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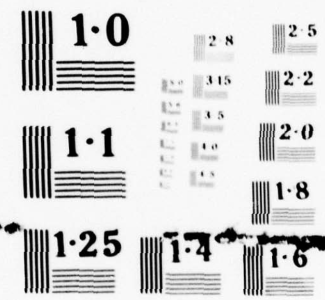

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STRUCTURAL INTEGRITY MONITORING SYSTEM

FINAL REPORT

Prepared By

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February 28, 1979

FINAL REPORT

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PREPARED FOR:

NAVAL AIR DEVELOPMENT CENTER
WARMINSTER, PENNSYLVANIA 18974

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

CONTAINED WITHIN THIS REPORT IS:

A) A description of all work performed knowledge gained and results achieved on the SIMS program.

B) A Complete technical description of the SIMS, equipments developed supported by, Drawing, sketches and schematics.

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20 Abstract

C) Detailed information on test methods, procedures and equipment used in establishing the characteristics and performance of developed hardware.

D) Rational for all conclusions and recommendations.

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1.0 SUMMARY

This final report is being submitted to the Naval Air Development Center per Data Item Description UDI-E-21353A(AE-219-E) of Contract Number N62269-77-C-0349. The scope of this contract was to develop, manufacture, test, and deliver a 12-channel Structural Integrity Monitoring System (SIMS) consisting of:

(a) An airborne Solid State Recorder (SSDR):

(b) A Ground Based Interrogator (GBI):

(c) A Tape Transcriber (TT).

The SSDR functional requirements for the SIMS system were satisfactorily demonstrated by a completely solid state design, packaged within an envelope of 9" L x 7" W x 8½" H, excluding mounting flanges. The physical size was primarily accomplished by the use of MNOS solid state memories, hybrid packaging of the analog input circuits and a compact packaging design. The 8080A microprocessor was chosen to electronically control the SSDR unit including the flow of data to and from the memory. The GBI and TT support equipment provided the required data transfer functions with the GBI constructed as a portable unit and the TT consisting of modified commercial equipment. The GBI and TT are electronically controlled by an 8085A microprocessor.

The approach utilized proved successful and is recommended for future aircraft systems where small size and high reliability is required. This is based on the following attributes of the system:

(a) High flexibility due to a microprocessor controlled SSDR unit which can be altered by software changes.

(b) Use of a non-volatile solid state memory for the SSDR unit which is available in the -55° C to +100° C temperature range.

(c) High reliability and compact SSDR size due to complete use of solid state devices.

2.0 INTRODUCTION

The scope of this contract was to develope, manufacture, test, and deliver a 12-channel Structural Integrity Monitoring System (SIMS) consisting of:

(a) One airborne Solid State Recorder (SSDR);

(b) a Ground Based Interrogator (GBI);

(c) Tape Transcriber (TT).

The SSDR is an aircraft mounted unit used to obtain histories (sequential peaks and troughs) of kinematic parameters and strains at critical sites as well as the number of times that certain parameters or combinations of parameters are attained. These data are required in order to estimate the fraction of the fatigue life of the structure that has been expended. One GBI was required to service the five SSDR delivered for this project. It is intended that the SSDR will be interrogated by the GBI once per month and that the data be recorded on a tape cassette. The tape cassette will be forwarded to NADC, where it will be transcribed onto tape compatible with the CDC 6600 computer by the TT.

A technical description of the SSDR, GBI, and TT is provided as Appendix A, B and C to this report. Contained within the main body of this report is:

(a) A description of all work performed, knowledge gained and results achieved in the SIMS program;

(b) Detailed information on test methods, procedures, and equipment used in establishing the characteristics and performance of developed hardware;

(c) Rationale for all conclusions and recommendations.

2.1 Description of Work Performed on SSDR

Review of the SSDR system requirements indicated the following input requirements:

(a) Twelve (12) channels, 4 high level and 8 low level, of independent transducers and/or strain gage bridges.

(b) An aircraft power supply of 28 ± 3 V DC with data acquisition controlled by a "weight-on-wheels" switch signal.

The SSDR using these inputs was required:

(a) To store 14,400 significant events in the order of their occurrance for each of the 12 input channels.

(b) To retain data in a non-volatile memory for a minimum of two months.

(c) To record elapsed flight time in minutes.

(d) To store the number of occurrances of each of 12 intersections of normal acceleration and roll rate with normal acceleration sectioned into 12 sub-ranges and roll rate into six sub-ranges for a total of 72 storage registers.

(e) Provide conditioning for eight (8) strain gage bridges with the remaining four (4) channels to be high level transducers.

(f) Package the SSDR within an envelope of approximately 7" x 7" x 9" and a weight of 12 pounds.

Given the above requirements, initial consideration was given to selection of the microprocessor for system control. The 8080 microprocessor was selected since it was a multiple sourced industry standard fully capable of performing all system requirements.

A second consideration was the processing of all input signals. This was accomplished by means of an instrumentation amplifier consisting of two integrated circuit chips followed by a 6-pole Butterworth filter. The Butterworth filter is designed to give a flat response from 0 to 2 Hz, with a 3 db fall at 2.7 Hz and a minimum of 30 db per octave thereafter. The instrumentation amplifier and the filter circuitry was packaged within a single hybrid hermetically sealed package. This standard package could be used for all twelve signal inputs since external resistors to adjust the gain of the instrumentation amplifier are provided to accommodate low level strain gages at 20 mv maximum, and high level transducers at 5.0 volts maximum input levels. The twelve analog channels are multiplexed to a A/D converter under microprocessor control.

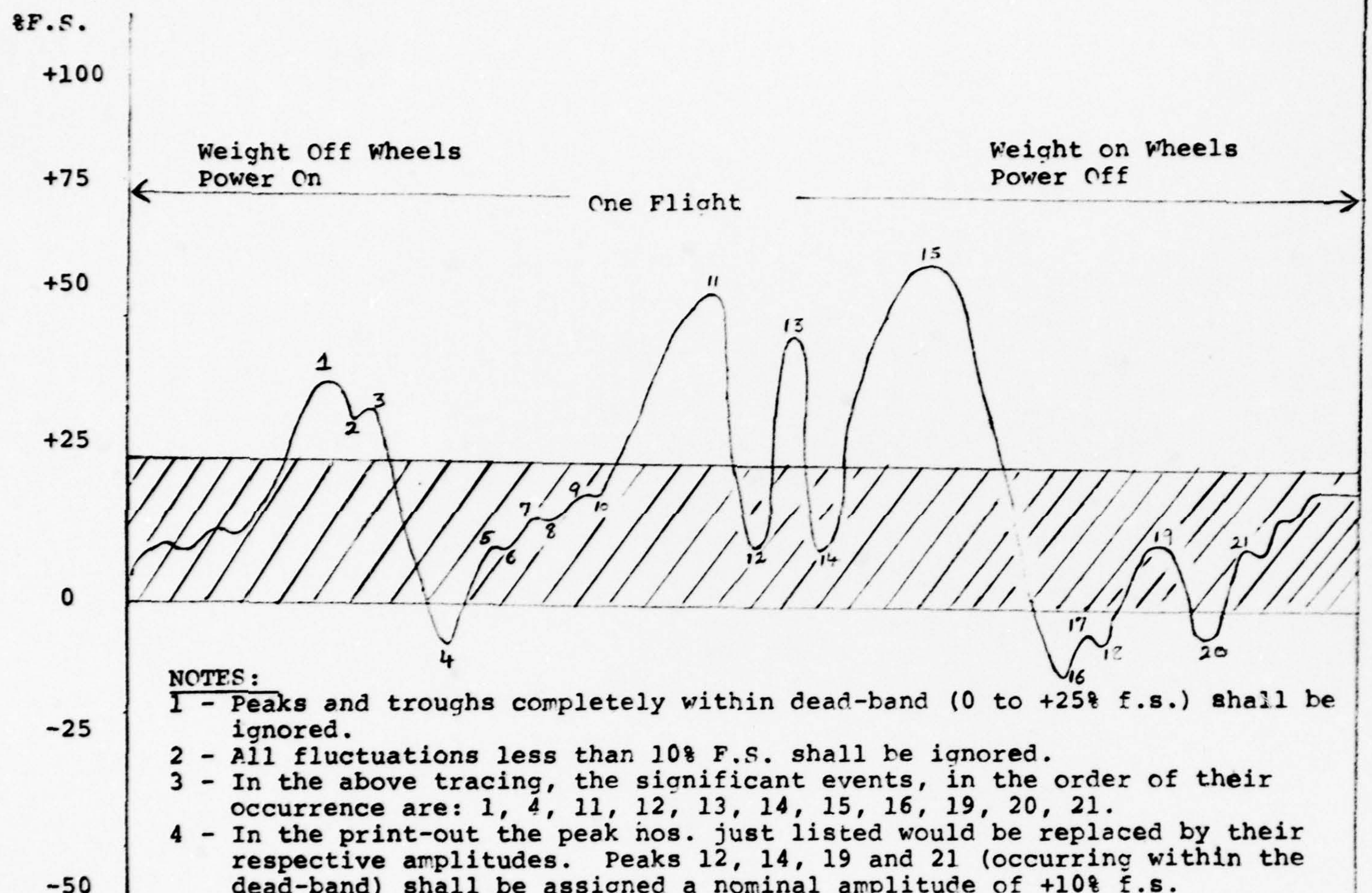
The non-volatile memory consists of 42 devices organized 2K x 4 bits providing a total 42K bytes of non-volatile memory. 2K bytes are allocated for the roll rate and acceleration values matrix and the balance for peak and valley and time slice data. Figure 1 presents typical data to be collected. MNOS technology was selected since it had demonstrated a capability of operating over the military temperature range of -55° C to +125° C and had satisfactorily performed on other airborne military programs. The 8K, 2805 EAROM was the largest memory size available in the MNOS technology.

The program for the 8080 microprocessor resides in 3 each 1K x 8 bit PROM memory units. Scratch pad functions are provided by eight each 1K x 4 bit RAM units . The data is converted from 8-bit parallel data to serial data for transmission over the GBI interface cable.

Other design areas of effort included:

* Provisions for a 5 second power interrupt by storing microprocessor initialization and matrix data in a 256K 8 bit CMOS memory, subsequently powered by a charged capacitor.
* A switching type power supply with outputs of -24 V, -15 V, ± 12 V DC and a 10 V DC reference to 8 strain gages.
* A record of elapsed time for each flight in minutes up to 511 minutes.
* A capability to check calibration of the strain gage by means of an FET switch.
* Provision for adjusting balancing of strain gages by shunting two legs of the bridge with resistors.

Figure 1 - Significant Events



NOTES:

1 - Peaks and troughs completely within dead-band (0 to +25% f.s.) shall be ignored.

2 - All fluctuations less than 10% F.S. shall be ignored.

3 - In the above tracing, the significant events, in the order of their occurrence are: 1, 4, 11, 12, 13, 14, 15, 16, 19, 20, 21.

4 - In the print-out the peak nos. just listed would be replaced by their respective amplitudes. Peaks 12, 14, 19 and 21 (occurring within the dead-band) shall be assigned a nominal amplitude of +10% f.s.

2.2 Description of Work Performed on GBI

The GBI contractual requirements consist of:

a) A portable read-write tape recorder with self-contained power supply.

b) Manual input of aircraft serial number and date.

c) Calibration for each channel.

d) Balance strain gage bridges for zero level.

e) Generally check the operations of the SSDR.

f) Verify the recording, then erase all data in the SSDR non-volatile memory except for the matrix information.

The work performed to satisfy the above requirements was the development, manufacture and test of a GBI consisting of the basic GBI electronic package and its associated portable power pack.

One of the first considerations was to select a tape transport for recording data from the SSDR on a cassette tape. The MFE transport was selected since, in addition to meeting the electrical and physical requirements, it contained a minimum number of moving parts for high reliability. The 8085 was selected to control the electronics. A keyboard with 12 entry keys was chosen to allow operator interface with the microprocessor and supported by a 6-digit LED display. A separate battery charging unit was developed to allow the GBI to be compatible to portability.

The Gates sealed lead acid battery was selected since it had a wide operating temperature of -40° F. to +65° C. in addition to being a low cost, reliable, rugged, and long life unit, providing up to 2 1/2 hours use between charges. Other design areas of effort included:

* Interface cabling to the SSDR and between the basic GBI and its power pack.
* Battery charging capability for the power pack within 8 hours.
* Microprocessor control of the tape transport functions.

* Verification of data extracted from SSDR before erasing this data from the MNOS memory.
* Calibration of the strain gauges on the SSDR.

2.3 Description of Work Performed on TT

The functional requirements for the TT are that it transfers data from tapes generated by the GBI onto tapes compatible with the CDC 6600 computer at NADC. Additionally, the TT was required to operate at 110 volts, 60 hertz. The efforts to accomplish these requirements consisted of developing an interface card to control the operation of the following commercial units:

* Kennedy Model 9832 9-track Tape Transport
* Texas Instruments Model 700 Silent Printer
* MFE Model 250B Digital Cassette Tape Transport

A printed circuit board common to the GBI was developed, since both units contained many similar functions with both being electronically controlled by the 8085 microprocessor.

The Kennedy unit provides the conversion to 9-track tape compatible to the CDC 6600 computer. The Silent 700 provides the human interface with the microprocessor to allow processing of tapes and printout of data parameters in different formats.

Other design areas of effort include:

* Extracting data from tape cassettes in different formats.
* Data verification between SSDR, GBI and TT.

2.4 Description of Software Effort

The contract requires that software be provided to enable a printout of the sequential data in three forms:

(a) All significant events shall be tabulated in order of their occurrance regardless of channel. This data sequence shall include, in its proper time order, the time cuts required when the normal acceleration is greater than 2.0g and less than 0.0g.

(b) All strain significant events shall be tabulated in the order of their occurrance but sorted by channel.

(c) All significant normal accelerations ($2.0G < N_z < 0G$) and the accompanying time cuts of the other 11 channels shall be printed out in the order of their actual occurrance. In addition, the numbers accumulated in each of the 72 registers shall be printed out with appropriate identification.

In format (1), the elapsed time to the nearest minute for each flight shall be printed out. The maximum value for the elapsed time of any one flight is five (5) hours. A "flight" is defined as the period between power-on and power-off.

To accomplish the above and other contractual requirements necessitated the development of three software programs. The first program was for the SSDR, and is basically a data acquisition program which includes the communication interface to the GBI.

The second program was the GBI program which provided for communication interface between the GBI and SSDR. The communication includes extracting data from the SSDR non-volatile memory for storage in a tape cassette and erasing the data after its verification. Also, the GBI can look at data on any one of the 12 channels upon request, as when balancing the strain bridges for zero level.

The third program is for the TT, which takes the data from the tape cassette and either puts it on a 9-track recording tape or prints data on a silent 700 in the requested format. The TT program also erases the cassette tape when requested.

The above programs were developed using an IMSAI CPM operating system and a Process Technology Simulator.

2.5 Knowledge Gained

The total work effort for the SIMS programs provided an opportunity to increase our knowledge in the following significant areas:

(a) A more comprehensive understanding of the parameters associated with MNOS non-volatile memory was achieved. This included various techniques for control circuitry.

(b) Electrodynamics hybrid facility developed the hybrid packaged for the analog filter and instrumentation amplifier. Further experience and knowledge in this type of design was gained.

(c) Softwares techniques in the area of data compression, tape to microprocessor conversion and formatting of data for human interface.

(d) Initial production units experienced loss of the +10 V reference supply output. This was caused by insufficient current limiting. The power supply limiting current was reduced and can now survive a short circuit in excess of 20 seconds.

(e) During data transfer, the MNOS devices draw larger amounts of current than a standard TTL logic, therefore additional ground plane shielding was required for each printed circuit board containing EAROMS for good noise isolation.

4.5.2 Test Procedure (continued)

2.6 Results Achieved

The SIMS Program was concluded with the successful completion of all contractual requirements. A solid state recorder of lightweight construction, small size, and high reliability was delivered with the following features:

(a) A SSDR with a non-volatile solid state memory capable of operating over a -55 to +95 degree C environment.

(b) A microprocessor controlled SSDR, GBI and TT for flexibility in making system changes by changing software.

(c) A SSDR with a qualified capability for operating in an aircraft environment of temperature, vibration, EMI, etc.

(d) The SIMS contract called for a SSDR of approximately 7" x 7" x 9" in size and a weight of 12 pounds. The final systems was 9" L x 7" W x 8½" H, excluding mounting flanges and weighed 16 pounds, which was acceptable to the customer.

(e) The SSDR is capable of handling and combinations of low level signal and high level signal for a total of 12 channel, except that a maximum of 8 low level channels can be serviced under the present design.

4.7.1 Conducted Susceptibility (CS06) (continued)

a) Retrieved data on print-outs shall meet:

3.0 SCOPE OF TESTING PARAMETERS

Sections 3 and 4 of this Final Report define all test conditions and procedures that were performed on the SIMS System to confirm compliance with the specifications and standards called out in the contract. The complete test sequence consists of eight separate tests designed to exercise the equipment's operating capability over the designated environmental range. It should be noted that not every SSDR has undergone the entire sequence of tests. Only one unit was subjected to all tests described herein. Subsequent four units have undergone all tests except temperature shock, vibration, EMI, and dielectric test. Environmental test data is available from Electrodynamics upon request.

The complete list of tests described herein is listed below:

1. Dielectric Test
2. Static Calibration Test
3. Functional Test
4. Temperature Shock Test
5. Low Temperature Test
6. High Temperature Test
7. EMI & Transient Test
8. Vibration Test

3.1 Standard Test Conditions

Unless otherwise specified in the individual test procedures, room ambient temperature, humidity and atmospheric pressure are applicable to the tests conducted herein. For room ambient conditions, the range of values are:

4.8 Vibration (continued)

3.1 Standard Test Conditions (continued)

Temperature	13 to 33° C.
Humidity	20 to 80 per cent R.H.
Pressure	28 to 33 inches of Hg.

3.2 Input Voltage

Unless otherwise specified, the SSDR will be tested with an applied voltage of 28 $\pm$ 0.5 VDC.

4.0 TEST METHODS, PROCEDURES AND EQUIPMENT

4.1 Dielectric Test

4.1.1 Test Equipment

The following equipment is required for the dielectric test.

a) Solid state data recorder

b) Associate Research Model 2850 Tester or equivalent.

4.1.2 Test Procedure

The dielectric test shall be performed on SSDR connectors J1, J2 and J3 using the following procedures:

a) Short all pins on the connector under test.

b) Connect a "megger" between connector pins and case using an Associated Research Model 2850 Tester or equivalent.

c) Apply a potential of 500 VDC for 5 seconds between pins and case and record insulation resistance. The value measured shall not be less than 3.5 megohms.

d) Repeat the test on the other two connectors and record results.

4.2 Static Calibration Test

Each SSDR is capable of recording flight stress data from any or all of 12 inputs. Because of the voltage level variation of these inputs (channels), certain channels have been designed to accept high level signals while the remainder will accept low level signals. Table 4.2-1

4.8 Vibration (continued)

identifies each of the input channels (software control number) and the input signal level.

	Channel
High Level Signal Channels	0
	1
	2
	3
Low Level Signal Channels	4
	5
	6
	7
	8
	9
	10
	11

TABLE 4.2-1 - CHANNEL INPUT LEVELS

4.2.1 Test Equipment

The following equipment is required for the static calibration test.

a) Ground Base Interrogator

b) Solid State Data Recorder

c) Portable Power Pack

d) Imsai 8080 or equivalent

e) G.R. type 1432-P Decade Resistor Box or equivalent

f) Transducer Simulator Board (all channels)

g) D.V.M. H.P. Model 3465 or equivalent

Connect the equipment as shown in Figure 4.2.1-1.

4.2.2 Zero Values for All Channels

Zero values for all channels must be determined before proceeding with the static calibration and linearity test. This test section is to be used to determine the zero values for all channels. Disconnect cable from SSDR J1 input.

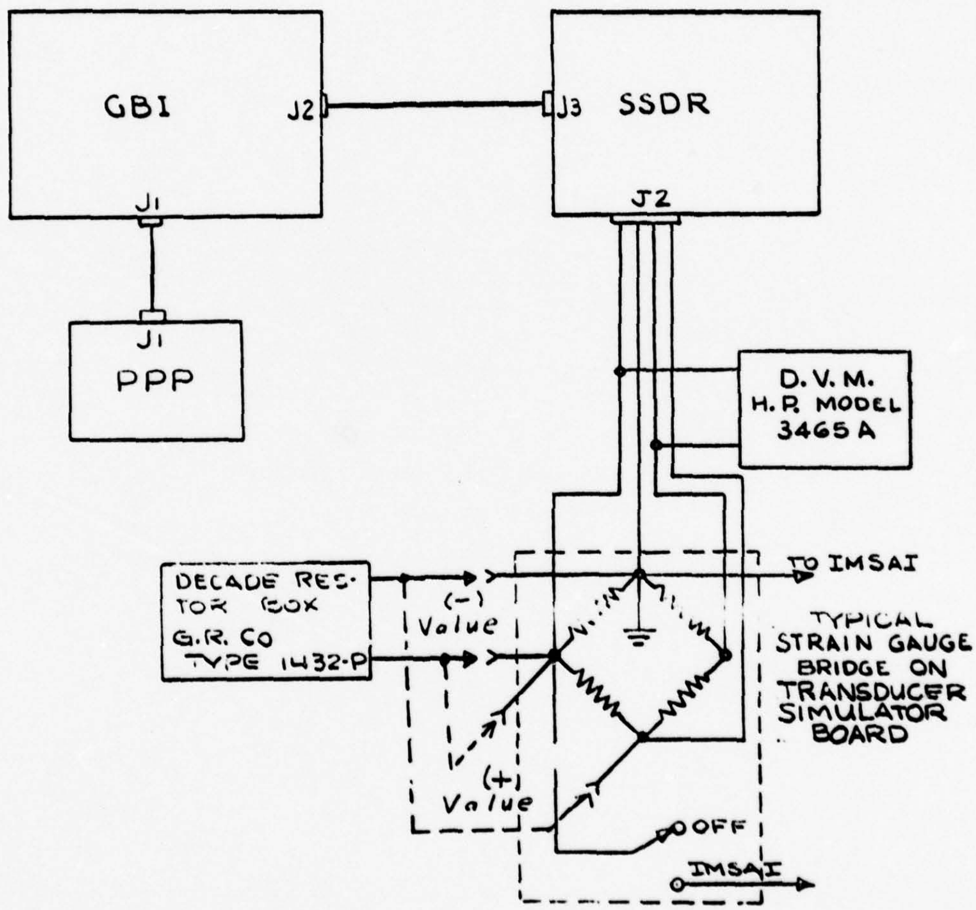


FIGURE 3.2.1-1 TEST SET-UP – STATIC CALIBRATION TEST

4.2.2 <u>Zero Values for All Channels</u> (continued)

a) Set all GBI switches in the down or OFF position.

b) Set all Transducer Simulator Board switches in the OFF position.

c) Apply power to the system by setting the GBI power switch to ON position.

d) Set GBI AIRCRAFT SYSTEM CHECK ZERO switch in the UP position.

e) Enter a two-digit number for the channel under test on the GBI keyboard. (00, 01, ----11)

f) Press START on the keyboard. After an initial delay of up to 10 seconds, the test channel zero value will be displayed on the GBI readout.

g) Record the channel number and zero value displayed. Press CLEAR on the keyboard.

h) Repeat steps e, f and g for each of the remaining elevel channels.

4.2.3 <u>Low Level Channel Calibration and Linearity Procedure</u>

This test section is to be used to determine the calibration and linearity of the low level channels 4, 5, 6, 7, 8, 9, 10 and 11 only.

a) Set all GBI switches in the down or OFF position.

b) Set all Transducer Simulator Board switches in the OFF position.

c) Apply power to the system by setting the GBI power switch to the ON position.

d) Set GBI AIRCRAFT SYSTEM CHECK ZERO switch in the UP position.

e) Connect a decade resistor box to the simulated strain gauge bridge for the test channel selected as shown in Figure 4.2.1-1 (+ position).

f) Set the decade resistor box for 40,000 ohms.

g) Enter a two-digit number for the channel under test on the GBI keyboard. (04, 05, ----11)

h) Press START on GBI keyboard to display the selected channel calibrate value.

4.2.3 Low Level Channel Calibration and Linearity Procedure

i) Record the channel number and value displayed. Press CLEAR on GBI keyboard.

j) Subtract the zero value obtained in Section 4.2.2 from the calibrated reading.

k) Repeat Steps f through j for the remaining resistive values shown in Table 4.2.3-1. The voltage outputs for the remaining resistive values shall track within 1% of the full scale voltage output obtained in Step j for Rc = 40k after compensating for a 39 mV (1 bit) quantizing error at each reading for the zero and full scale outputs. (At extreme temperatures of -54° C. and +95° C, tracking shall be within 3%.)

l) Repeat Steps f through k for the remaining seven channels.

m) Reconnect the decade resistor box to the negative position (-) as shown in Figure 4.2.1-1. Repeat Step procedures f through l for all eight low channels.

Rc (Ω)	Volts Out (Approx.)
40,000	4.0
53,450	3.0
80,350	2.0
161,050	1.0
322,450	0.5
645,250	0.25

TABLE 4.2.3-1 - Shunt Rc for Strain Gage Bridge Linearity Test

4.2.4 High Level Channel Calibration and Linearity Procedure

This test section is to be used to determine the calibration and linearity of the high level channels 0, 1, 2 and 3 only.

a) Interconnect the equipment as shown in Figure 4.3-1. Set all GBI

1.0 DESCRIPTION OF EQUIPMENT

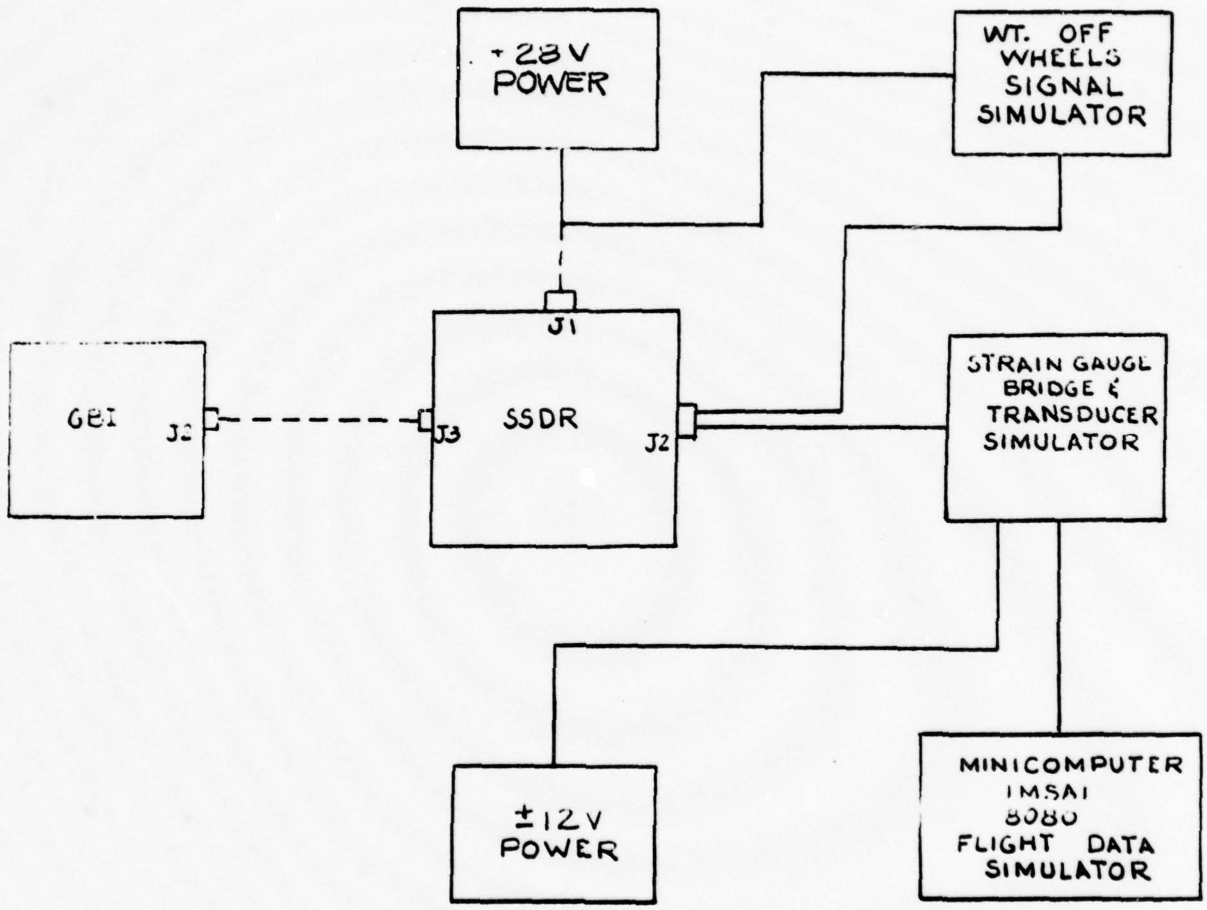


FIGURE 3-1 TEST SET-UP FOR SIMULATING FLIGHT DATA ACQUISITION, PROCESSING & STORAGE

switches in the down or OFF position and connect the GBI to the SSDR. Leave the 28V power cable to J1 disconnected. Set Transducer Simulator Board switches to IMSAI position and the Weight-Off-Wheels switch to OFF position.

b) Connect a DVM to the output test point of the Transducer Simulator Board for one of the channels 0, 1, 2 or 3.

c) Apply power to the IMSAI and $\pm$ 12 volts to the Transducer Simulator Board.

d) Press IMSAI STOP switch to down position, then release.

e) Enter 9180_H into the ADDRESS PROGRAMMED INPUT switches.

f) Press EXAMINE switch to UP position, then release.

g) Press RUN switch to UP position, then release. Set the GBI ZERO switch to ON position.

h) Enter the channel number selected in Step b above on the GBI keyboard (00, 01, 02 or 03).

i) Set the ADDRESS PROGRAMMED INPUT switches to each of the following settings. Press GBI START on keyboard and record the input reading on the DVM and the measured value on the GBI display:

Positive Values	Negative Values
8000H	7F00H
C000H	3F00H
E000H	1F00H
F000H	0F00H
F800H	0700H
FC00H	0300H

j) Subtract the zero values of Test Section 4.2.2 from the positive calibrate readings. The voltage output results of the remaining address inputs shall track within 1% of full scale voltage output of address input 8000H after compensating for a 39 mV (1 bit) quantizing error at each reading for the zero and full scale outputs. (At extreme temperatures of -54° C. and 95° C. tracking shall be within 3%.)

l) Press CLEAR on GBI keyboard.

m) Repeat Steps b and Steps h through l for the remaining three high level channels. Set the GBI zero switch to OFF and power down the system.

4.3 Dynamic Test

4.3.1 Test Equipment

The following equipment is required for the Dynamic Test:

1) Ground Base Interrogator with Tape Cassette
2) Solid State Data Recorder
3) 28 VDC Supply
4) 12 VDC Supply
5) Weight-Off-Wheels Signal Simulator
6) Strain Gauge Bridge and Transducer Simulator
7) Tape Transcriber

Connect the equipment as shown in Figure 4.3-1.

4.3.2 Test Procedure

The dynamic functional test described here will be performed to verify proper operation of SSDR.

a) Interconnect the system as shown in Figure 4.3.1, except leave the GBI cable J3 disconnected until later in the test. Connect 28V supply to SSDR. Set all the Transducer Simulator Board switches to the IMSAI position and the Weight-Off-Wheels switch to OFF.

b) Apply power to the IMSAI and ± 12 volts to the Transducer Simulator Board.

4.3.2 <u>Test Procedure</u> (continued)

c) To initialize the IMSAI for zero input levels to the SSDR:

1) Press STOP switch to down position, then release.

2) Enter 9180_H into the ADDRESS PROGRAMMED INPUT switches.

3) Press EXAMINE switch to up position, then release.

4) Press RUN switch to up position, then release.

5) Enter 0000_H into the ADDRESS PROGRAMMED INPUT switches.

d) With the Weight-Off-Wheels switch in the OFF position, apply 28 volt power to the system and simultaneously start a stop watch. Approximately 35 seconds after power application, close the Weight-Off-Wheels switch.

e) Apply sawtooth waveforms of 0.1 Hz spaced 15° apart in phase to the SSDR from the IMSAI by the following steps:

1) Press the STOP switch to down position, then release.

2) Enter 9000_H into the ADDRESS PROGRAMMED INPUT switches.

3) Press EXAMINE switch to up position, then release.

4) Press RUN switch to up position, then release.

5) Enter 9200_H into the ADDRESS PROGRAMMED INPUT switches to set a frequency of 0.1 Hz.

f) After 5 minutes from power on, open the Weight-On-Wheels switch. Wait for 10 additional seconds and then power the system down.

g) To recover the data from the SSDR, use the following procedure:

1) Disconnect cable from SSDR J1 input. Connect the GBI cable to the SSDR J3 input. Set all GBI switches to down position or OFF.

2) Insert a tape cassette (side "A" up) into the GBI and place POWER switch to ON position.

3) Set the DATE, and RECORD switches in the down position.

4) Press IDENTIFICATION switch to up position and type any 5-digit number on the GBI keyboard. Press START key.

4.3.2 Test Procedure (continued)

5) Place IDENTIFICATION switch in down position and then place DATE switch in up position. Type a five-digit date on the keyboard (one digit for year, two digits for month, two digits for day). Press START key.

6) Place DATE switch in down position and place RECORD switch up. Press START key.

7) Cassette tape will move, then stop within 10 seconds. If no tape movement occurs, repeat above steps 1 through 6.

8) After the tape stops, press ERASE REQUEST. The ERASE ENABLE green light should turn on. (If light does not turn on, press CLEAR, then START, and another recording will be made. After the tape stops, press ERASE REQUEST again. The green light should come on. If the green light does not turn on, there is a problem with the tape cassette, the GBI, or the SSDR.)

9) After obtaining the green light, press the ERASE AIRCRAFT MEMORY switch up and the RECORD switch down. The ERASE ENABLE light will go off. This will erase all the SSDR non-volatile memory except for the MATRIX DATA. Power down the system.

10) Remove the tape cassette from the GBI and rewind tape using the Tape Transcriber.

h) Print out the contents of the cassette tape using the tape transcriber. The data printed must agree with the data inputted with no data errors or losses.

4.4 Temperature Shock Test

4.4.1 Test Equipment

The following test equipment is required for the temperature shock test:

1) Tenney JR Model TJR Environmental Chamber or equivalent.
2) Solid State Data Recorder

4.4.1 Test Equipment (continued)

3) Equipment specified in Section 4.3.1.

4.4.2 Test Procedure

a) Place the SSDR in an environmental chamber.

b) Subject the SSDR to the temperature shock test of MIL-STD-810C, Method 503.1, except that the high temperature shall be 95° C. and the low temperature shall be -54° C.

c) Upon completion of the test, the SSDR shall be subjected to a functional test in accordance with paragraph 4.3.

4.5 Low Temperature Test

4.5.1 Test Equipment

The following test equipment is required for the low temperature test:

1) Delta MK6300 Chamber or equivalent.

2) Solid State Data Recorder

3) Equipment and Set-up per Section 4.2.1.

4) Equipment and Set-up per Section 4.3.1.

4.5.2 Test Procedure

a) Place the SSDR in a cold chamber (Delta Design MK6300 or equivalent) and interconnect the system as shown in Figure 4.3-1, with GBI disconnected.

b) Subject the SSDR to a temperature of -54° C for a period of two hours.

c) At the end of 2 hours and while still at -54° C, perform a static calibration test in accordance with paragraph 4.2 for two low level and two high level channels selected at random. (4 channels)

d) At the end of two hours and while still at -54° C, perform a functional test in accordance with paragraph 4.3, Steps a through f only.

4.5.2 Test Procedure (continued)

e) At the completion of the above, raise the temperature, wait until the unit cools to room ambient, and perform Steps g and h of Paragraph 4.3.

4.6 High Temperature Test

4.6.1 Test Equipment

a) Same as Section 4.5.1.

4.6.2 Test Procedure

a) Place the SSDR in a heat chamber (Delta Design MK6300 or equivalent) and interconnect the system as shown in 4.3-1, with GBI disconnected.

b) Subject the SSDR to a temperature of 95^{o} C. for a period of two hours.

c) At the end of two hours, and while still at 95^{o} C, perform a static calibration test in accordance with Paragraph 4.2 for the 4 randomly selected channels of 4.5(c).

d) At the end of two hours and while still at 95^{o} C, perform a functional test in accordance with Paragraph 4.3, Steps a through f only.

e) At the completion of the above, lower the temperature, wait until unit cools to room ambient, and perform Steps g and h of Paragraph 4.3.

4.7 EMI and Transient Test

All tests to be conducted at room ambient temperature and with 28 volts DC input to the SSDR. During these tests, serialized input data (see Section 4.3) will be fed and stored in the SSDR memory and later retrieved and evaluated to test conditions 1 and 2 of Sections 4.7.1 and 4.7.2.

4.7.1 Conducted Susceptibility (CS06)

a) Energize the SSDR and strain gauge bridges (or their equivalent).

b) Inject electrical spikes (as shown in Figure 19 of MIL-STD-461A) into the power leads of the SSDR as specified in Method CS06 of MIL-STD-462.

4.7.1 Conducted Susceptibility (CS06) (continued)

c) Retrieved data or print-outs shall meet:

Condition 1: With no data input, no events shall register.

Condition 2: With a 0.1 Hertz full scale sawtooth input signal, the recorded peaks and troughs shall agree completely with the input signal.

d) Subject the SSDR to the voltage limit test (Paragraph 5.3.3.1 and Figure 12) and the voltage transient test (Paragraph 5.3.2 and Figure 10) of MIL-STD-704C.

e) Retrieved data or print-outs shall meet test conditions 1 and 2 as outlined in Section 4.7.1(c).

4.7.2 Radiated Susceptibility (RS02)

a) *Energize the SSDR and strain gauge bridges (or their equivalent).*

b) Subject the test sample to the spike test as specified in MIL-STD-461, Method RS02.

c) Retrieved data or print-outs shall meet test conditions 1 and 2 as outlined in Section 4.7.1(c).

4.8 Vibration

Conduct all tests at ambient room temperature and with 28 volts DC applied to the system. The time specified in Table 4.8-1 applies to each of three mutually perpendicular axes of the SSDR.

TABLE 4.8.1

Vibration Test Schedule

(Time shown refers to one axis of vibration.)

Number of Resonances	0	1	2	3
Total Vibration Time at Resonance *	-	1/2 hr.	1 hr.	1 1/2 hr.
Cycling Time	3 hr.	2 1/2 hr.	2 hr.	1 1/2 hr.

* 30 Minutes at each resonance

4.8 Vibration (continued)

The SSDR shall be normally mounted on the vibration equipment. The mounting shall simulate service installation orientation and the test fixture shall be free of resonance through 500 cps. During the resonance vibration and cycling tests, serialized input data (see Section 4.3) will be fed and stored in the SSDR memory and later retrieved and evaluated to test conditions 1 and 2 of Sections 4.8, Steps 1 and 2. Power shall be applied to the SSDR with the strain gage bridges (or their equivalent) connected and energized during the following steps.

Step 1 - Resonance Survey

Resonance modes and/or minimum performance points of the equipment shall be determined by varying the frequency of applied vibration slowly through the range of 5 to 500 cps at a double amplitude not exceeding those indicated in Table 4.8-2.

TABLE 4.8-2

Vibration Amplitude Schedule

5	-	15 Hz	±	0.3 inches D.A.
15	-	32 Hz	±	3G
32	-	60 Hz	±	0.06 inches D.A.
60	-	500 Hz	±	10G

Individual resonance survey shall be conducted with vibration applied along each of the three mutually perpendicular axes of the SSDR.

Step 2, Resonance Vibration

With the SSDR mounted on the test fixture, vibration shall be applied at each of the individual resonance points obtained in Step 1 at the double amplitude indicated in Table 4.8-2 Vibration shall be 30 minutes at each resonance and/or minimum performance points. If more than 3 resonance (channels), certain channels have been designed to accept high level signals while the remainder will accept low level signals. Table 4.2-1

4.8 <u>Vibration</u> (continued)

modes and/or minimum performance points are noted for any one axis, the three most severe shall be used for each axis. At the completion of this step, the SSDR shall be inspected for evidence of any mechanical failure. After the test has been completed, data will be retrieved from the SSDR memory and evaluated to the following criteria.

Condition 1: With no input signal applied, there shall be no events recorded.

Condition 2: With a 0.1 Hertz full scale sawtooth input signal applied, the recorded peaks and troughs shall agree completely with the input signal.

<u>Step 3, Cycling</u>

The SSDR shall be vibrated in accordance with the requirements of Table 4.8-2 over the frequency range of 5 to 500 cps. The variation in frequency shall be at a logarithmic rate; however, if logarithmic cycling is not available a linear rate of frequency change may be used. The cycle from 5 to 500 cps and return to 5 cps shall be accomplished in approximately 15 minutes including at least 3/4 minute in the region below 25 cps if the linear rate of frequency change is used. The Vibration Test Schedule, Table 4.8-1, indicates the time required for cycling. At the completion of this step, the SSDR shall be inspected for evidence of any mechanical failure. After the test has been completed, data will be retrieved from the SSDR memory and evaluated to the following criteria.

Condition 1: With no input signal applied, no event shall be recorded.

Condition 2: With a 0.1 Hertz full scale sawtooth input signal applied, the recorded peaks and troughs shall agree completely with the input signal.

Repeat Steps 1 through 3 above for each of three mutually perpendicular to be used to determine the zero values for all channels. Disconnect cable from SSDR J1 input.

4.8 Vibration (continued)

axes of the SSDR.

FIGURE 3.2.1-1 TEST SET-UP - STATIC CALIBRATION TEST

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5.0 Rationale for All Conclusions and Recommendations

The approach utilized for the design, development, and manufacture of the SIMS System proved successful and is recommended for future aircraft systems where a small size, light weight, and reliable solid state system is required.

As a result of knowledge gained, second generation systems can be designed at low cost, size and weight by incorporating the following features:

(a) A second microprocessor in the SSDR to control the MNOS memory, resulting in a lower chips count.

(b) A more efficient software program for data control such as recording data in 2K blocks to allow for easier control by the Kennedy tape transport.

keyboard. (04, 05, ----11)

h) Press START on GBI keyboard to display the selected channel calibrate value.

SOLID STATE DATA RECORDER

APPENDIX A

to

STRUCTURAL INTEGRITY MONITORING SYSTEM

of the high level channels 0, 1, 2 and 3 only.

a) Interconnect the equipment as shown in Figure 4.3-1. Set all GBI

1.0 DESCRIPTION OF EQUIPMENT

1.1 General System Description

The Structural Integrity Monitoring System (SIMS) functions to store, retrieve and transcribe aircraft flight parameters, roll rate and structural strain data in a form suitable for computer analysis.

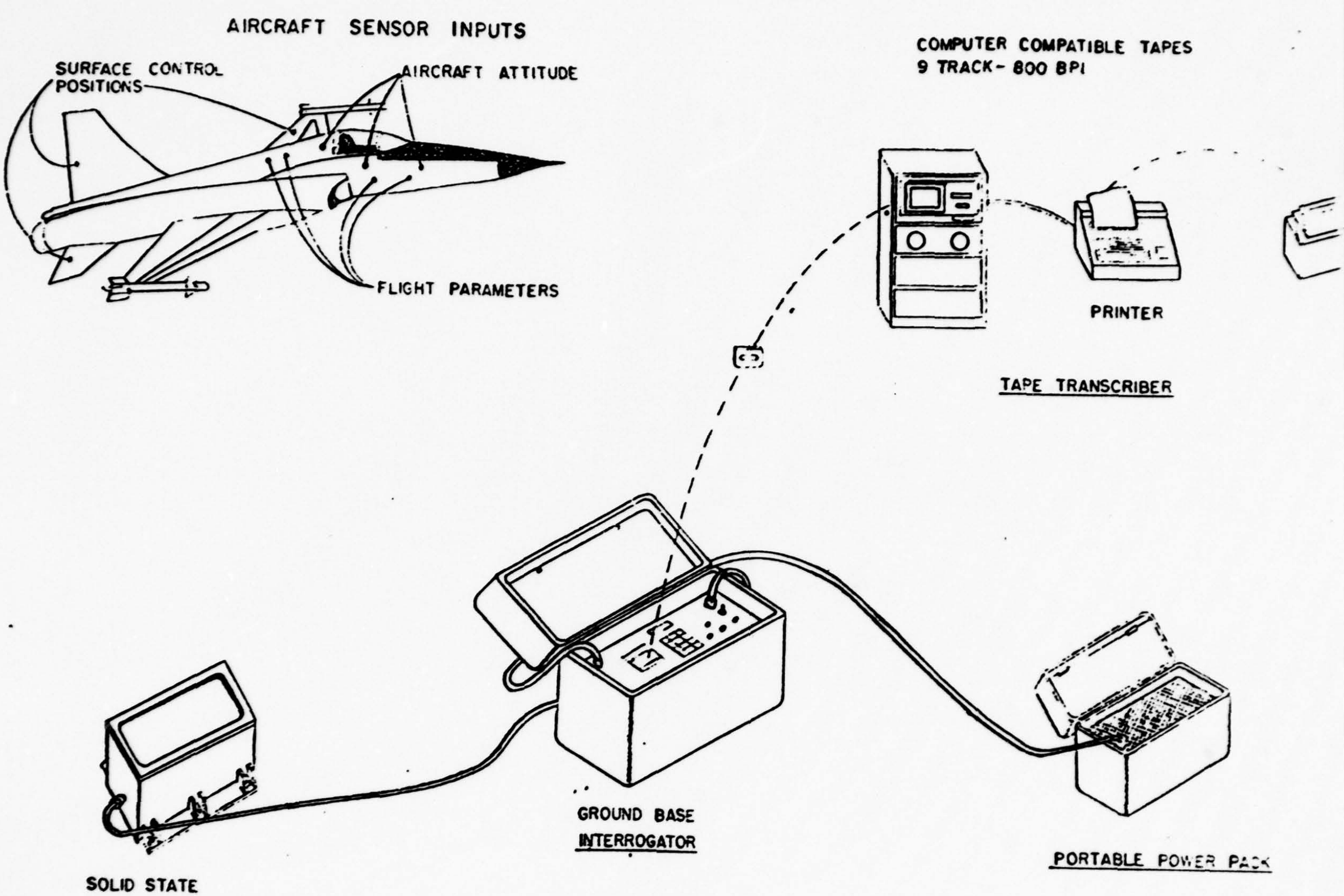
The Solid State Data Recorder (SSDR) is that portion of the system mounted within the aircraft structure. Its function is to record, within its semiconductor memory, three sets of data gathered during flight. The first set consists of flight data recorded from up to 12 individual channels composed of either strain gauges or transducers. The second set of data consists of the simultaneous recording of all 12 channels when a significant value of vertical acceleration occurs. The third set consists of a matrix formed by 12 levels of vertical acceleration and six levels of roll rate.

The semiconductor memory within the SSDR possesses the unique capability of retaining the stored data when aircraft power is removed. Thus, data is accumulated from a number of successive flights, stored in memory and retained there until retrieved by the Ground Based Interrogator.

Figure 1.1-1 shows the interrelationships of the various equipments to each other and to the aircraft. The Ground Base Interrogator is discussed in Appendix B and the Tape Transcriber in Appendix C.

1.2 Packaging and Physical Description

The Solid State Data Recorder (SSDR) consists of a number of printed circuit boards enclosed in an aluminum housing.



SIMS

STRUCTURAL INTEGRITY MONITORING STSTEM

Appendix A FIGURE 1.1-1

FIGURE .3-1 TEST SET-UP FOR SIMULATING FLIGHT DATA ACQUISITION, PROCESSING & STORAGE

calibrate readings. The voltage output results of the remaining address inputs shall track within 1% of full scale voltage output of address input 8000H after compensating for a 39 mV (1 bit) quan-
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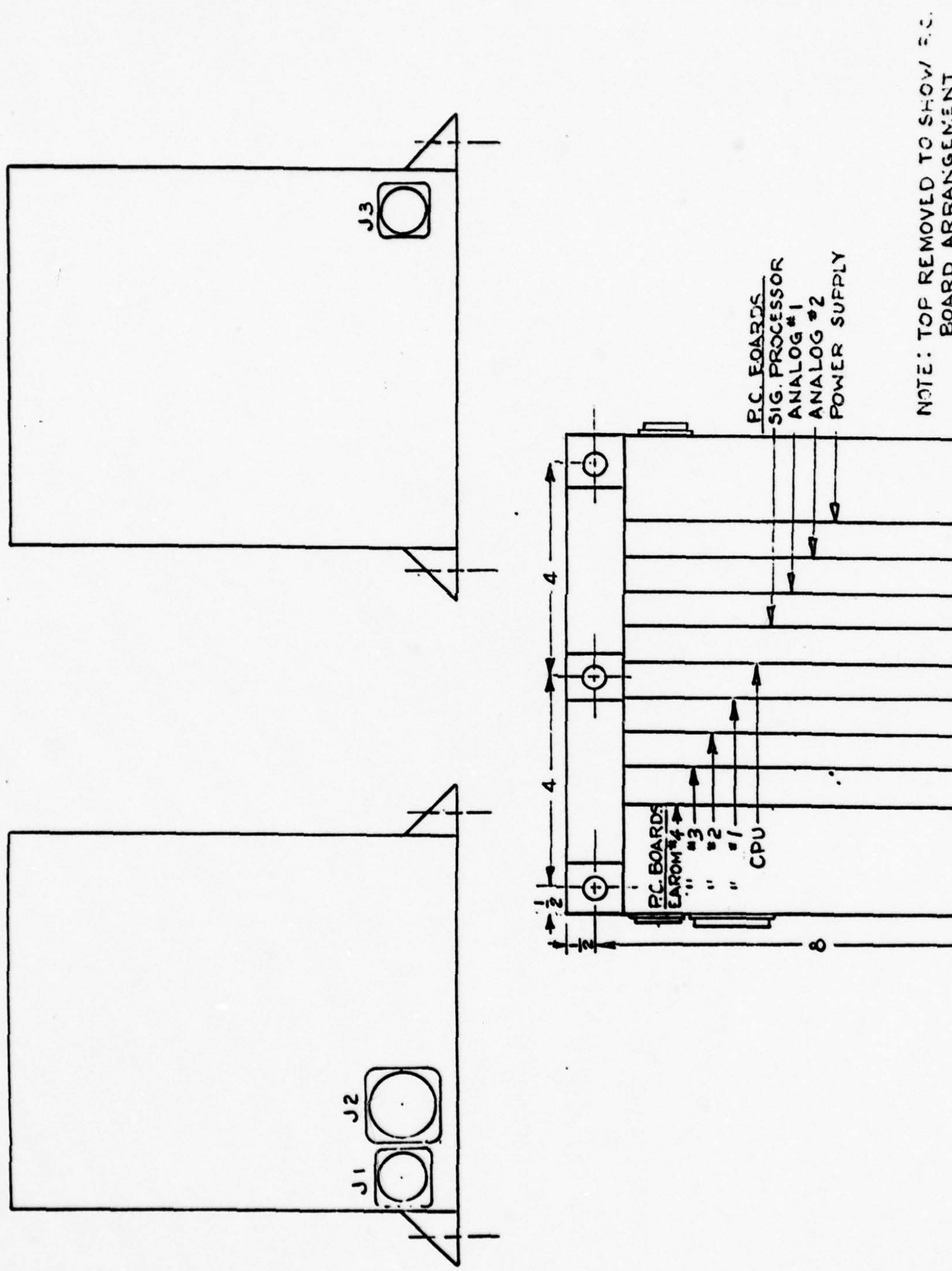
The housing provides required rigidity for shock and vibration plus thermal conduction paths to the aircraft mounting surface. Mounting brackets are welded to the side plate for added stiffness and to provide the attachment points for mounting to the aircraft structure. The SSDR measures approximately 9 x 9 x 8 1/2 inches and weighs 16 pounds. The top panel is removable and provides access to the printed circuit boards and internal wiring.

Eight printed circuit boards and a power module contain the active electronic circuitry as shown in Figure 1.2-1. An interconnect board (motherboard) is used as interface between active p.c. boards. Each printed circuit board (motherboard excepted) is approximately 5 x 6 inches and contains stiffners along its outer edges. The p.c. assembly is held in tracks positioned on the inside surface of the housing. The motherboard is approximately 8 x 6 inches and mounts horizontally near the bottom of the housing. The eight active printed circuit cards and power supply from rear to front are:

1. EAROM #4
2. EAROM #3
3. EAROM #2
4. EAROM #1
5. CPU
6. Signal Processor
7. Analog #1
8. Analog #2
9. Power Supply Module

b) Apply power to the IMSAI and $\pm$ 12 volts to the Transducer Simulator Board.



Appendix A FIG. 1.2-1 PHYSICAL CONFIGURATION & MOUNTING

4) Press IDENTIFICATION switch to up position and type any 5-digit number on the GBI keyboard. Press START key.

The power supply module is composed of two additional printed circuit boards.

1.3 Interfaces and Power Requirements

Three external connectors are provided as shown in Figure 1.2-1. Connector J3 connects to the Ground Based Interrogator. Connectors J2 and J1 are the interfaces for the aircraft transducers and power respectfully. Figures 1.3-1 and 1.3-2 show the pin functions of the interface cables. While the aircraft is powered, the SSDR draws energy, from the aircraft 28V bus. For proper operation the 28V bus is expected to remain between 25 and 31 volts. The SSDR requires approximately 30 watts of power at minimum line voltage.

2.0 INSTALLATION AND OPERATION

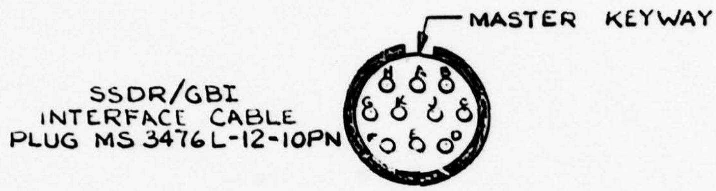
2.1 Mounting and Cabling

The Solid State Data Recorder mounts to a suitable surface within the aircraft structure. Aside from providing a smooth, flat heat transfer surface for the bottom plate of the SSDR, no other mounting requirements are specified. Figure 1.2-1 depicts the mounting hole pattern.

The rear panel of the SSDR contains the connectors for the strain-gauge/transducer and aircraft power inputs. The front panel contains the connector for interfacing with

1) Tenney JR Model TJR Environmental Chamber or equivalent.

2) Solid State Data Recorder

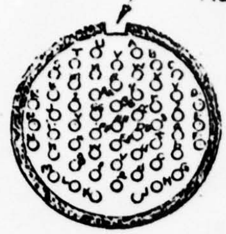


PIN FUNCTIONS

A. +28V
B. +28V
C. GND
D. GND
E. ERASE MEMORY
F. GBI INPUT
G. GBI STATUS
H. GBI OUTPUT
J. NO CONNECTION
K. GBI CONNECTED SIGNAL (+5V)

Appendix A FIGURE 1.3-1 PIN FUNCTIONS - SSDR/GBI INTERFACE CABLE TO SSDR CONNECTOR J3 f only.

SSDR/AIRCRAFT
INTERFACE CABLE
PLUG - MS 3475L 22-55 PN
TO SSDR CONNECTOR J2



PIN FUNCTIONS

A	CHAN. 6 REF. GROUND	a	CHAN. 4 INPUT (−)	AA	CHAN. 11 INPUT (+)
B	CHAN. 7 REF. GROUND	b	N/C	BB	CHAN. 9 INPUT (+)
C	CHAN. 4 REF. GROUND	c	N/C	CC	CHAN. 6 INPUT (−)
D	N/C	d	CHAN. 2 INPUT (+)	DD	N/C
E	N/C	e	CHAN. 3 INPUT (−)	EE	N/C
F	WT. OFF WHEELS SIG.	f	CHAN. 0 INPUT (+)	FF	N/C
G	N/C	g	CHAN. 1 INPUT (+)	GG	CHAN. 11 INPUT (−)
H	N/C	h	N/C	HH	CHAN. 9 INPUT (−)
J	CHAN. 2 INPUT (−)	i	CHAN. 10 INPUT (−)		
K	CHAN. 0 INPUT (−)	j	CHAN. 10 INPUT (+)		
L	CHAN. 1 INPUT (−)	k	CHAN. 10 REF. VOLTAGE		
M	CHAN. 8 INPUT (−)	m	CHAN. 5 REF. VOLTAGE		
N	CHAN. 8 INPUT (+)	n	CHAN. 11 REF. VOLTAGE		
P	CHAN. 8 REF. VOLTAGE	p	CHAN. 9 REF. VOLTAGE		
R	CHAN. 8 REF. GROUND	q	CHAN. 6 INPUT (+)		
S	CHAN. 10 REF. GROUND	r	CHAN. 7 INPUT (+)		
T	CHAN. 5 REF. GROUND	s	CHAN. 7 INPUT (−)		
U	CHAN. 11 REF. GROUND	t	N/C		
V	CHAN. 9 REF. GROUND	u	N/C		
W	CHAN. 6 REF. VOLTAGE	v	CHAN. 3 INPUT (+)		
X	CHAN. 7 REF. VOLTAGE	w	N/C		
Y	CHAN. 4 REF. VOLTAGE	x	N/C		
Z	CHAN. 4 INPUT (+)	y	CHAN. 5 INPUT (−)		
		z	CHAN. 5 INPUT (+)		

NOTES: (1) N/C = NO CONNECTION

SSDR/POWER
INTERFACE CABLE
PLUG MS 3475L 14-4SN
TO SSDR CONNECTOR J1

PIN FUNCTIONS

A	+28V
B	N/C
C	GROUND
D	N/C

Appendix A FIGURE 1.3-2 PIN FUNCTIONS - INTERFACE CABLES the Ground Based Interrogator.

2.2 Initial Operation and Calibration

After mounting the SSDR and attaching strain-gauge, power and interface cables, the unit is automatically powered each time the aircraft 28V bus is energized. No ON/OFF power switching is provided for the SSDR. The SSDR is programmed to store in memory values corresponding to each channels' reference voltage and zero level prior to each flight. Actual storage of strain gauge or transducer data begins with a signal from the weight-off-wheels switch plus significant values of acceleration or strain.

Channel calibration adjustments are not performed on the SSDR. Gain and off-set nulling are established for each channel at the factory by use of fixed resistor networks. Channel verification is made at monthly intervals using the Ground Based Interrogator. Zero and full scale values are verified for channels 4 through 11. Only a zero value verification is made for channels 0 through 3. The zero value for all channels should be within 0.00 $\pm$ 0.2 volts. The high channel full scale values should be approximately 4.0 volts. In the event that actual voltage values differ significantly from those given, the cause should be investigated. Specific procedures for verifying each channel's zero and full scale voltages are described in the manual for the Ground Based Interrogator.

N O T E

During installation of the SSDR to the aircraft structure, the following connections are required:

CHANNEL	CONNECTION
0	Normal Acceleration
1	Roll Rate
10	Air Speed or Altitude
11	Air Speed or Altitude

2.2.1 Bridge Balancing Procedure

For each installation of the SSDR into an aircraft, the strain Gauge bridges must be individually balanced to provide a zero output signal. This is accomplished by reading the zero strain output for each channel from the bridge with the GBI, and using fixed resistors to balance the Bridge for zero volts output. The following procedure presents the steps required to achieve a balanced channel output:

a) Interconnect the GBI, PPP and SSDR as shown in Figure 2.2-1. Aircraft cable to SSDR input J1 must be disconnected.

b) Set all GBI switches in the down or OFF position.

c) Remove the bottom cover of the SSDR using a #1 Phillips screwdriver.

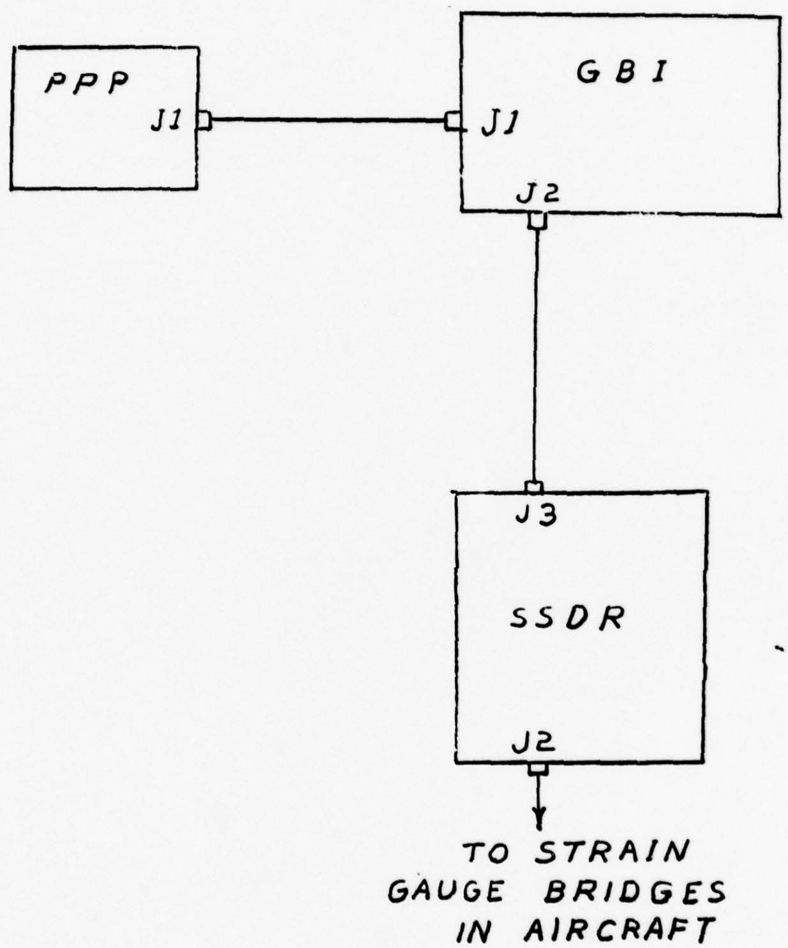
d) Apply power to the system by setting the GBI power switch to ON position.

e) Set GBI AIRCRAFT SYSTEM CHECK ZERO switch in the up position.

f) Enter a two digit number for the channel under test on the GBI keyboard. (00, 01, ----11)

g) Press START on the keyboard. After an initial delay of up to 10 seconds, the test channel zero Value will be displayed on the GBI readout.

h) If the value is less than ± 80 mv then no balancing is required.



Appendix A

FIGURE 2.2-1 TEST SETUP-BRIDGE BALANCING

i) If the value observed is minus and greater than 80 mv a shunt resistor will have to be added between the input (-) pin and reference ground pin. If the value observed is plus and greater than 80 mv a shunt resistor will have to be added between the input (-) pin and V_R pin.

j) Jumper a General Radio Co. Decade Resistor, Type 1432 or equivalent, to the terminals as determined in step f above to the strain gauge to be balanced. Refer to Figure 2.2-2 showing physical arrangement of balancing resistor terminals.

k) Start with the 100K switch and work downward in resistance until a minimum zero value is presented on the GBI digital readout. For each change in resistance the GBI must be sequenced through the following three steps:

   . Press CLEAR button

   . Enter channel number desired to be viewed

   . Press START button

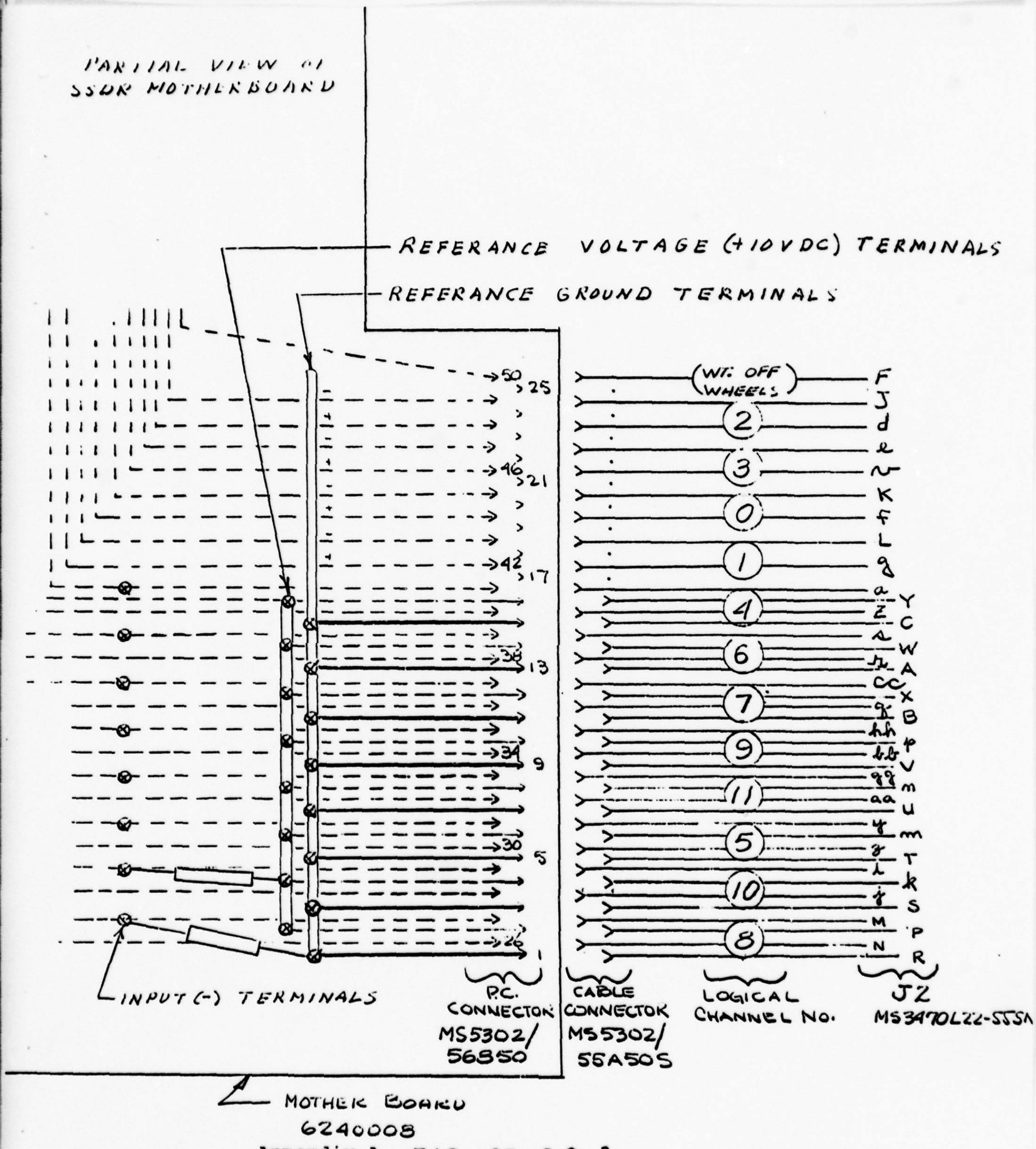
l) Select a 1% resistor as close to the value on decade box as possible and solder to terminals provided on SSDR mother board.

m) Repeat steps f through l for the remaining strain gauge channels (4 through 11).

n) Power down the system.

o) Replace the bottom cover to the SSDR.

p) Connect cable J1 to SSDR.



Appendix A FIGURE 2.2-2
PHYSICAL ARRANGEMENT FOR BRIDGE BALANCING RESISTOR TERMINALS

3.0 THEORY OF OPERATION

3.1 Circuit Description and Functions

The Solid State Data Recorder's active circuitry is packaged on eight printed circuit boards and a power supply module. Circuitry is logically arranged so that each p.c. board performs readily identifiable functions. Refer to Figure 3.1-1.

The power supply module consists of a d.c. to d.c. converter incorporating multiple outputs. Input power is taken from the 28 volt aircraft bus. The outputs of the power supply module consist of:

A. ± 12V

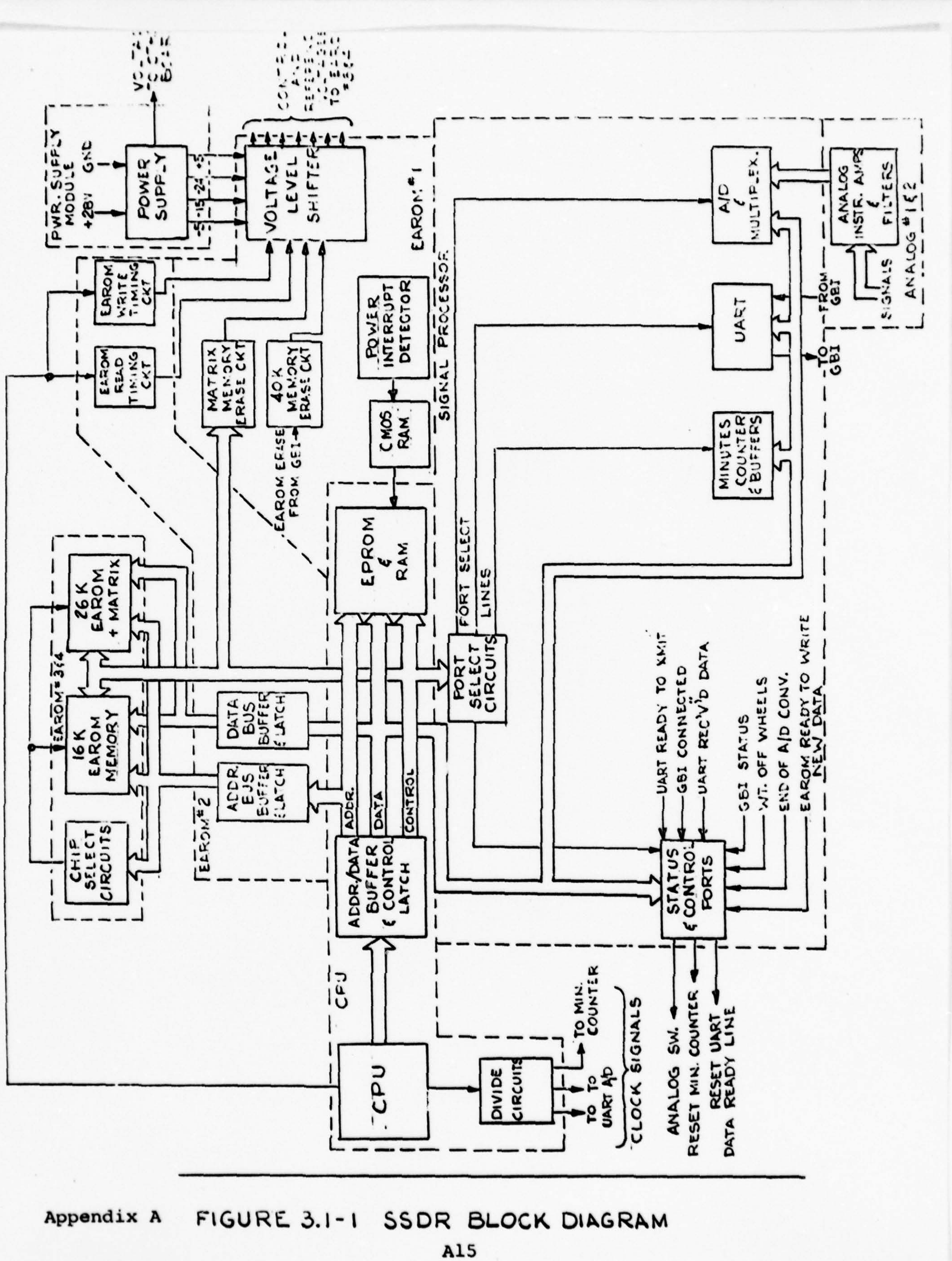
B. ± 5V

C. - 15V

D. - 24V

All output voltages except the +5V output are controlled by series regulators. A switching regulator controls the +5V supply.

Two analog p.c. boards each containing six hybrid instrumentation amplifiers and filters provide the signal conditioning for the strain-gauge and accelerometer inputs. The two fixed resistors connected to pins 21 and 22 of each hybrid establish the zero reference level for each channel.



Appendix A FIGURE 3.1-1 SSDR BLOCK DIAGRAM

A resistor network connected to pins 2, 4 and 6 of each hybrid establishes the high level reference for each channel. Switching of the reference voltage output for verification on the GBI or for memory storage prior to flight is accomplished by analog FET switches connected to pin #5 of each hybrid.

The signal processor board contains circuitry which controls the conversion of analog data to digital data. Two analog multiplexers carry the analog voltages to the A/D converter. Multiplexers are addressable under program control. Switching that connects each selected channel's analog data to the 8-bit A/D converter is controlled by the central processor unit (CPU). Speed of the conversion is controlled by a flip-flop acting as a clock. Address latches are provided to hold the address of the selected channel prior to conversion. A UART provides the ports to transfer the digital data to memory or from memory at the request of the GBI.

The CPU board contains the microprocessor which controls the overall functioning of the SSDR. The CPU board also contains the master clock, a series of buffers and drivers for both address and data busses plus memory elements for storage of the controlling program. Three, 1K x 8 bit PROM memory units comprise the read-only-memory. In addition, eight - 1K x 4 bit RAM units are provided for temporary storage of channel data and status information.

Four EAROM boards contain the non-volatile memory, memory erase interface and control circuitry and buffer circuitry.

A total of 42 EAROMS (organized 2K x 4 bit) memory units are used to store the flight data. Figure 3.1-1 shows a block diagram of the SSDR.

4.0 PERFORMANCE STANDARDS

4.1 Performance Requirements

Performance requirements for the SSDR are defined in Sections 3 & 4 of this report.

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GROUND BASE INTERROGATOR

APPENDIX B

to

STRUCTURAL INTEGRITY MONITORING SYSTEM

1.0 INTRODUCTION

1.1 Purpose and Scope

This appendix is intended as a guide for the initial set up and subsequent operation of the Ground Based Interrogator equipment portion of the Structural Integrity Monitoring System. It contains information and instructions for initial set up, operation, data verification and retrieval. Included is information regarding both physical characteristics and electrical performance of the Ground Based Interrogator and its associated Portable Power Pack.

1.2 General Systems Description

The Structural Integrity Monitoring System (SIMS) functions to store, retrieve and transcribe aircraft flight parameters roll rate and structural strain data in a form suitable for computer analysis.

The Ground Based Interrogator (GBI) and Portable Power Pack (PPP) are those pieces of the SIMS equipment that function to extract the data stored in the memory of the SSDR and transfer it onto magnetic cassette tapes for further processing. The GBI contains an integral keyboard for manual entry of data onto the cassette tape. Aircraft identification numbers, date of entry, and other pertinent record management information can be entered on tape in this manner. This equipment also provides the capability to verify channel calibration and to erase the memory within the SSDR, thus allowing for the storage of new data.

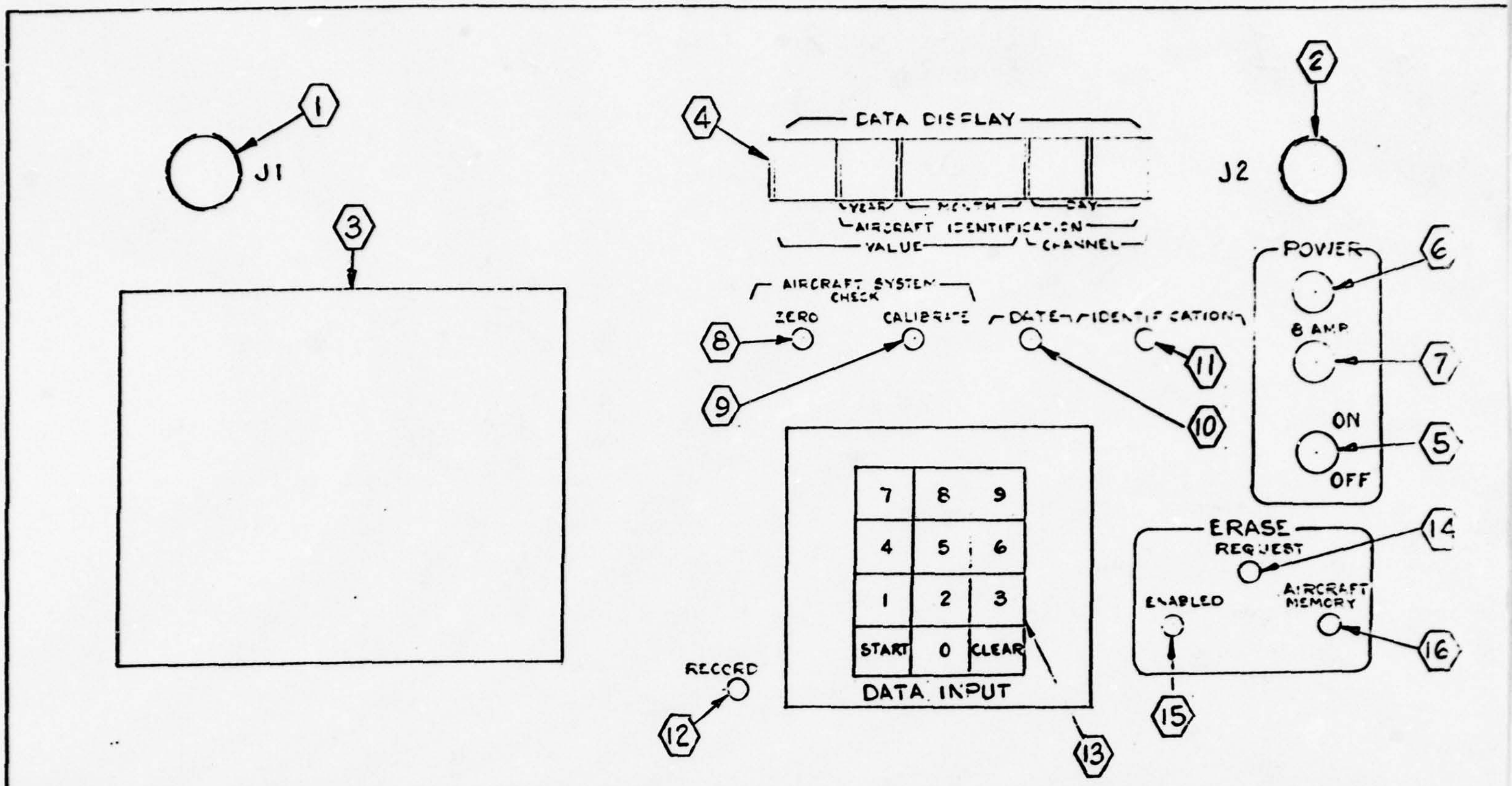
2.0 INSTALLATION AND INITIAL OPERATION

2.1 Description of Ground Based Interrogator and Portable Power Pack

The Ground Based Interrogator (GBI) provides for the data retrieval, system calibration and operational verification. The unit is enclosed in an inner case which is shock-isolated from a larger, outer case. Overall size is 22" x 10" x 16". The overall weight is approximately 30 pounds. The case is secured by two latches mounted on the front surface. Carrying handles are provided for ease of transport. A cable, which connects to the aircraft-mounted Solid State Data Recorder (SSDR), is stored in the top portion of the GBI behind the carrying handle.

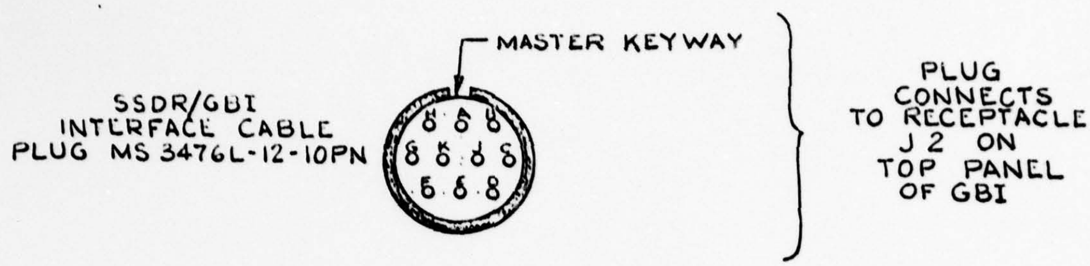
The panel of the GBI contains all the controls required for data recording, and system verification. Two interface connectors are provided. Connector J2 is used to connect the GBI to the SSDR mounted in the aircraft. Connector J1 is used for connecting the Portable Power Pack (PPP) to the GBI. Figures 2.1-1 and 2.1-2 depict the GBI control panel and pin functions for the two interface cables.

The Portable Power Pack (PPP) is housed in a separate transit case somewhat smaller than the GBI but very similar in construction. The PPP weighs approximately 50 pounds. The cable which connects the PPP to the GBI is stored in the top cover and provides power to both the GBI and SSDR during



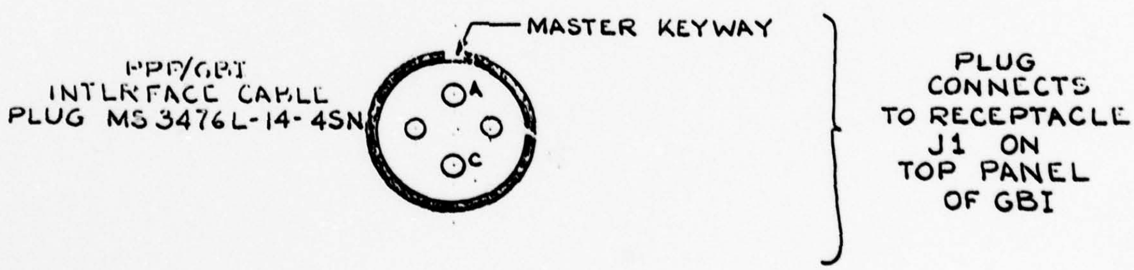
NO.	CONTROL/INDICATOR	DESCRIPTION OF CONTROL/INDICATOR
1	RECEPTACLE J1	POWER CABLE INTERFACE - GBI TO PPP
2	" " J2	DATA CABLE INTERFACE - GBI TO AIRCRAFT
3	TAPE RECORDER	CASSETTE TAPE RECORDER
4	DATA DISPLAY	DISPLAYS CHANNEL NO., CHAN. CALIBRATION ETC. (5 DIGITS & ± SIGN)
5	POWER SWITCH	ON-OFF POWER SWITCH
6	FUZE (8 AMPERE)	OVERLOAD PROTECT FUZE
7	LAMP, POWER ON INDICATOR (AMBER)	INDICATES POWER ON (WHEN LIT)
8	CHANNEL ZERO SWITCH	USED TO CHECK LOW LEVEL REFERENCE VOLTAGE FOR EACH CHANNEL
9	CHANNEL CALIBRATE SWITCH	USED TO CHECK HIGH LEVEL REFERENCE VOLTAGE FOR EACH CHANNEL
10	DATE ENTRY SWITCH	ALLOWS DATE TO BE RECORDED ON TAPE
11	AIRCRAFT IDENTIFICATION ENTRY SW.	ALLOWS A/C IDENTIFICATION TO BE RECORDED ON TAPE
12	RECORD DATA SWITCH	ALLOWS DATA TO BE RECORDED ON TAPE FROM AIRCRAFT
13	KEYBOARD	USED FOR LOCAL DATA ENTRY, CALIBRATION, ETC.
14	ERASE REQUEST SWITCH	SENDS ERASE REQUEST TO SSDR
15	LAMP, ERASE ENABLED (GREEN)	INDICATES SSDR READY TO ACCEPT ERASE SIGNAL
16	AIRCRAFT MEMORY ERASE SWITCH	ERASES SSDR MEMORY

APPENDIX B FIGURE 2.1-1 CONTROLS & INDICATORS - GBI



PIN FUNCTIONS

A. +28 V
B. +28 V
C. GROUND
D. GROUND
E. ERASE MEMORY
F. GBI INPUT
G. GBI STATUS
H. GBI OUTPUT
J. NO CONNECTION
K. GBI CONNECTED SIGNAL (+5V)



PIN FUNCTIONS

A. +28 V
C. GROUND

APPENDIX B FIGURE 2.1-2 PIN FUNCTIONS - INTERFACE CABLES record or verification sequence. The battery located in the PPP is recharged using the 110 VAC line cord located in the top cover of the transit case. Controls are located at the left hand side of the top panel. These consist of a power ON/OFF switch and a LOW BATTERY light.

2.2 Initial Set-Up and Cabling

Prior to placing the GBI into operation several activities are required. Place the GBI and the PPP on a firm level surface near the aircraft.

CAUTION

The connecting cable between the GBI cover and the main case MUST be disconnected before attempting to remove the cover from the case.

Verify that airplane power is off and that power switches on the GBI and the PPP are in the OFF position. Connect one end of the cable located in the cover of the PPP to the connector on the top panel of the PPP. Connect the other end to J1 on the GBI. Remove the cable from the cover of the GBI and connect one end to J2 on the top panel. Connect the other end to the SSDR output connector at the aircraft. Allow sufficient slack in the two cables so as not to place strain on the wire terminations within the cables. Tighten all connectors securely.

2.3 Operating Instructions

In order to record data stored in the SSDR memory on the cassette tape proceed as follows:

A. Verify that cables have been securely fastened to their respective connectors. Place all switches on the GBI to their OFF or deactivated positions.

B. Place the Power OFF/ON switch located on the GBI to the ON position.

C. Place an unused cassette in the recorder and secure in place using the hold down levers. Verify that the correct side of the cassette is facing upward. prior to locking into position.

Note: Each tape cassette should be used until full or until all aircraft have been interrogated.

D. Activate the DATE switch located above the keypad.

E. Enter the current date in the DATA DISPLAY using the keypad. Enter one digit for year, two digits for month and two digits for the day. For example, June 18, 1978 is entered 80618.

F. Press the START button on the keypad.

G. Deactivate the DATE Switch and activate the IDENTIFICATION switch.

H. Enter the aircraft identification number (maximum 5 digits) in the Data Display using the keypad. Press the START button.

   Note: If an incorrect date or identification number is entered, press the CLEAR key and re-enter the correct information. Corrections must be made prior to step K. If more than one switch is activated, the GBI will not operate and no data can be entered in the display.

I. Deactivate the IDENTIFICATION switch.

J. Activitate the RECORD switch on the GBI.

K. Press the START button on the keypad.

The data stored in the SSDR should now be recording on the cassette. Rotation of the cassette spindles should be observed at this time. Data from the SSDR will be recorded on the tape and verified under control of the GBI and SSDR. Data can be transferred from the SSDR to the tape in approximately 35 seconds.

L. Upon completion of the data recording operation, deactivate the RECORD switch.

M. Activate the <u>ERASE REQUEST</u> switch.

N. When the ERASE ENABLED light comes on, activate the AIRCRAFT MEMORY ERASE switch. Erasure is completed within 5 seconds.

O. Deactivate the AIRCRAFT MEMORY ERASE & ERASE REQUEST switches.

Note: Tape rewind operations are not performed on the GBI.

P. Place power switch on the GBI in the OFF position. Disconnect cables and store in their respective transit cases. In the event that the ERASE ENABLE light does not come on after an ERASE REQUEST, verify that sufficient tape remains or tape is not jammed. If sufficient tape remains, press CLEAR and repeat procedure beginning at step J.

2.4 Battery Charging

Each Portable Power Pack (PPP) contains built-in circuits for battery charging. Consequently, battery charging is readily accomplished by connecting the PPP to a 110 VAC power outlet. The batteries within the PPP may be used up to 2 1/2 hours between charges. Charging is accomplished in 8 hours.

Charging is accomplished as follows:

1. Place PPP power switch in the OFF position. Connect the 110 VAC power cable to a source of 110/120 VAC 60 cycle power. Turn the power switch ON.

2. Charging is completed in 8 hours or less depending on battery depletion. No other operations are required.

3.0 VERIFICATION PROCEDURES

3.1 Verification Requirements.

Periodic verification of channels' zero point and reference voltage is advised. Verification is most readily accomplished at the time of data transfer from SSDR to tape. This occurs at approximately 30 day intervals. Periodic verification is accomplished with the GBI.

3.2 Detailed Procedures

Two types of amplifiers are used for the input signals to the SSDR. The first of these is designed to amplify low level strain-gauge signals to a level useable for data extraction and storage. The second type is designed to act as a buffer for high level signals from accelerometers and other such devices. Because of the high signal level input to the second type, the buffer provides no increase in signal level.

Verification procedures differ slightly for the two types. Channels 0, 1, 2 and 3 are the high level channels, for which, only the zero point is verified. For channels 4 through 11, both zero point and reference voltage are verified. To verify channels 0 through 3, complete steps A through D. To verify channels 4 through 11, complete steps A through E.

Verification proceeds as follows:

A. Interconnect the SSDR, GBI and PPP as described in Section 2.2 of this manual.

B. Place the power switche on the GBI to the ON position.

C. Activate the switch on the GBI labeled AIRCRAFT SYSTEM ZERO.

D. Type the desired channel number on the keyboard. Press START key, the data display should indicate channel number and voltage value. The value displayed should be 0.00 ± 0.2V. If displayed values on any one channel exceed specified limits, system calibration is required as outlined in SSDR Manual.
<u>Note that the display contains no decimal point.</u> Voltage values are displayed as volts, tenths and hundredths reading from left to right. The sign of the voltage value (+ or -) is shown to the left of the value. To repeat this process for the remaining channels, press CLEAR, then START and type in new channel number. When completed, deactivate the zero switch.

E. Activate the CALIBRATE switch. Type the desired channel number on the keyboard. Press START key. The data displayed should indicate the channel number and reference voltage Value. The Value displayed should be 3.85 ± 0.4V.

<u>NOTE:</u> When CALIBRATE switch or ZERO switch is first activated, a delay of up to 25 seconds may be experienced prior to displaying the reference voltage.

If displayed values on any one channel exceed specified limits, system calibration is required as outlined in the SSDR Manual. Upon completion of the verification sequence, return all switches to their OFF or deactivated positions. Disconnect and store cables.

4.0 THEORY OF OPERATION

4.1 Functional Description

The primary function of the Ground Based Interrogator (GBI) is to record on magnetic cassette tape the digital voltage values corresponding to aircraft acceleration levels and strain gauge values. Its secondary function is to verify calibration of the Solid State Data Recorder (SSDR). The GBI performs its various functions under control of a microprocessor. This element, acting as master control for all GBI functions, operates in conjunction with other computer logic elements to effect data transfer and to verify SSDR calibration. The GBI is, therefore, a specialized form of computer containing a stored program which allows it to communicate with the memory of the SSDR, display voltage values for calibration purposes and control the recording sequence of the cassette tape unit.

Although physically packaged as a single unit within its transit case, the GBI can be functionally separated into two parts. These are: 1) the GBI logic, display and control portion and 2) the cassette recorder and its associated control electronics. Figure 4.1-1 and Figure 4.1-2 show the block diagrams for these two portions. Enclosed with this manual is the "Operation and Interface Manual" for the MFE Model 250B Digital Cassette Tape Transport.

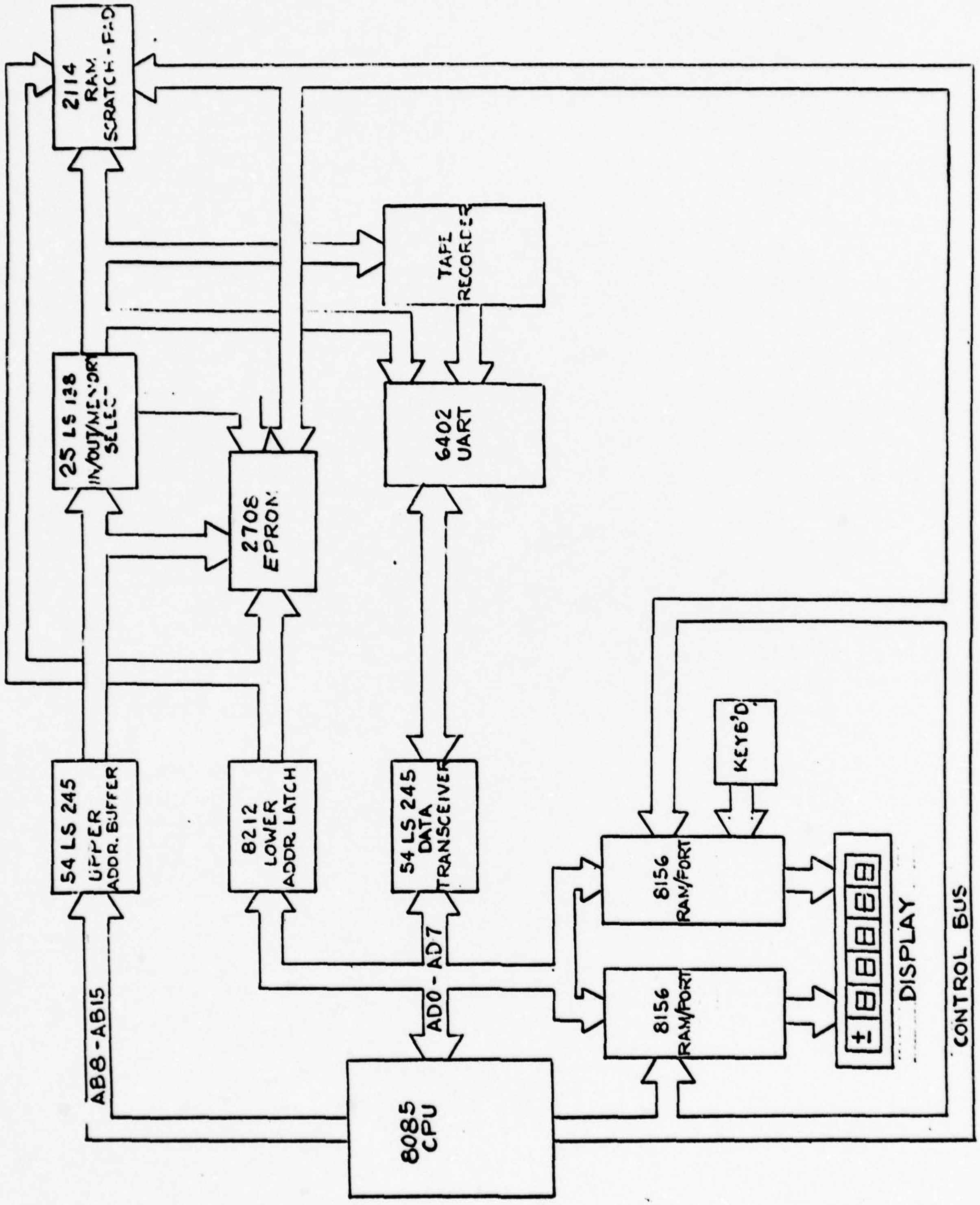
The Portable Power Pack provides the necessary power source for the GBI and SSDR data transfer and calibration operations. The voltages supplied are derived from a 28 volt rechargeable battery housed in the transit case. DC to DC converters transform the 28V source into ±12V and ±5V supplies.

4.2 Circuit Operation

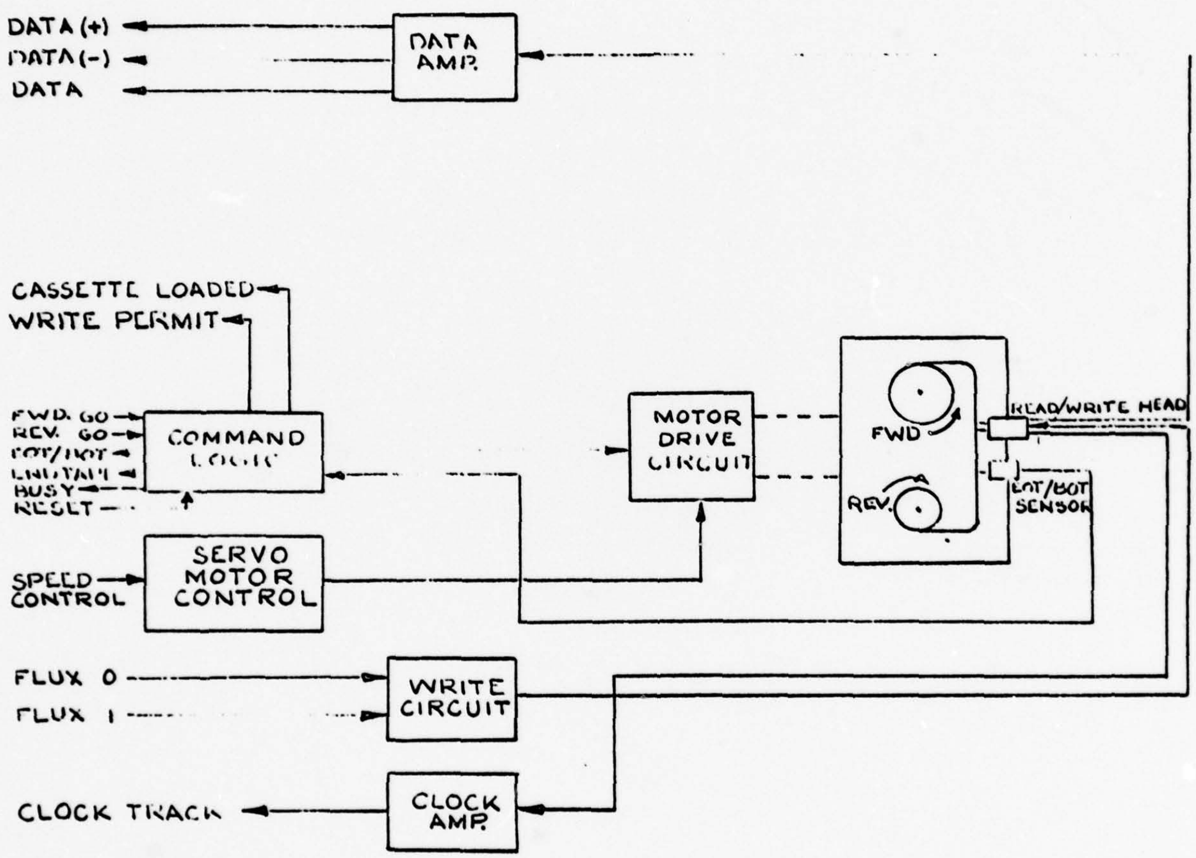
The control circuitry for the Ground Based Interrogator (GBI) is composed largely of integrated circuits mounted on one large and several smaller printed circuit boards.

Functionally the GBI can be separated into 5 major parts. These are:

1. The Central Processor Unit (CPU)
2. Erasable Programmable Read-Only-Memory (EPROM)



APPENDIX B FIGURE 4.1-1 GROUND BASED INTERROGATOR-BLOCK DIAGRAM



APPENDIX B FIGURE 4.1-2 CASSETTE RECORDER BLOCK DIAGRAM

3. Random Access Memory (RAM)
4. Input/Output (I/O) Ports
5. Select circuitry

The GBI is centered around the type 8085 CPU which provides overall control for the record and calibrate functions. The lower address lines from the 8085 are latched into the type 8212 chip in the beginning of each machine cycle. The higher address line and IO/$\overline{M}$ are buffered for more drive capability through a 54LS245 chip. The data lines are also buffered through a 54LS245 chip. The 8085 receives its instructions from two 2708 EPROMS. The EPROMS can store up to 2K bytes of coded instructions. The RAM which functions as a "scratch pad" is located in two 2114 chips and two 8156 chips. Together the two 2114 chips can store 1K bytes of data. Each 8156 chip can store 256 bytes of data. I/O ports are located on two 8156 chips, the 6402 UART chip and the USRT chip located in the tape unit.

The 6402 UART has one port for receiving data from the SSDR and one for transmitting data to the SSDR. The clock frequency of the UART is 1MHZ obtained by dividing the 3MHZ signal from the 8085 by 3.

The MFE tape recorder interface consists of 6 ports. These are:

A. Two ports for status information.

B. One port for tape transport control.

C. One port for transmitting the sync character to the USRT within the MFE.

D. One port for transmitting data to the tape.

E. One port for receiving data from the tape.

In addition to random access memory (RAM) each 8156 chip contains two 8-bit ports and one 6-bit port. Each port may be programmed to be either input or output. The memory and port select lines are derived from three 25LS138 chips. One is used to select memory, one to select input ports and one to select output ports.

5.0 PERFORMANCE STANDINGS

Along with data retrieval, the GBI also provides the capability for verifying individual channel calibration of the SSDR. Initial calibration of the SSDR is done on all channels at the Electrodynamics factory facility. If field calibration is required, adjustments can be made by the customer as outlined in Appendix A.

Report NADC-77101-30

TAPE TRANSCRIBER

APPENDIX C

to

STRUCTURAL INTEGRITY MONITORING SYSTEM

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1.0 Description of Equipment

1.1 General System Description

The Structural Integrity Monitoring System (SIMS) functions to store, retrieve and transcribe aircraft flight parameters, roll rate and structural strain data in a form suitable for computer analysis.

The Tape Transcriber (TT) is that portion of the SIMS equipment that is used for formatting data to IBM compatability. When loaded into the Tape Transcriber, the cassette tapes are transferred onto 9 track, 0.5 inch tapes capable of being processed by CDC 6600 machines. The Tape Transcriber is composed of several commercially available units including a Kennedy Model 9832 Buffered Tape Transport and a Texas Instruments Model 700 Silent Printer.

1.2 Tape Transcriber Physical Description

The Tape Transcriber (TT) is housed in a painted sheet metal cabinet measuring approximately 24" x 20" x 22". The Tape Transcriber is composed of three major units, two of which are purchased from commercial sources. These are the Kennedy Model 9832 9-Track Tape Transport and the MFE Model 250B Digital Cassette Tape Transport. The Kennedy measures approximately 12x17x19 inches and is mounted in the lower portion of the TT cabinet. The MFE is smaller, measuring approximately 5 and 1/2 x 4 and 1/2 x 4 inches and is located above the Kennedy. Enclosed with the TT Manual is the "Operation and Maintenance Manual" for the Kennedy Model 9832 Buffered Tape Transport and "Operation and Interface Manual" for the MFE Model 250 B Digital Cassette Tape Transport.

The control logic and memory circuits which control the transcription process are mounted on a large printed circuit board. This printed circuit board is mounted inside the TT cabinet at the rear for easy access.

The Kennedy 9-Track Tape Transport contains a number of controls and indicators located at the lower right corner of the transport unit. The following gives a description of the functions of these controls and indicators.

1. End of File Pushbutton and Indicator - This pushbutton and its associated indicator is used to generate an end of file sequence before rewinding tape in the event that this sequence is not provided by the stored programs or the cassette tape.

2. On Line Pushbutton and Indicator - When this pushbutton is first activated, the tape unit is placed in an on-line condition. When the tape unit is on-line it can be remotely selected provided that the tape is loaded to or past the load point. When activated again it takes the unit off-line. The indicator is illuminated when the unit is on-line.

3. Load Pushbutton and Indicator - This pushbutton activates the reel servos (tape tensioning) and starts the load sequence. The indicator is illuminated when the reel servos is activated and tape is under tension.

4. Rewind Pushbutton and Indicator - This pushbutton activates the rewind operation. This control is enabled only when the tape is tensioned and the unit is off-line. The indicator is lit during the rewind operation.

5. Write Status Indicator - This indicator is illuminated whenever the tape unit is on-line and write status is selected.

6. Data In Memory Indicator - This indicator is lit whenever there is data in memory which has not been transferred to the tape.

7. Write Enable Indicator - This indicator is illuminated whenever a reel with a write enable ring is mounted on the supply (file) hub.

2.0 Tape Transcriber Set-Up and Operation

2.1 Initial Set-Up

The initial set-up of the Tape Transcriber is readily accomplished. The Tape Transcriber should be placed on a firm level surface, preferably a sturdy bench or table top. Connect the Silent 700 printer/keyboard to the Tape Transcriber. Connect the Transcriber and Printer to a source of 110V AC power using the line cord provided. No other operations are required.

2.2 Operating the Tape Transcriber

Only three external commands are used in the operation of the Transcriber. The "TAPE" command transfers data from the cassette to the Kennedy 9-track tape. The "PRINT" command causes the data on the cassette to be printed on the Silent 700. The "ERASE" command initiates erasure of the cassette tape. Commands are entered using the Silent 700 keyboard.

1. To initiate a "PRINT" sequence, perform the following:

   (a) Load the cassette into the MFE and lock into position. Turn the power switch located adjacent to the cassette unit to ON.

   (b) Type "PRINT" on the Silent 700 keyboard and press the "RETURN" key. The cassette tape will be automatically rewound to the beginning and its contents printed on the Silent 700. No other operations are required. There are four command instructions for obtaining print outs. These are discussed in Section 4.3.2.

2. To initiate an "ERASE" sequence, proceed as follows:

(a) Load cassette and turn cassette unit power ON.

(b) Type "ERASE" on Silent 700 and press "RETURN" key. The Transcriber has been programmed to respond with a message asking whether all data has been transcribed and whether you wish to proceed with the erasure. To erase, type Y (yes) on the keyboard. To abort the erase sequence, type N (no) on the keyboard.

(c) Tape will be rewound and the erasure will proceed automatically. In the event that the cassette tape is not completely erased, a message to this effect will be printed on the Silent 700. Should this occur, repeat step b.

3. To initiate a "TAPE" sequence, proceed as follows:

(a) Load cassette and turn cassette unit power ON.

(b) Install tape supply and take-up reels on the Kennedy 9-track tape unit.

(c) Press the LOAD pushbutton located at the lower right section of the Kennedy. When tape is tensioned the indicator light will come on.

(d) Press the ON LINE pushbutton. When the unit is in the on-line condition, the indicator will light.

(e) Type "TAPE" on Silent 700. The cassette tape will automatically be rewound and the transfer of data will begin. Additional cassette tapes can be transcribed onto the Kennedy by repeating this step.

(f) When the Kennedy 9-track supply reel is nearly exhausted press END OF FILE pushbutton.

(g) After the end-of-file lamp lights, press ON-LINE pushbutton to take Kennedy off-line. The on-line indicator lamp should extinguish.

(h) To rewind the Kennedy tape press REWIND button. During the rewind operation the rewind indicator lamp will be illuminated.

No further operations are required. Cassette tapes will be rewound during the "ERASE" sequence.

3.0 Theory of Operation

3.1 General

The command logic and control circuitry for the Tape Transcriber is packaged on one printed circuit board. With slight differences, this circuitry is both physically and functionally the same as that used in the

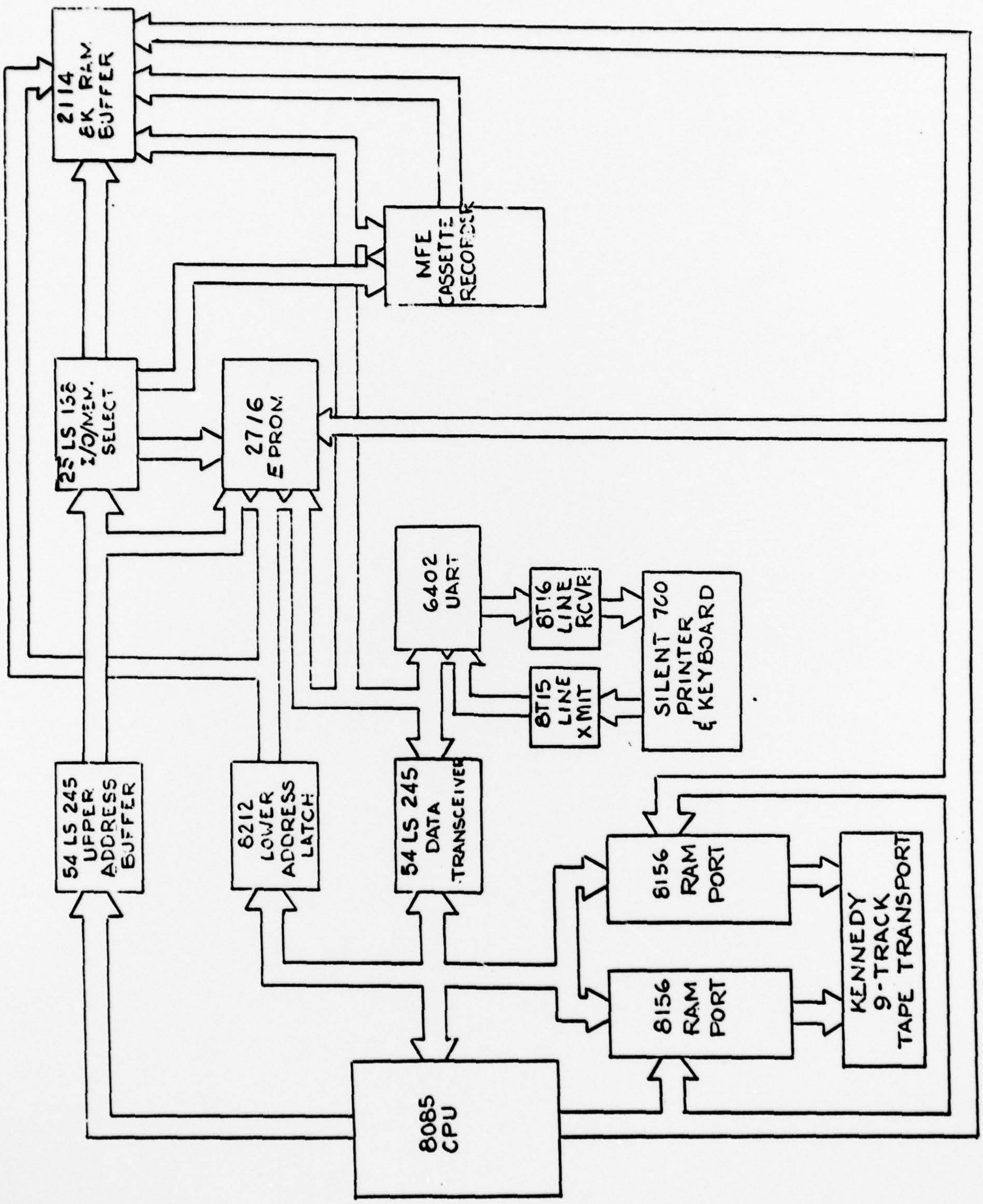
Ground Based Interrogator. The major differences occur at the interfaces. A block diagram of the Tape Transcriber is shown in Figure 4.1-1.

Under the control of the CPU, data from the cassette tape is dumped and stored in 8K Memory (2114 RAM) and manipulated by the software instructions programmed into the 2716 E PROMS. The CPU is interfaced to the Kennedy Tape Transport and Silent 700 printer through (8156) RAM I/O ports. Keyboard "COMMANDS" enable transfer of data from memory to either the Kennedy Tape or paper printout. Transmission of data occurs through the 6402 UART.

3.2 <u>Circuit Description and Function</u>

The principle control element for the Transcriber is the 8085 microprocessor which functions as the central processing unit (CPU) and which exerts control over all transcribing functions. The program instructions (software) are stored in two 2716 erasable programmable read-only memories (EPROM). Together these contain 4K x 8 bits of memory capacity.

An additional 7K of random access memory (RAM) is provided by 14 type 2114 devices. These function as both a "scratch-pad" memory and buffer for the data read from the cassette tape. Two additional RAM devices (type 8156) act as input/output ports for the Kennedy 9 Track Tape Transport unit.



APPENDIX C FIGURE 4.1-1 TAPE TRANSCRIBER BLOCK DIAGRAM

I/O port select lines along with memory select lines are derived from four 25LS138 chips.

Two sets of address lines are derived from the CPU. The upper address lines are buffered through a 54LS245 to either a memory or an input select chip (54LS138). Lower address lines are latched to an 8212 leading to RAM and EPROM. Bidirectional data transmission is accomplished using a second 54LS245.

A Texas Instruments Silent 700 printer/keyboard provides the command word capability for initiating transcription and allows read-out of the data being transcribed. The Silent 700 is connected directly to a line transmitter (8T15) and receiver (8T16) pair which provide increased drive capability for proper operation. Interfacing for the Silent 700 is accomplished through a 6402 universal asynchronous receiver/transmitter (UART). The UART is clocked at a rate compatible with the Silent 700 data I/O rate (300 Baud).

3.3 Data Transcription and Control

Three basic command instructions are used in the operation and control of the Tape Transcriber:

1) Tape
2) Print
3) Erase

These commands are typed on the keyboard of the Silent 700 Printer and echoed back onto a hard copy. Commands to be entered follow a left arrow designation (>). A character typed in error in a command instruction can be deleted by pressing the "Rub-Out" key with the resulting echo back character having a back arrow designation (<).

All command instructions contain three types of messages during the print-out operation. These messages are either Directives, Statements or Questions.

DIRECTIVES - Tells operator what to do. In the case of the Transcriber, the only necessary directive is to press the "RETURN" key on the keyboard after message has been printed.

STATEMENTS - Messages that give the operator some information on what is presently happening.

QUESTIONS - Messages that require yes or no answers. Depress "Y" key on keyboard for yes and "N" key for no.

3.3.1 "Tape" Command

"Tape" Command instruction allows the Transcriber to transfer data information from a cassette onto a Kennedy Tape. After the data transfer has been completed, a statement is printed out to tell the operator if the transfer has been completed successfully. If the transfer has been successful, another cassette can be loaded and the transfer procedure repeated. After all of the cassettes have been transferred, an automatic end-of-file mark is placed onto the Kennedy tape.

If data transfer is not successful (tape error) or all transfer of cassettes have been completed, the Kennedy tape should be replaced. If a cassette jam error occurs, that portion of data following the jam-up will not be transferred. All data before the jam-up will be transferred.

3.3.2 <u>"Print" Command</u>

There are four command instructions for obtaining print outs on flight information data. They are:

- "Print-Hex"
- "Print"
- "Print-Sort"
- "Print-Mini"

Command instruction "Print-Hex" gives all flight information data in hexidecimal form. Command Instruction "Print" gives a sequential print of peaks and valleys along with time slices in their respective time positions. Command "Print-Sort" gives channel sorts of all peaks and valleys by their channel number with the time slice information printed out in channel 0 position only. Command "Print-Mini" gives channel sort for channel 0 only, so that the print-out is mainly on time slice data.

All printouts also include the matrix data. Each matrix or flight begins and ends with a line of asteriks (*). Commands "Print-Sort" and "Print-Mini" contain individual channel numbers with data separated by a line of minuses (-). "Print", "Print-Sort", and "Print-Mini" printouts all have date identification, serial number, flight number, and initialization values. All data values are in volts relative to the 0% value. The 0% and 100% initialization values are expressed in absolute volts.

Five initialization values contain data for 12 separate channels, beginning with channel 0 on Line 1 and ending with channel 11 on Line 12. Time slice data is read horizontally on 3 lines. Line 1 contains data for channels 0 thru 3; Line 2 - channels 4 thru 7; Line 3 - channels 8 thru 11. Additional information included is flight time, a touch and go, and power failure in flight.

Six roll rates and twelve normal acceleration values are represented in a 72 position matrix. The six roll rate values are:

1) -4.97 to -3.32	4) -0.04 to 1.60
2) -3.32 to -1.68	5) 1.60 to 3.25
3) -1.68 to -0.04	6) 3.25 to 5.00

The twelve normal acceleration values are:

1)	-4.97 to -1.99	($<$ -3 g's)
2)	-1.99 to -1.49	(-3 g's to -2 g's)
3)	-1.49 to -0.98	(-2 g's to -1g)
4)	-0.98 to +0.55	(-1g to 0g's)
5)	0.55 to 1.06	(2 g's to 3 g's)
6)	1.06 to 1.56	(3 g's to 4 g's)
7)	1.56 to 2.07	(4 g's to 5 g's)
8)	2.07 to 2.58	(5 g's to 6 g's)
9)	2.58 to 3.09	(6 g's to 7 g's)
10)	3.09 to 3.60	(7 g's to 8 g's)
11)	3.60 to 4.11	(8 g's to 9 g's)
12)	4.11 to 5.00	($>$ 9 g's)

Roll rates and normal acceleration values are in absolute volts.

There are two features added for the convenience of the operator to use during a print-out routine.

Pressing the "S" key during a printing routine will cause all printing to stop. Pressing the "S" key again will cause printing to continue. This routine is useful if paper has to be changed during a print out.

The second feature is the "Escape" key. This gives the operator the choice of skipping flight data or channels, or just printing parts of a cassette.

Pressing the "Escape" key:

a) During data printout of a particular channel in a "Print-Sort" or "Print-Mini",will result in stopping the printing of that channel and proceed to printing data on the following channel.

b) During data print out at the end of a channel (Minus Line) in a "Print-Sort" or "Print-Mini" will stop printing data of that flight and proceed to printing data of next flight.

c) During print out at end of flight or matrix (asterik line), will result in stopping the cassette.

d) During the reading of the cassette, when no printout is occurring, the Cassette will stop reading and no more data will be printed.

WARNING - Maximum memory storage capability of the tape transcriber on any one flight is limited to 7K Bytes of data. Only the data after 7K Bytes will not be transferred from the cassette onto the Kennedy Tape or printed out on the Silent 700 printer. Printout message will read "Memory Overflow".

3.3.3 "ERASE" Command

"ERASE" command instruction erases data information on cassette tape. (NOTE: It is important to make sure data information has been Transferred successfully onto a Kennedy tape before erasing cassette.) The "ERASE" command also checks to see if the cassette tape has been erased.

4.0 PERFORMANCE STANDARDS

A master cassette with simulated test data and all data print outs are supplied by Electrodynamics to the customer for performance evaluation of the tape transcriber.