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JET AIRCRAFT DATA ACQUISITION SYSTEMS

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Abstract

The article presents systems, which record parameters of flight in modern aircraft F-16, which was delivered to Polish Airforce in 2006. With the current level of technical development of the aviation industry, data acquisition systems are an important element of all aircrafts. These systems are responsible for the flight safety, allow reading and storing the most important flight parameters, and combined with digital control and safety systems allow to counteract dangerous situations, which especially can happen often in the case of military aircraft such as the F-16 due to their combat purpose. Systems records basics parameters of plane and engine, as specific fuel consumption or height of flight provides video and audio recording, and aerial combat assistance. These systems record even failures of a braking system during landing. Thanks to modern technology, and devices like those described in this article, F-16 is one of the best fighters in the world. The amount of data provided by analogue and digital sensors is so large that it requires the partitioning of parameters and use of several basic recorders of the entire system is the unit called DAU, or Data Acquisition Unit, which records the most important flight parameters, such as flight time, engine speed, or altitude.

Keywords: *aircraft, safety, jet engine, aviation*

1. Introduction

With the current level of technical development of the aviation industry, data acquisition systems are an important element of all aircrafts. These systems allow to read and storage the most important flight parameters, and combined with digital control and safety systems allow to counteract dangerous situations, which especially can happen often in the case of military aircraft such as the F-16 (Fig. 1) due to their combat purpose.

Fig. 1. F-16 during take-off [7]

The amount of data provided by analogue and digital sensors is so large that it requires the partitioning of parameters and use of several basic recorders, which will be listed in chapter 2. Each of the recorders has a specific task, i.e. data processing or storage, and processes certain parameters, e.g. Engine Monitoring System is responsible for data obtained from a turbine jet engine. The heart of the entire system is the unit called DAU, or Data Acquisition Unit, which records the most important flight parameters, such as flight time, engine speed, or altitude.

2. Modern jet fighter data types

Data Acquisition System consists of two units that contain solid-state non-volatile memory: DAU (Data Acquisition Unit) and Enhanced Crash Survivable Memory Unit.

The DAU (Fig. 2) use the following interfaces to acquire date:

- Aircraft analogue and discrete sensors connected to DAU,
- MIL-STD-1553B Avionics Multiplex Bus (AMUX) data (BMUX, Left CMUX, Right CMUX and DMUX are connected to the DAU but currently not used),
- Two serial channels from Digital Flight Control Computer (DFLCC),
- One RS-422 serial communication channel for the Digital Electronic Engine Control (DEEC),
- One audio channel connected to the aircraft intercommunication system.

Fig. 2. Data Acquisition Unit [2]

The DAU contains data Types 2, 3, and 4 for service life monitoring and engine usage data and also Type 5 data for avionics health diagnostics data. The DAU's memory capacity is such that time history data of data type 3 and 4 from at least 30 hours is stored. Approximately 20 hours of Type 5 data is stored in DAU memory. The DAU is not crash hardened.

Type 2 data contains individual aircraft tracking data in terms of normal acceleration, gross weight, number of landing gear extensions and retractions, number of landings, number of flights, total flight time, and number of flights with conformal fuel tanks. This data is generally not useful for mishap investigations.

Type 3 data consists of continuously measured parameters, also discrete measured parameters, mux parameters and calculated parameters:

- Engine RPM,
- Longitudinal Stick Force,
- Leading Edge flap position,
- Main Landing Gear Weight on Wheels (WOW, discrete parameter),
- Mach Number (MUX),
- Dynamic Pressure (calculated parameter).

Type 3 data is primarily used for the collection of structural loads data. In the event that any of the parameters from AMUX massages are identified as being invalid, unlike Type 1 data, the last valid values of those parameters shall be used for continued Type 3 data processing until next

valid value is received. Data is recorded based on peak/valley search algorithms and on the occurrence of specific events:
- Take-off,
- Landing,
- Peak/valley of longitudinal acceleration,
- Landing Gear Down Command.

Type 4 data consists of measured analogue and calculated parameters that are important for monitoring engine usage, for e.g.:
- Throttle position,
- Fuel flow, due to control flow data systems it provides to proper formation of flame in combustion chamber [3],
- Mach number,
- The angle of attack,
- Temperatures in the compressor, combustion chamber, turbine, exhaust nozzle, and afterburner, to prevent overheating, but also to decrease the production of NOx and other toxic substances in regular flight [6].

Type 5 data is a copy of Type 1 flight data recorded internally to the DAU. Only parametric data is recorded in Type 5; audio data is not stored in Type 5. All of Type 1 detailed recording requirements for parametric data are applicable to Type 5 data, except that the data is stored in the DAU.

3. Modern jet fighter data types

The Enhanced Crash Survivable Memory Unit (Fig. 3) houses non-volatile memory that contains what is called Type 1 data. This data consists of a discrete event, analogue parameters and audio that has been recorded for the primary purpose of mishap investigation. Recording normally starts when the main generator comes on line after ground engine start. Recording normally stops on engine shutdown after the flight. The crash protected memory is sized to record approximately 30 hours of parametric data and approximately six hours of audio data.

Fig. 3. Enhanced Crash Survivable Memory Unit [3]

Due to the time required for signal transmissions and processing, the DAS cannot store data up to the very instant of impact or power loss. Approximately ½ second of data is in the accumulation and processing phase and will not be obtainable.

In the case of data stored in ESCMU, there is protected data. Data recorded for 30 seconds following take-off (WOW) are protected from overwriting until the protected memory space is full. The take-off event is called the baseline event. Some other selected events are protected from overwriting; these events are called special events. Protected memory space is available for approximately five baseline events. The oldest one will be overwritten by the latest event data. ECSMU data is presented in Tab. 1.

Tab. 1. Continuous parameters recorded by ECSMU

Label [Unit label]	Parameter	Frequency [Hz]	Resolution
Eng N1 Fan [%RPM]	N1 RPM	2	0.5% RPM
Flt NormG Nz [G]	Normal Accel (Nz)	8	0.1 G
Eng N2 Core [%RPM]	N2 RPM	2	0.5% RPM
Thrott Angle [(EPLA) deg]	Engine power lever angle (EPLA)	4	1.5º

Discrete signals recorded in Type 1 are recorded with a frequency equal to 16 Hz. All signals except FLCS RESET and VALID WEAPONS RELEASE have a two-sample filter applied (filtered discrete) before the change of state is recorded in crash protected memory. A filtered discrete signal must maintain its new state for two consecutive samples before the new state is recorded. Valid state changes for the discrete signals FLCS RESET and VALID WEAPON RELEASE are recorded in crash protected memory upon detection of the new change of state.

Serial data from the Engine Diagnostic Unit (EDU) received by the DAU and recorded in Type 1 data on an interrupt basis. Tab. 2 shown examples of parameters, which recorded by DAU, from EDU, such as exhaust nozzle position and burner pressure, which allows predicting flow structure on the outflow of the nozzle [1]. The DAU receives on an interrupt basis the same serial data from Digital Flight Control Computer that is recorded in the Flight Control System Seat Data Recorder. Periodic records are made every 15 seconds beginning with the weight off either main landing gear on take-off and continuing until 7 seconds after weight on both main landing gear on landing. Untimed recordings can be triggered by events such as flight control systems failures or change in state of the landing gear handle, weight on wheels switches, air-refuelling door. The data is recorded in Type 1 data. Examples of the data recorded from DFLCC are shown in Tab. 3.

Tab. 2. Parameters from EDU

Label	Scale	Unit	Description
AJ	130	%	Exhaust Nozzle Position
MOP	256	Psid	Oil pressure
N1	18000	RPM	Low rotor speed
N2	18000	RPM	High rotor speed
TAS	2048	Knots	True airspeed
PB	650	PSIA	Burner pressure
ALPHA	180	Degrees	Angle of Attack
MACH	3	–	Mach number

Tab. 3. Parameters send by DFLCC

Label	Scale	Unit	Description
Obs Warn	0=OFF | 1=ON	–	Obstacle warning
Rudder Pos	0.2555	Degrees	Surface position RUDPOS (+=Left)
Pitch Att	1.40625	Degrees	Pitch attitude (+=Nose up)

In the Data Acquisition System, there is also Active Maintenance Fault List (MFL) Data. DAS records at last 16 active MFLs in Type 1 data. The listing of active MFLs from the Modular

Mission Computer (MMC) is sampled twice per second and is recorded at least every ten minutes and also when a Baseline Event occurs. New unique MFLs that occur between the ten-minute minimum update intervals are recorded as soon as the DAU receives information from MMC. The time of the first occurrence is DAS time, not MMC time.

Audio data is recorded in ECSMU by DAS, in Type 1 data only. The audio records consist of radio and interphone communications and also tones and voice messages generated by aircraft systems.

ECSMU is equipped with an emergency beacon, which automatically activates upon immersion in water. When activated, the unit produces a 35.7 kHz; 160.5 dB acoustical signal for a minimum of 30 days.

EMS – Engine Monitoring System is made by some cooperating devices:

- Built-on engine:
  a) DEEC (Digital Electronic Engine Control),
  b) EDU (Engine Diagnostic Unit);
- Assistance devices for engine monitoring system:
  a) EMMS, Engine Monitoring and Management System,
  b) EMATS, Engine Monitoring and Tracking System.

EDU stores data from engine and sensors built on aircraft in six categories:

- Documentary Data,
- Time Cycle Data (e.g. Engine Operating Time),
- Error codes,
- Event Data/Maintenance Data (recording starts in the case of engine failure, e.g. angle of attack at the event, core speed at the event),
- Transient data (recorded with 8 s before and 2 s after the event or after pilot demand),
- Performance data (recorded during take-off and landing).

4. Conclusion

With the development of aviation, it has become evident to use high reliable safety monitoring systems. Such systems can be found today in almost every aircraft, no matter whether it is a glider or a large airliner. In the case of combat aircraft such as F-16 or MiG-29, which can carry weapons, it is important that there no adverse events that can lead to disaster and losses. Particularly dangerous situations that are prevented by data recording systems are blocking of the weaponry, too little or no fuel flow or activation of hydrazine-fuelled backup installation [4], which is particularly dangerous for the civilian population if such failure occurred over the city. These systems detect failures before they lead to dangerous situations [5], thus reducing losses to a minimum and often allowing the pilot to make an emergency landing that can take place without loss.

References

[1] Bartoszewicz, J., Kłosowiak, R., Bogusławski, L., *The analysis of the flow structure in a jet at variable geometry of the reverse chamber*, International Journal of Heat and Mass Transfer, Vol. 55, 11, pp. 3239-3245, 2012.

[2] GE Aviation, *GE Aviation's Data Aquisition System: the next generation data and recording system, Grand Rapids,* https://www.geaviation.com/sites/default/files/DAS-datasheet.pdf.

[3] Jójka, J., Ślefarski, R., *Dimensionally reduced modeling of nitric oxide formation for premixed methane-air flames with ammonia content*, Fuel, Vol. 217, pp. 98-105, 2018.

[4] Satkowski, W., *Gospodarka materiałami niebezpiecznymi w bazach lotnictwa wojskowego w zmiennych warunkach działania*, rozprawa doktorska, Politechnika Poznańska, Poznan 2016.

[5] Trelka, M., *Monitorowanie uszkodzeń zespołu napędowego w zmiennych warunkach działania samolotu MiG-29*, rozprawa doktorska, Politechnika Poznańska, Poznan 2016.
[6] Urbaniak, R., Bartoszewicz, J., Kłosowiak, R., *Main causes of NOx emissions by low-power boilers*, Polish Journal of Enviromental Studies, Vol. 24, 5, pp. 2223-2230, 2015.
[7] http://www.poznan.pl/mim/info/news/60-lecie-polskich-skrzydel-na-krzesinach,73293.html, access 12.10.2017.

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