SOLID STATE FLIGHT DATA RECORDERS

AND THEIR APPLICATION IN THE FLIGHT OPERATION ANALYSIS

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Abstract

The paper describes a family of solid state flight data recorders. These SSFDR replace the optomechanical recorders used on-board of civil and military aircraft.
The data recorder consists of three components: the interface unit, the digital flight data acquisition unit and the memory.

Different computer-based ground station systems for the processing of the collected airborne data will be presented.

The evaluation program SIROM enables fast automatic data processing and the display of graphics for detailed analysis. Following the requirements on modern diagnostic programs the TEMES analysis program was developed. TEMES has three display and analysis features, there is the view of the aircraft instrument panel, the reconstructed flight trajectory and graphics of selected parameters can be shown in parallel on two high resolution monitors.

1. INTRODUCTION

The family of fully electronic solid state flight data recorders (SSFDR) and a computerized display and evaluating system (DAR-2, SIROM and TEMES) have been designed primary to replace the soviet made opto-mechanical and digital recorders used on-board of a series of civil and military aircraft.

There exist six versions of the SIROM SSFDR covering the requirements of the different types of aircraft.

In addition to the parameters recorded by the updated system the acquisition of further signals became feasible. The construction of SIROM satisfies the requirements of crash FDR's.

For a fast and high quality evaluation of the recorded flight data and engine parameters a computer based ground station system was developed. Different programs are available for data readout, detailed flight analysis and engine diagnostics.

2. DESCRIPTION OF THE SIROM SSFDR

2.1. Recorded data

The recorder is able to accept 12 analog and 12 two-state signals. For the different type of aircraft these channels are used for the recording of the corresponding input signals. For example in the SIROM-H-24 helicopter version the channels are designed as follows:

ANALOG SIGNALS

Channel	Parameter	Sampling frequency
1.	Altitude	1/sec
2.	Air speed	1/sec
3.	Pitch	2/sec
4.	Rotor RPM	2/sec
5.	Roll	1/sec
6.	Rotor position	2/sec
7.	Engine temp (right)	1/sec
8.	Engine temp (left)	1/sec
9.	Compressor RPM (right)	1/sec
10.	Compressor RPM (left)	1/sec
11.	Controller pos.(longit.)	2/sec
12.	Vertical acceleration	2/sec

TWO-STATE SIGNALS

Channel	Parameter	Sampling frequency(*)
1.	Low hydraulic pressure	10/sec
2.	Low booster pressure	10/sec
3.	Fire control	10/sec
4.	Low fuel	10/sec
5.	Left engine vibration	10/sec
6.	Right engine virbration	10/sec
7.	Altitude (barometer/radio)	10/sec
8.	Low engine oil press (left)	10/sec
9.	Low engine oil press.(right)	10/sec
10.	Low reductor oil pressure	10/sec
11.	IN-IR switch position	10/sec
12.	Gun trigger	10/sec

(*) The state of the input signals isrecorded once a second

The recording capacity for the different SIROM versions are 1.5 - 2.5 hours.

2.2. Internal elements

The recorder consists of three units :

- Interface,
- Data processor,
- Memory cassette.

The Interface unit

All signals are isolated from the electrical ground and from one another to achieve high common-mode noise suppression. Each channel has a wide bandwidth input filter network against differential mode noise. All analog channels have their own analog-to-digital converter generating serial data streams.

In the version SIROM-V-75 six types of analog signal channels are used :

1. For resistive transducers; each channel is equipped with its high stability voltage reference (6V). The input impedance is high to reduce the noise of worn sensors.

2. For tachometer transducers; the three-phase AC voltage is rectified and filtered.

3. For current sources; in version V-75 the output of the radiometric altitude measuring equipment is connected to this channel.

4. For synchro transducers; the three--phase synchro signals are electronically transformed to resolver format then these signals are rectified by phase sensitive rectifiers synchronized by the on-board 400 Hz line. After digitalization the signals are fed into a microprocessor system which is common for two and more inputs (usually roll and pitch). The microcomputer calculates the angles based on the input information and sends these to the data processor unit in digital form.

5. For thermopair sensors; the low EMF of thermopair temperature sensors is amplified by a high stability amplifier and the signal is then digitized.

6. For engine vibration; the signal of a vibration pick up after amplification and filtering by an electronic bandpass filter, is fed to a rectifier. The rectified signal is digitized by the analog-to-digital converter.

Similar input sections are used in other versions of the Interface Unit.

The two-state inputs are also isolated and all channels have effective input protection and differential-mode filtering. An additional digital filtering is implemented in the Data Processor Unit for these signals.

All digital output lines are driven by low impedance driver circuits, so the maximum distance between the Interface and Data Processing Unit can be up to 15 m.

The main power supply is located in the Interface Unit. It produces isolated internal DC voltages for all circuits from the on-board 27 V supply. The efficiency of this switching power supply is very high to reduce internal dissipation and can operate with input voltages between 10 V and 40 V. Its special design ensures very high noise compression to avoid dropouts and disturbance on the internal voltages in case of noisy or unstable 27 V supply. The specification of the power supply exceeds the requirements of the applicable standards.

The Data Processing Unit

This device receives the digital output signals of the Interface Unit and converts these to the form which is required by the large capacity Memory Cassette for data storage.

The data are sent to the Memory Cassette in serial form. The data is arranged in blocks. The length of the blocks is between 96 and 272 bits depending on the specific application. Blocks are transferred to the memory with a rate of 1 block/sec. Each block begins with a start synchron word and every 16 bits of information have a parity bit. These are needed for the reconstruction of the serial data during evaluation.

The first block after power-up contains information about the aircraft (aircraft identifier) and some other housekeeping information. The next block is similar to the blocks generated under normal operating conditions but the inputs of the analog channels are connected to 50% full--scale reference voltage. The correct operation of the system can be tested prior to the evaluation by checking the recorded values of this second block. Beginning with the third block the true data recording commences.

The editing of the output blocks is performed by a microprocessor system. The microprocessor program is stored in an 8 Kb Read-Only Memory. The processor clock is produced by a high stability crystal oscillator which guarantees the exact timekeeping i.e. the precise time identification at the evaluation. A special "watch-dog" circuit restarts the processor following an occasional disturbance. The unit has a local switching type voltage regulator for the microprocessor circuit.

The Memory Cassette

The memory must be separated from the Data Processing Unit for data readout. The information stored in the memory must be retained during this time. This is assured by powering the semiconductor CMOS memories by rechargable batteries in the Cassette. During normal operation the batteries are charged by the internal DC voltages of the system.

The cassette contains a serial-to-parallel converter circuit since the data transfer takes place in serial form to the memory module. An address counter generates the correct address for the memory. This counter advanced by special signals from the Data Processor Unit. The address counter resets itself to zero when the address reaches the end of the memory (196 608). The design of the circuits makes it possible to disconnect or reconnect the cassette during operation without effecting the content of the memory.

The Memory Cassette is also equipped with a heating circuit which prevents the drop of the internal temperature of the cassette below 5° C.

The simplified block diagram of the Data Processor and the Memory Cassette is shown in Fig. 1.

2.3. Construction

Since this FDR has been designed primarily to replace the SARP-12 electro-optical data recorder, there was the requirement that its appearance had to be identical to the former system. The mechanical construction of the SIROM was designed corresponding to the requirements of crash recorders in order to increases the chance of survival of data in an event of a crash situation. The construction ensures protection against mechanical damage due to impact, fire damage and effects of chemicals and sea water for limited time.

3. READOUT AND EVALUATION SYSTEM

After landing the Memory Cassette has to removed from the Data Recorder Unit and placed on the data readout device connected to the IBM PC compatible computer.

3.1. General purpose evaluation program SIROM

The menu-driven general-purpose evaluation program realizes the following operations:

Data readout

The content of the cassette is transferred to the memory of the computer. Following a quick test of the Memory Cassette, the cassette is ready for reuse. This procedure takes about 35 seconds.

Fast evaluation

During this information analysis the take-off and landing times are identified, then the time durations of the different modes of operation of the engines are calculated. For all measured parameters the minimum and the maximum values are determined in different phases of the flight. If the parameters are between the preset limits the flight status "OK" is granted. In case of any deviation the

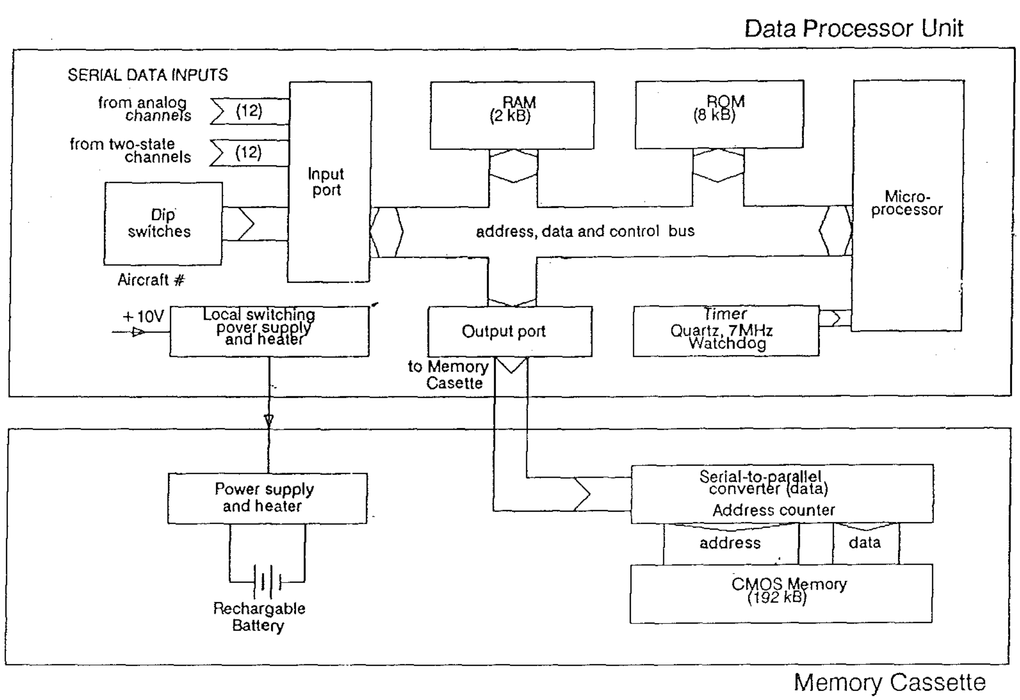

Fig.1. Simplified block diagramm of the data processor unit and memory casette

program displays the time and value of the abnormal parameter. (Fig.2)

Detailed analysis

The measured flight data and engine parameters are graphically displayed on the color screen, separately the 12 analog and the 12 two-state parameters. The time scale can be selected as desired. The curves can be scanned by a cursor across the screen, the time and the corrected and linearized values are digitally in physical dimensions also shown on the screen (Fig.3).

Calibration

Since the characteristics of the sensors are nonlinear or deviate from the ideal curve, the sensors have to be calibrated individually, usually during the periodical maintenance. The individual calibration data are stored in the evaluating computer. Before the evaluation the program identifies the aircraft by reading the aircraft identifier and uses the calibration data of the specific sensors for linearization and correction. The correct data can then be shown in physical dimensions (e.g. altitude in meters or feet, speed in km/h or knots etc.) after the evaluation. Fig. 4 shows the calibration curve for the airspeed sensor.

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Time of rec.  :  Jan 23 20:05:12 1990

Pilot's name         : LASZLO
Id. no. of plane     : 6145
Id. no. of mission   : 225
Number of takeoff    : 4
Comment ( 1 )     : 002
Comment ( 2 )        :
Comment ( 3 )        :

Engine op. times
Full time          :  59:24
Ground time        :  11:02
Airborn time       :  48:22
Air. time (mil.) :   1:31
Afterburner        :   0:33
Special eng. mode:   0:00

Airspeed maximum              :  800.00 km/h  16:45
Altitude maximum              :    4154 m     13:39
Engine n1 RPM maximum         :  100.00 %     15:54
Engine n2 RPM maximum         :   98.89 %      7:20
V. acceleration maximum       :    1.69 g     55:40
V. acceleration minimum       :    0.67 g     11:21

Rec. length  :  60:30
Takeoff      :     7:20   Landing      :  55:42
Engine start :     0:48   Eng. cutoff:  60:16
S-P-S on     :   54:19   Length       :  84 s
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Warning	Start	End	Length
Airspeed too low	52:57	53:01	0:05
Airspeed too low	53:11	53:25	0:15
Airspeed too low	53:33	53:46	0:14
Airspeed too low	53:52	53:57	0:06
Airspeed too low	54:03	54:07	0:05
Airspeed too low	54:14	54:18	0:05
Airspeed too low	54:30	55:01	0:32
n1 RPM too high	6:31	18:36	12:06
n1 RPM too high	19:05	23:30	4:26
n1 RPM too high	24:44	29:52	5:09
n1 RPM too high	29:54	29:59	0:06
n1 RPM too high	30:16	30:23	0:08
n1 RPM too high	30:41	30:54	0:14

Fig.2. The printed results of the fast evaluation

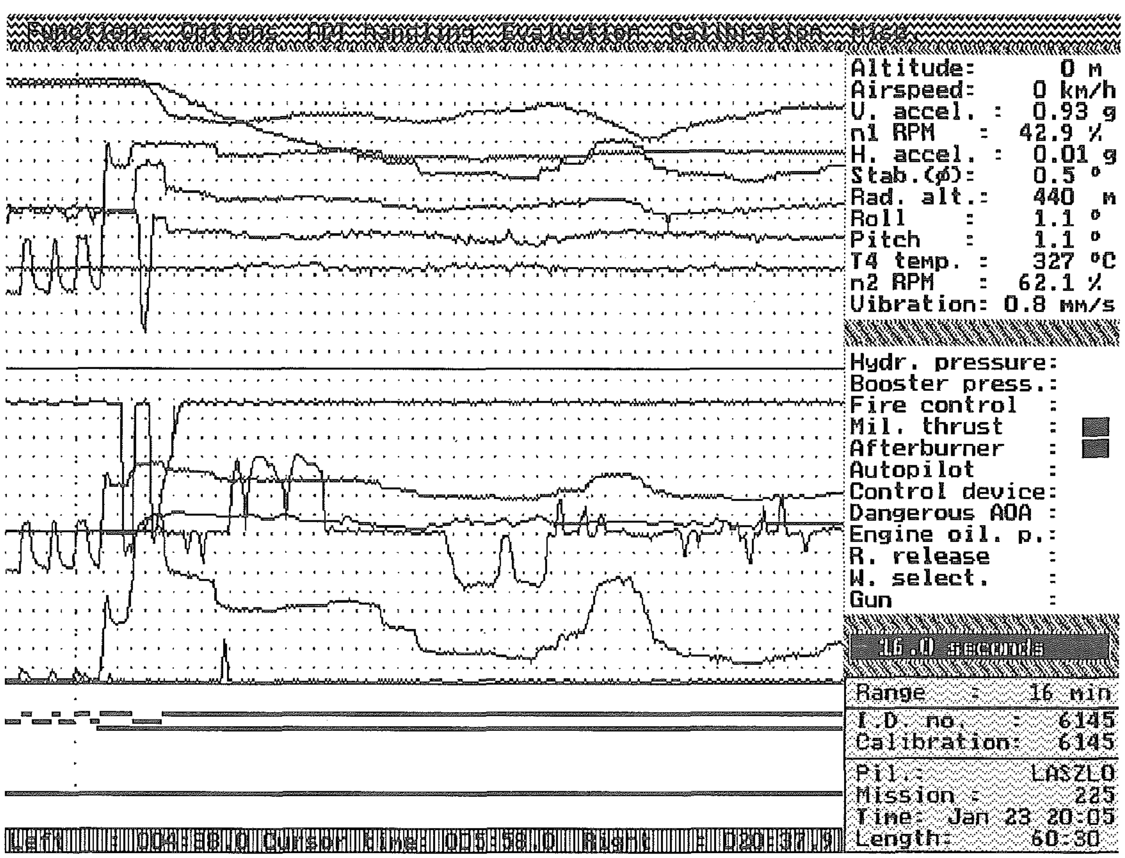

Fig.3. The measured flight data shown on the screen

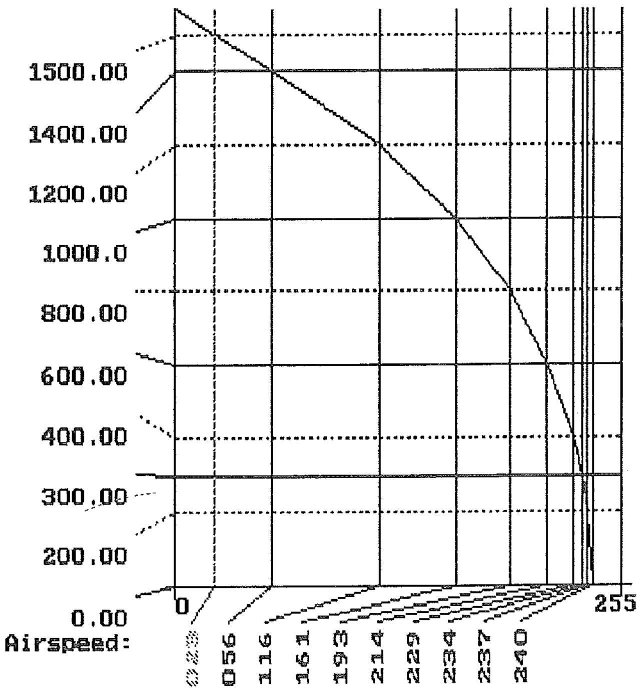

Fig.4. The calibration curve of the airspeed sensor

Data file handling

The flight data can be stored into disk files and reloaded by the program on request.

3.2. Advanced Flight Data Analysis Program TEMES

Based on our own and our customer's experience in the development of FDRs and flight data diagnostic programs the program TEMES has been developed. The main idea is to bring reality in the analysis process. General the analysis programs show the airborne data as curves. This display is suitable for technical staff. But pilots get a deeper feeling of the flight situation not by viewing the collected data, rather than to see a the instrument panel of the aircraft. In order to fit these requirements TEMES has three different display modes, shown in parallel on two high resolution monitors.

Instrument Panel Display

On a large 21" monitor the accurate representation of the aircraft's instrument panel is displayed.(Fig.5) Selecting this display mode, the flight data will be played-back on the instruments. This feature gives the pilot the real impression sitting in the aircraft and flying back the recorded flight. The play-back speed can be accelerated or slowed.

Trajectory Display

This display mode can be selected in parallel to the first one and gives a view

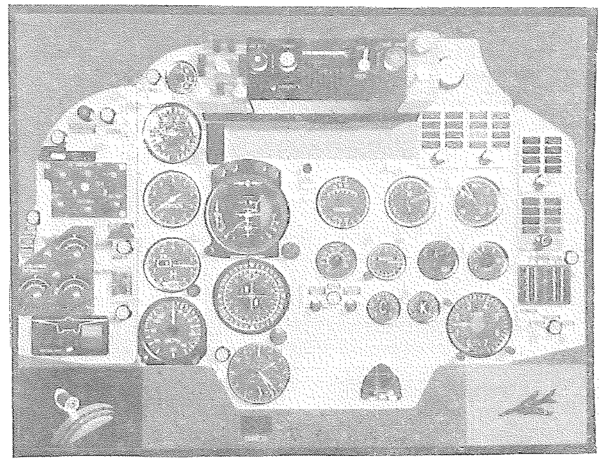

Fig.5. The instrument panel for replaying the recorded flight data on the screen

of the reconstructed flight trajectory. During the play-back process the position of the aircraft is shown by a small aircraft moving along the trajectory (Fig.6). There is the possibility to enlarge the displayed trajectory, to select the starting point of the play-back procedure and get the suitable view of the trajectory by a rotation around three axis.

Fig.6. The aircraft flight trajectory shown on the screen

Graphics display

Alternatively to the trajectory, but in parallel with the instrument panel the graphics of the flight data and engine parameters can be displayed (Fig.7). By choosing the parameters of interest this display mode gives the possibility for a very detailed step-by-step analysis. The program has the option of displaying the data in one or more windows. A zoom feature completes the graphics mode.

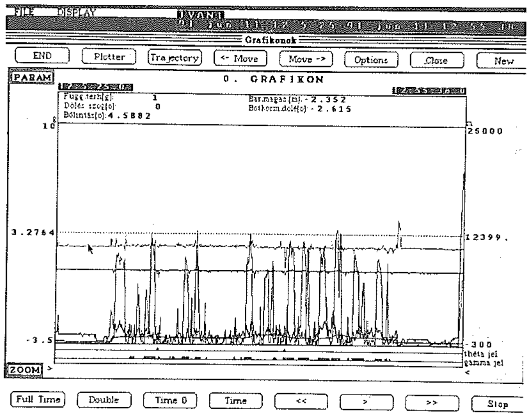

Fig.7. The flight data displayed by system TEMES

Application Fields

The different display modes for the flight analysis process makes the TEMES program to an ideal tool for the pilot training. Another field of application is the incident/accident analysis. The applied low-cost hardware of TEMES system and the user friendly software makes the system most attractive.

The present version is realized for an fighter aircraft and has been proved to be highly effective in operation by the Hungarian Air Forces. The module structure of the software guarantees an easy adapting to any other civil aircraft and any type of FDR.

4. RECORDING OF PHYSIOLOGICAL PARAMETERS

The most frequent reason for pilots loosing their license are heart diseases. Following the regular medical checks of the pilots remains sometimes a slight doubt about the fitness of the pilot under real flight conditions. In order to overcome this problem it seems to be necessary to record the pilot's physiological parameters during the flight.

The questions to be solved are the kind of parameters to record without interfering the pilot's activity, the type of recorder and the synchronization with the SIROM SSFDR.

During a study a SIROM-MEDICINE will be developed. The recorded parameters in this first version are :

- ECG,
- pulse rate,
- respiration rate,
- temperature,
- skin resistance.

The ECG measurement is assumed to be two-channels with 500 samples per second and 10..12 bit resolution. A real-time data reduction can reduces the amount of information. The SIROM-MEDICINE consists of an analog, a digital unit and the data memory. The memory is a solid state memory card with a capacity of 1-8 Mbyte.

During the evaluation procedure there is the possibility to access simultaneously both the physiological and the flight data and to observe the pilot's condition in dependence of the flight situations.

5. CONCLUSION

The demonstrated SIROM Flight data recorder is regularly applied since several years. The main advantages of this SSFDR over optical or magtape recorders are :

- significant improvement in reliability,
- periodic maintenance no longer required (no moving mechanical part),
- improved resistance to environments,
- add-on capability.

The fast, comfortable and flexible evaluation systems permits easy data analysis, engine diagnostics and increases the flight safety.

Improved medical investigations of the pilot's fitness are possible by the simultaneous usage of SIROM-SSFDR and SIROM-MEDICNE recorders.