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DIGITAL DATA ACQUISITION SYSTEM OF THE JAPANESE ANTARCTIC RESEARCH AIRCRAFT PILATUS PORTER PC-6

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Abstract: Digital Data Acquisition System of the Japanese Antarctic Research aircraft (JARDAS) was developed and installed on Pilatus Porter PC-6. JARDAS consists of 8 interfaces with the external navigational and observational devices, data processor and data cartridge. As for the 4 channels of analog devices, DC voltage outputs from the radar altimeter, atmospheric pressure transducer, thermometer and vertical-gyro system are analog-to-digital converted in the data processor. As for the 4 channels of digital devices, data from the ULF/omega receiver, GPS receiver, proton magnetometer and ice radar video pulse digitizer are selected, code-transformed and re-arranged to make one data block sequence. The one data block corresponds to 1 s sampling data, and consists of 1 byte of start mark, 150 bytes of 7-bit with even parity ASCII data for navigational and geomagnetic total intensity data, 658 bytes of binary data for ice radar video pulse waveform 1 and 2 bytes of end mark, which amounts to a total of 811 bytes. JARDAS can record 12 hrs' output data blocks continuously on one 450 ft (7700 bpi) 3-M type cartridge tape.

1. Introduction

For the last seven years, Japanese Antarctic Research Expedition (JARE) has been operating Pilatus Porter PC-6 aircraft for airborne surveys such as aerial photography, magnetic survey and radio-echo sounding. PC-6 had played an important role in glaciological and geophysical investigations over the Mizuho Plateau, Lützow-Holm Bay and the Yamato Mountains. PC-6 had, however, no integrated data recording system of both navigational and observational data controlled by a single system-clock. Data processing had, therefore, to be based on qualitative consideration of flight logs such as estimate time of elapse and others, when we assign geophysical coordinates to each observed value.

In order to obviate this inconvenience, we designed the Digital Data Acquisition System of the Japanese Antarctic Research aircraft PC-6 (JARDAS) and started operation in the 1985–1986 field season.

This article describes the constitution of JARDAS briefly. The performance estimation of JARDAS will need detailed data analyses of several test flights and field survey flights, and the results will be shown in a separate paper.

2. Outline of JARDAS

Figure 1 illustrates schematically the constitution of JARDAS. There are four

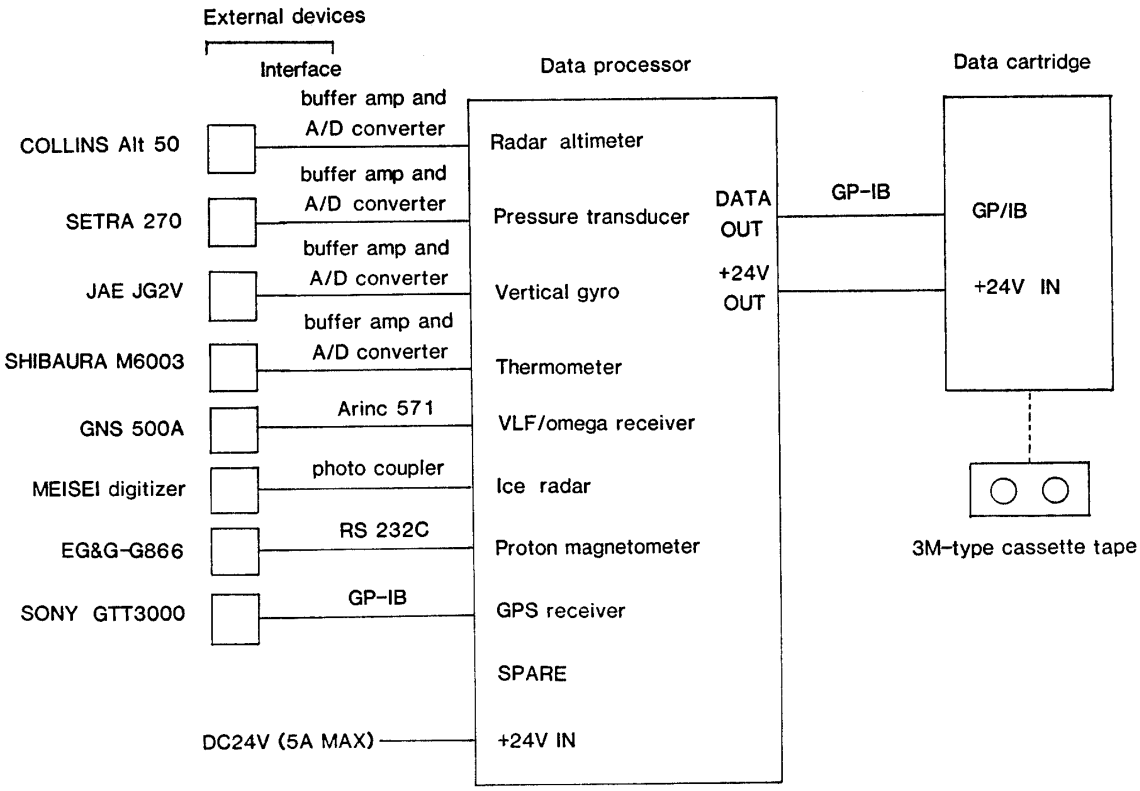

Fig. 1. System constitution of JARDAS.

devices of analog inputs; radar altimater, atmospheric pressure transducer, thermometer and vertical gyro system. There are four devices of digital inputs of different data codes and interfaces; VLF/omega receiver, GPS (Global Positioning System) receiver, proton magnetometer and ice radar video pulse digitizer. Analog inputs from the above four channels are digitized by the data processor. Digital inputs from the above four channels are code-transformed and re-arranged together with the A/D converted signals. The re-formatted 8-channel data are the output with the assigned 1 s interval time code to the data cartridge through the GP-IB interface bus. JARDAS can be operated directly by the DC28V aircraft battery within 140W power consumption. It should be noted that, though the data processor can handle the outputs from the proton magnetometer and ice radar video pulse digitizer simultaneously, a concurrent survey of the two devices cannot be made on PC-6 because of weight and space limit.

3. Interfacing with the External Devices

Table 1 summarizes the acquired signal items, used devices, interfaces and other specifications. Figure 2 shows front and rear views of JARDAS which are mounted on a specially-designed duralumin rack. Interfacing of JARDAS with the external devices is explained below.

Table 1. List of external devices, interfaces and signal processing.

Data item	Device	Model name	Signal form	Interface	Signal processing	Remark
Height above ground	Radar altimeter	COLLINS ALT-50	analog DC 0.4–16.4 V	buffer amp	8-bit A/D	0–762 m (0–2500 ft)
Height above sea level	Pressure transducer	SETRA MODEL 270	analog DC 0–5V	buffer amp	10-bit A/D	0–1.37×10^5 N/m^2 (0–20 psia)
Air temperature	Thermometer	SHIBAURA M6003	analog DC 0–5V	buffer amp	10-bit A/D	−50–50°C
Roll (Pitch) angle	Vertical-gyro	JAE JG2V	analog DC −10–10V	buffer amp	10-bit A/D	−90–90°
Latitude, longitude, heading	VLF/omega receiver	GNS MODEL 500A	digital BCD	ARINC571	code transform	1 s sampling
Latitude, longitude, height, heading, velocity, time	GPS receiver	SONY GTT3000	digital JIS	GP-IB	code transform	1 s sampling
Geomagnetic total force	Proton magnetometer	EG & G G866	digital ASCII	RS232C	data re-arrange	1 s sampling
Reflected radio-echo waves	Ice radar video pulse digitizer	MEISEI	digital TTL binary	Photo-coupler	data re-arrange	12.5 kHz digitizing 0.5 s sampling

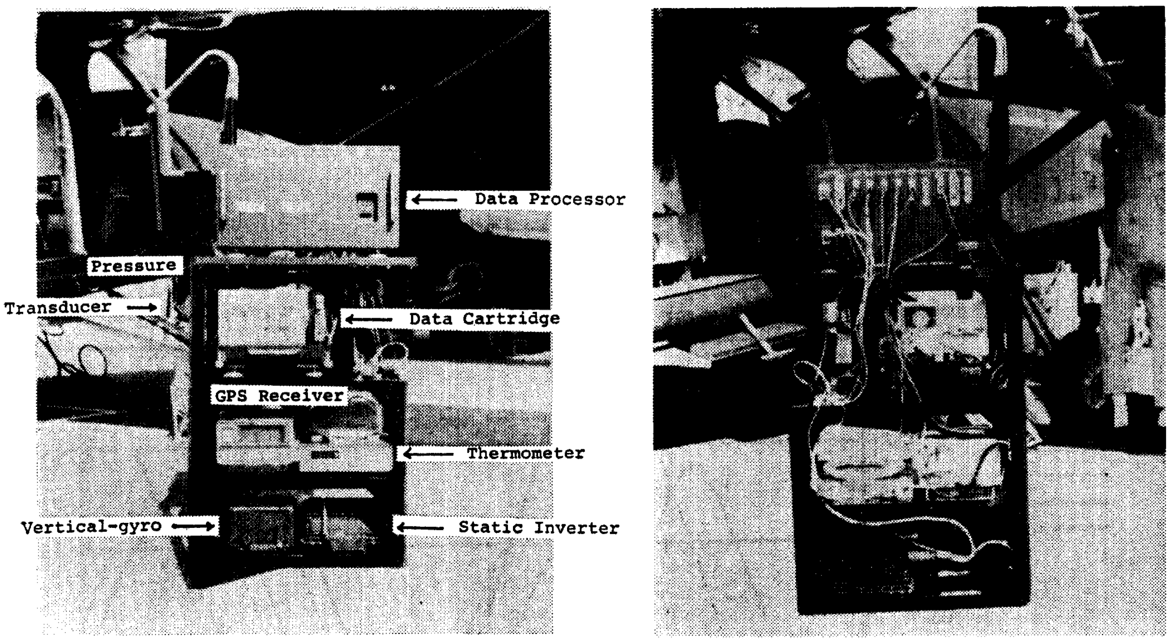

Fig. 2. Front and rear views of JARDAS.

3.1. Radar altimeter

COLLINS ALT-50 radar altimeter is installed on PC-6. The DC output voltage against height above ground is illustrated in Fig. 3a. The DC output voltage is digitized using 8 bits for a full-range, and the resolution is about 0.3 m for 0–152 m range and 2.1 m for 152–762 m range, respectively.

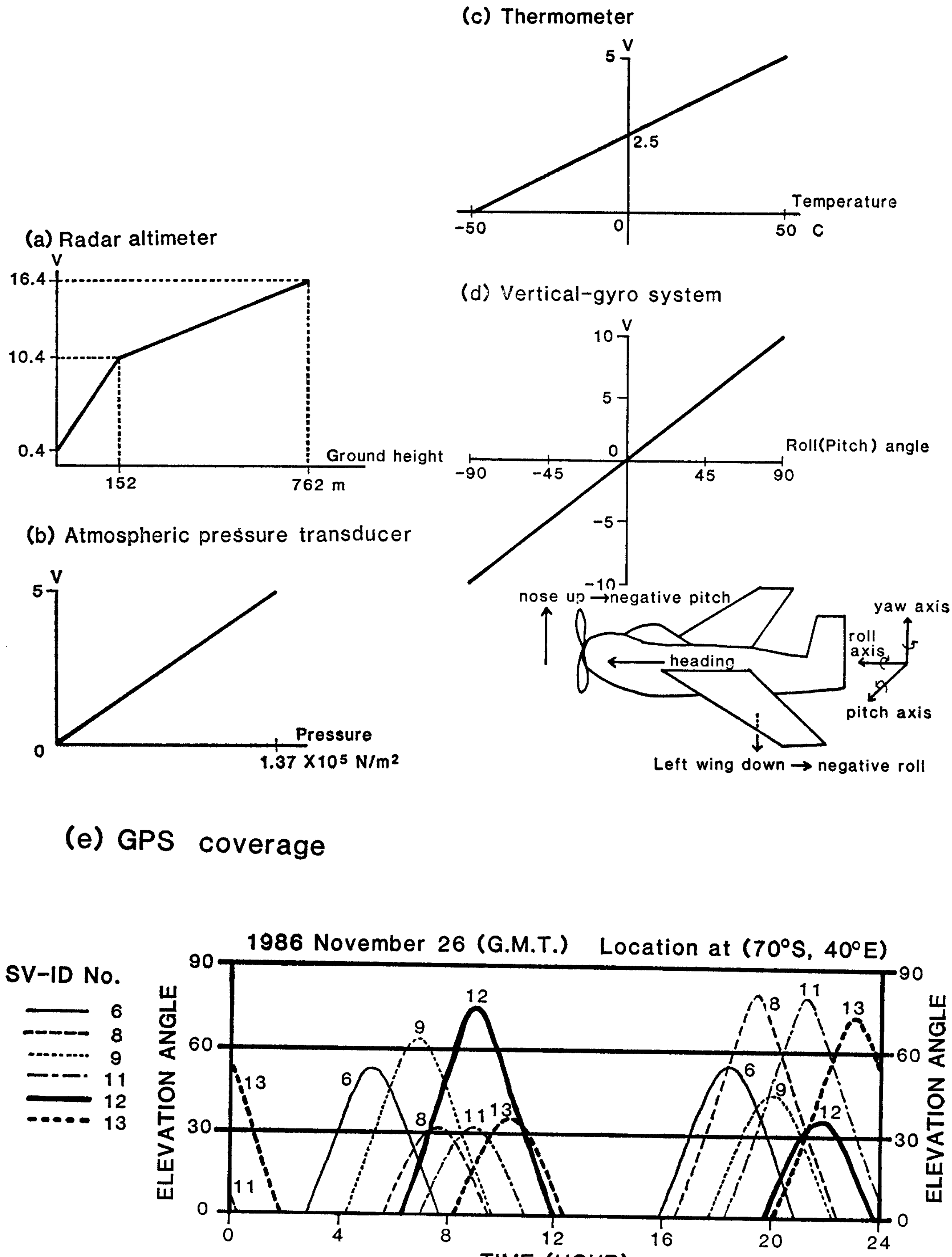

Fig. 3. *(a) DC output voltage vs. height above ground. (b) DC output voltage vs. atmospheric pressure. (c) DC output voltage vs. air temperature. (d) DC output voltage vs. roll (pitch) angle. Negative roll angle corresponds to left wing down, while negative pitch angle corresponds to nose up as shown in the lower part. (e) Coverage of GPS satellites (70°S, 40°E) on 26 November 1986. SV-ID indicates satellite identification number. Elevation angle is measured from horizon (0°) to zenith (90°).*

3.2. Atmospheric pressure transducer

SETRA Model 270 pressure transducer is installed. Figure 3b illustrates the DC full-output range of 0–5 V which is linearized against the absolute pressure range of 0–1.37×10^5 N/m^2. The guaranteed linearity for a full-scale voltage is $\pm0.05\%$ and the offset error at zero pressure is within ±5 mV. According to Fig. 3b, the atmospheric pressure of 1.0133×10^5 N/m^2 (1013.3 mb) corresponds to 3.698 V. The DC output voltage from the pressure transducer is digitized using 10 bits with the resolution of 5 mV. Conversion from the digitized voltage in milivolt to barometric height above sea level h in meter has to be conducted later according to the following formulas;

$$h=h_0+0.0036610\,tv\cdot h_0\,,$$

$$h_0=18410.0\log(V_0/V)\,,$$

where V_0 is 3698 mV (corresponding to 1.0133×10^5 N/m^2) and tv is the average air temperature in Celsius between sea level and flight height.

3.3. Thermometer

SHIBAURA M6003 thermometer is installed. It has both a digital monitoring display and a linearized analog output; the DC output voltage versus temperature relation is illustrated in Fig. 3c. The sensing thermister covers the range of -50 to 50°C with the absolute accuracy of ±0.3°C and the resolution of 0.1°C. The DC output voltage is digitized using 10 bits with the resolution of 5 mV (0.1°C).

3.4. Vertical-gyro system

JAE JG2V vertical-gyro system is installed, in order to monitor the aircraft attitude for future system development of airborne gravimeter and analysis of radio-echo sounding. Figure 3d illustrates the DC output voltage versus roll angle or pitch angle relation, where negative roll angle means left wing down and negative pitch angle means nose up. This reverse sense of porality compared with the ordinary specification of JG2V comes from the alignment of the device opposite to the heading of the aircraft.

JG2V requires a DC-AC inverter of 400 Hz in frequency for 115 V gyromotor and 30 V torquers, and the AVIONIC Model 250A static inverter is installed as shown in the lower part of Fig. 2. For a stabilized voltage output, a DC-DC converter of high-precision linearity output is included in JG2V.

3.5. VLF/omega receiver

GNS500A VLF/omega receiver is installed on PC-6. Latitude, longitude and azimuth of flight direction from true north are the inputs through the ARINC571 interface to the data processor at intervals of 1 s.

3.6. GPS receiver

SONY GTT3000 GPS receiver is installed. Latitude, longitude, height above the Earth's normal ellipsoid, velocity against ground, azimuth of flight direction are the inputs through the GP-IB interface to the data processor at intervals of 1 s. GTT3000 is also used as the system clock which is synchronized with the UTC

(Coordinated Universal Time) within 100 μs.

In the Antarctic region, the coverage by 4 GPS satellites, which is necessary for three-dimensional dynamic positioning, is yet limited to 6–7 h in a day as illustrated in Fig. 3e. The coverage by 3 GPS satellites attains to 12 h, which make it possible to make two-dimensional positionings with fixed heights assumed, being considered to be of practical approach in the aero-survey operations.

3.7. *Proton magnetometer*

EG&G G866 proton magnetometer can be installed on PC-6. Total intensity data at 1 s intervals with a resolution of 0.1 nT are the input through the RS232C interface to the data processor.

3.8. *Ice radar video pulse digitizer*

MEISEI radio-echo sounding system can be installed on PC-6. The amplitude decay of the reflected radio-echo waves by the ice surface and the subglacial bedrock is digitized at a sampling rate of 12.5 kHz. The digitized video pulses of every 0.5 s interval are fed to the data processor through a photo-coupler. Detailed specification of the ice radar video pulse digitizer will be explained in a separate paper.

4. Data Recording

As summarized in Table 1, there are many kinds of input signals to the data processor. The data processor digitized the analog inputs, code-transforms the digital inputs, re-formats and re-arranges the data sequence, then outputs the standardized data series to the data cartridge through the PG-IB interface.

Figure 4 illustrates the one-block data format. One-block data of fixed 811 bytes from the start mark STX (1 byte) to the end mark ETX (2 bytes) consist of

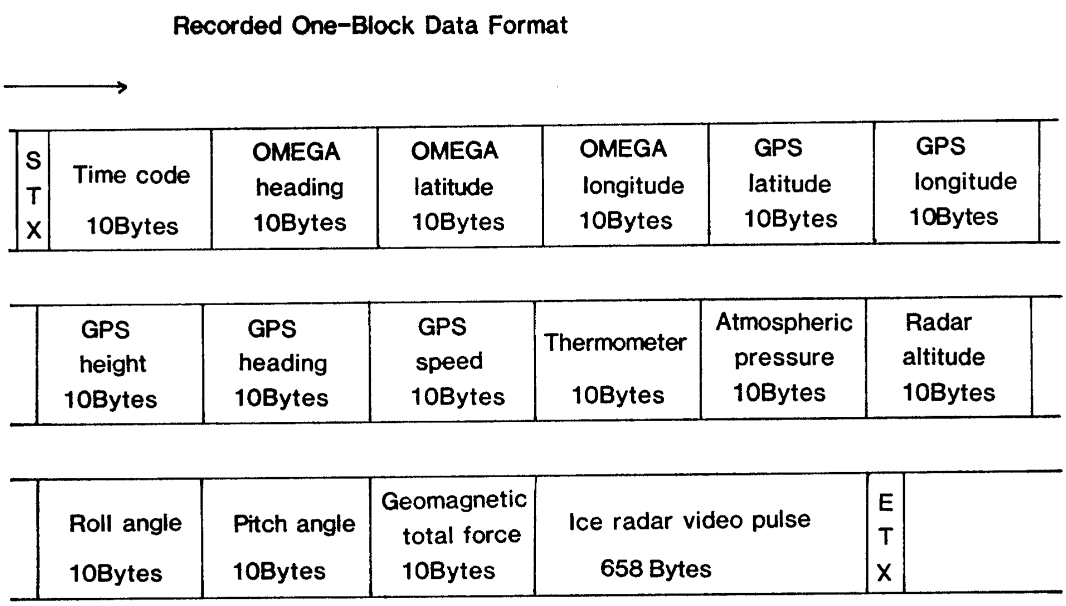

Fig. 4. One-block data format of 811 bytes from the start mark (STX) to the end mark (ETX). Examples of recorded data from time code to proton magnetometer are shown in Fig. 5.

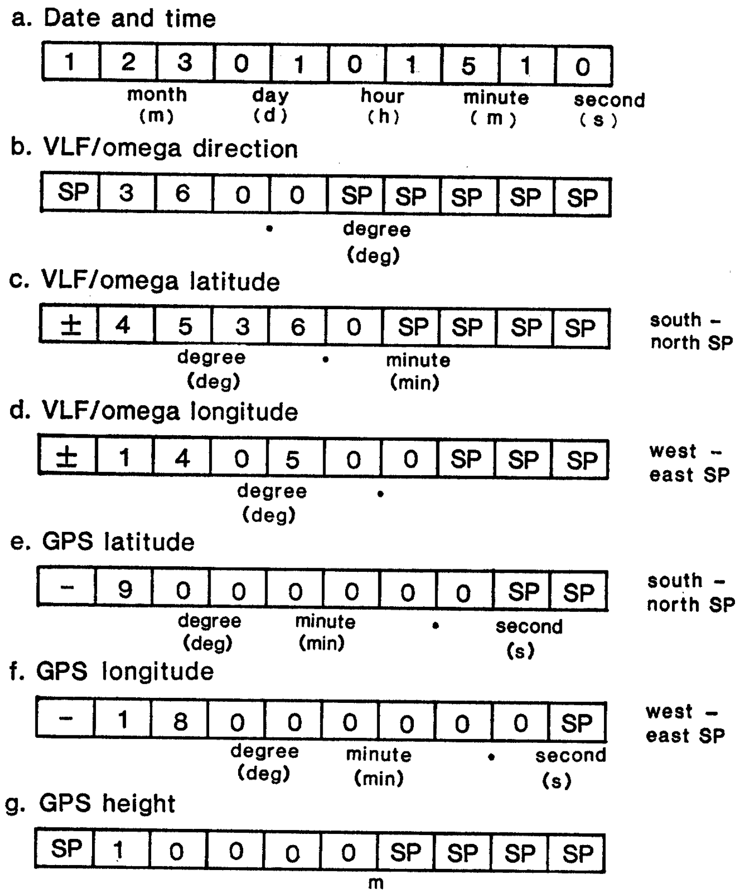

Fig. 5. Example of the data record. SP indicates space code and "•" shows the position of one-tenth digit.

navigational and observational quantities of every 1 s sampling. Except for the ice radar video pulses, 15 data (GPS time code to the geomagnetic total force) in Fig. 4 are given respectively by 10 bytes of 7-bit ASCII with even parity code. Even when there is any disconnected sensor from the data processor among the 8 channels (see Fig. 1), the data areas of the corresponding channel are not skipped but are filled in with space code. Examples of the 15 data are shown in Fig. 5. As for the ice radar video pulses, the 329 bytes of binary code obtained 0.5 s before and after a certain second mark are pasted to give 658 bytes of every 1 s data.

Sequential data of 12 h continuous output series can be recorded on a 450 ft (7700 bpi) 3M-type cartridge tape. The data cartridge (ANRITSU DMT750) adopts a serpentine recording head of two-tracks, and the head is shifted four times to fill in the 8 tracks. Since the serpentine head is likely to be affected by shocks and vibrations, the data cartridge is mounted on 4 shock absorbers (BARRY MOUNT L64-BA-10, 4.5–10.0 lbs) in order to prevent write-errors.

In the aero-survey operations, it is essentially important that the recorded data can be checked just after the survey flight for the next flight planning. Readout of the cartridge data obtained by JARDAS can easily be made by the BASIC program with specially prepared control commands of the data cartridge using a personal

h. GPS heading

SP	3	6	0	0	SP	SP	SP	SP	SP

• degree (deg)

i. GPS speed

SP	1	0	0	0	0	SP	SP	SP	SP

• km/h

j. Thermometer

SP	3	6	0	0	SP	SP	SP	SP	SP

mV

resolution 5 mV

k. Atmospheric pressure transducer

SP	2	4	0	0	SP	SP	SP	SP	SP

mV

resolution 5 mV

l. Radar altimeter

SP	2	5	0	0	SP	SP	SP	SP	SP

feet (ft)

resolution
1 ft (0–500 ft)
7 ft (500–2500 ft)

m. Roll angle by vertical-gyro

−	4	9	9	SP	SP	SP	SP	SP	SP

• degree (deg)

−—left wing down
resolution 0.2°

n. Pitch angle by vertical-gyro

+	5	0	0	SP	SP	SP	SP	SP	SP

• degree (deg)

+—nose down
resolution 0.2°

o. Proton magnetometer

SP	4	6	7	8	9	0	SP	SP	SP

• nT

Fig. 5 (continued).

computer. Interfacing of the data cartridge with the host computer is made by the GP-IB interface bus. The utility program package for field data analysis is now under development.

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