testing, the team may have to rely upon calculation and estimation where non-destructive testing is not available or appropriate. This is not anticipated to change the cost or timeline of the project.

This literature review confirms the importance of FDRs and CVRs to unmanned operations. The improvements in safety from having requirements for these devices are expected to follow the same improvements seen in the manned industry. Without the development of these requirements, the unmanned industry's integration into the National Airspace System (NAS) will likely be slower than needed.

1 INTRODUCTION

1.1 Background

Flight Data Recorders (FDRs) are devices that store flight information made by an aircraft or airborne platform while in flight which can later be recalled and reviewed. In the case of an aircraft accident, FDRs are essential to help investigators determine the underlying causes. There are other important uses for flight data stored on FDRs, including use for proactive and predictive hazard identification.

What constitutes flight data? Flight data at its most basic level includes information about altitude, airspeed, and heading. However, most aircraft have the capability to record many more parameters at increased refresh rates and fidelity. Contemporary FDRs can store massive amounts of data, with the most modern commercial jets able to store terabytes of data for each flight.

Although FDRs are widely used across the manned aviation industry, their use with unmanned systems has not yet achieved widespread adoption. Additionally, there are no regulatory standards yet published or approved for unmanned FDRs.

1.2 History

The concept of using FDRs can be traced back to the 1950s where a few aircraft around the world were equipped with analog recorders which used mechanical recording means and photography [1]. Modern generation flight recorders have greatly improved and in some cases can record and store over 3,000 parameters [2].

Development of FDRs occurred in four generations [3]. The first generation used analog recorders during the 1950s. The second generation, occurring in the 1960s, used wire recorders with more capabilities. The third generation used tape media and lasted from the early 1970s to the mid-1980s. The fourth and current generation started with the Airbus A320 and includes the now standard solid-state capabilities.

1.3 Purpose/Significance

Originally, FDRs were used almost exclusively for accident investigation and recreation. The safety theory behind accident investigation revolves around the concept that if an accident occurs, there were likely accident precursors that were either undetected or incorrectly assessed. After an investigatory process is completed, the hope is any precursors could be identified and then shared with others with the intent of not repeating previous accidents. Although necessary, this process is completely reactionary, and the manned industry has evolved to using these recorders in more proactive and predictive situations

Walker [3] explains, “Instead of a post hoc accident analysis tool, something that needs an accident as a ‘lagging indicator’ of future risks, black boxes can be used as a predictive safety assurance tool, a supplier of ‘big data’ from which leading indicators of strategic risks can be derived in novel ways (page 14).”

This study will seek to establish minimum standards for unmanned FDRs. Because the development and deployment of manned FDRs is very robust and industry-permeating, the natural starting point for a thorough examination of unmanned standards will start on this manned side.

However, it is very clear from the onset of this project that standards for manned FDRs can diverge for those of unmanned operations. Accordingly, an independent analysis of needed standards on the unmanned side will not make any assumptions or necessarily attempt to construct parallels between the two sides.

Even though the primary focus will be on accident investigation and other safety reactive measures, the ability to use unmanned flight data within contemporary Safety Management Systems, like Flight Operations Quality Assurance or Flight Data Monitoring, will also be considered.

2 DESIGN AND OPERATION STANDARDS

2.1 Current Manned Aircraft

Design standards are detailed in the applicable aircraft certification regulations, including 14 Code of Federal Regulations (CFR) 23 (Part 23) and 25 (Part 25). Part 23 covers normal category aircraft while Part 25 describes the standards for transport category aircraft. Typically, Part 23 aircraft are for smaller and lighter aircraft, like those used in general aviation; while Part 25 aircraft include commercial air carrier aircraft. Both parts describe the required for flight performance, flight characteristics, aircraft structures, design and construction, powerplants, and other aircraft systems.

2.2 Unmanned Aircraft

An Unmanned Aircraft System (UAS), or Unmanned Aerial Vehicle (UAV), is an aircraft that operates without an onboard pilot but is either controlled autonomously or manually by an operator on ground using a remote controller. This is achieved by several elements or systems both onboard the aircraft (airborne) and ground based (Command and Control(C2)/telemetry).

2.2.1 Airborne

A large percentage of UAS's components are airborne. A typical UAS consists of the following basic elements:

2.2.1.1 The Airframe

This can range from materials like foam (polystyrene or Styrofoam), to composites like carbon fiber and carbon glass depending on the mission of the UAS. Generally, foam materials are used for light duty aircraft and short hour flights while composite materials are used for heavy duty and longer flights.

2.2.1.2 The Propulsion System

The system gives the forward movement to UASs (fixed wings), it can range from the simple electric brushless motors and propellers (form small UASs) to gas powered engines for larger UASs. The propulsion system to be used for any UAS depends on the operations to be performed by the UAS.

2.2.1.3 Avionics System

The word Avionics is derived from "aviation" and "electronics". Avionics generally refers to all electronic components onboard an aircraft (UAS) except for the power distribution system. The avionics system of an aircraft is sometimes referred to as the brain power of the system, as literally every output of the aircraft is as a result of the operation of one or several parts of the avionic systems. The avionic setup for an autonomous aircraft is quite different from a manual one. Autonomous aircraft make use of autopilot systems for operation which can either be Commercial-Off-The-Shelf (COTS) such as Pixhawk, Micropilot, etc., or Government-Off-The-Shelf (GOTS) autopilot system for larger UAVs, along with other avionics components like actuators (e.g., servos), signal cables, receiver, electronic speed controller, etc.

2.2.1.4 Detect and Avoid Technology

This is any form of device or technology that works out obstacle avoidance in an unmanned aircraft. This is an assistive device for small UAS operators to avoid collision with fixed or moving obstacles in its path. But this is a must-have component if UASs are to be integrated into the manned airspace to fulfil the "well-clear" criteria of aircraft operating in such airspace. Some of the currently available technologies for this are Automatic Dependent Surveillance-Broadcast (ADS-B) technology, airborne radars, etc.

2.2.1.5 Launch and Recovery System

This has to do with the system of launching and recovering the UAS which may be on ground as in catapult launch, bungee etc., which remains on ground and the aircraft on recovery lands on its belly or the use of wheels that goes airborne with the UAS and is recovered with the wheels also. Larger UASs make use of wheels for launch and recovery, while smaller aircraft use other means.

2.2.1.6 Payload

This is any component, device or system integrated into an unmanned aircraft to carry out specifically the mission of the UAS, this could be cameras (for Intelligent, Surveillance and Reconnaissance (ISR), survey, data capture, etc.), actuators with attached materials (for UAS delivery, etc.). The payloads in themselves don't contribute to the flight of an unmanned aircraft, but they give purpose and meaning to unmanned aircraft. It helps perform the mission of the aircraft. The type of payload to be integrated still largely depends on aircraft mission.

2.2.2 Ground-Based (C^2/Telemetry)

This has to do with all UAS C2 operations that take place on the ground. These operations are carried out from the Ground Control Station (GCS). The GCS consists of a set of hardware and software ground-based equipment that enables UAS crew to communicate, command and control the UAS directly or through some preset parameters for autonomous flights. The GCS can range from a small handheld remote controller with integrated screen, laptop computers to large 5-10 UAS crew members workspace (portable or fixed GCS). A good GCS is designed to be ergonomic which contributes immensely to the smooth operation of an unmanned aircraft and consequently reduces crash probability.

C2 has to do with the communication link between the UAS and the crew on ground (GCS) to the end that control and overall management of the aircraft is guaranteed and effected. The C2 links to be established depends on the range of aircraft (UAS) operations.

For Line of Sight (LOS) Drones, Radio Frequency links (RF links) such as Very High Frequency (VHF) or Ultrahigh Frequency (UHF) are used. But for very short ranges, say, 1km or less, Wi-Fi is typically used. Beyond Line of Sight drones, which are often bigger drones with ISR capabilities (like military drones), use some sort of Satellite Communication such as iridium. Protected spectrum can also be used for high altitude, sensitive operations. Protected Spectrum is a part of RF spectrum that deals with critical application C2 links.

3 FLIGHT AND VOICE RECORDER STANDARDS

Different institutions define different standards for flight and voice recorders. Therefore, standards of the US, the International Civil Aviation Organization (ICAO) and the European Organization for Civil Aviation Equipment (EUROCAE) are summarized and evaluated. The gaps between manned and unmanned flight recorders are also taken into consideration.

3.1 United States Regulations

3.1.1 14 CFR 23

This document describes the Cockpit Voice Recorder (CVR), and FDR required standards and installation method for Normal Category Airplanes. The required standards CVR and FDR for Normal Category Airplanes can be found in the second column of Tables 1 and 2 respectively.

3.1.2 14 CFR 25

This document describes the CVR, and FDR required standards and installation method for Transport Category Airplanes. The required standards CVR and FDR for Transport Category Airplanes can be found in the third column of Tables 1 and 2 respectively.

3.1.3 14 CFR 27

This document describes the CVR, and FDR required standards and installation method for Normal Category Rotorcraft. The required standards CVR and FDR for Normal Category Rotorcraft can be found in the fourth column of Tables 1 and 2 respectively.

3.1.4 14 CFR 29

This document describes the CVR, and FDR required standards and installation method for Transport Category Rotorcrafts. The required standards CVR and FDR for Transport Category Rotorcrafts can be found in the fifth column of Tables 1 and 2 respectively.

Table 1. Airworthiness Standards for Cockpit Voice Recorders. **AIRWORTHINESS STANDARDS**

COCKPIT VOICE RECORDER				
STANDARDS	**Normal Category Airplanes** [4]	**Transport Category Airplanes** [5]	**Normal category Rotorcraft** [6]	**Transport Category Rotorcraft** [7]
All installed cockpit recorder must record all voice communication in the airplane by radio, on flight deck by flight crewmembers, on airplane's interphone system, audio signal	YES	YES	YES	YES

navigation or approach aids, passenger loudspeaker by flight crew members and all datalink communication (if installed)				
Cockpit -mounted area microphone must be positioned to cover ALL communications in the flight deck, with intelligible recording under flight cockpit noise conditions	YES	YES	YES	YES
Each Cockpit recorder must record all communications (even sidetones) without interruption, on separate channels • First Channel for first pilot station • Second Channel for Second pilot station • Third Channel for cockpit mounted area microphone. Fourth Channel for all communication devices from third and fourth crew member station.	YES	YES	YES	YES
All cockpit voice recorder must have: • Reliable electrical power • Always powered • Prevent all erasure feature by stopping the recorder automatically within 10 minutes after a crash. • Preflight check of recorder's proper operation through visual or aural means. • Independent power source • Unaffected by external electrical failure. In a separate container always or a combination unit when used with a flight data recorder (Provided all necessary requirements for both recorders are met).	YES	YES	YES	YES
Recorder container must be installed such that container rupturing and heat damage to the recorder is minimized.	YES	YES	YES	YES
Cockpit voice recorder with bulk erasure device must be installed such that inadvertent operation and device actuation is minimized during crash impact.	YES	YES	YES	YES
Each recorder container must be bright orange or yellow, have reflective external surface to facilitate under water location and	YES	YES	YES	YES

have underwater locating device on or inseparably adjacent to it in a crash.				

Table 2. Airworthiness Standards for Flight Data Recorders.

AIRWORTHINESS STANDARDS				
FLIGHT DATA RECORDER				
STANDARDS	**Normal Category Airplanes** [4]	**Transport Category Airplanes** [5]	**Normal category Rotorcraft** [6]	**Transport Category Rotorcraft** [7]
Each Flight Recorder must: • Be Supplied with airspeed, altitude and directional data from sources that meet the requirements and functionality of aircraft system level • Vertical acceleration sensor is rigidly attached and located longitudinally within the approved center of gravity limits of the aircraft or rotorcraft. • Receive electrical power from the most reliable bus and remain powered for as long as possible without jeopardizing emergency operation of aircraft or rotorcraft. • Have aural of visual preflight checks of recorder for proper recording of storage medium data. • Be unaffected by electrical failure external to the recorder. • In a separate container always or a combination unit when used with a cockpit voice recorder (Provided all necessary requirements for both recorders are met). Prevent all erasure feature by stopping the recorder automatically within 10 minutes after a crash.	YES	YES	YES	YES
Each non-ejectable record container is installed locations where container eruption probability from crash impact and subsequent damage to the record from fire is minimized.	YES	YES	YES	YES

Flight recorders reading of airspeed, altitude and heading must correlate with the first pilot corresponding reading, covering the aircraft's operational range of airspeed, altitude and 360 degrees of heading.	YES	YES	YES	YES
Each recorder container must be bright orange or yellow, have reflective external surface to facilitate under water location and have underwater locating device on or inseparably adjacent to it in a crash.	YES	YES	YES	YES
Recorder container must be installed such that container rupturing and heat damage to the recorder is minimized.	YES	YES	YES	YES
Evaluation of all novels, unique or operational characteristics of aircraft for possible modification of flight recorders dedicated parameters.	YES	YES	YES	YES

3.1.5 14 CFR 91

This CFR highlights the general operating and flight rules of cockpit voice recorder and FDR as it relates to aircraft and rotorcraft, and states:

No holder of an air carrier operating certificate, operating certificate, or an operator other than the holder of an air carrier or commercial operator certificate may conduct any operation with an aircraft except under the following circumstances:

- Transport an aircraft with faulty FDR or CVR only to a place where repair of it is to be made.
- Continue a flight as planned, if the FDR and CVR becomes inoperative after aircraft has taken off.
- Conduct airworthiness test for which FDR or CVR is turned off to test it or other communication equipment.
- Ferry newly acquire aircraft from the place of possession to a place where FDR and CVR would be installed.
- Operate an aircraft for more than 15 days while the FDR and CVR is removed for repair with a maintenance record of failure date and a placard in view of pilot to show how that the recorder(s) is faulty and for an additional 15 days (for longer repair time) as authorized by a certificated person with maintenance records of additional repair time.
- Flight recorders must be in continuous operation from take-off to landing.
- In the event of an accident, all records of FDR and CVR must be kept for 60 days
- All aircraft manufactured after April 7, 2010, must meet the requirements for FDR and CVR as stated in the table above.

All other rules for general operating and flight rules of CVR and FDR for aircraft and rotorcraft can be found here [8] which may not relate to UAVs.

3.1.6 14 CFR 121

3.1.6.1 Cockpit Voice Recorder (CVR)

- No certificate holder should operate pressurized large aircraft without an approved CVR installed.
- In the event of an accident requiring immediate notification of the National Transport Safety Board (NTSB) all recording of CVR must be kept for at least 60 days or longer, if required.
- All CVR from April 7, 2012, should retain at least 2 hours of recorded information using a standard recorder
- All other CVR requirements must be followed as stated in the CVR table above.

Other requirements for cockpit voice recorder under instrument and equipment requirements can be found [9] which may not be relevant to UAVs.

3.1.6.2 Flight Data Recorder

- No person may operate above 25,000ft any large aircraft (multi-engine or turbine powered) certificated before October 1, 1969, after September 30, 1969, after October 11, 1991 (with digital bus and Aeronautical Radio Inc (ARINC) 717 Digital Flight Acquisition Unit) or manufactured after October 11, 1991, unless it is equipped with one or more flight recorders that uses a digital method of recording, storing and readily retrieving data from the storage medium. This must be recorded in the parameters, ranges, accuracies, and sampling intervals as specified by paragraphs (a), (b), (c) and (d) respectively under Flight Data Recorder section of [9]. All installed flight recorders must operate continuously from takeoff roll to landing roll at an airport.
- All recorded data of the installed FDR must be kept for at least 25 hours of the operating time before erasure, and for at least 60days (or longer if required) in the event of an accident that requires immediate notification of the National Transport Safety board.
- All requirements for FDR installation should be carried out as specified in Table 2.

3.1.6.3 Digital Flight Data Recorder

No person may operate any turbine-engine-powered transport category airplane unless it is equipped with one or more aproned flight recorder that utilizes a digital method of recording, storing and readily retrieving the data from a storage medium. The 91 operational parameters required to be recorded by the digital flight data recorder can be found in paragraph (a) under Digital Flight Data Recorder of [9] The parameters to be recorded largely depends on the manufacturing date of the turbine-engine transport category airplanes also, which can be found in paragraphs (a) through (f) of Digital Flight Data Recorder in [9], whose dates may not be relevant to UAVs.

All flight recorders installed in this section must operate continuously from the airplane’s take-off roll to its landing roll. All recorded data of the installed FDR must be kept for at least 25 hours of the operating time before erasure, and for at least 60 days (or longer if required) in the event of an accident that requires immediate notification of the NTSB.

All requirements for FDR installation should be carried out as specified in Table 2. All installed flight recorders must meet the requirements specified in the transport category airplane column of Table 2. Other Digital Flight Data Recorder requirements can be found in [9] which may not be relevant to UAVs.

3.1.6.4 Flight Data Recorder: Filtered Data

A flight data signal is said to be filtered if the original sensor signal is said to be changed in any way other than the changes necessary to achieve

I. Analog to digital conversion of the signal

II. Digital signal formatting to be Digital Flight Data Recorder (DFDR) compatible

III. Removal of high frequency component of a signal that is outside the operational bandwidth of the sensor.

A signal filtering is permitted only if it continues to meet the requirement of the ranges, accuracies and sampling intervals of the parameters measured else, the filtering must be removed or demonstrate and be approved by the Federal Aviation Administration (FAA) that the original signal can be reconstructed from the recorded data

All other requirements under this section can be found under Flight Data Recorder: Filtered Data in [9] which may have been summarized above or not relevant to UAVs.

3.1.7 14 CFR 125

This section describes the required parameters along with the range, accuracy (sensor input to DFDR readout), sampling interval (per second) and resolution readout of Air Carriers and Operators for Compensation or Hire: Certification and Operations for:

- Part 121 - Operating Requirements: Domestic, Flag, and Supplemental Operations [10]
- Certification and Operations: Airplanes Having a Seating Capacity of 20 or More Passengers or
- a Maximum Payload Capacity of 6,000 Pounds or More; and Rules Governing Persons on Board

Such Aircraft can be found in [11] Certification and Operations: Airplanes Having a Seating Capacity of 20 or More Passengers or a Maximum Payload Capacity of 6,000 Pounds or More; and Rules Governing Persons on Board Such Aircraft, which can be found in [12].

3.1.8 14 CFR 129 Operations

No person may pilot an aircraft under part 14 CFR 129 that is registered in the US unless it is equipped with approved cockpit flight recorders [13]. From the storage medium, flight data recorders use a digital method of recording and storing data [13]. If the aircraft were operating under Part 121, 125, or 135, then the flight data recorder must record the parameters for those parts along with being installed by the compliance times standards [13].

3.1.9 14 CFR 135

Any aircraft certificated after September 30, 1969, must record time, altitude, airspeed, vertical acceleration, heading, time of each radio transmission either to or from air traffic control, pitch attitude, roll attitude, longitudinal acceleration, pitch trim position, control column or pitch control surface position, control wheel or lateral control surface position, rudder pedal or yaw control surface position, thrust of each engine, position of each thrust reverser, trailing edge flap or cockpit flap control position, and leading edge flap or cockpit flap control position [14].

Aircraft built after October 11, 1991, when a flight recorder is installed, it must operate throughout the whole flight from the second the airplane begins the takeoff roll or rotorcraft begins the lift-off though the aircrafts landing roll or rotorcraft has landed at its destination. For recording keeping purposed of the data collected from the flight recorder, operators shall keep data for at least 25 hours and for airplanes until the airplane has been operating for a minimum of 25 hours or for rotorcraft there is a minimum of at least 10 hours, but no records need to be kept more than 60 days [14]. Only a total of 1 hour of the flight data or flight recorder system may be deleted for the purpose of testing and must be the oldest recorded data. If there is an accident or incident that involves the NTSB that resulted in termination of the flight, the flight data shall be removed from the aircraft for at least 60 days or longer if requested by the Board or Administrator [14].

Aircraft manufactured on or before August 18, 2000, each flight recorder must be installed in accordance with the requirements specifically outlined in this ruling [14]. The standards need to be established only on one aircraft of a group of aircraft if:

I. The aircraft are of the same type.
II. The flight recorder models, and their installation procedures are the same.
III. There are no differences in type of designs.

For aircraft manufactured after August 18, 2000, each flight data recorder must be installed in accordance with the requirements specifically outlined in this ruling. The values recorded by the flight data recorder and the designated values must be correlated. To view the recorded values a correlation must contain a sufficient number of correlation points to engineer full operating range [14]. The same standards need to be established at previously stated up above.

When the flight data recorder is submerged under water must have an approved and certified device to assist in locating the flight data recorder.

All aircraft newly manufactured on or after April 7, 2010, must have a flight data recorder installed that meets the requirements of these requirements along with retaining the 25 hours of recorded information.

3.1.10 14 CFR 830

Operators of aircraft involved in an accident or incident are responsible for preserving any and all wreckage from the aircraft including record mediums, maintenance, and voice recorders pertaining to the aircraft and airmen. Before the Board or representative takes over custody of the accident wreckage, everything must remain undisturbed unless it’s to remove people injured or trapped, to protect wreckage from further damage, or to protect the public. If wreckage is to be moved, photographs, notes, and sketches are to be made to document the scene to be accurately recreated.

3.1.11 49 USC 1114

Any information abstracted from the cockpit voice recorder, video recorder, transcript of oral communications by and between flight crew members and ground stations my not be disclosed publicly in the event of an accident or investigation [15].

In the event of a public hearing on the accident or incident, information relevant involving the transcript or any written depiction of visual information may become public. If a public hearing is not held at the time many of the other factual reports are placed in the public docket [15].

To maintain the confidentiality of recordings in an accident investigation, recordings cannot be disclosed publicly any part of voice or video recordings, transcripts of oral communications by drivers, employees, companies. Any part of a recording’s transcript or written depiction of visual information are permitted to become public if it is decided relevant to aid the accident public hearing or if placed into the public docket.

Use of the cockpit voice recorder, related to an accident investigation may be used when making safety recommendations [15].

3.1.12 49 USC 1154

Any part of a cockpit or surface vehicle recorder transcript may not be made available to the public that the NTSB has not already made available, when in a judicial hearing [13]. For a fair trial the cockpit or surface vehicle recorder may be reviewed and used [16]. If a part of a cockpit or surface vehicle recorder transcript is not made available to the public but the court allows for it in a judicial proceeding [16]. The court issues a protective order to limit the use of the recording, prohibit any person that does not need access, and place the recording under seal to prevent the use after the proceeding [16].

Use of the cockpit voice recorder, related to an accident investigation may be used when making safety recommendations [16].

3.1.13 49 USC 20137

A device that records speed, throttle position, brake application, brake operations, and any other function that the Secretary of Transportation considers mandatory to be of use in observing the operations safety is an "event recorder" [17].

The Secretary of Transportation shall issue regulations and issue orders that may enhance the safety by mandating event recorders [17]. Those recorders need to be installed not later than one year after the regulations are issued and published, unless if the Secretary of Transportation deems it impracticable to equip the aircraft in the one-year period and extension may be issued not later than 18 months after the originally regulations are published [17].

3.1.14 49 USC 44901

The Secretary of Transportation established a grant program to fund pilot projects to conduct research and development to expedite the recovery, development, and analysis of information from aircraft accidents to determine the cause of the accident by including removable flight deck, voice recorders, and remote location recording devices [18].

3.2 ICAO Annexes

The 18 Annexes of the ICAO describe various regulations and requirements for aircraft. The annexes especially relevant for the purpose of this project are 6, 10, 11 and 12, which are discussed in more detail in the following sections.

3.2.1 Annex 6

Within the documents standards for the operation of aircraft are defined. Due to the rapidly changing requirements for aircraft, this annex was updated on a regular basis and parts were added. There are a total of 3 parts, which complement each other. The first requirements for international commercial air transport were decided at an international conference in 1949. These regulations form the basis for Part 1. The 2nd part deals exclusively with international general aviation and the 3rd part exclusively with helicopters. Within the document, both FDRs and CVRs are discussed. In this context, particular attention is paid to the data that must be recorded. It is noticeable that commercial aviation is more strictly regulated than general aviation. Accordingly, the requirements in Part 2 can be seen as a minimum standard. Part 2 defines a total of 82 parameters that are recorded during the flight. However, many of these parameters are not relevant for the operation of a UAV. This annex focuses directly on FDR and CVR, therefore it is the most relevant annex considering the project goals. The requirements that can be extracted from this annex provide a good basis, but they need adjustment to be applicable to UAVs.

3.2.2 Annex 10

Annex 10 focuses on aeronautical communications, navigation, and surveillance. Annex 10 is divided into 5 volumes and provides Standards and Recommended Practices (SARPs), Procedures for Air Navigation Services (PANS) and guidance material. These volumes are:

- Volume I — Radio Navigation Aids
- Volume II — Communications Procedures including those with PANS status
- Volume III — Communication Systems
- Volume IV — Surveillance Radar and Collision Avoidance Systems
- Volume V — Aeronautical Radio Frequency Spectrum Utilization

Volume 1 defines needed Systems to provide radio navigation aids. It lists parameters for different systems. The information contains power requirements, frequency, modulation, signal characteristics and monitoring needed to ensure that the aircraft receives signals in every part of the world.

Volumes 2 and 3 cover voice and data communications in international civil aviation. This includes Ground-Ground and Air-Ground communication. Volume 2 focuses on general, administrative, and operational procedures while Volume 3 focuses on SARPs and guidance material for various air-ground and ground-ground voice and data communication systems.

Volume 4 contains SARPs and guidance material for Secondary Surveillance Radar and Airborne Collision Avoidance Systems.

Volume 5 covers SARPs and guidance material on the utilization of aeronautical frequencies.

3.2.3 Annex 11

Annex 11 is intended to ensure that states implement systematic and appropriate air traffic services (ATS) safety management programs. This is to ensure that aircraft do not collide. In addition, the annex establishes regulations to ensure orderly flow so that air traffic is safe and efficient. This section deals with the information required by an aircraft when flying in accordance with either Instrument Flight Rules (IFR) or Visual Flight Rules (VFR). The information includes significant meteorological information, changes in the serviceability of navigation aids and other information that are likely to affect safety. The bottom line of this annex is that good and ensured communication has high priority. Rules are defined accordingly. For UAVs, equally secure communication is required. Due to this high importance, it can be found in all regulations for flight data recorders that the communication must be recorded.

3.2.4 Annex 12

Annex 12 deals with search and rescue of aircraft. Corresponding standards and proposals are defined. Three distinct phases are defined:

I. Uncertainty Phase – The Radio contact has been lost and cannot be re-established. The Rescue Coordination Centre (RCC) is activated.
II. Alert Phase - The RCC contacts Search and Rescue units.
III. Distress Phase – Aircraft is in distress. The RCC take action to support the Aircraft and determine its location.

It is recommended that every RCC records the operational efficiency of the search and rescue organization.

3.3 Industry

3.3.1 American Society for Testing and Materials (ASTM)

ASTM International seeks to keep aircraft of all sizes safe by developing crucial standards worldwide. More specifically, ASTM has a committee that looks at significant aircraft systems standards and all types of general aviation aircraft.

3.3.1.1 ASTM F3228-17 Standard Specification for Flight Data and Voice Recording in Small Aircraft

This is the published international standard for the flight recording aspects of airworthiness for small aircraft. While this is applicable to manned, there are likely some congruencies with unmanned aircraft.

3.3.2 Radio Technical Commission for Aeronautics (RTCA)

RTCA, founded in 1935, aims to create and implement performance standards that change global aviation while ensuring the safety, security, overall health of the aviation industry.

3.3.2.1 Future Flight Data Collection Committee Final Report

RTCA is examining contemporary concepts for flight data collection [18]. Data sources come in many forms on an aircraft [18]. If a sensor remains connected and functional with uninterrupted power, it is possible to keep processing and recording [18].

FDRs can provide accident investigators with details of the flights, but more importantly can provide information about the safety issues and what corrective action needs to be taken for the future. The FDR often provides an unequivocal record as to what occurred on an accident flight, thus allowing investigators to focus on finding the precursors. FDRs accurate and useable data compared to secondary measures, such as radar data [18].

There are other types of FDRs, such as deployable recorders. Deployable FDRs are an alternative to fixed recorders. Fixed recorders are manufactured to withstand the severest crash scenarios and are installed in the airframe [18]. A deployable recorder is housed with an assembly called the Deployable Beacon Airfoil Unit (BAU [18]). The BAU contains the Flight Recorder Memory Unit and an Emergency Locator Transmitter [18].

3.3.3 ARINC Aeronautical Radio Inc.

3.4 EUROCAE MOPS

The EUROACE regulations ED-112A and ED-115 define Minimum Operational Performance Specifications (MOPS) for different airborne/flight recording systems. In the following sections, those requirements are summarized and evaluated.

3.4.1 ED-55/ED-112A Minimum Operational Performance Specification for Crash Protected Airborne

ED-112A is a comprehensive document and contains information on most aspects relevant to the project. It was published in September 2013 by EUROCAE and supersedes ED55 (May 1990). The document covers requirements for airplanes and helicopters.

The first part of the document deals with Cockpit Voice Recorder (CVR) systems. It defines the minimum specifications to be met for all aircraft required to carry a CVR. According to EUROCAE, the systems must be equipped with a variety of equipment, depending on the capabilities of the aircraft.

These include

I. Cockpit equipment including controls for test and bulk erase functions, a monitor, failure indication and area microphones with associated preamplifiers,
II. an alternate power source,
III. a means of converting a synchronization signal to a format which can be recorded,
IV. digital data busses and/or networks providing communication between elements of the system,
V. and for helicopters an interface device suitable for converting a signal representing the main rotor rotation speed into a recordable format [21, pp. 83-84].

Furthermore, the document specifies various classes of CVR. A total of 6 different classes are defined. All classes must fulfil the MOPS specified in the document but differ in how long data must be stored during flight operations. The requirement ranges from 30 minutes up to 25 hours [21, p. 84].

According to EUROCAE, every CVR must be able to simultaneously record data in reference to a timescale. The recorded data must include the inputs of each microphone, including voice communications and the aural environment of the cockpit. The recording of the voice communication must cover the interphone system and the public address system if installed. Furthermore, the navigation aids, warnings and alters that are introduced into a speaker or headset must be recorded. The CVR must also record the rotation speed of the main rotor in helicopters without a FDR. Furthermore, ED-112A defines flight test procedures to check the functionality of the CVR [21, p. 84].

The second part of the document defines the minimum specification to be met for all aircraft required to carry a FDR system. It defines the

I. typical operational objectives,
II. the general design specification,
III. the minimum system performance under environmental and standard test conditions,
IV. the tests and procedures to determine compliance with performance requirements,
V. and the equipment's performance requirements including ground tests and flight tests.

Additionally, guidance on maintenance practices, data compression techniques and electronic documentation standards are provided by the 4 previously mentioned Annexes [21, p. 127].

According to EUROCAE, the FDR system must be equipped with multiple items depending on the aircraft. This equipment is used to acquire and process analogue and digital sensor signals, store the recorded data, and when necessary, support dedicated sensors [21, p. 128].

ED-112A defines multiple classes of FDR based on number and type of parameters to be recorded. These requirements are minimum operational standards and therefore, the operational rules of each ICAO member state take precedence over EUROCAE MOPS. The classes relevant for the project are EUROCAE FDR Class A and Class B. Class A refers to FDRs for airplanes and Class B for helicopters. The requirements for a Class A recorder are according to EUROCAE equivalent to an ICAO Type Ia recorder while Class B recorder requirements are equivalent to the ICAO Type IVa recorder requirements [10, p. 129]. Regarding the general objective of a FDR, ED-112A refers to ICAO Annex 6, Parts I, II and III. ICAO defines seven different recorders. Out of these recorders only recorder ICAO Type IIA refers to airplanes under 5700 kg. Therefore, this recorder is especially relevant for further evaluation and assessment [21, p. 130]. The exact specifications of the data to be recorded are listed within Annex II-A for both aircraft and helicopters. For the respective parameter the

I. minimum recording range,
II. maximum recording interval in seconds,
III. recording accuracy,
IV. and recording resolution is specified [21, pp. 148-171].

Some of the requirements defined in the document are clearly requirements for larger manned aircraft. In total, 82 parameters are defined for airplanes and 53 for helicopters. Some of these requirements are not necessary for UAVs. For example, the pressure inside the cabin [21, pp. 148-171]. In addition, UAVs have a larger number of possible designs and propulsion types. Accordingly, the requirements found in ED-112A must be fine-tuned and adjusted to be applicable to UAV's.

3.4.2 ED-155 Minimum Operational Performance Specification for Lightweight Flight Recording Systems

ED-115 defines standards for light weight aircraft. The document was published by EUROCAE in 2009. Like ED-112A, the document covers Cockpit Audio Recording Systems (CARS) in the first part and Aircraft Data Recording Systems (ADRS) in the second part. Since ED-112A is more oriented towards larger airplanes and helicopters, the document ED-155 is very well suited as a supplement to assess requirements for smaller UAVs.

Part I of the document discusses CARS including

I. typical operational goals,
II. a description of the CARS,
III. general design specifications,
IV. performance under standard and environmental test conditions,
V. and test procedures (ground and flight tests) [20, p. I2].

The equipment requirements for the CARS defined in ED-155 are reduced in comparison to ED-112A. According to EUROCAE, the CARS only need the same cockpit equipment as defined in ED-112A, a means of converting the analogue audio signals to a digital format and audio equipment including signal summing amplifiers [20, p. I2]. The equipment should be installed in a way that the aural environment of the cockpit is recorded as well as the pilot's headset audio.

The second part of the document deals with ADRS. Here, similar to ED-112A, the typical operational requirements, the design, tests, and performance requirements are defined. The ADRS should have the necessary equipment to record all sensor data and synchronize it with the other airborne recording systems. Furthermore, the communication between the elements of the system should be provided by data busses or networks and the data should be stored on a robust medium [20, p. II2].

ED-155 presents the required parameters like ED-122A in a table. The light weight aircraft is differentiated into fixed wing, rotary wing, sail plane, lighter than air, piston engine and turbine engine. Accordingly, it is noted which parameter applies to which type of aircraft. Due to this division, the table is much more suitable for the project than the tables from ED-112A and can thus be transferred in a similar form to the requirements for UAVs [20, pp. II16 - II22].

3.5 Gaps Between Manned and Unmanned Recorders

It turns out that current regulations and guidelines are strongly related to larger aircraft, which means that not all the regulations required in the lists can and should be followed. In addition, the design of UAS is usually much more versatile. So, it makes sense as a first step to define various categories of UAS. These categories should include whether it is a fixed-wing or rotary wing aircraft, what weight class it belongs to, and to what degree it is capable of autonomous flight. Thus, general requirements and requirements specifically based on the category should be established.

However, some additional data must be recorded for unmanned aircraft. For example, in the previously analyzed texts, it is required to record which value is selected for the speed and which speed the aircraft has in reality. Since these values must be transmitted for unmanned aircraft, the value before and after the transmission, as well as the actual value should be stored here. For autonomous aircraft, the transparency of the algorithms must also be considered to ensure the recording of the necessary data.

4 ACCIDENTS AND INCIDENTS INVESTIGATION IN TECHNICAL STANDARD ORDERS (TSOS)

4.1 Technical Standard Orders

The FAA has published two Technical Standard Orders (TSOs) covering both FRDs and CVRs. The FAA defines a TSO as "…a minimum performance standard for specified materials, parts, and appliances used on civil aircraft. When authorized to manufacture a material, part, or appliances to a TSO standard, this is referred to as TSO authorization. Receiving a TSO authorization is both design and production approval [22]."

The TSO for FDRs is contained in TSO-C124b [23]. One of the major requirements of this TSO is that all FDRs manufactured on or after April 10, 2007 must meet the Minimum Performance Standards (MPSs) of EUROCAE publication ED-112 (discussed previously). In addition, RTCA requirements must be met for environmental conditions. The document also outlines requirements for both the software and hardware components of FDRs.

Similarly, the requirements for CVRs are outlined in TSO-C123c [24]. This TSO also requires the EUROCAE ED-112 standard for CVRs, as well as the RTCA environmental requirements (discussed above).

4.2 Advisory Circulars

The FAA publishes Advisory Circulars (ACs) which includes information designed "…to inform the aviation public in a systematic way of nonregulatory material. Unless incorporated into a regulation by reference, the contents of an advisory circular are not binding on the public. [25]. In essence, ACs help people who operate within the National Airspace System (NAS) of guidelines and recommendations for safe operation. While not regulatory in nature, ACs have become an essential resource and often represent de facto standards.

The AC for FDRs is AC 20-141B [26]. This AC goes into substantial details regarding the use, preferrable data standards, and instructions on how to derive or filter some forms of flight data. The newer FDRs can store a large number of parameters, but the parameters specifically mentioned in this AC are included in Table 3.

Table 3. AC 20-141B Appendix 5 Parameters.

Time	Lateral Acceleration
Pressure Altitude	Pitch trim surface positions
Airspeed	Trailing Edge Flaps
Heading	Leading Edge Flaps/Slats
Vertical Acceleration	Thrust Reverser Position
Pitch Attitude	Ground Spoiler Position
Roll Attitude	OAT/TAT
Manual Microphone keying	Autopilot Modes
Engine thrust	Radio Altimeter
Autopilot engagement	Localizer Deviation
Longitudinal Acceleration	Glideslope Deviation
Pitch Control Positions	Marker Beacon
Lateral Control Positions	Master Warning
Yaw Control Positions	Air/Ground Sensing
Pitch Control Surface Conditions	Angle of Attack
Lateral Control Surface Conditions	Hydraulic Pressure Low

Yaw Control Surface Conditions	Ground Speed

The CVR AC is AC 20-186 [27]. Similar to the FDR AC, this AC, "…provides guidance for compliance with applicable regulations for the airworthiness and operational approval for required cockpit voice recorder (CVR) systems. Non-required installations may use this guidance when installing a CVR system as a voluntary safety enhancement. This AC is not mandatory and is not a regulation. This AC describes an acceptable means, but not the only means, to comply with Title 14 of the Code of Federal Regulations (14 CFR). However, if you use the means described in this AC, you must conform to it in totality for required installations. [27]."

5 TEST METHOD AND METRICS FOR DATA RECORDER SURVIVAILITY

5.1 Modelling/Non-destructive

There are several engineering methods used to test structure and system survivability. In general, they are dived into two broad categories, non-destructive and destructive. The non-destructive techniques usually involve engineering calculations or modelling and simulation while destructive techniques actually require structures be taken against their limits to the point of failure.

There are several manned survivability requirements that can modelled and applied to an FDR mounted on a UAS. This modelling can help determine whether an FDR would be recoverable in the event of an accident. Of the survivability requirements listed in both TSOs C123 and C124, the following items will likely be able to be modelled (instead of using destructive methods):

- Impact Shock – 3,400G's for 6.5ms
- Static Crush – 5,000 pounds for 5 minutes on each axis
- Penetration Resistance – 500 lbs. dropped from 10feet with a ¼-inch diameter contact point.
- Hydrostatic Pressure – Pressure equivalent to a depth of 20,000 feet

5.2 Destructive

There are several survivability parameters that would likely have to be taken to destruction in order to determine survival suitability as outlined in the TSOs. These include:

- Fire (High Intensity) - 1100°C flame covering 100% of recorder for 30 minutes. (60 minutes if ED56 test protocol is used)
- Fire (Low Intensity) - 260°C Oven test for 10 hours
- Fluid Immersion - Immersion in aircraft fluids (fuel, oil etc.) for 24 hours
- Water Immersion - Immersion in sea water for 30 days

6 LITERATURE REVIEW CONCLUSION

It is clear that for the manned industry, FDRs and CVRs have had a long history. These devices have proven valuable for accident investigation, proactive and predictive safety programs, and ultimately have led to a better overall safety environment. Throughout this history, the collected parameters and its associated storage have changed often, especially has technology has improved.

Although the use of FDRs and CVRs in the manned industry is well established, the same cannot be said for the unmanned industry. There are FDRs that fit the size, weight, and power requirements of many UAS platforms, there is still no standardization. UAS telemetry, often able to be collected through C2 transmissions, and stored locally on a GCS, also offers a potentially viable avenue for flight data recordings. In fact, the storing of data away from an aircraft increases the survivability aspect of the recordings.

What parameters should be collected for unmanned aircraft? A good starting point for this question is with already created parameter recordings on the manned side, as shown in Table 3. Of course, there are many parameters recorded on the manned side that would not necessarily be germane to unmanned aircraft (depending on the platform). And there would also be additional parameters specific to UAS which would not necessarily be important on the manned side.

Appendix A shows the type of data with formats and refresh rates typically found in manned aviation, in this case as stored in the National General Aviation Flight Information Database. Although this data is primarily a manned data solution, the formats listed in the appendix can give an idea of the types of information that contemporary manned FDRs generate.

The telemetry streams generated by small UASs and stored on the GCS also generate a vast amount of data. Appendix B depicts telemetry format found on three different types of small UAS platforms. Although this data can be radically disparate to the manned side, there are also many similarities, especially when looking at a basic FDR data recording useful for accident investigation.

The primary goal of this study is to identify the requirements for unmanned FDRs and CVRs. Based upon the foundation and underpinnings identified in this literature review, when combined with statistical modelling and other techniques, the requirements for an unmanned FDR and CVR will be identified and data-driven. Further, this project will leverage the vast amount of knowledge obtained from the manned side to determine the exact needs for recorders. Undoubtedly, accident investigators and safety professionals throughout the unmanned industry will be able to obtain the necessary tools needed to help ensure adequate safety margins.

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8 APPENDICES

8.1 Appendix A

Technical Description of NGAFID Parameters

1	**Field:**	id	**Type:**	bigint(20)	**Required**
	Units:	Integer	**Range:**	0-18,446,744,073,709,551,615	
	Description:	Individual record id, will be auto-incremented			
	Example:	1			

2	**Field:**	flight	**Type:**	bigint(20)	**Required**
	Units:	Integer	**Range:**	0-18,446,744,073,709,551,615	
	Description:	Used for flight identification.			
	Example:	52			

3	**Field:**	phase	**Type:**	tinyint(3)	**Required**
	Units:	Integer	**Range:**	0-255	
	Description:	Phase of flight, to be foreign keyed to a master phase of flight table. Phase field will be used in the development of exceedances and other concept tools.			
	Example:	15			

4	**Field:**	time	**Type:**	Bigint(20)	**Required**
	Units:	Milliseconds	**Range:**	0-18,446,744,073,709,551,615	
	Description:	The millisecond that the field recorded occurred during flight (**not** the time the data was entered in the database).			
	Example:	29888824			

5	**Field:**	pressure_altitude	**Type:**	float(7,2)	**Not Required**
	Units:	Feet	**Range:**	-99,999.99 - 99,999.99	
	Description:	Pressure altitude if recorded (not derived).			
	Example:	12,432.11			

6	**Field:**	msl_altitude	**Type:**	float(7,2)	**Not Required**
	Units:	Feet	**Range:**	-99,999.99 - 99,999.99	
	Description:	Altitude above mean sea level.			
	Example:	12,432.11			

7	**Field:**	indicated_airspeed	**Type:**	float(6,2)	**Not Required**
	Units:	Knots	**Range:**	-9,999.99 - 9,999.99	
	Description:	Indicated airspeed.			
	Example:	124.21			

8	**Field:**	tas	**Type:**	float(6,2)	**Not Required**
	Units:	Knots	**Range:**	-9,999.99 - 9,999.99	
	Description:	True airspeed (not derived)			
	Example:	124.21			

9	**Field:**	mach	**Type:**	float(3,2)	**Not Required**
	Units:	Mach	**Range:**	-9.99 - 9.99	
	Description:	Mach number (not derived)			
	Example:	.86			

10	**Field:**	heading	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees	**Range:**	0-359.99	
	Description:	Compass heading, as recorded.			
	Example:	227.41			

11	**Field:**	course	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees	**Range:**	0-359.99	
	Description:	Magnetic course (not derived)			
	Example:	301.34			

12	**Field:**	pitch_attitude	**Type:**	float(7,4)	**Not Required**
	Units:	Degrees	**Range:**	-180.0000 - 180.0000	
	Description:	Pitch attitude, negative denotes down, positive denotes up.			
	Example:	6.8724			

13	**Field:**	Roll_attitude	**Type:**	float(7,4)	**Not Required**
	Units:	Degrees	**Range:**	-180.0000 - 180.0000	
	Description:	Roll attitude, negative denotes left, positive denotes right.			
	Example:	6.8724			

14	**Field:**	radio_transmit	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Radio transmission in progress.			
	Example:	no			

15	**Field:**	eng_1_rpm	**Type:**	float(7,2)	**Not Required**
	Units:	RPM	**Range:**	0 - 99999.99	
	Description:	Engine #1 RPM			
	Example:	2315.62			

16	**Field:**	eng_2_rpm	**Type:**	float(7,2)	**Not Required**
	Units:	RPM	**Range:**	0 - 99999.99	
	Description:	Engine #2 RPM			
	Example:	2315.62			

17	**Field:**	eng_3_rpm	**Type:**	float(7,2)	**Not Required**
	Units:	RPM	**Range:**	0 - 99999.99	
	Description:	Engine #3 RPM			
	Example:	2315.62			

18	**Field:**	eng_4_rpm	**Type:**	float(7,2)	**Not Required**
	Units:	RPM	**Range:**	0 - 99999.99	
	Description:	Engine #4 RPM			
	Example:	2315.62			

19	**Field:**	eng_1_mp	**Type:**	float(6,3)	**Not Required**
	Units:	Inches of HG	**Range:**	0 - 999.999	
	Description:	Engine #1 Manifold Pressure			
	Example:	25.812			

20	**Field:**	eng_2_mp	**Type:**	float(6,3)	**Not Required**
	Units:	Inches of HG	**Range:**	0 - 999.999	
	Description:	Engine #2 Manifold Pressure			
	Example:	25.812			

21	**Field:**	eng_3_mp	**Type:**	float(6,3)	**Not Required**
	Units:	Inches of HG	**Range:**	0 - 999.999	
	Description:	Engine #3 Manifold Pressure			
	Example:	25.812			

22	**Field:**	eng_4_mp	**Type:**	float(6,3)	**Not Required**
	Units:	Inches of HG	**Range:**	0 - 999.999	
	Description:	Engine #4 Manifold Pressure			
	Example:	25.812			

23	**Field:**	prop_1_angle	**Type:**	float(6,4)	**Not Required**
	Units:	Degrees	**Range:**	-99.9999 - 99.9999	
	Description:	Propeller blade angle, engine #1			
	Example:	54.1092			

24	**Field:**	prop_2_angle	**Type:**	float(6,4)	**Not Required**
	Units:	Degrees	**Range:**	-99.9999 - 99.9999	
	Description:	Propeller blade angle, engine #2			
	Example:	54.1092			

25	**Field:**	prop_3_angle	**Type:**	float(6,4)	**Not Required**
	Units:	Degrees	**Range:**	-99.9999 - 99.9999	
	Description:	Propeller blade angle, engine #3			
	Example:	54.1092			

26	**Field:**	prop_4_angle	**Type:**	float(6,4)	**Not Required**
	Units:	Degrees	**Range:**	-99.9999 - 99.9999	
	Description:	Propeller blade angle, engine #4			
	Example:	54.1092			

27	**Field:**	autopilot	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"off", "on"	
	Description:	Status of autopilot (is the autopilot on or off?)			
	Example:	off			

28	**Field:**	pitch_control_input	**Type:**	float(7,3)	**Not Required**
	Units:	Degrees	**Range:**	-9999.999 - 9999.999	
	Description:	Pitch control input at the control yoke			
	Example:	-14.871			

29	**Field:**	lateral_control_input	**Type:**	float(7,3)	**Not Required**
	Units:	Degrees	**Range:**	-9999.999 - 9999.999	
	Description:	Aileron control input at the control yoke			
	Example:	19.212			

30	**Field:**	rudder_control_input	**Type:**	float(7,3)	**Not Required**
	Units:	Degrees	**Range:**	-9999.999 - 9999.999	
	Description:	Rudder control input at the rudder pedals			
	Example:	-6.691			

31	**Field:**	pitch_control_surface_position	**Type:**	float(7,3)	**Not Required**
	Units:	Degrees	**Range:**	-9999.999 - 9999.999	
	Description:	Position of pitch control surface (elevator or stabilator)			
	Example:	-6.691			

32	**Field:**	lateral_control_surface_position	**Type:**	float(7,3)	**Not Required**
	Units:	Degrees	**Range:**	-9999.999 - 9999.999	
	Description:	Position of aileron control surface			
	Example:	4.812			

33	**Field:**	yaw_control_surface_position	**Type:**	float(7,3)	**Not Required**
	Units:	Degrees	**Range:**	-9999.999 - 9999.999	
	Description:	Position of rudder control surface			
	Example:	1.772			

34	**Field:**	vertical_acceleration	**Type:**	float(6,3)	**Not Required**
	Units:	g's	**Range:**	-999.999 - 999.999	
	Description:	Amount of vertical g's recorded			
	Example:	1.282			

35	**Field:**	longitudinal_acceleration	**Type:**	float(6,3)	**Not Required**
	Units:	g's	**Range:**	-999.999 - 999.999	
	Description:	Amount of longitudinal g's recorded			
	Example:	-0.113			

36	**Field:**	lateral_acceleration	**Type:**	float(6,3)	**Not Required**
	Units:	g's	**Range:**	-999.999 - 999.999	
	Description:	Amount of lateral g's recorded			
	Example:	1.102			

37	**Field:**	pitch_trim_surface_position	**Type:**	float(6,3)	**Not Required**
	Units:	Degrees	**Range:**	-999.999 - 999.999	
	Description:	Deflection of pitch trim surface			
	Example:	-2.881			

38	**Field:**	trailing_edge_flap_selection	**Type:**	Tinyint(4)	**Not Required**
	Units:	Degrees	**Range:**	-128 - 127	
	Description:	Flap selection from cockpit, trailing edge device			
	Example:	15			

39	**Field:**	leading_edge_flap_selection	**Type:**	Tinyint(4)	**Not Required**
	Units:	Degrees	**Range:**	-128 - 127	
	Description:	Flap selection from cockpit, leading edge device			
	Example:	15			

40	**Field:**	thrust_reverse_position_1	**Type:**	float(6,3)	**Not Required**
	Units:	Degrees	**Range:**	-999.999 - 999.999	
	Description:	Amount of thrust reverse lever application, engine #1			
	Example:	0.000			

41	**Field:**	thrust_reverse_position_2	**Type:**	float(6,3)	**Not Required**
	Units:	Degrees	**Range:**	-999.999 - 999.999	
	Description:	Amount of thrust reverse lever application, engine #2			
	Example:	0.000			

42	**Field:**	thrust_reverse_position_3	**Type:**	float(6,3)	**Not Required**
	Units:	Degrees	**Range:**	-999.999 - 999.999	
	Description:	Amount of thrust reverse lever application, engine #3			
	Example:	0.000			

43	**Field:**	thrust_reverse_position_4	**Type:**	float(6,3)	**Not Required**
	Units:	Degrees	**Range:**	-999.999 - 999.999	
	Description:	Amount of thrust reverse lever application, engine #4			
	Example:	0.000			

44	**Field:**	ground_spoiler_speed_brake_ position	**Type:**	Tinyint(4)	**Not Required**
	Units:	Degrees	**Range:**	-128 - 127	
	Description:	Cockpit control position of speed brake selector			
	Example:	5			

45	**Field:**	oat	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Outside Air Temperature			
	Example:	-28.31			

46	**Field:**	afcs_mode	**Type:**	smallint(6)	**Not Required**
	Units:	NA	**Range:**	0 - 65,535	
	Description:	Autopilot mode.			
	Example:	3			

47	**Field:**	radio_altitude_actual	**Type:**	mediumint(9)	**Not Required**
	Units:	feet	**Range:**	0 - 16,777,215	
	Description:	Radio (radar) altitude of aircraft as recorded.			
	Example:	1,672			

48	**Field:**	radio_altitude_derived	**Type:**	mediumint(9)	**Not Required**
	Units:	feet	**Range:**	0 - 16,777,215	
	Description:	Radio (radar) altitude of aircraft as calculated from msl altitude minus terrain altitude.			
	Example:	21,199			

49	**Field:**	localizer_deviation	**Type:**	float(5,3)	**Not Required**
	Units:	Degrees	**Range:**	-99.999 - 99.999	
	Description:	Degrees off of localizer course, negative denotes left, positive right.			
	Example:	3.012			

50	**Field:**	glideslope_deviation	**Type:**	float(5,3)	**Not Required**
	Units:	Degrees	**Range:**	-99.999 - 99.999	
	Description:	Degrees off of glideslope, negative denotes low, positive high.			
	Example:	-1.912			

51	**Field:**	marker_beacon_passage	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Outer marker beacon being overflown.			
	Example:	no			

52	**Field:**	master_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Master warning indication displayed.			
	Example:	no			

53	**Field:**	weight_on_wheels	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"ground", "air"	
	Description:	Weight on wheels sensed.			
	Example:	air			

54	**Field:**	aoa	**Type:**	float(5,3)	**Not Required**
	Units:	Degrees	**Range:**	-99.999 - 99.999	
	Description:	Angle of attack.			
	Example:	7.183			

55	**Field:**	hydraulic_pressure_low	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Hydraulic pressure low indication.			
	Example:	no			

56	**Field:**	groundspeed	**Type:**	float(7,3)	**Not Required**
	Units:	Knots	**Range:**	-9,999.999 - 9,999.999	
	Description:	True airspeed (not derived)			
	Example:	124.219			

57	**Field:**	terrain_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Terrain warning present.			
	Example:	no			

58	**Field:**	landing_gear_position	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"up", "down", "transit"	
	Description:	Position of landing gear.			
	Example:	up			

59	**Field:**	drift_angle	**Type:**	float(6,3)	**Not Required**
	Units:	Degrees	**Range:**	-999.999 - 999.999	
	Description:	Drift angle.			
	Example:	17.227			

60	**Field:**	wind_speed	**Type:**	float(6,3)	**Not Required**
	Units:	Knots	**Range:**	0.000 - 999.999	
	Description:	Speed of wind			
	Example:	119.426			

61	**Field:**	wind_direction	**Type:**	float(6,3)	**Not Required**
	Units:	Degrees	**Range:**	-999.999 - 999.999	
			Actual:	0.000-359.999	
	Description:	Magnetic direction of wind			
	Example:	340.736			

62	**Field:**	latitude	**Type:**	float(8,6)	**Not Required**
	Units:	Degrees	**Range:**	-99.999999 - 99.999999	
			Actual:	-90.0000000 - 90.0000000	
	Description:	Latitude of aircraft, negative denotes southern hemisphere, positive denotes northern.			
	Example:	43.567143			

63	**Field:**	longitude	**Type:**	float(9,6)	**Not Required**
	Units:	Degrees	**Range:**	-999.999999 - 999.999999	
			Actual:	-180.0000000 - 180.0000000	
	Description:	Longitude of aircraft, negative denotes western hemisphere, positive denotes eastern.			
	Example:	-121.387255			

64	**Field:**	stall_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Stall warning present.			
	Example:	no			

65	**Field:**	stick_shaker	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Stick shaker activated.			
	Example:	no			

66	**Field:**	stick_pusher	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Stick pusher activated.			
	Example:	no			

67	**Field:**	windshear	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Windshear warning active.			
	Example:	no			

68	**Field:**	throttle_lever_position_1	**Type:**	float(6,3)	**Not Required**
	Units:	Degrees	**Range:**	-999.999 - 999.999	
	Description:	Position of throttle lever, engine #1			
	Example:	58.712			

69	**Field:**	throttle_lever_position_2	**Type:**	float(6,3)	**Not Required**
	Units:	Degrees	**Range:**	-999.999 - 999.999	
	Description:	Position of throttle lever, engine #2			
	Example:	58.712			

70	**Field:**	throttle_lever_position_3	**Type:**	float(6,3)	**Not Required**
	Units:	Degrees	**Range:**	-999.999 - 999.999	
	Description:	Position of throttle lever, engine #3			
	Example:	58.712			

71	**Field:**	throttle_lever_position_4	**Type:**	float(6,3)	**Not Required**
	Units:	Degrees	**Range:**	-999.999 - 999.999	
	Description:	Position of throttle lever, engine #4			
	Example:	58.712			

72	**Field:**	traffic_alert	**Type:**	smallint(6)	**Not Required**
	Units:	NA	**Range:**	0 - 65,535	
	Description:	Traffic alert status.			
	Example:	3			

73	**Field:**	dme_1_distance	**Type:**	float(6,3)	**Not Required**
	Units:	DME units	**Range:**	-999.999 - 999.999	
			Actual:	-199.999 - 199.999	
	Description:	Distance Measuring equipment (DME) #1 receiver distance.			
	Example:	72.192			

74	**Field:**	dme_2_distance	**Type:**	float(6,3)	**Not Required**
	Units:	DME units	**Range:**	-999.999 - 999.999	
			Actual:	-199.999 - 199.999	
	Description:	Distance Measuring equipment (DME) #2 receiver distance.			
	Example:	72.192			

75	**Field:**	nav_1_freq	**Type:**	float(6,3)	**Not Required**
	Units:	MHz	**Range:**	-999.999 - 999.999	
			Actual:	110.000 - 118.000	
	Description:	Selected frequency Nav 1.			
	Example:	114.30			

76	**Field:**	nav_2_freq	**Type:**	float(6,3)	**Not Required**
	Units:	MHz	**Range:**	-999.999 - 999.999	
			Actual:	110.000 - 118.000	
	Description:	Selected frequency Nav 2.			
	Example:	112.725			

77	**Field:**	obs_1	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees	**Range:**	00.000-359.99	
	Description:	Course set into Omni Bearing Selector (OBS) 1			
	Example:	125.00			

78	**Field:**	obs_2	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees	**Range:**	00.000-359.99	
	Description:	Course set into Omni Bearing Selector (OBS) 2			
	Example:	125.00			

79	**Field:**	altimeter	**Type:**	float(4,2)	**Not Required**
	Units:	Inches of HG	**Range:**	00.00-99.99	
			Actual:	20.00-35.00	
	Description:	Altimeter setting			
	Example:	29.92			

80	**Field:**	selected_altitude	**Type:**	mediumint(9)	**Not Required**
	Units:	feet	**Range:**	0 - 16,777,215	
	Description:	Selected altitude in altitude setting system (or alerter).			
	Example:	15000			

81	**Field:**	selected_speed	**Type:**	smallint(4)	**Not Required**
	Units:	knots	**Range:**	0 - 9999	
	Description:	Selected speed in AFCS.			
	Example:	150			

82	**Field:**	selected_mach	**Type:**	float(3,2)	**Not Required**
	Units:	mach	**Range:**	-9.99 - 9.99	
	Description:	Selected Mach number in autopilot system.			
	Example:	.86			

83	**Field:**	selected_vertical_speed	**Type:**	smallint(5)	**Not Required**
	Units:	Feet per minute	**Range:**	-99,999 - 99,999	
	Description:	Selected vertical speed in autopilot			
	Example:	-1500			

84	**Field:**	selected_heading	**Type:**	smallint(3)	**Not Required**
	Units:	Degrees	**Range:**	0-359	
	Description:	Selected heading in autopilot			
	Example:	047			

85	**Field:**	selected_flight_path*	**Type:**	tinyint(3)	**Not Required**
	Units:	NA	**Range:**	0 - 256	
	Description:	Selected flight path mode in autopilot.			
	Example:	3			

86	**Field:**	selected_decision_height	**Type:**	smallint(5)	**Not Required**
	Units:	feet	**Range:**	-99,999 - 99,999	
	Description:	Selected decision height in autopilot			
	Example:	200			

87	**Field:**	efis_display_format*	**Type:**	tinyint(3)	**Not Required**
	Units:	NA	**Range:**	0 - 256	
	Description:	Selected EFIS format/mode.			
	Example:	3			

88	**Field:**	mfd_display_format*	**Type:**	tinyint(3)	**Not Required**
	Units:	NA	**Range:**	0 - 256	
	Description:	Selected MFD format/mode.			
	Example:	3			

89	**Field:**	thrust_command	**Type:**	varchar(8)	**Not Required**
	Units:	percent	**Range:**	Undefined	
	Description:	Description of commanded thrust for auto-throttle equipped aircraft, will be aircraft specific.			
	Example:	92.6			

90	**Field:**	thrust_target	**Type:**	varchar(8)	**Not Required**
	Units:	percent	**Range:**	Undefined	
	Description:	Description of thrust target set, will be aircraft specific.			
	Example:	92.6			

91	**Field:**	fuel_quantity_total	**Type:**	float(8,3)	**Not Required**
	Units:	Lbs.	**Range:**	0 - 99,999.999	
	Description:	Total fuel quantity as recorded (not dervived).			
	Example:	288.761			

92	**Field:**	fuel_quantity_left_main	**Type:**	float(8,3)	**Not Required**
	Units:	Lbs.	**Range:**	0 - 99,999.999	
	Description:	Fuel quantity left main tank as recorded.			
	Example:	145.412			

93	**Field:**	fuel_quantity_right_main	**Type:**	float(8,3)	**Not Required**
	Units:	Lbs.	**Range:**	0 - 99,999.999	
	Description:	Fuel quantity right main tank as recorded.			
	Example:	145.412			

94	**Field:**	fuel_quantity_aux_1	**Type:**	float(8,3)	**Not Required**
	Units:	Lbs.	**Range:**	0 - 99,999.999	
	Description:	Fuel quantity auxiliary tank # 1 as recorded.			
	Example:	91.765			

95	**Field:**	fuel_quantity_aux_2	**Type:**	float(8,3)	**Not Required**
	Units:	Lbs.	**Range:**	0 - 99,999.999	
	Description:	Fuel quantity auxiliary tank # 2 as recorded.			
	Example:	91.765			

96	**Field:**	fuel_quantity_aux_3	**Type:**	float(8,3)	**Not Required**
	Units:	Lbs.	**Range:**	0 - 99,999.999	
	Description:	Fuel quantity auxiliary tank # 3 as recorded.			
	Example:	91.765			

97	**Field:**	fuel_quantity_cg_trim_tank	**Type:**	float(8,3)	**Not Required**
	Units:	Lbs.	**Range:**	0 - 99,999.999	
	Description:	Fuel quantity Center of Gravity (CG) trim tank as recorded.			
	Example:	91.765			

98	**Field:**	eng_1_fuel_flow	**Type:**	float(8,3)	**Not Required**
	Units:	Lbs. per hour	**Range:**	0 - 99,999.999	
	Description:	Fuel flow engine #1			
	Example:	128.311			

99	**Field:**	eng_2_fuel_flow	**Type:**	float(8,3)	**Not Required**
	Units:	Lbs. per hour	**Range:**	0 - 99,999.999	
	Description:	Fuel flow engine #2			
	Example:	128.311			

100	**Field:**	eng_3_fuel_flow	**Type:**	float(8,3)	**Not Required**
	Units:	Lbs. per hour	**Range:**	0 - 99,999.999	
	Description:	Fuel flow engine #3			
	Example:	128.311			

101	**Field:**	eng_4_fuel_flow	**Type:**	float(8,3)	**Not Required**
	Units:	Lbs. per hour	**Range:**	0 - 99,999.999	
	Description:	Fuel flow engine #4			
	Example:	128.311			

102	**Field:**	primary_nav_system_reference*	**Type:**	tinyint(3)	**Not Required**
	Units:	NA	**Range:**	0 - 256	
	Description:	Primary navigation used for system reference.			
	Example:	3			

103	**Field:**	icing	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Ice detection system status.			
	Example:	no			

104	**Field:**	eng_1_vibration_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Engine #1 vibration indication.			
	Example:	no			

105	**Field:**	eng_2_vibration_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Engine #2 vibration indication.			
	Example:	no			

106	**Field:**	eng_3_vibration_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Engine #3 vibration indication.			
	Example:	no			

107	**Field:**	eng_4_vibration_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Engine #4 vibration indication.			
	Example:	no			

108	**Field:**	eng_1_overtemp_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Engine #1 overtemp warning indication.			
	Example:	no			

109	**Field:**	eng_2_overtemp_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Engine #2 overtemp warning indication.			
	Example:	no			

110	**Field:**	eng_3_overtemp_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Engine #3 overtemp warning indication.			
	Example:	no			

111	**Field:**	eng_4_overtemp_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Engine #4 overtemp warning indication.			
	Example:	no			

112	**Field:**	eng_1_oil_press	**Type:**	float(5,2)	**Not Required**
	Units:	psi	**Range:**	-999.99 - 999.99	
	Description:	Oil pressure engine #1			
	Example:	87.22			

113	**Field:**	eng_2_oil_press	**Type:**	float(5,2)	**Not Required**
	Units:	psi	**Range:**	-999.99 - 999.99	
	Description:	Oil pressure engine #2			
	Example:	87.22			

114	**Field:**	eng_3_oil_press	**Type:**	float(5,2)	**Not Required**
	Units:	psi	**Range:**	-999.99 - 999.99	
	Description:	Oil pressure engine #3			
	Example:	87.22			

115	**Field:**	eng_4_oil_press	**Type:**	float(5,2)	**Not Required**
	Units:	psi	**Range:**	-999.99 - 999.99	
	Description:	Oil pressure engine #4			
	Example:	87.22			

116	**Field:**	eng_1_oil_press_low_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Engine #1 low oil pressure warning.			
	Example:	no			

117	**Field:**	eng_2_oil_press_low_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Engine #2 low oil pressure warning.			
	Example:	no			

118	**Field:**	eng_3_oil_press_low_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Engine #3 low oil pressure warning.			
	Example:	no			

119	**Field:**	eng_4_oil_press_low_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Engine #4 low oil pressure warning.			
	Example:	no			

120	**Field:**	eng_1_oil_temp	**Type:**	float(6,3)	**Not Required**
	Units:	Degrees	**Range:**	-999.999 - 999.999	
	Description:	Engine #1 oil temperature			
	Example:	107.218			

121	**Field:**	eng_2_oil_temp	**Type:**	float(6,3)	**Not Required**
	Units:	Degrees	**Range:**	-999.999 - 999.999	
	Description:	Engine #2 oil temperature			
	Example:	107.218			

122	**Field:**	eng_3_oil_temp	**Type:**	float(6,3)	**Not Required**
	Units:	Degrees	**Range:**	-999.999 - 999.999	
	Description:	Engine #3 oil temperature			
	Example:	107.218			

123	**Field:**	eng_4_oil_temp	**Type:**	float(6,3)	**Not Required**
	Units:	Degrees	**Range:**	-999.999 - 999.999	
	Description:	Engine #4 oil temperature			
	Example:	107.218			

124	**Field:**	eng_1_overspeed_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Engine #1 overspeed warning.			
	Example:	no			

125	**Field:**	eng_2_overspeed_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Engine #2 overspeed warning.			
	Example:	no			

126	**Field:**	eng_3_overspeed_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Engine #3 overspeed warning.			
	Example:	no			

127	**Field:**	eng_4_overspeed_warning	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Engine #4 overspeed warning.			
	Example:	no			

128	**Field:**	eng_1_cht_l	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #1 Cylinder Head Temperature (CHT) for cylinder #1			
	Example:	204.11			

129	**Field:**	eng_1_cht_2	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #1 Cylinder Head Temperature (CHT) for cylinder #2			
	Example:	204.11			

130	**Field:**	eng_1_cht_3	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #1 Cylinder Head Temperature (CHT) for cylinder #3			
	Example:	204.11			

131	**Field:**	eng_1_cht_4	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #1 Cylinder Head Temperature (CHT) for cylinder #4			
	Example:	204.11			

132	**Field:**	eng_1_cht_5	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #1 Cylinder Head Temperature (CHT) for cylinder #5			
	Example:	204.11			

133	**Field:**	eng_1_cht_6	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #1 Cylinder Head Temperature (CHT) for cylinder #6			
	Example:	204.11			

134	**Field:**	eng_2_cht_1	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #2 Cylinder Head Temperature (CHT) for cylinder #1			
	Example:	204.11			

135	**Field:**	eng_2_cht_2	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #2 Cylinder Head Temperature (CHT) for cylinder #2			
	Example:	204.11			

136	**Field:**	eng_2_cht_3	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #2 Cylinder Head Temperature (CHT) for cylinder #3			
	Example:	204.11			

137	**Field:**	eng_2_cht_4	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #2 Cylinder Head Temperature (CHT) for cylinder #4			
	Example:	204.11			

138	**Field:**	eng_2_cht_5	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #2 Cylinder Head Temperature (CHT) for cylinder #5			
	Example:	204.11			

139	**Field:**	eng_2_cht_6	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #2 Cylinder Head Temperature (CHT) for cylinder #6			
	Example:	204.11			

140	**Field:**	eng_3_cht_1	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #3 Cylinder Head Temperature (CHT) for cylinder #1			
	Example:	204.11			

141	**Field:**	eng_3_cht_2	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #3 Cylinder Head Temperature (CHT) for cylinder #2			
	Example:	204.11			

142	**Field:**	eng_3_cht_3	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #3 Cylinder Head Temperature (CHT) for cylinder #3			
	Example:	204.11			

143	**Field:**	eng_3_cht_4	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #3 Cylinder Head Temperature (CHT) for cylinder #4			
	Example:	204.11			

144	**Field:**	eng_3_cht_5	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #3 Cylinder Head Temperature (CHT) for cylinder #5			
	Example:	204.11			

145	**Field:**	eng_3_cht_6	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #3 Cylinder Head Temperature (CHT) for cylinder #6			
	Example:	204.11			

146	**Field:**	eng_4_cht_1	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #4 Cylinder Head Temperature (CHT) for cylinder #1			
	Example:	204.11			

147	**Field:**	eng_4_cht_2	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #4 Cylinder Head Temperature (CHT) for cylinder #2			
	Example:	204.11			

148	**Field:**	eng_4_cht_3	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #4 Cylinder Head Temperature (CHT) for cylinder #3			
	Example:	204.11			

149	**Field:**	eng_4_cht_4	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #4 Cylinder Head Temperature (CHT) for cylinder #4			
	Example:	204.11			

150	**Field:**	eng_4_cht_5	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #4 Cylinder Head Temperature (CHT) for cylinder #5			
	Example:	204.11			

151	**Field:**	eng_4_cht_6	**Type:**	float(5,2)	**Not Required**
	Units:	Degrees F	**Range:**	-999.99 - 999.99	
	Description:	Engine #4 Cylinder Head Temperature (CHT) for cylinder #6			
	Example:	204.11			

152	**Field:**	eng_1_egt_1	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #1 Exhaust Gas Temperature (EGT) cylinder #1			
	Example:	200.31			

153	**Field:**	eng_1_egt_2	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #1 Exhaust Gas Temperature (EGT) cylinder #2			
	Example:	200.31			

154	**Field:**	eng_1_egt_3	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #1 Exhaust Gas Temperature (EGT) cylinder #3			
	Example:	200.31			

155	**Field:**	eng_1_egt_4	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #1 Exhaust Gas Temperature (EGT) cylinder #4			
	Example:	200.31			

156	**Field:**	eng_1_egt_5	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #1 Exhaust Gas Temperature (EGT) cylinder #5			
	Example:	200.31			

157	**Field:**	eng_1_egt_6	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #1 Exhaust Gas Temperature (EGT) cylinder #6			
	Example:	200.31			

158	**Field:**	eng_2_egt_1	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #2 Exhaust Gas Temperature (EGT) cylinder #1			
	Example:	200.31			

159	**Field:**	eng_2_egt_2	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #2 Exhaust Gas Temperature (EGT) cylinder #2			
	Example:	200.31			

160	**Field:**	eng_2_egt_3	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #2 Exhaust Gas Temperature (EGT) cylinder #3			
	Example:	200.31			

161	**Field:**	eng_2_egt_4	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #2 Exhaust Gas Temperature (EGT) cylinder #4			
	Example:	200.31			

162	**Field:**	eng_2_egt_5	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #2 Exhaust Gas Temperature (EGT) cylinder #5			
	Example:	200.31			

163	**Field:**	eng_2_egt_6	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #2 Exhaust Gas Temperature (EGT) cylinder #6			
	Example:	200.31			

164	**Field:**	eng_3_egt_1	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #3 Exhaust Gas Temperature (EGT) cylinder #1			
	Example:	200.31			

165	**Field:**	eng_3_egt_2	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #3 Exhaust Gas Temperature (EGT) cylinder #2			
	Example:	200.31			

166	**Field:**	eng_3_egt_3	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #3 Exhaust Gas Temperature (EGT) cylinder #3			
	Example:	200.31			

167	**Field:**	eng_3_egt_4	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #3 Exhaust Gas Temperature (EGT) cylinder #4			
	Example:	200.31			

168	**Field:**	eng_3_egt_5	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #3 Exhaust Gas Temperature (EGT) cylinder #5			
	Example:	200.31			

169	**Field:**	eng_3_egt_6	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #3 Exhaust Gas Temperature (EGT) cylinder #6			
	Example:	200.31			

170	**Field:**	eng_4_egt_1	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #4 Exhaust Gas Temperature (EGT) cylinder #1			
	Example:	200.31			

171	**Field:**	eng_4_egt_2	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #4 Exhaust Gas Temperature (EGT) cylinder #2			
	Example:	200.31			

172	**Field:**	eng_4_egt_3	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #4 Exhaust Gas Temperature (EGT) cylinder #3			
	Example:	200.31			

173	**Field:**	eng_4_egt_4	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #4 Exhaust Gas Temperature (EGT) cylinder #4			
	Example:	200.31			

174	**Field:**	eng_4_egt_5	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #4 Exhaust Gas Temperature (EGT) cylinder #5			
	Example:	200.31			

175	**Field:**	eng_4_egt_6	**Type:**	float(6,2)	**Not Required**
	Units:	Degrees F	**Range:**	-9999.99 - 9999.99	
	Description:	Engine #4 Exhaust Gas Temperature (EGT) cylinder #6			
	Example:	200.31			

176	**Field:**	yaw_trim_surface_position	**Type:**	float(6,4)	**Not Required**
	Units:	Degrees	**Range:**	-99.9999 - 99.9999	
	Description:	Rudder trim surface position, negative denotes left, positive denotes right			
	Example:	-4.1092			

177	**Field:**	roll_trim_surface_position	**Type:**	float(6,4)	**Not Required**
	Units:	Degrees	**Range:**	-99.9999 - 99.9999	
	Description:	Roll trim surface position, negative denotes left, positive denotes right			
	Example:	6.7884			

178	**Field:**	brake_pressure_system_1	**Type:**	float(8,4)	**Not Required**
	Units:	psi	**Range:**	0 - 9999.9999	
	Description:	Brake pressure system #1			
	Example:	74.2187			

179	**Field:**	brake_pressure_system_2	**Type:**	float(8,4)	**Not Required**
	Units:	psi	**Range:**	0 - 9999.9999	
	Description:	Brake pressure system #2			
	Example:	74.2187			

180	**Field:**	brake_pressure_system_3	**Type:**	float(8,4)	**Not Required**
	Units:	psi	**Range:**	0 - 9999.9999	
	Description:	Brake pressure system #3			
	Example:	74.2187			

181	**Field:**	brake_pedal_application_left	**Type:**	float(8,4)	**Not Required**
	Units:	Degrees	**Range:**	0 - 9999.9999	
	Description:	Left side brake pedal application.			
	Example:	22.1237			

182	**Field:**	brake_pedal_application_right	**Type:**	float(8,4)	**Not Required**
	Units:	Degrees	**Range:**	0 - 9999.9999	
	Description:	Right side brake pedal application.			
	Example:	22.1237			

183	**Field:**	sideslip_angle	**Type:**	float(8,4)	**Not Required**
	Units:	Degrees	**Range:**	-9999.9999 - 9999.9999	
	Description:	Angle of sideslip as recorded (not derived), negative denotes left, positive denotes right.			
	Example:	-2.1659			

184	**Field:**	eng_1_bleed_valve_position	**Type:**	float(8,4)	**Not Required**
	Units:	Degrees	**Range:**	0 - 9999.9999	
	Description:	Amount of opening in bleed valve, engine 1. 0 denotes fully closed.			
	Example:	13.8772			

185	**Field:**	eng_2_bleed_valve_position	**Type:**	float(8,4)	**Not Required**
	Units:	Degrees	**Range:**	0 - 9999.9999	
	Description:	Amount of opening in bleed valve, engine 2. 0 denotes fully closed.			
	Example:	13.8772			

186	**Field:**	eng_3_bleed_valve_position	**Type:**	float(8,4)	**Not Required**
	Units:	Degrees	**Range:**	0 - 9999.9999	
	Description:	Amount of opening in bleed valve, engine 3. 0 denotes fully closed.			
	Example:	13.8772			

187	**Field:**	eng_4_bleed_valve_position	**Type:**	float(8,4)	**Not Required**
	Units:	Degrees	**Range:**	0 - 9999.9999	
	Description:	Amount of opening in bleed valve, engine 4. 0 denotes fully closed.			
	Example:	13.8772			

188	**Field:**	deicing_system_selection*	**Type:**	tinyint(2)	**Not Required**
	Units:	NA	**Range:**	0 - 99	
	Description:	Selection of onboard de-icing.			
	Example:	3			

189	**Field:**	computed_cg	**Type:**	float(9,4)	**Not Required**
	Units:	Inches aft of datum	**Range:**	-99,999.9999 - 99,999.9999	
	Description:	Computed CG as recorded (not derived).			
	Example:	64.9992			

190	**Field:**	ac_bus_1_status	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"powered", "not powered"	
	Description:	AC Bus #1 status.			
	Example:	powered			

191	**Field:**	ac_bus_2_status	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"powered", "not powered"	
	Description:	AC Bus #2 status.			
	Example:	powered			

192	**Field:**	ac_bus_3_status	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"powered", "not powered"	
	Description:	AC Bus #3 status.			
	Example:	powered			

193	**Field:**	ac_bus_4_status	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"powered", "not powered"	
	Description:	AC Bus #4 status.			
	Example:	powered			
194	**Field:**	dc_bus_1_status	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"powered", "not powered"	
	Description:	DC Bus #1 status.			
	Example:	powered			

195	**Field:**	dc_bus_2_status	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"powered", "not powered"	
	Description:	DC Bus #2 status.			
	Example:	powered			

196	**Field:**	dc_bus_3_status	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"powered", "not powered"	
	Description:	DC Bus #3 status.			
	Example:	powered			

197	**Field:**	dc_bus_4_status	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"powered", "not powered"	
	Description:	DC Bus #4 status.			
	Example:	powered			

198	**Field:**	system_1_volts	**Type:**	float(5,2)	**Not Required**
	Units:	Volts	**Range:**	0 - 999.99	
	Description:	Electrical system #1 voltage.			
	Example:	27.21			

199	**Field:**	system_2_volts	**Type:**	float(5,2)	**Not Required**
	Units:	Volts	**Range:**	0 - 999.99	
	Description:	Electrical system #2 voltage.			
	Example:	27.21			

200	**Field:**	system_1_amps	**Type:**	float(5,2)	**Not Required**
	Units:	Amps	**Range:**	0 - 999.99	
	Description:	Electrical system #1 amperage.			
	Example:	27.21			

201	**Field:**	system_2_amps	**Type:**	float(5,2)	**Not Required**
	Units:	Amps	**Range:**	0 - 999.99	
	Description:	Electrical system 2 amperage.			
	Example:	27.21			

202	**Field:**	apu_bleed_valve_position	**Type:**	float(8,4)	**Not Required**
	Units:	Degrees	**Range:**	0 - 9999.9999	
	Description:	Amount of opening in APU bleed valve. 0 denotes fully closed.			
	Example:	13.8772			

203	**Field:**	hydraulic_1_pressure	**Type:**	float(8,4)	**Not Required**
	Units:	psi	**Range:**	0 - 9999.9999	
	Description:	Hydraulic pressure system #1.			
	Example:	82.1117			

204	**Field:**	hydraulic_2_pressure	**Type:**	float(8,4)	**Not Required**
	Units:	psi	**Range:**	0 - 9999.9999	
	Description:	Hydraulic pressure system #2.			
	Example:	82.1117			

205	**Field:**	hydraulic_3_pressure	**Type:**	float(8,4)	**Not Required**
	Units:	psi	**Range:**	0 - 9999.9999	
	Description:	Hydraulic pressure system #3.			
	Example:	82.1117			

206	**Field:**	hydraulic_4_pressure	**Type:**	float(8,4)	**Not Required**
	Units:	psi	**Range:**	0 - 9999.9999	
	Description:	Hydraulic pressure system #4.			
	Example:	82.1117			

207	**Field:**	loss_cabin_pressure	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Loss of cabin pressure indication.			
	Example:	no			

208	**Field:**	fms_failure	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	FMS failure detected.			
	Example:	no			

209	**Field:**	hud_status	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Heads-up display (HUD) status.			
	Example:	no			

210	**Field:**	synthetic_vision_display_status	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Synthetic Vision System (SVS) status.			
	Example:	no			

211	**Field:**	paravisual_display_status	**Type:**	enum	**Not Required**
	Units:	NA	**Range:**	"no", "yes"	
	Description:	Paravisual display status.			
	Example:	no			

212	**Field:**	pitch_trim_control_selection	**Type:**	float(8,4)	**Not Required**
	Units:	Degrees	**Range:**	-9999.9999 - 9999.9999	
	Description:	Pitch trim selection from flight deck, negative denotes down trim, positive denotes up trim.			
	Example:	-3.1117			

213	**Field:**	roll_trim_control_selection	**Type:**	float(8,4)	**Not Required**
	Units:	Degrees	**Range:**	-9999.9999 - 9999.9999	
	Description:	Roll trim selection from flight deck, negative denotes left trim, positive denotes right trim.			
	Example:	-1.2761			

214	**Field:**	yaw_trim_control_selection	**Type:**	float(8,4)	**Not Required**
	Units:	Degrees	**Range:**	-9999.9999 - 9999.9999	
	Description:	Yaw trim selection from flight deck, negative denotes left trim, positive denotes right trim.			
	Example:	6.1276			

215	**Field:**	trailing_edge_flap_position	**Type:**	float(8,4)	**Not Required**
	Units:	Degrees	**Range:**	-9999.9999 - 9999.9999	
	Description:	Trailing edge device actual control surface position.			
	Example:	6.1276			

216	**Field:**	leading_edge_flap_position	**Type:**	float(8,4)	**Not Required**
	Units:	Degrees	**Range:**	-9999.9999 - 9999.9999	
	Description:	Leading edge device actual control surface position.			
	Example:	6.1276			

217	**Field:**	spoiler_position	**Type:**	float(8,4)	**Not Required**
	Units:	Degrees	**Range:**	0 - 9999.9999	
	Description:	Spoiler actual control surface position.			
	Example:	15.0081			
218	**Field:**	spoiler_selection	**Type:**	float(8,4)	**Not Required**
	Units:	Degrees	**Range:**	-9999.9999 - 9999.9999	
	Description:	Spolier selection from flight deck.			
	Example:	14.9823			

8.2 Appendix B

Table 1

Data Architecture of DJI Telemetry Recording (.DAT) Files for Modern Platforms

Prefix	Name	Description	Freq (HZ)	Derive	UAS Unique?
General	Tick#	Internal bus clock	Varies	No	
	relativeHeight	Meters. Altitude above Home Point	10	No	
	absoluteHeight	Meters. Populated if the Home Point Elevation has been set.	200	Yes	
	flightTime	Milliseconds. Can be used to sync with .txt log files. I.e., HealthyDrones, DJI Go App, Litchi	10	No	
	gpsHealth	[0 -5] 5 is a measure of the FC's confidence in the lat, long coords that are computed from the GPS and IMU data	200	No	
	vpsHeight	Meters. Height from VPS sensor. Blank if VPS height isn't valid.	200	No	
	flyCState	Duplicate of flyCState field in the .txt file. Manual, Atti, Atti_CL, Atti_Hover, Hover, GPS_Blake, GPS_Atti, GPS_CL, GPS_HomeLock, GPS_HotPoint, AssitedTakeoff, AutoTakeoff, AutoLanding,AttiLangding,NaviGo, GoHome, ClickGo, Joystick, Atti_Limited, GPS_Atti_Limited, NaviMissionFollow, NaviSubMode_Tracking, NaviSubMode_Pointing, PANO, Farming, FPV, SPORT, NOVICE, FORCE_LANDING, TERRAIN_TRACKING, NAVI_ADV_GOHOME, NAVI_ADV_LANDING, TRIPOD_GPS, TRACK_HEADLOCK, ASST_TAKEOFF, GENTLE_GPS,OTHER	10	No	Yes

flycCommand	AUTO_FLY, AUTO_LANDING, HOMEPOINT_NOW, HOMEPOINT_HOT, HOMEPOINT_LOC, GOHOME, START_MOTOR, STOP_MOTOR, Calibration, DeformProtecClose, DeformProtecOpen, DropGohome, DropTakeOff, DropLanding, DynamicHomePointOpen, DynamicHomePointClose, FollowFunctioonOpen, FollowFunctionClose, IOCOpen, IOCClose, DropCalibration, PackMode, UnPackMode, EnterManaualMode, StopDeform), DownDeform, UpDeform, ForceLanding, ForceLanding2, OTHER			Yes
flightAction	NONE, WARNING_POWER_GOHOME, WARNING_POWER_LANDING, SMART_POWER_GOHOME, SMART_POWER_LANDING, LOW_VOLTAGE_LANDING, LOW_VOLTAGE_GOHOME, SERIOUS_LOW_VOLTAGE_LANDIN G, RC_ONEKEY_GOHOME, RC_ASSISTANT_TAKEOFF, RC_AUTO_TAKEOFF, RC_AUTO_LANDING, APP_AUTO_GOHOME, APP_AUTO_LANDING, APP_AUTO_TAKEOFF, OUTOF_CONTROL_GOHOME, API_AUTO_TAKEOFF, API_AUTO_LANDING, API_AUTO_GOHOME, AVOID_GROUND_LANDING, AIRPORT_AVOID_LANDING, TOO_CLOSE_GOHOME_LANDING, TOO_FAR_GOHOME_LANDING,AP P_WP_MISSION, WP_AUTO_TAKEOFF, GOHOME_AVOID, GOHOME_FINISH, VERT_LOW_LIMIT_LANDING, BATTERY_FORCE_LANDING, MC_PROTECT_GOHOME	10	No	Yes
nonGPSCause	Duplicate of nonGPS_Cause field in the .txt file. A value other than	10	No	

		ALREADY means a "compass error". Other possible values are FORBIN, GPSNUM_NONENOUGH), GPS_HDOP_LARGE, GPS_POSITION_NONMATCH, SPEED_ERROR_LARGE, YAW_ERROR_LARGE, COMPASS_ERROR_LARGE, UNKNOWN			
	connectedToRC	Connected, NotConnected	10	No	Yes
	gpsUsed	True/False. GPS is used by FC to compute horizontal velocity	10	No	
	visionUsed	True/False. Vision system is used by FC to compute horizontal velocity	10	No	
IMU_ATTI(IMU#)	Longitude	degrees. Computed by the FC from GPS, Accelerometer, and Gyro data.Blank until valid.	200	No	
	Latitude		200	No	
	numSats				
	barometer:Raw	Meters. Raw data from barometer.	200	No	
	barometer:Smooth	Meters. Smoothed barometer data	200	No	
	accel:<Axis>	Meters/second. Acceleration along the X, Y and Z axes	200	No	
	accel:Composite	Meters/second. sqrt (accelX**2 + accelY**2 + accelZ**2)	200	Yes	
	gyro:<Axis>	Degrees/second. Rotation about the X, Y and Z axes	200	No	
	gyro:Composite	sqrt(gyroX**2 + gyroY**2 + gyroZ**2)	200	Yes	
	mag:<Axis>		50	No	
	mag:Mod	sqrt(magX**2 + magY**2 +magZ**2)	50	Yes	
	Vel:<North, East, Down>	Meters/second. Velocity North, East, Down	200	No	
	velComposite	Meters/sec. Velocity. Sqrt(velN*velN + velE*velE +velD*velD)	200	Yes	
	velH	Meters/sec. Horizontal velocity. Sqrt(velN*velN + velE*velE)	200	Yes	

GPS-H	Meters/second. Difference between velocity computed from successive GPS coordinates and horizontal velocity computed from IMU sensors(Vel:Horizontal).	200	Yes
quat<W,X, Y, Z>	Quaternion	200	No
roll	Degrees. Note, the yaw value will be corrected for geomagnetic declination after GPS data is valid. I.e. Yaw will be true and not magnetic.	200	Yes
pitch		200	Yes
yaw		200	Yes
yaw360	Degrees. Range 0 -360.	200	Yes
totalGyro:<Axis>	Degrees. Integration and summation of Gyro:<Axis>. Can be used to compute Gyro:<Axis> error. Also useful for checking roll, pitch, and yaw values coming from Flight Controller.	200	Yes
magYaw	Yaw value computed from magnetometers and corrected with pitch and roll. Not the same as Yaw which comes from the Flight Controller.	200	Yes
Yaw-magYaw		200	Yes
distanceHP		200	Yes
distanceTravelled	Meters. Computed from successive latitude/longitude coordintes	1	Yes
directionOfTravel[mag]	Degrees. Range = [-180,180]. Computed from successive latitude/longitude coordinates. Not corrected with local geomagnetic declination. I.e. value can be compared against P3 yaw.	1	Yes
directionOfTravel[true]	Degrees. Range = [-180,180]. Computed from successive latitude/longitude coordinates. Corrected with local geomagnetic declination. I.e. value can not be compared against P3 yaw.	1	Yes
temperature	IMU temp. Steady state = 65 C	200	No
ag_<Axis>		200	No

	gb_<Axis>		200	No	
Battery	lowVoltage	lowVoltage warning; 1 = warning, 0 = normal	1	No	
	status	OK, NotReady, Commerror, VolVeryLow, VolNotSafe	1	No	
Battery(Batt#)	cellVolts<Cell#>		1	No	
	current		1	No	
	totalVolts		1	Yes	
	Temp	Celcius	1	No	
	battery%				
	FullChargeCap	Battery Full Charge Capacity	1	No	Yes
	RemainingCap	Battery Remaining Capacity	1	No	Yes
	voltSpread	maximum cell voltage - minimum cell voltage	1	Yes	
	watts		1	Yes	
	minCurrent	Minimum Current since Battery On	1	Yes	Yes
	maxCurrent	Maximum Current since Battery On	1	Yes	Yes
	avgCurrent	Average Current since Battery On	1	Yes	Yes
	minVolts	Minimum totalVolts since Battery On	1	Yes	Yes
	maxVolts	Maximum totalVolts since Battery On	1	Yes	Yes
	avgVolts	Average totalVolts since Battery On	1	Yes	Yes
	minWatts	MinimumWatts since Battery On	1	Yes	Yes
	maxWatts	Maximum Watts since Battery On	1	Yes	Yes
	avgWatts	Average Watts since Battery On	1	Yes	Yes
BattInfo	Vol		50	No	
	Current		50	No	
	remainingTime		50	No	Yes
	CellVol		50	No	Yes
	LowVolThreshold		50	No	Yes
	BatVol		50	No	

	BatCurrent		50	No	
	FullChargeCap		50	No	
	Remaining%		50	No	
	BatTemp		50	No	
	BatDataCnt		50	No	
	OriginalCap		50	No	
	Ad_v		50	No	
	r_time		50	No	
	AvgCurrent		50	No	
	vol_t		50	No	
	Pack_ve		50	No	
	RemainingCap		50	No	
	Temp		50	No	
	right		50	No	
	l_cell		50	No	Yes
	dyna_cnt		50	No	
	FullCap		50	No	
	out_ctl		50	No	
	out_ctl_f		50	No	
SMART_BATT	goHome%	percentage at which a go home will be requested	1	No	Yes
	land%	percentage at which landing will be requested	1	No	Yes
	goHomeTime	time at which a go home will be requested	1	No	Yes
	landTime	time at which landing will be requested	1	No	Yes
	voltage%	current battery percentage			
	Status	OK, NotReady, Commerror, VolVeryLow, VolNotSafe	1	No	Yes
	GHStatus	None, GoHome, GoHomeAlready	1	No	Yes
Controller	gpsLevel	Same as General:gpsHealth. Useful when looking at a tablet .DAT	50	No	

	ctrl_level	Unknown, maybe a gpsHealth for the RC	50	No	
GPS(gps#)	Long	Degrees. May not be valid if DOP is large.	5	No	
	Lat	Degrees. May not be valid if DOP is large.	5	No	
	Date	Integer that contains date, e.g. 20171003 means 2017-10-03 GMT	5	No	
	Time	Integer that contains time, e.g. 100334 means 10:03:34 GMT	5	No	
	dateTime	DateTime in ISO-8601 format. Not available in CsvView	5	No	
	heightMSL	Meters, Height above mean sea level	5	No	
	hDOP	Horizontal dilution of precision. Units unknown.	5	No	
	pDOP	Position dilution of precision. Units unknown.	5	No	
	sAcc	Some kind of accuracy measure.			
	numGPS	Number of GPS satellites	5	No	
	numGLNAS	Number of GLONAS satellites	5	No	
	numSV	Total number of satellites	5	No	
	vel:<North, East, Down>	Meters/second. Velocity North, East, Down	200	No	
HP	Longitude	Coordinates of Home Point. Obtained from eventLog. Altitude is set by A/C to be 20 meters higher than the barometric altitude.	N/A	No	Yes
	Latitude		N/A	No	Yes
	Altitude		N/A	No	Yes
	rthHeight	meters	N/A	No	Yes
IMUEX(imu#)	vo_v<Axis>		200		
	vo_p<Axis>		200		
	us_v		200		
	us_p		200		

	vo_flag_Navi		200	
	cnt		200	
	rtk_Longitude		200	
	rtk_Latitude		200	
	rtk_Alti		200	
	err	None, SPEED_LARGE_ERROR, GPS_YAW_ERROR, MAG_YAW_ERROR, GPS_CONSIST_ERROR, US_FAIL_ERROR	200	
Motor	Speed:<motor>	Actual Motor Speed. RPM.	50	No
	EscTemp:<motor>	ESC temperature, not motor temperature	50	No
	PPMrecv:<motor>		50	No
	V_out:<motor>		50	No
	Volts:<motor>		50	No
	Current:<motor>		50	No
	Status:<motor>	0 = Normal, other values unknown	50	No
	PPMsend:<motor>			
	thrustAngle	Degrees. Computed from motor speeds. Direction the A/C is being pushed by the motors. Relative to the A/C, not the inertial frame.	200	Yes
MotorCtrl	Status	0 = Normal, other values unknown	50	No
	PWM:<motor>	Pulse Width Modulation. Can be used to determine commanded motor speed. Range 0 - 100%	50	No
MotorPwrCalcs	Volts:Avg:<motor>		50	Yes
	Volts:Avg:All		50	Yes
	Current:Avg:<motor>		50	Yes
	Current:Avg:All		50	Yes
	Watts:Avg:<motor>		50	Yes
	Watts:Avg:All		50	Yes
	WattSecs:<motor>		50	Yes

	WattSecs:All		50	Yes
	WattSecs/Dist:<motor>		50	Yes
	WattSecs/Dist:All		50	Yes
	WattSecs/TotalDist:<motor>		50	Yes
	WattSecs/TotalDist:All		50	Yes
	Watts/VelH:<motor>		50	Yes
	Watts/VelH:All		50	Yes
	Watts/VelD:<motor>		50	Yes
	Watts/VelD:All		50	Yes
MVO	vel<Axis>		10	No
	pos<Axis>		10	No
	hoverPointUncertainty1		10	No
	hoverPointUncertainty2		10	No
	hoverPointUncertainty3		10	No
	hoverPointUncertainty4		10	No
	hoverPointUncertainty5		10	No
	hoverPointUncertainty6		10	No
	velocityUncertainty1		10	No
	velocityUncertainty2		10	No
	velocityUncertainty3		10	No
	velocityUncertainty4		10	No
	velocityUncertainty5		10	No
	velocityUncertainty6		10	No
	height		10	No
	heightUncertainty		10	No
OA	avoidObst		10	No
	emergBrake	Off, On	50	No

	radiusLimit		10	No
	airportLimit		10	No
	groundForceLanding		10	No
	horizNearBoundary		10	No
	vertLowLimit		10	No
	vertAirportLimit		10	No
	roofLimit		10	No
	hitGroundLimit		10	No
	frontDistance		10	No
RC	Aileron	Range [-10000, 10000] Neutral = 0. Stick left or down = -10000. Stick right or up = 10000.	50	No
	Elevator		50	No
	Rudder		50	No
	Throttle		50	No
	ModeSwitch	P, Sport	50	No
	sigStrength	Percentage based on the number of valid frames per unit time. I.e., not an RF measurement.	50	Yes
	failSafe	Hover, Landing, GoHome, Unknown	50	No
	dataLost	"", lost	50	No
	appLost	"", lost	50	No
	connected	Connected, Disconnected	50	No
InertialOnlyCalcs(imu#)	Vel:<North, East, Down>	Meters/sec^2. Velocity	200	Yes
	Pos:<North, East, Down>	Meters. Position relative to HP.	200	Yes
	ag:<North, East, Down>	Meters/sec^2. Acceleration relative to ground.	200	Yes
	aB:<North, East, Down>	Meters/sec^2. Acceleration relative to AC.	200	Yes
	getVelN() - vgX	Difference between velocity computed by IMU and velocity computed here	200	Yes
	getVE() - vgY		200	Yes

	getVd() - vgZ		200	Yes
Mag(mag#)	<Axis>	Magnetometer values for each group of magnetometers. The AC uses just one group at a time with group 0 being the default.	50	No
	Mod		50	Yes
	magYaw		50	Yes
	Yaw-magYaw		50	Yes
	raw<Axis>	Raw magnetometer data. See the eventLog stream for the scale and bias values used to compute the above values.	50	No
	rawMod		50	Yes
AirComp	AirSpeedBody:X	These fields aren't fully understood.	5	No
	AirSpeedBody:Y		5	No
	Alti		5	No
	VelNorm		5	No
	VelTime:1		5	No
	VelTime:2		5	No
	VelLevel		5	No
	WindSpeed		5	No
	Wind:X		5	No
	Wind:Y		5	No
	MotorSpeed		5	No
	WindHeading	Computed from some of above values.	5	Yes
	WindMagnitude		5	Yes
	WindMagnitude:2		5	Yes
AirCraftCondition	int_fsm		50	No
	last_fsm		50	No
	UP_state		50	No
	safe_fltr		50	No
	launch_acc_dur		50	No

launch_free_fall_dur	50	No
launch_free_fall_delta_v	50	No
thrust	50	No
gyro	50	No
land_dur_press	50	No
land_dur_sonic	50	No
thrust_body	50	No
thrust_gnd	50	No
thrust_gnd_compen	50	No
safe_tilt_raw	50	No
sat_timer	50	No
fsmState	50	No
landState	50	No
UP_acc_t	50	No
UP_TF_t	50	No
craft_flight_mode	50	No
launch_acc_duration	50	No
launch_delta_v	50	No
launch_state	50	No
thrust_proj_gnd	50	No
thrust_proj_gnd_compen	50	No
thrust_compensator	50	No
hover_thrust	50	No
dynamic_thrust	50	No
cos_safe_tilt	50	No
safe_tilt	50	No
nearGround	50	No
gyro_acc	50	No
land_dur	50	No

Table 2

Data Architecture of DJI Telemetry Recording (.DAT) Files for Phantom 3 / Inspire 1 Platforms

Name	**Description**	**Freq (HZ)**	**Derived**	**UAS Unique**
tickNo	P3 internal bus clock	600	No	
offSetTime	See User Manual	200	Yes	
longitude	degrees. Converted from radians	200	No	
latitude	degrees. Converted from radians	200	No	
numSats	Number of Satellites	N/A	No	
gpsHealth	0 - 5. 5 is best condition.	N/A	No	
baroRaw	Meters. Raw data from barometer.	50	No	
baroAlt	Meters. Smoothed barometer data	200	No	
vpsHeight	Meters. Height from VPS sensor. Blank if VPS height isn't valid (generally > 3 meters above ground)	200	No	
accelX	Meters/second. Acceleration along the X, Y and Z axes	200	No	
accelY		200	No	
accelZ		200	No	
accel	Meters/second. sqrt (accelX**2 + accelY**2 + accelZ**2)	200	Yes	
gyroX	Degrees/second. Rotation about the X, Y and Z axes	200	No	
gyroY		200	No	
gyroZ		200	No	
gyro	sqrt(gyroX**2 + gyroY**2 + gyroZ**2)	200	Yes	
errorX	Precise description unknown. Probably an error term representing the difference between the measured and predicted orientation	200	No	
errorY		200	No	
errorZ		200	No	
error	sqrt (errorX**2 + errorY**2 +errorZ**2)	200	Yes	

magX		50	No
magY		50	No
magZ		50	No
magMod	sqrt(magX**2 + magY**2 +magZ**2)	50	Yes
quatW	Quaternion. The orientation of the P3. QuatW is the scalar. (QuatX, QuatY, QuatZ) is the vector part. See https://en.wikipedia.org/wiki/Quaternion	200	No
quatX		200	No
quatY		200	No
quatZ		200	No
Roll	Degrees. Computed from the Quaternion above. Note, the yaw value appears to be corrected for geomagnetic declination; I.e. yaw is true and not magnetic.	200	Yes
Pitch		200	Yes
Yaw		200	Yes
Yaw360	Degrees. Range 0 -360.	200	Yes
totalGyroZ	Degrees. Integration and summation of gyroZ . Can be used to compute gyroZ drift.	200	Yes
magYaw	Yaw value computed from magnetometers and corrected with pitch and roll. Not the same as Yaw which comes from the Flight Controller.	200	Yes
thrustAngle	Degrees. Computed from motor speeds. Direction the A/C is being pushed by the motors. Relative to the A/C, not the inertial frame.	200	Yes
velN	Meters/second. Velocity North, East, Down	200	No
velE		200	No
velD		200	No
vel	Meters/sec. Speed. Sqrt(velN*velN + velE*velE +velD*velD)	200	Yes
velH	Meters/sec. Horizontal speed. Sqrt(velN*velN + velE*velE)	200	Yes

velGPS-velH	Meters/second. Difference between velocity computed from successive GPS coordinates and velocity computed from IMU sensors(velH).	200	Yes	
homePointLongitude	Coordinates of Home Point. Obtained from eventLog. Altitude is set by A/C to be 20 meters higher than the barometric altitude.	N/A	No	Yes
homePointLatitude		N/A	No	Yes
homePointAltitude		N/A	No	Yes
geoMagDeclination	degrees	N/A	Yes	Yes
geoMagInclination	degrees. Down is positive, up is negative	N/A	Yes	Yes
distanceHP	Meters. Distance from Home Point	200	No	Yes
distanceTraveled	Meters. Computed from successive latitude/longitude coordintes	1	Yes	Yes
relativeHeight	Meters. Altitude above Home Point	10	No	Yes
flightTime	Milliseconds. Can be used to synch with .txt log files. I.e., HealthyDrones, DJI Go App, Litchi	10	No	
directionOfTravel	Degrees. Range = [-180,180]. Computed from successive latitude/longitude coordinates. Corrected with local geomagnetic declination. I.e. value can be compared against P3 yaw.	1	Yes	
directionOfTravelTrue	Degrees. Range = [-180,180]. Computed from successive latitude/longitude coordinates. Not corrected with local geomagnetic declination. I.e. value can not be compared against P3 yaw.	1	Yes	
Control:Aileron	Range [-10000, 10000] Neutral = 0. Stick left or down = -10000. Stick right or up = 10000.	50	No	
Control:Elevator		50	No	
Control:Throttle		50	No	
Control:Rudder		50	No	
Control:ModeSwitch	2=P, 1=A, 0=F, 4 = remote control switched off	50	No	

flightMode	Derived from eventLog. Deprecated, use flyCState below. 1 = ATTI, 2 = GPS_ATTI. Removed in version 2.2.8 and later	N/A	Yes
flightMode.string			
flightRegime	Derived from eventLog. Deprecated, use flyCState below. 1 = engineStart, 2 = asstTakeOff, 3 = autoTakeOff, 4 = autoLanding. Removed in version 2.2.8 and later	N/A	Yes
flightRegime.string			
navMode	Derived from eventLog. Deprecated, use flyCState below. 1 = goHome, 2 = waypoint, 3 = folowMe, 4 = hotPoint. Removed in version 2.2.8 and later	N/A	Yes
navMode.string			
flyCState	Duplicate of flyCState field in the .txt file. Manual(0), Atti(1), Atti_CL(2), Atti_Hover(3), Hover(4), GPS_Blake(5), GPS_Atti(6), GPS_CL(7), GPS_HomeLock(8), GPS_HotPoint(9), AssitedTakeoff(10), AutoTakeoff(11), AutoLanding(12), AttiLangding(13), NaviGo(14), GoHome(15), ClickGo(16), Joystick(17), Atti_Limited(23), GPS_Atti_Limited(24), Follow_Me(25),OTHER(100);	10	No
flyCState:String			
nonGPSCause	Duplicate of nonGPS_Cause field in the .txt file. ALREADY(0), FORBIN(1), GPSNUM_NONENOUGH(2), GPS_HDOP_LARGE(3), GPS_POSITION_NONMATCH(4), SPEED_ERROR_LARGE(5), YAW_ERROR_LARGE(6), COMPASS_ERROR_LARGE(7), UNKNOWN(8);	10	No
nonGPSCause:String			

DW flyCState	Dashware helper. Maps values in flyCState to a different set of values. Manual(1), Atti(2), Atti_CL(3), Atti_Hover(4), Hover(5), GPS_Blake(6), GPS_Atti(7), GPS_CL(8), GPS_HomeLock(9), GPS_HotPoint(20), AssitedTakeoff(30), AutoTakeoff(40), AutoLanding(50), AttiLangding(60), NaviGo(70), GoHome(80), ClickGo(90), Joystick(200), Atti_Limited(300), GPS_Atti_Limited(400), Follow_Me(500),OTHER(600);	10	Yes
connectedToRC	0 = not connected, 1 = connected	10	No
Current	Amps	1	No
Volt1	Cell voltages. Volt5 and Volt6 will be blank unless the A/C is an Inspire.	1	No
Volt2		1	No
Volt3		1	No
Volt4		1	No
Volt5		1	No
Volt6		1	No
totalVolts		1	No
voltSpread	maximum cell voltage - minimum cell voltage	1	No
Watts	toltalVolts * Current	1	Yes
minCurrent	Minimum Current since Battery On	1	Yes
maxCurrent	Maximum Current since Battery On	1	Yes
avgCurrent	Average Current since Battery On	1	Yes
minVolts	Minimum totalVolts since Battery On	1	Yes
maxVolts	Maximum totalVoltssince Battery On	1	Yes
avgVolts	Average totalVolts since Battery On	1	Yes
minWatts	MinimumWatts since Battery On	1	Yes
maxWatts	Maximum Watts since Battery On	1	Yes
avgWatts	Average Watts since Battery On	1	Yes
batteryTemp	Celcius	1	No
ratedCapacity	maH	N/A	No

remainingCapacity	maH		1	No	
percentageCapacity			1	No	
percentageVolts			1	No	
batteryStatus	UserBatteryReqGoHome(1), UserBatteryReqLand(2), SmartBatteryReqGoHome(4), SmartBatteryReqLand(8), MainVoltageLowGoHOme(16), MainVoltageLowLand(32), BatteryCellError(64), BatteryCommunicateError(128), VoltageLowNeedLand(256), BatteryTempVoltageLow(512), BatteryNotReady(1024), BatteryFirstChargeNotFull(2048), BatteryLimitOutputMax(4096), BatteryDangerous(8192), BatteryDangerousWarning(16384)		1	No	Yes
batteryGoHomeStatus	NON_GOHOME(0), GOHOME(1), GOHOME_ALREADY(2)		1	No	Yes
batteryGoHome	percentage at which a go home will be requested by the smart battery		1	No	Yes
usefulTime	seconds		1	No	Yes
batteryCycles		N/A		No	
batteryLife		N/A		No	
batteryBarCode	Bar Code visible on battery	N/A		No	

MotorCmnd:RFront	Commanded Motor Speed. Range 0 - 10000.		50	No	
MotorCmnd:LFront			50	No	
MotorCmnd:LBack			50	No	
MotorCmnd:Rback			50	No	
MotorSpeed:RFront	Actual Motor Speed. RPM. Blank for P3 Standard which doesn't report motor speed.		50	No	
MotorSpeed:LFront			50	No	
			50	No	
MotorSpeed:Rback			50	No	
MotorLoad:RFront	Motor Load. Blank for P3 Standard which doesn't report motor loads.		50	No	

MotorLoad:LFront		50	No
MotorLoad:LBack		50	No
MotorLoad:Rback		50	No
Gimbal:Roll	Degrees. Orientation of gimbal with respect to P3. I.e. not absolute orientation	50	No
Gimbal:Pitch		50	No
Gimbal:Yaw		50	No
Gimbal:XRoll	Degrees. Related to Gimbal and A/C orientation. Precise relationship unknown	50	No
Gimbal:XPitch		50	No
Gimbal:XYaw		50	No
tabletLongitude	Degrees. Non blank only during a Follow Me mission using the DJO Go App	15	No
tabletLatitude		15	No

Table 3

Data Architecture of Telemetry Recording Files for Yuneec Platforms

Prefix	**Name**	**Description**	**Format**	**Derive**	**UAS Unique**
Teleme try	Date / Time	Date / time including milliseconds	JJJJMMTT hh:mm:ss:zzz; poor=>2s; reasonable=600ms-2s	No	
	fsk_rssi	Received Signal Strength Indication from copter's receiver	dBm, poor=>85, reasonable=70-85, good=55-70, very good<55	suppos ed	Yes
	voltage	Voltage off light accu	V	No	
	current	Current of flight accu, if sensor available (not for Q500 or Typhoon H)	dA	suppos ed for H920	
	altitude	Ascent relative to starting point	m	No	
	latitude	Latitude - GPS coordinates of copter	decimal degrees	No	

longitude	Longitude - GPS coordinates of copter	decimal degrees	No	
tas	True Air Speed, Speed of the aircraft, computed from GPS coordinates I guess. So it is groundspeed, not really TAS	m/s	No	
gps_used	GPS usage (true/false)	boolean	No	
fix_type	GPS Fix Type	?	?	
satelites_num	Number of detected satellites	number	No	
roll	Roll	*	supposed	
yaw	Gier	*	supposed	
pitch	Nick	*	supposed	
motor_status	Motor Status, bitwise. Motor numbers according to the picture in the GUI		supposed	
imu_status	IMU Status (intertial meassurement unit)	bits	supposed	
gps_status	GPS unit status	bits	supposed	
cgps_used	C-GPS (unknown meaning)	?		
press_compass_status	Sensor Status (Barometer/Magnetometer)	bits	supposed	
f_mode	Code for different flight modes	code	No	
gps_pos_used	GPS position used (true, false)	boolean	No	
vehicle_type	Copter Type	1=Yunnec H920 2=Yuneec Q500 3=Blade 350QX 4=Blade Chroma (380QZ) 5=Yuneec Typhoon H	No	Yes

	error_flags1	Error flags, sum bitwise	0=ERROR_FLAG_VOLTAGE_WARNING1 1=ERROR_FLAG_VOLTAGE_WARNING2 2=ERROR_FLAG_MOTOR_FAILSAFE_MODE 3=ERROR_FLAG_COMPLETE_MOTOR_ESC_FAILURE 4=ERROR_FLAG_HIGH_TEMPERATURE_WARNING 5=ERROR_FLAG_COMPASS_CALIBRATION_WARNING 6=ERROR_FLAG_FLYAWAY_CHECKER_WARNING 7=ERROR_FLAG_AIRPORT_WARNING	No
	gps_accH	Horicontal GPS accuracy. Seems to be HDOP	HDOP, poor=>2.5, reasonable=1.8-2.5, good=1-1.8, very good=<1	supposed
Remote GPS	Date / Time	Date / Time including miliseconds	JJJJMMTT hh:mm:ss:zzz	No
	lon	Longitude - GPS coordinates of ground station	decimal degrees	No
	lat	Latitude - GPS coordinates of ground station	decimal degrees	No
	alt	Height from GPS relative to sea level	m	supposed
	accuracy	Accuracy of GPS	?	
	speed	Speed, unknown source (maybe computed from GPS coordinates, unknown unit	?	
	angle	Angle of moving direction to north	*	supposed

Remote	Date / Time	Date / Time including miliseconds	JJJJMMTT hh:mm:ss:zzz	No	
	CH0	Channel 1: J1 throttle/ascent (thr)	0=Motor start/stop (B3) 2048=neutral	No	
	CH1	Channel 2: J4 roll (ail)	2048=neautral	No	
	CH2	Channel 3: J3 nick (ele)	2048=neautral	No	
	CH3	Channel 4: J2 yaw (rud)	2048=neautral	No	
	CH4	Channel 5: S4 Flight mode	3412=Smart 2048=Angle 683=RTH	No	
	CH5	Channel 6: A02 - RTH	2048=neutral 4095=RTH	No	Yes
	CH6	Channel 7: K2 Camera Tilt	683=horizontal (0 deg) 3413=vertical down (-90 deg)	No	Yes
	CH7	Channel 8: K1 Camera pan		No	Yes
	CH8	Channel 9: S1 Gimbal Tilt Mode	A=2184, V=3412	No	
	CH9	Channel 10: S2 Gimbal Pan Mode	F=683, Center=1502, G=3412	supposed	
	CH10	Channel 11: S5 Landegestell	0.0=up 1.0=down	No	
	CH11	Channel 12: A08			
	CH12	Channel 13: A09			
	CH13	Channel 14: A10			
	CH14	Channel 15: A11			
	CH15	Channel 16: A12			
	CH16	Channel 17: A13			
	CH17	Channel 18: A14			
	CH18	Channel 19: A15			
	CH19	Channel 20: A16			
	CH20	Channel 21: A17			
	CH21	Channel 22: A18			
	CH22	Channel 23: A19			
	CH23	Channel 24: A20			
f_mode	0	FMODE_BLUE_SOLID	Stability mode (Blue Solid)		
	1	FMODE_BLUE_FLASHING	Blue flashing		

2	FMODE_BLUE_WOULD_BE_SOLID_NO_GPS	Blue, no GPS	
3	FMODE_PURPLE_SOLID	Angle mode (Purple solid)	
4	FMODE_PURPLE_FLASHING	Purple flashing	
5	FMODE_PURPLE_WOULD_BE_SOLID_NO_GPS	Angle mode (Purple solid) - no GPS	
6	FMODE_SMART	Smart mode	
7	FMODE_SMART_BUT_NO_GPS	Smart mode - no GPS	
8	FMODE_MOTORS_STARTING	Motor starting	
9	FMODE_TEMP_CALIB	Temperature calibration	
10	FMODE_PRESS_CALIB	Pressure calibration	
11	FMODE_ACCELBIAS_CALI	Accelerator calibration	
12	FMODE_EMERGENCY_KILLED	Emergency/killed	
13	FMODE_GO_HOME	RTH coming	
14	FMODE_LANDING	RTH landing	
15	FMODE_BINDING	Binding	
16	FMODE_READY_TO_START	Initializing, Ready to start	
17	FMODE_WAITING_FOR_RC	Waiting for RC	
18	FMODE_MAG_CALIB	Magnetometer calibration	
19	FMODE_UNKNOWN	Unknown mode	
20	FMODE_RATE	Agility mode (Rate)	
21	FMODE_FOLLOW	Smart mode - follow me	
22	FMODE_FOLLOW_NO_GPS	Smart mode - follow me - no GPS	
23	FMODE_CAMERA_TRACKING	Smart mode - camera tracking	Yes
24	FMODE_CAMERA_TRACKING_NO_GPS	Camera tracking - no GPS	Yes
26	FMODE_TASK_CCC	Task Curve Cable Cam	
27	FMODE_TASK_JOUR	Task Journey	
28	FMODE_TASK_POI	Task Point of Interest	
29	FMODE_TASK_ORBIT	Task Orbit	
32		Indoor Positioning System	