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SOFTWARE FOR AN EXPERIMENTAL AIR-GROUND DATA LINK
Volume II: System Operation Manual

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E. Rachlis

OCTOBER 1975
FINAL REPORT

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16. Abstract

This report documents the complete software system developed for the Experimental Data Link System which was implemented for flight test during the Air-Ground Data Link Development Program (FAA-TSC Project Number FA-13).

The software development is presented in three volumes as follows:

Volume I: - - Functional Description and Flowcharts
Volume II: - - System Operation Manual
Volume III: - - Program Listing.

The material contained in Volume II describes the system operation and is intended as a user's guide. Volume II is a complementary document to Volumes I and III.

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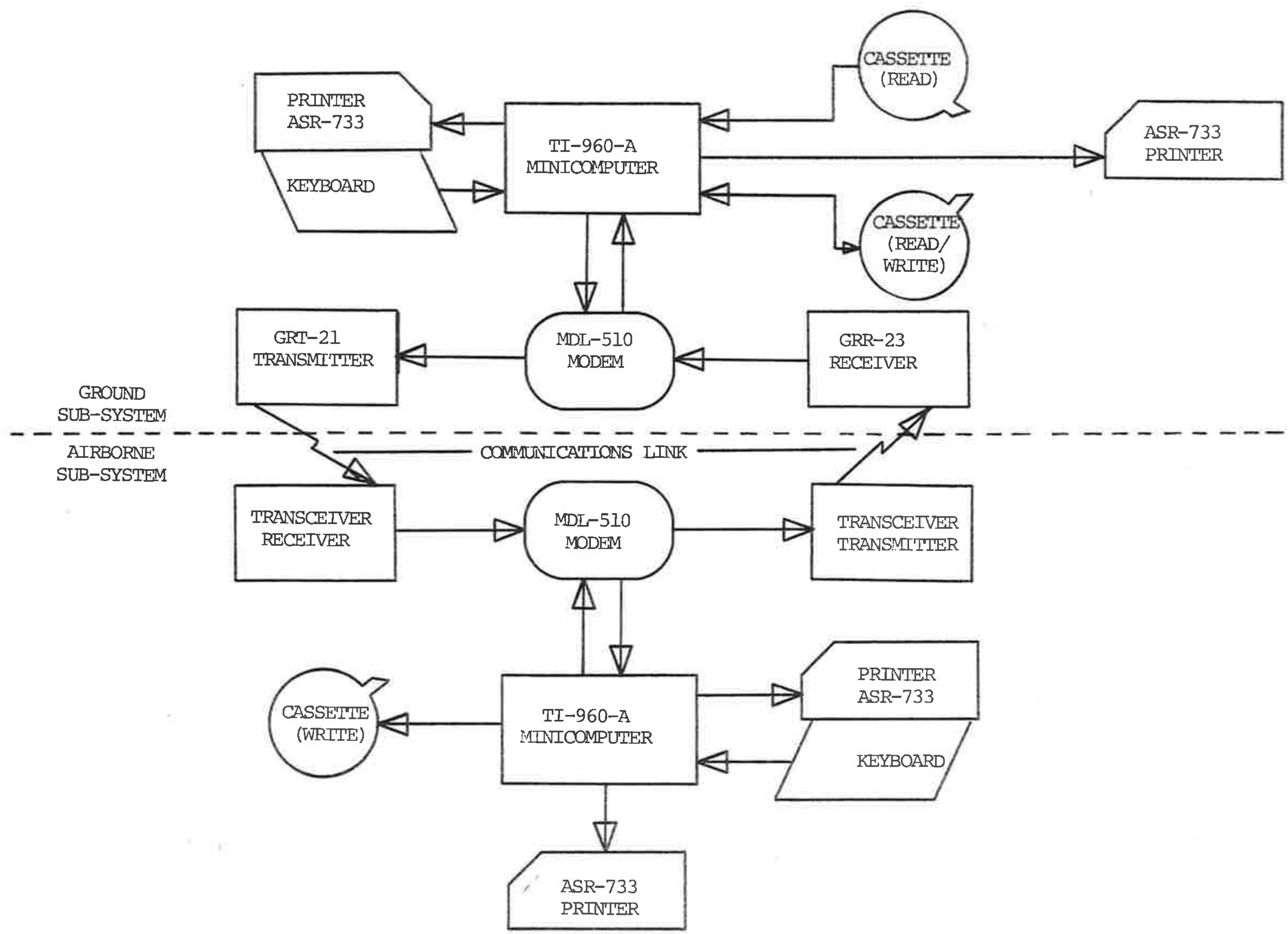
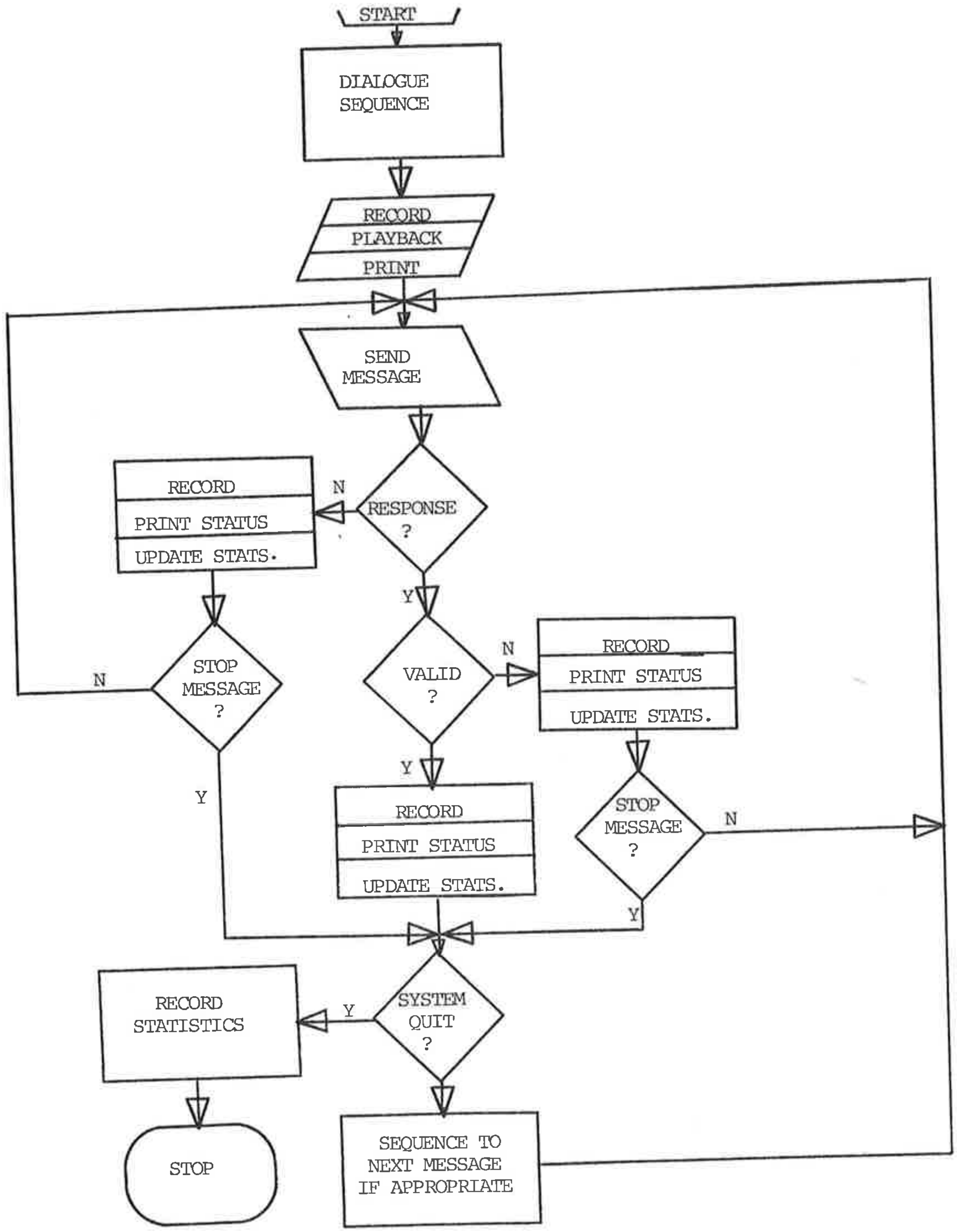
I. SYSTEM OBJECTIVE/FUNCTION

The Data-Link communications system is a dual-computer, simplex system designed to provide a test bed facility to determine the link management requirements for a Data-Link in an air traffic control environment. The system provides the facility for investigating system entry techniques, polling schemes, error coding and detection, message priority structure, message queue requirements and frequency management requirements.

Operating in the environment of a master/slave discipline, the system uses digital cassette magnetic tapes as a history logging device. The data which is recorded on the cassettes represents both events and statistics reflecting system performance. Using a post-experiment data-reduction program, the entire recorded history may be selectively printed by "type" of event desired for display. For example, all occurrances of communication errors detected at either the ground station or the airborne station, or both, may be displayed; or any combination may be displayed; or no events may be displayed. Regardless of the mix of displays, a statistical summarization is always printed. This summarization details system performance by two types of messages (echo/non-echo) and four classifications of message length. A second post-experiment data reduction program gives a visual plot of the communications channel in an in-

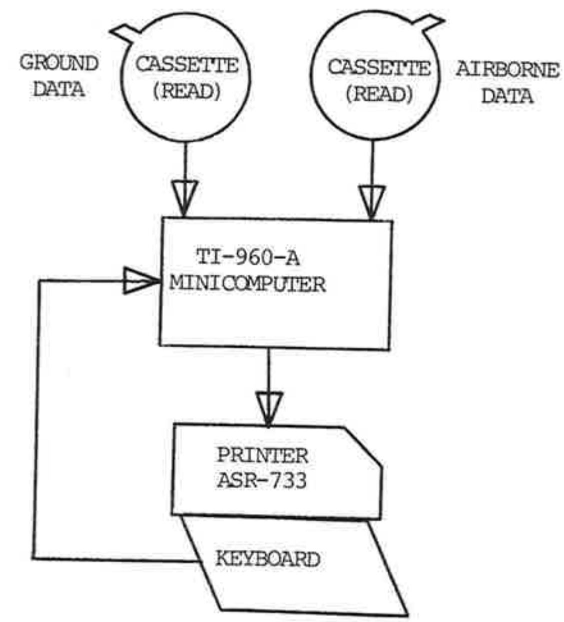


DATA-LINK COMPONENT BLOCK DIAGRAM



GROUND STATION

SYSTEM BLOCK DIAGRAM



DATA-LINK DATA-REDUCTION
COMPONENT BLOCK DIAGRAM

communication/out-of-communication frame of reference. Significant events are shown at the proper points on the plotted graph.

The theory of operation maintains that the ground station is in complete control of the communication environment (master) and the airborne station responds only upon stimulation (slave).

Both stations' programs are loaded from a single cassette by a station operator. The airborne station announces itself on the primary printer and awaits the operator's "GO"command (a keyboard character of acknowledgement). When the "GO" command is recognized by the airborne computer, the airborne station is ready to communicate.

The ground station announces itself and then directs the station operator through a short, uncomplicated dialogue sequence (computer asks at printer/operator responds at keyboard). The responses requested of the operator are system operational parametric controllers. These responses are used by the ground station to decide when to proceed to another message, when to "give up" on a failure of a particular message, which messages (stored in computer memory) to use, which bit-rate (2400 or 4800 band) is to be used for transmission, etc.

There is a cassette which contains the messages used for Data-Link experimentation. The messages are read from their cassette into computer memory as soon as the ground station's operator indicates dialogue completion, the messages (scenario) are played-back into memory, and the communications discipline automatically begins. The operator at either station may "break" the normal sequence of the scenario by "keying-in" any message he desires the operator at the other station to see. The message will be transmitted and displayed on the opposite station's secondary printer, and the scenario will automatically resume.

During the period of message communication each stations' computer is recording eventful occurrences, and accumulating statistical data in memory. When the period of communication is ended by operator keyboard control, the statistics are formulated and rolled out to the data acquisition cassette, for the post-experiment data analysis program to analyze.

During the entire period of communication, each station uses its secondary printer to give a constantly updated indication of system status. Each message transmission at a station is indicated by a hyphen (-), and each reception by one of a set of characters, shown in figures 1 and 2.

Figure 3 displays a typical ground station dialogue sequence. On the final entry (ENTER DESIRED DATA), the operator terminated the entry with a non-printing control character. All of the dialogue information was recorded, as an identifier record, on the data acquisition cassette, and then played-back and printed, as an operator confidence check.

Figure 4 displays a typical status printer output. The status is mixed with the messages sent by the opposite station's operator, but the messages are set-off on separate lines (always preceded by the time-of-day as an automatic feature of the system).

Figure 5 displays a typical statistical summarization produced by the data analysis program.

Figure 6 displays a typical "message successfully completed" ground station record.

Figure 7 shows a typical "message successfully received" airborne station record.

Figure 8 shows a typical clear text error record.

Figure 9 shows a typical transparent text error record. Note that the text is recorded in an encoded manner (see system documentation) and is not visually apparent.

Figure 10 shows a typical "message unsuccessfully completed" ground station record.

Figure 11 displays the graph-format display.

GLOSSARY OF GROUND STATION STATUS TERMINAL CODES

CHARACTER	CASE	INDICATION
.	N/A	Message received with acknowledge and good BCS.
B	Upper	BCS error received with acknowledge.
B	Lower	BCS error received without acknowledge.
I	Upper	Bit-compare error received without acknowledge.
L	Upper	Message received too long with acknowledge.
L	Lower	Message received too long without acknowledge.
N	Upper	Message received without acknowledge, but good BCS.
R	Upper	No response received.
S	Upper	Message received too short with acknowledge.
S	Lower	Message received too short without acknowledge.
W	Upper	Message received with improper address with acknowledge.
W	Lower	Message received with improper address without acknowledge.
-	N/A	Message sent.

Figure 1

GLOSSARY OF AIRBORNE STATION STATUS TERMINAL CODES

CHARACTER	CASE	INDICATION
.	N/A	Message received with acknowledge and good BCS.
B	Upper	BCS error received with acknowledge.
B	Lower	BCS error received without acknowledge.
L	Upper	Message received without acknowledge.
N	Upper	Message received without acknowledge.
S	Upper	Message received too short.
W	Upper	Message received with improper address.
-	N/A	Message sent.

Figure 2

```
DATA LINK SYSTEM - SCENARIO TAPE TO UNIT 1
(PLAYBACK) AND RECORD TAPE TO UNIT 2 (RECORD).
HOUR:MINUTE:SECOND = 00:00:00  10:30:00

BIT-RATE = 2400
# OF NON-RESPONSES = 10 5


# OF NAK (S) = 10 5

# OF BCS ERRORS = 10 5

# OF PREKEYS = 150 30

# OF MESSAGE REPEATS = 10000 5

FIRST SCENARIO MESSAGE = 1 16

LAST SCENARIO MESSAGE = 16
ENTER DESIRED INFORMATION
TEST VERSION 5/8/75 BLDG 224 TO 301
10:30:00  02400  00005  00005  00040  00005  00016
TEST VERSION 5/8/75 BLDG 224 TO 301
```

Figure 3

```
START OF EXPERIMENT --


.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-

12:28:29:310
TEXT AT 4800 5/28/75 BLDG 224 TO 310   301  THAT IS
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
.-.-.-.-.-.-.-.-.-.-.-
12:30:12.857
LOOKS GOOG D HERE LETS LET IT RUN AWHILE
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
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.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
12:37:51.694  ARE U THERE?
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.
12:38:46.372



HI
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-LN-.-.-.-.-.-.-.
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
.-.-.-.-.-.-.-.-.-.-.-.-.-
12:40:28.617
ARE THEY BIGGER THAN U?
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.- .-.-.-.-.-.-.-.-.-.-.-
12:40:07.917
IF NOT TAKE IT BACK
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
12:41:26.238  TOGETHER
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
```

Figure 4

MSG LNGTH	AVG TRANS TIME	#SUCC	#UNSUCC	%SUCC
000-001	: : .	0000	0000	.
002-030	00:00:00.539	4435	0006	099.864
031-120	: : .	0000	0000	.
121-999	: : .	0000	0000	.

DOWNLINK STATISTICS:
END TIME 16:33:44.120

MSG LENGTH........		000,001.....	002-030.....	031-120.....	121-999
ECHO					
ACKNOWLEDGE	#	00000	00000	00000	00000
	%	.	.	.	.
NON-ACKNOW	#	00000	00000	00000	00000
	%	.	.	.	.
NON-RESP	#	00000	00000	00000	00000
	%	.	.	.	.
BCS ERROR	#	00000	00000	00000	00000
	%	.	.	.	.
TOTAL BITS	#	0000000000	0000000000	0000000000	0000000000
BIT ERRORS	#	0000000000	0000000000	0000000000	0000000000
	%	.	.	.	.
NON-ECHO					
ACKNOWLEDGE	#	00024	04453	00011	00003
	%	100.000	099.308	100.000	050.000
NON-ACKNOW	#	00000	00007	00000	00000
	%	000.000	000.156	000.000	000.000
NON-RESP	#	00000	00022	00000	00003
	%	000.000	000.490	000.000	050.000
BCS ERROR	#	00000	00002	00000	00000
	%	000.000	000.044	000.000	000.000

UPLINK STATISTICS:
END TIME 16:33:54.890

MSG LENGTH........		000,001.....	002-030.....	031-120.....	121-999
ECHO					
ACKNOWLEDGE	#	00000	00000	00000	00000
	%	.	.	.	.
NON-ACKNOW	#	00000	00000	00000	00000
	%	.	.	.	.
BCS ERROR	#	00000	00000	00000	00000
	%	.	.	.	.
NON-ECHO					
ACKNOWLEDGE	#	00025	04454	00012	00004
	%	100.000	099.619	085.714	080.000
NON-ACKNOW	#	00000	00009	00000	00000
	%	000.000	000.201	000.000	000.000
BCS ERROR	#	00000	00008	00002	00001
	%	000.000	000.178	014.285	020.000

Figure 5

C9876A0825386910825394062;3:

MTR Class	C	
Message I. D.	9876A	
Start Time	082538691	
End Time	082539406	
Text Count	2;	(2B)
Mode	3	
Scenario Message Number	:	(A)

Figure 6

1458599971?900>017#9702B21?

Time	14:58:59.997	
Altitude	1?9	(1F9)
Pitch	00>	(E)
Roll	017	
UTR Sentinel	#	
Message I.D.	9702B	
Mode	2	
Text Count	1?	(1F)

Figure 7

11130011720=00900?B+½½¼21018A01AQQ%THE QUICK BROWN

FOX JUMPED OVER THE LAZY DOF¢ $B_1B_2B_3B_4$

Time	11:13:00.117	
Altitude*	20=	(20D)
Pitch*	009	
Roll*	00?	(F)
Sentinel	B	(BCS error)
Preamble	+*½½¼21018A01AQQ%	
Text	THE QUICK BROWN FOX JUMPED OVER THE LAZY DOF	
Postamble	¢B_1B_2	
Calculated BCS	B_3B_4	

NOTE: In the preamble	- -	½	represents	the	non-printing	SYN	char.
	- -	¼	"	"	"	SOH	"
	- -	A	"	"	"	ACK	"
	- -	%	"	"	"	STX	"
In the postamble	- -	¢	"	"	"	ETX/ETB	char.
	- -	B_1	"	"	encoded	BCS	"
	- -	B_2	"	"	"	"	"
	- -	B_3	"	"	"	"	"
	- -	B_4	"	"	"	"	"

*Not present in ground error records.

Figure 8

2359598017?=><:??9N+*½½¼H0198ƀQQ%09414243??=>454>4

4¢$B_1B_2B_3B_4$

Time	23:59:59.801	
Altitude	7?=	(7FD)
Pitch	><:	(ECA)
Roll	??9	(FF9)
Sentinel	N	(NAK)
Preamble	+*½½¼H0198ƀQQ%	
Text (Encoded)	08414243??=>454>44	
Postamble	¢B_1B_2	
Calculated BCS	B_3B_4	

Note - - See previous page for preamble and postamble definitions.

Note - - Decoding of the text produces (in binary):

(09)	00001001	Byte - Count
(41)	01000001	ASCII A
(42)	01000010	ASCII B
(43)	01000011	ASCII C
(??)	11111111	Transparent FF
(=)	11011110	Transparent DE
(45)	01000101	ASCII E
(4)	01001110	ASCII N
(44)	01000100	ASCII D

Figure 9

B9876A0825386910825394062;3:

MTR Class	B	
Message I. D.	9876A	
Start Time	082538691	
End Time	082539406	
Text Count	2;	(2B)
Mode	3	
Scenario Message Number	:	(A)

Figure 10

GROUND TRANSACTION GRAPH

```
PARAMETERS OF TEST:
15:35:00 04800 00005 00005 00005 00060 00005 00001 00016
TEST 1    2  May    8, 1975

TIME OF DAY   ELAPSED TIME                 MSG#  MODE SCEN#
15:35:00.000(00:00:00.000)
15:36:52.972(00:01:52.972)***************0001  D    K
                                         *
                                         *
15:39:44.060(00:02:51.088)***************0271  3    6
15:39:44.548(00:00:00.488)*0272  B
15:39:45.058(00:00:00.510)***************0273A 3    6
                                         *
                                         *
15:42:22.102(00:02:37.044)***************0520  2    7
15:42:22.711(00:00:00.609)*0521  N
15:42:23.292(00:00:00.581)***************0522A 2    8
                                         *
                                         *
                                         *
                                         *
                                         *
                                         *
                                         *
                                         *
15:50:29.949(00:08:06.657)***************1291  1    14
15:50:31.612(00:00:01.663)*1292  R
15:50:32.555(00:00:00.943)***************1293A 1    14
                                         *
15:51:57.854(00:01:25.299)***************1422  3    8

15:51:58.268(00:00:00.414) ABORTED
```

Figure 11

II. SYSTEM OVERVIEW/DESCRIPTION

The ground station data-link software system operates on three levels. Functionally, there is an initialization level which operates in a communications-inactive, dialogue (computer requests/operator responds) environment. There is a communications environment in which an ongoing communications scheme is maintained. There is also a third (transparent) level, input-output processing and interrupt recognition/handling, which is maintained transparently to the current function (initialization or communication). The air station data-link software system hasn't any dialogue-type initialization; it does, however, have an ongoing communications environment and the input-output and interrupt recognition/handling processing.

The ground station configuration consists of the following equipment:

a) A Texas Instruments TI-960A minicomputer with 16,384 sixteen bit words of memory and interval-timer (real-time clock).

b) Two Texas Instruments Silent-700 ASR-733 electronic data terminals consisting of a keyboard, printer, and twin cassette units, and computer interface.

c) A McDonnell-Douglas, MDL-510, 2400/4800 bit-per-second minimum shift keying modulator-demodulator (modem), and computer interface.

d) V.H.F. receive and transmit antennae (type CA-1781, swastika).

e) A V.H.F. transmitter (ITT, GRI-21).

f) A V.H.F. receiver (ITT, GRR-23).

(NOTE: The receiver, transmitter, and antenna are not connected with the minicomputer, except as incidental through the modem).

The air station configuration consists of the following equipment:

a) Same as ground station.

b) Same as ground station.

c) Same as ground station.

d) An aircraft Blade antenn (type 37R-2U, VHF/UHF).

e) A three-channel analog-to-digital converter, with computer interface.

f) A V.H.F. transceiver (in accordance with ARINC Characteristic 566A).

The ground station software is comprised of fifteen separate software modules; all of which are linked together such that the system appears as one load module. The modules are functionally inter- and intra-dependent. The selection of module division is one of software design and programming consideration and not necessarily functional consideration. Full advantage was taken of the Texas Instruments assembler, linker, and loader in the construction of the baseline data-link system.

In the broad generalities, the following statements may be made about the fifteen modules of the ground station:

Module	Function
DATALP-DATALF-DATALD	Dialogue initialization
GSUPR	Communications supervisor
GSUPRA	Communications supervisor
GU	Comm. supervisor utilities
DLFS-DLDS	Comm. supervisor data-base
SIH	Input-output-Interrupt handling
SIHA	"
SIHD-DSB	"
SIHK	"
SIHO	"
INS	"
SDRP	"
SDRF-SDRD	"
SIHI	"

The air station software is comprised of fourteen separate software modules. The following table is designed to be similar to the table shown for the ground station software.

Module	Function
ASUPR	See GSUPR
ASUPRA	See GSUPRA
AU	" GU
ABF-ABD	" DLFS-DLDS

Module	Function
SIH	See ground station table
SIHA	"
SIHD-DSB	"
SIHK	"
SIHB	"
SIHO	"
INS	"
SDRP	"
SDRF-SDRD	"
SIHI	"

The data reduction and analysis program is comprised of fifteen separate software modules. In broad generalities the modules have the following functions:

Module	Function
UTIL	Data reduction utilities
VTIL	"
MTR	Message transactor buffer
GREC	Ground error buffer
AREC	Airborne error buffer
MAIN	Data reduction merge and supervisor
FIN	Statistical calculation
PRINRE	Printing utilities and controller

Module	Function
SIH	See ground station table
SIHA	"
SIHD-DSB	"
SIHK	"
SIHB	"
SIHO	"
INS	"
SDRP	"
SDRF-SDRF	"
SIHI	"

The graphical data reduction and analysis program is comprised of thirteen separate software modules. The modules have the following functions:

Module	Function
GPAP35	Controller/Output/Calculations
MATHØ7	Arithmetic Utilities
GRADØ3-GRFL	Buffers and flags
SIH	See ground station table
SIHA	"
SIHD-DSB	"
SIHK	"
SIHB	"
SIHO	"
INS	"

Module	Function
SDRP	See ground station table
SDRF-SDRF	"
SIHI	"

It is not the purpose of this document to describe the engineering design and operation of the equipment utilized, nor to describe the utility software utilized for data-link system preparation. It will be stated that the editor used to create and alter source files is TSE-960. The assembler used is either SAL-960 or SALM. The linker used is LRL-960 and the loader used is Texas Instruments bootstrap, relocating loader. The editor, linker, and assemblers are supplied by Texas Instruments and run in the environment of T.I.'s programming support monitor (PSM) or process automation monitor (PAM). It should be noted that the object which results from assembling under SAL-960 is indistinguishable from the object which results from assembling under SALM.

III. COMPUTER INTIALIZATION/LOADING

The T.I. 960-A minicomputers have MOS memory, rather than core memory; hence, during a total power loss, all memory locations are destroyed. Each computer has a battery pack which allows the A.C. power to be shut off during non-operational periods. When the A.C. is off, the battery maintains memory; when the A.C. is on, the battery is being charged.

This procedure must be used to bring the Data Link system to operational condition, WHEN A TOTAL POWER LOSS is experienced (both A.C. and battery power loss).

The procedure requires entering a minimal amount of data into computer memory by means of the front panel console up/down toggle switches. Figure 12 is a representation of the computer's console. The power lamp is lighted when A.C. power is 'on' (A.C. on/off switch is on the computer's back panel, as is the battery on/off switch). To use the front panel console switches, the dual-position key switch must be rotated clockwise to the 'unlock' position. This enables the panel. All of the sixteen switches in the top row are up/down, dual-position switches, as are the bottom row 'MPO', 'MODE', 'SIE', and 'CLOCK' switches. The remaining bottom row switches are up/down, spring-loaded switches, which always return to the 'neutral' control position after use.

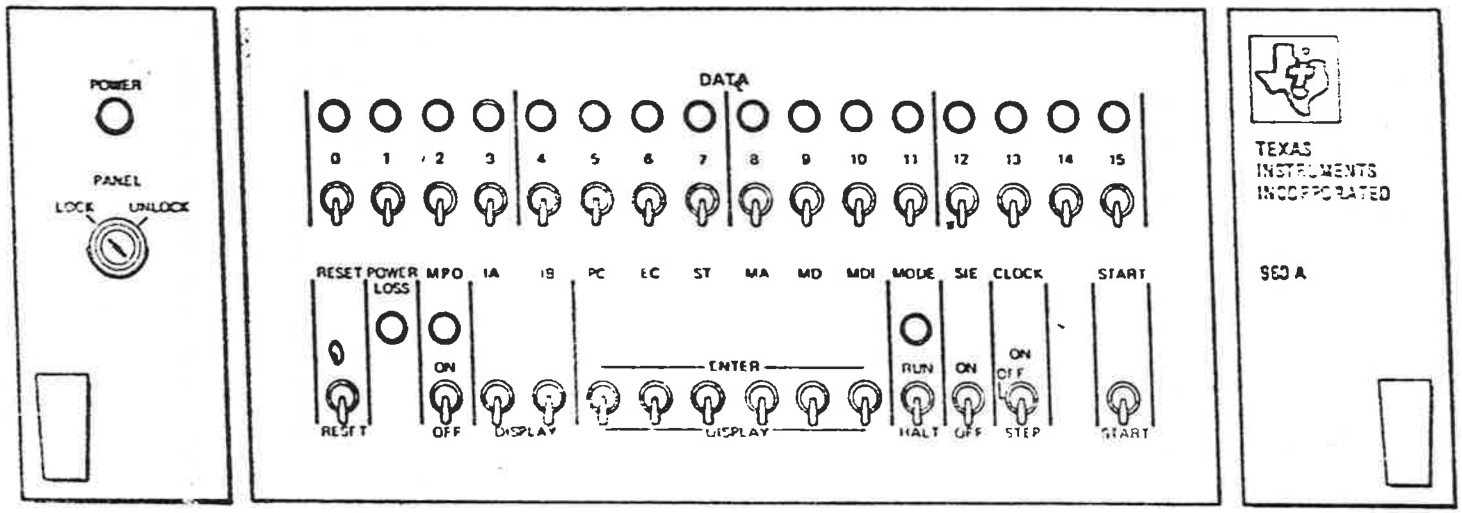


FIGURE 12. STANDARD OPERATOR CONSOLE CONTROL PANEL

To enter information into a memory location, two steps are required. The memory location must be made available to the computer by entering its address into the 'MA' register (done by toggling the address into the 'DATA' top row switches and moving the 'MA' (memory address) switch to the up position). The data to be placed into the address is toggled into the 'DATA' switches, and then the 'MD' (memory data) switch is moved to the up position. The display of the value contained in a memory location is accomplished by entering the address into the 'MA' register (as above), and then moving the 'MD' switch to the down position. The value will be displayed in the sixteen LED displays, just above the top-row toggle switches. To enter or display a series of consecutive memory locations is a similar procedure; simply enter the first address (lowest hexadecimal value) into the 'MA' register and then successively use the 'MDI' (memory data and increment) switch instead of the 'MD' switch. The consecutive entries are made from the 'DATA' top row switches which are set for each entry before lifting the 'MDI' switch. The consecutive displays are seen in the LED displays with each depression of the 'MDI' switch.

1. MEMORY INITIALIZATION

   a) Depress consecutively the 'RUN/HALT' and 'RESET' switches.
   b) 'MPO' switch to up position.
   c) Enter the following values into the following locations (all values/addresses shown are hexadecimal).

ADDRESS	VALUE
0080	4881
0081	0090
0082	4081
0083	0001
0084	7082
0085	0080

d) Enter 0100 into the 'ST' (status register).

e) Enter 0080 into the 'PC' (supervisor program counter).

f) 'RUN/HALT' switch to the up position.

g) Depress the 'START' switch.

h) After a couple of seconds, depress the 'RUN/HALT' switch. When this procedure is complete, a small program (which is what was entered) will have executed which will have caused each memory location from 0090 through, and including 3FFF to contain itself. That is, location 0090 will contain 0090, location 10AC will contain 10AC, etc. Incidentally, location 3FFF is the highest memory address and represents 16,383 or 16K of memory.

2. LOAD PRIMATIVE LOADER (Hardware ROM)

a) 'MPO' off

b) Enter 0400 into the 'MA' register

c) 'RESET' switch to up position.

(NOTE: This is the ONLY time the 'RESET' switch will ever be put in the up position).

3. LOAD RELOCATING BOOTSTRAP LOADER

   a) Depress 'RUN/HALT' switch.

   b) Depress 'RESET' switch.

   c) Enter the follwoing values into the following locations:

ADDRESS	VALUE
0085	04E0
0086	0000
0087	0F00

   d) Enter 01C0 into the 'ST' register.

   e) Enter 04E0 into the 'PC' register.

   f) Put the cassette containing the Relocation Bootstrap Loader into the playback unit. Rewind the tape and then force it to the 'READY' position by depressing the 'FF' switch (on the cassette unit) ONCE.

   g) 'MPO' on.

   h) 'RUN/HALT' to run.

   i) Depress 'START'.

   The horn will sound from the terminal while the tape is loading and will become silent when the load is complete. 'MPO' off when horn stops sounding.

4. LOAD SYSTEM SOFTWARE (GROUND STATION/AIRCRAFT)

a) It is imperative that all of the system external devices be plugged into the I/O line at this time. The primary terminal must be plugged into slot EF0; the interval-timer clock) into slot EF1; the modem into slot EF3; the secondary terminal into slot EF5; and the A/D converters (Airborne System ONLY) into slot EF6. All other slots must be vacant.

Be sure the A/C power is on at both terminals and at the Modem. The Modem must be set for the desired bit-rate and in the 'normal' position. The keyboard/printer/play-back/record devices at both terminals must be on-line.

Cassette unit 2 of the primary terminal must be the record unit, and have a scratch cassette at the ready position.

b) 'MPO' off and 'RESET' down.

c) System cassette to playback unit and bring tape to ready position.

d) Enter 0100 into memory location 0080.

e) Enter 0100 into the 'ST' register.

f) Enter 0002 into the 'PC' register.

g) 'RUN/HALT to run.

h) Depress 'START'.

The tape will be read into memory and the software will self-start. The AIRBORNE system will simply wait for the GROUND STATION to begin sending messages. It is important the cassette unit 2 have a scratch tape at the 'READY' position BEFORE loading the airborne software from cassette unit 1. THE GROUND SOFTWARE will await operator responses of necessary operational parameters.

Once steps 1, 2, and 3 are accomplished, it should not be necessary to repeat them, IF the battery doesn't lose its charge. If any of steps 1, 2, or 3 are not completed successfully, it is necessary that the procedure be re-started from step 1.

For more detailed information on the start-up of the operational Data Link GROUND STATION and AIRCRAFT software, refer to their individual instructions.

(NOTE: 'MPO' is a memory protect override. Memory locations 0000 through, and including 007F are read-only memory, IF the 'MPO' switch is in the off position).

IV. GROUND STATION OPERATION

The software for the Ground Station is self-starting. That is, once the loading procedure is manually started the ground station software is loaded and executed automatically.

The system begins with a question/response dialogue sequence, wherein the computer guides the operator through a short series of questions.

Before responding to the questions, the operator must insure that the two cassette units on the primary terminal are properly loaded. Cassette unit 1 must be the playback unit, and must have the canned scenario cassette tape loaded and brought to the ready position. Cassette unit 2 must be the record unit, and have a scratch tape loaded and at the ready position. All switches should be set to the on-line position.

As each question is asked the current value for the associated parameter is given. To go to the next question the operator must answer the question 'legitimately'. All answers are terminated with the carriage-return key (CR). If the answer is acceptable as shown (i.e. no change), the operator may simply give a CR response, indicating no change. If there is to be a change, the operator simply enters the desired value, and follows it with a CR. If the answer is acceptable, the next question is asked; else, the same one again. When a question is still open (i.e. before the CR) a control/U character will force the same question to be asked again. At any time in the dialogue, a control/G will force the program to recycle to the first question. The questions are always asked in the same order and all of the questions are always asked. The control characters are entered by first depressing the control key and then (while holding the control key) the indicated key.

After the fixed set of questions, the program will print ENTER DESIRED INFORMATION. The desired information is entered in free-form. This information is recorded, but NOT USED by the software. To terminate free-form data entry a control/E character is used. Once the control/E is entered, it is TOO late to use either the control/U or control/G functions.

The control/E function will force the recording of the dialogue responses, the playing back and printing of the same, the playing back of the scenario message tape, and the start of the communications polling to the aircraft. During the free-form information there are one thousand characters which are accepted. If a control/E is not seen before the one thousand and first character, the control/E function is automatically forced.

The questions appear in the following formats. The values in parentheses indicate the acceptable limits.

```
HOUR:MINUTE:SECOND = (HH:MM:SS)
BIT-RATE = (2400 or 4800)
# OF NON-RESPONSES = (1-10)
# OF NAK(S) = (1-10)
# OF BCS ERRORS = (1-10)
# OF PREKEYS = (1-150)
# OF MESSAGE REPEATS = (1-10000)
FIRST SCENARIO MESSAGE = (1-16)
LAST SCENARIO MESSAGE = (1-16)
```

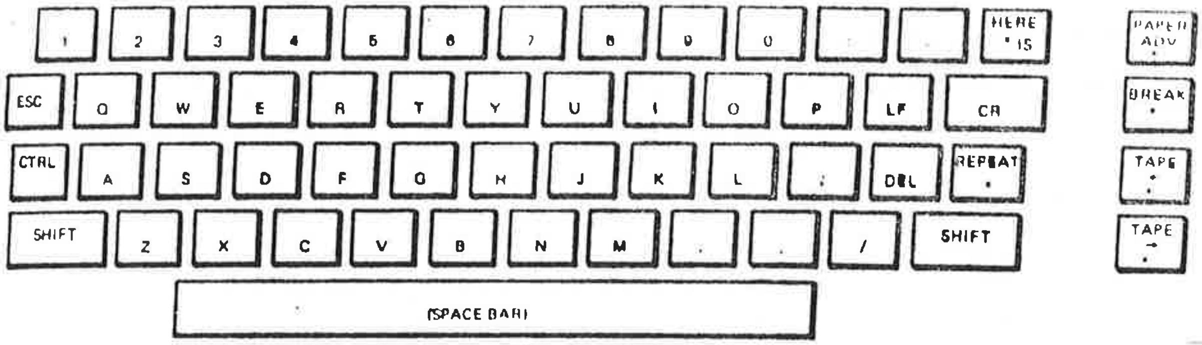
The time must be entered a three two-digit fields, separated by the colon. The last scenario message must be at least as great as the first scenario message. The system will operate on the first to last (as given), inclusive.

All operator-entered messages must be input at the primary terminal. All operator messages which are to be printed (i.e. entered at the primary terminal of the other system) are printed on the secondary terminal.

To stop system operation and simultaneously cause automatic restart, provision is made for the operator to enter an 'abort' character. The 'abort' character is control/A, and it MUST BE ENTERED AT THE PRIMARY TERMINAL. The receipt of control/A is acknowledged by showing a lower case 'A'.

It is required that the ground station 'gracefully' aborted in order for the post-test data reduction program to function properly. The abort causes a compilation of message transaction statistics to be dumped onto the record cassette. Without these statistics, it is not possible to perform data reduction. There is one case where an automatic abort occurs. If the ground station senses that the record cassette is almost expired (filled) an automatic abort is performed. The system always restarts the dialogue after the abort procedure.

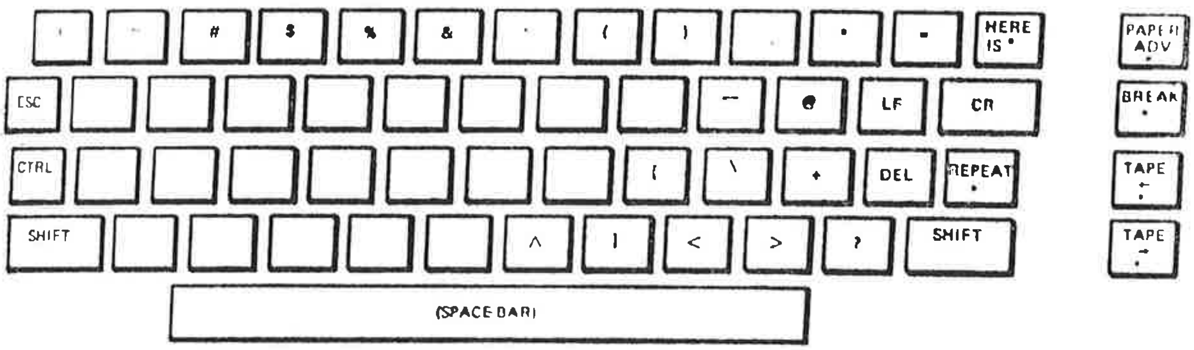
On-line, operator inserted, messages are keyed-in on the primary terminals of each station. Only the characters shown in figures 13 and 14 are acceptable for sending to the opposite station. Each message is compiled as it is keyed-in. To terminate, the key-in of one of two characters is required--either 'ETX' or 'ETB' (see figure 15). Upon receipt of either of these two characters (which is shown with a lower case 'W' for 'ETB' or lower case 'C' for 'ETX'), the message will be sent to the opposite station's secondary terminal.



NOTES. The above codes are generated when the labeled key is depressed but neither the SHIFT nor the CTRL key is depressed.

*Indicates that it is not a code generating key.

FIGURE 13. UNSHIFTED CHARACTERS, STANDARD ASCII KEYBOARD

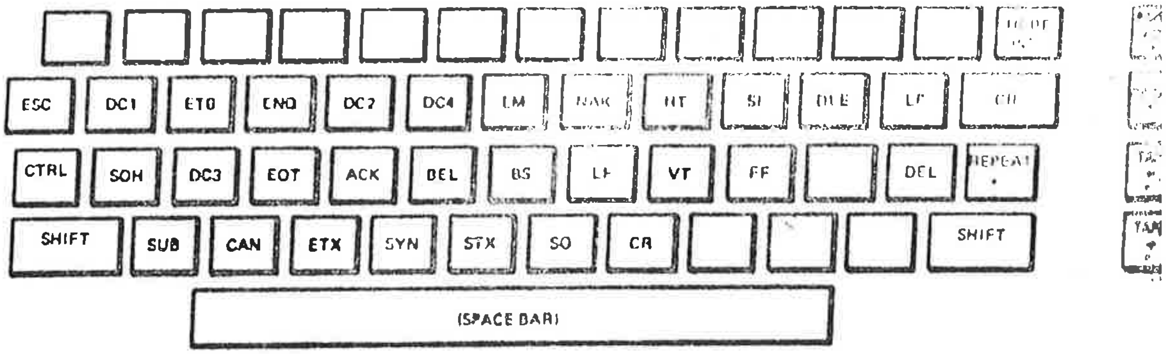


NOTES. The above codes are generated when the labeled key and the SHIFT key are depressed but the CTRL key is not depressed.

*Indicates that it is not a code generating key.

A blank key indicates a code is not generated when depressed.

FIGURE 14. **SHIFTED CHARACTERS, STANDARD ASCII KEYBOARD**

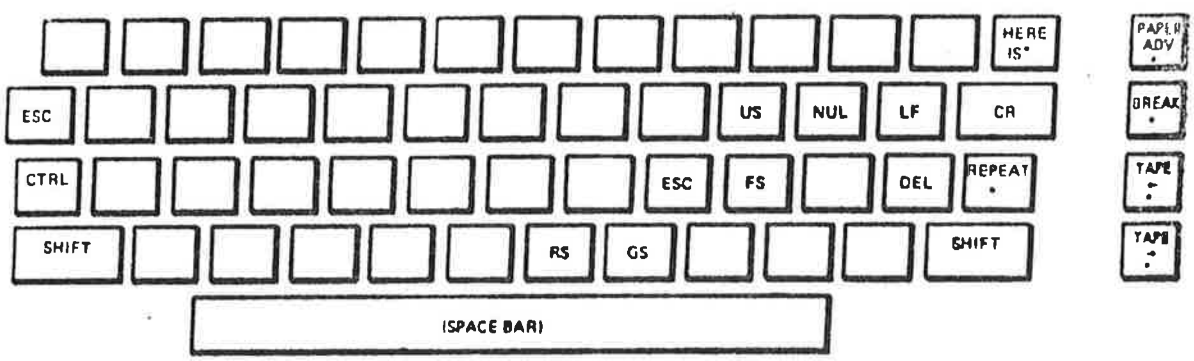


NOTES: The above codes are generated when the labeled key and the CTRL key are depressed but the SHIFT key is not depressed.

*Indicates that it is not a code generating key.

☐ A blank key indicates strobe inhibit.

FIGURE 15. **CONTROL CHARACTERS, STANDARD ASCII KEYBOARD**



NOTES: The above codes are generated when the labeled key and the SHIFT key and the CTRL key are depressed.

**Indicates not a code generating key.

☐ A blank key indicates strobe inhibit.

FIGURE 16. **SHIFT AND CONTROL CHARACTERS, STANDARD ASCII KEYBOARD**

V. AIRCRAFT STATION OPERATION

The software for the Aircraft Station is self-starting. There is no dialogue performed; the system is ready to communicate upon load completion. The airborne software slaves to the ground. It merely responds when requested to.

Before loading the system cassette, be sure there is a scratch cassette in unit 2 (record).

To abort system operation is an identical procedure as in the ground software -- control/A. As soon as the statistics are dumped, the system is ready to respond, and will respond, if the ground is sending. Good operating procedure requires that the ground station be aborted before the aircraft station.

HEXADECIMAL	BINARY
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

Figure 12

VI. DATA ANALYSIS AND REDUCTION PROGRAMS

There are two separate programs for analyzing and reducing the experimentally acquired data cassettes. The operating procedures and some examples of output are included in this section.

1) INPUT DATA

   There are two input data files on cassettes created by

   a) The Ground System

   b) The Air System

   during one (the same) experimental run.

2) OPERATING INSTRUCTIONS

   a) Loading

      Follow load procedures shown in Section III.

   b) Initial Setup

      After loading, a message is typed:

```
READY AIR & GRD TAPES FOR PLAYBACK
SET PANEL SWITCHES FOR PRINT OPTION:

    SW11 UP   =   INHIBIT PRINTING UPLNK TRANS RECS
    SW12 UP   =   ALL MTR'S
    SW12 DOWN=   ERR MTR'S
    SW13 UP   =   INHIBIT PRINTING AIR ERR RECS
    SW14 UP   =   INHIBIT PRINTING GRD ERR RECS
    SW15 UP   =   INHIBIT PRINTING MSG TRANS RECS
    CARRIAGE RETURN WHEN READY
```

At this time the two data cassettes (air and ground system) should be mounted for playback, one in each of the terminals attached to the computer. The program will run properly with either cassette in either terminal, but will run faster if the ground system cassette is played on a 1200 baud terminal.

If, upon reading the first record of each data cassette, the system is not satisfied that one air tape and one ground tape are mounted (i.e. one of the records is not in the proper format), it will type a message:

WRONG CASSETTES: TRY AGAIN

Also at this time the panel switches on the computer front panel (labelled 0-15) should be set for the desired print option. Only switches 11-15 affect the print options. The normal condition is all switches in the down (D) position, in which case all error records on the air and ground tapes are printed, as are the message transaction records (MTR) for any message that caused an error record to be written. Putting switches 13, 14 or 15 in the up (U) position, causes the air error records, ground error records, or MTR's respectively, not to be printed. If SW15 = U, no MTR's are printed at all, and SW12 has no effect. If SW15 = D however, and SW12 = U, then all MTR's will be printed, not just those associated with an error record.

When everything is ready, press carriage return to start execution.

The program will read a record from each cassette and type out the parameters of the test as they appeared on the ground system terminal at initialization of the test:

```
PARAMETERS OF TEST:
10:43:20  04800 00010 00010 00010 00005 00001 00001 00016
THIS IS FREE FORM DATA THAT THE OPERATOR TYPES
```

Next the print options at that time are displayed:

/// CURRENT PRINT OPTION: AREC = Y; GREC = Y; MTR = Y; ERR;
UTR = N

This example indicates that air error records and ground error records should be printed, and only MTR's associated with error records should be printed, i.e. panel switches 11-15 are all down.

c) Execution

During execution the program will be reading through the air and ground cassettes, printing error records and MTR's as appropriate. At any time the print options may be changed by resetting the panel switches. Whenever this is done, the new print options are indicated by a message on the terminal. Because of print stream buffering it may appear as if new print options do not take effect immediately.

When the end of the transaction is found on the air or ground cassette, a message is printed:

/// EOF IN AIR TAPE

Or /// EOF IN GRD TAPE

Do not unload a cassette just because an EOF message for it has been printed.

d) Termination

When all the air and ground transaction records have been processed, final statistics are read from both cassettes, processed and printed. Then a termination message is printed.

```
END OF RUN
TO REINITIALIZE THIS PROG HIT CARRIAGE
RETURN
```

At this time the data cassettes from the run just ended may be unloaded.

If data reduction is to be rerun, enter carriage return and turn to part 2b.

MESSAGE TRANSACTION RECORD

1	2	3	4	5	6	7	8
M	C	0001	10:44:31.582	10:44:31.845	001	D	01

1. M indicates MTR type record.
2. COMPLETION CODE is C in this example.
3. MSG. I.D. is 0001ƀ.
4. START TIME in hrs:mins:secs. msecs.
5. END TIME in hrs:mins:secs.msecs.
6. MSG LENGTH (text).
7. MODE
8. SCENARIO MSG NBR.

AIR SYSTEM ERROR RECORD

```
1        2              3       4     5     6    7     8    9    10 11 121314  15    16
                                                 ..110 . ...7. 7. . .. 0 1
A  02:02:00.003 30537  +60   +70   N   +*661 1 9997A 75 5 aA  2 8*9*A* 1278
```

1. A indicates air system error record.
2. TIME in hrs:mins:secs. msecs
3. ALTITUDE in feet.
4. PITCH in degrees (-60 to +60)
5. ROLL in degrees (-70 to +70)
6. COMPLETION CODE

PREAMBLE

7. Bit synch, bit synch, character synch, character synch, SOH
8. MODE
9. MSG. I.D.
10. AIRCRAFT ADDRESS
11. ACK/NAK
12. LABEL CHARACTERS
13. START OF TEXT

POSTAMBLE

14. END OF TEXT
15. BCS RECEIVED
16. BCS CALCULATED

TEXT

The second and successive lines contain the text. The sample message has transparent text which is printed as a string of hexadecimal digits, two per text character. The characters * in the text and in the BCS field indicate incorrect coding for binary type data, and should not normally appear.

GROUND SYSTEM ERROR RECORD

These records have the same format as air system error records, except for omission of the altitude, pitch, and roll data

```
                          ..110 . ..... .. 0 .. 0    0
G   02:02:00.001 B     +*661 2 9999A AD 6 QQ 2    3 567B  AB98

..................7................................................

ABCDEFGHIJKLMNOPQRAdSTUVWXYZABC.DEFGG.IJKLMNOPQRSTUVW.,.ABCDEFGHIJKLM

.................................................

NOPQRSTU VWXYZABCD.............QRSTUVWXYZABCDEFGHI
```

This example has normal (non-transparent) text, hence the double line print format to show 'true' characters (period over) or the hexadecimal representation: such as 0 over D for carriage return. Carriage returns, line feeds, etc., are shown in this manner in order not to disrupt the print format.

ADDITIONAL NOTES

A. A message may have no text, and no START OF TEXT field. It would be displayed as:

```
                        ..110 . ..... .. 0 ..  0
G 10:45:28.637  B  +*661 2 0002) 01 6 QQ  3 5F6F  12EB
```

B. If an air or ground error message has COMPLETION CODE = R, it is recorded and displayed without the bit synch, character synch, and SOH field. For example:

```
                        . ...... .. 1 0. .    1
G 02:02:00.090 R     1 9999A a Q 5 9  S    7 78+B  ABE7
++++++++0123456789ABCDEF0123456789ABCDEF12++142463+++++3232+
12++++2323++34+++++4
```

A ground error record with no text and completion code = R looks like:

```
                        . ...... ..  0  ..   0
G 14:58:27.871 R     2 0519  01  6  QQ   3  4058  CB12
```

GRAPH ANALYSIS

The following is an example of the type of visual analysis that is possible when Graph output is utilized. The example is a test run by NAFEC personnel in which both stations were on the ground. From the ground parameter information we know that this test was started at 15:35:00 on May 8, 1975 and that it was run at 4800 Baud, using scenarios 01-16.

By inspecting both air and ground Graph outputs, each transmission can be traced along the ground-air and air-ground path. For example, a no response ground error condition can occur either because,

1. The air station never received the ground message (message lost in ground-air path).
2. The ground station never received the air response (message lost in air-ground path).

In this situation, an inspection of the air graph will determine along which path the message was lost.

By such reasoning we will first look at the individual graphs and then combine this information to determine the path along which every error occurred.

The ground graph tells us that:

1. The ground sent #0272, and received the air response. There was a B error in that response. Assume error in air-ground path.

2. The ground sent #0521 and received the air response. There was an NAK in the response. Assume error in ground-air path.

3. The ground sent #1292 and received no response.

The air graph tells us that:

1. The air responded to #0272. This confirms (1) above.

2. The air saw a B error in #521 and responded with a NAK. This confirms (2) above.

3. The air never saw ground #1292. This tells us that there was a ground-air path difficulty.

Therefore, this experiment incurred three errors in communications:

#0272 Mode 3, Scen#06, B error in air-ground path

#0521 Mode 2, Scen#08, B error in ground-air path

#1292 Mode 1, Scen#14, lost in ground-air path

The Graph outputs (air & ground) for this experiment are in the following pages.

GROUND TRANSACTION GRAPH

```
PARAMETERS OF TEST:
15:35:00 04800 00005 00005 00005 00060 00005 00001 00016
TEST 1    2  May    8, 1975

TIME OF DAY   ELAPSED TIME                 MSG#  MODE SCEN#
15:35:00.000(00:00:00.000)
15:36:52.972(00:01:52.972)***************0001  D    K
                                        *
                                        *
15:39:44.060(00:02:51.088)***************0271  3    6
15:39:44.548(00:00:00.488)*0272  B
15:39:45.058(00:00:00.510)***************0273A 3    6
                                        *
                                        *
15:42:22.102(00:02:37.044)***************0520  2    7
15:42:22.711(00:00:00.609)*0521  N
15:42:23.292(00:00:00.581)***************0522A 2    8
                                        *
                                        *
                                        *
                                        *
                                        *
                                        *
                                        *
                                        *
15:50:29.949(00:08:06.657)***************1291  1    14
15:50:31.612(00:00:01.663)*1292  R
15:50:32.555(00:00:00.943)***************1293A 1    14
                                        *
15:51:57.854(00:01:25.299)***************1422  3    8

15:51:58.268(00:00:00.414) ABORTED
```

AIR TRANSACTION GRAPH

```
FIRST AIR RECORD:
001015727000??(??8#0001 D00

TIME OF DAY     ELAPSED TIME                   MSG# MODE NAK ATTITUDE

15:36:52.974(00:00:00.000)***************0002  2    FFD FFB FFD
                                         *
                                         *
15:39:44.089(00:02:51.115)               *0272  3    FFF FFD FFA
15:39:44.590(00:00:00.501)               *0273A 3 N  FFE FFC FFB
15:39:45.086(00:00:00.496)               *0274  3    000 FFC FF8
                                         *
                                         *
15:42:21.728(00:02:36.642)***************0520  2    FFD FFC 000
15:42:22.307(00:00:00.579)*0521  2 B                FFF FFC FF8
15:42:22.336(00:00:00.029)***************0521  2    FFF FFC FF8
                                         *
                                         *
                                         *
                                         *
                                         *
                                         *
                                         *
                                         *
15:50:29.262(00:08:06.926)               *1291  1    FFC FFE FF8
15:50:31.827(00:00:02.565)               *1293A 1 N  FFD FF9 FFE
15:50:32.948(00:00:01.121)               *1294  H    FF8 FFF FFD
                                         *
15:51:57.863(00:01:24.915)***************1423  2    FFC FF8 000

15:52:23.280(00:00:25.417) ABORTED
```

AIR TRANSACTION GRAPH

STATISTICS:
DURATION 00:15:04.889
OUT OF COM 00:00:00.579
IN COM 00:15:04.310

	TOTAL:	%ALL MSGS	MSGS/HOUR
#MC MSGS	1419	99.789%	5650
#NAK MSGS	0002	00.140%	0007
#BAD MSGS	0001	00.070%	0003
ALL MSGS	1422	100.000%	5662

GROUND TRANSACTION GRAPH

STATISTICS:
DURATION 00:15:04.882
OUT OF COM 00:00:02.760
IN COM 00:15:02.122

	TOTAL	%ALL MSGS	MSGS/HOUR
#MC MSGS	1419	99.789%	5650
#NAK MSGS	0001	00.070%	0003
#BAD MSGS	0002	00.140%	0007
ALL MSGS	1422	100.000%	5662
#GIVE UPS	0000	00.000%	0000

APPENDIX

This appendix shows the generalized message format and describes some of the special pre-amble characters. For the description of the specialized message formats (system entry poll, general poll, time re-synchronization poll, etc.) the reader is referred to the system specification.

MESSAGE FORMAT

FUNCTION	ASCII CODE	HEX	CHARACTERS
Prekey[1]		00	1-150
Bit Sync[1]	+	2B	1
Bit Sync[1]	*	2A	1
Character Sync[1]	+	2B	1
Character Sync[1]	+	2B	1
Bit Sync	+	2B	1
Bit Sync	*	2A	1
Character Sync	SYN	16	1
Character Sync	SYN	16	1
Start of Heading	SOH	01	1
Code	See Next Page		1
Message Number	Numeric		4
Message Alpha	Alpha		2
Address	Alphanumeric		2
Technical Acknowledgement	ACK/NAK	06/15	1
Label Character One	See Next Page		1
Label Character Two	See Next Page		1
Start of Text	STX	02	1
Text			235 max.
End of Text	ETX or ETB	03/17	1
Block Check Sequence			1
Block Check Sequence			1

[1] These are timing, modem, and modem controller characters. All characters following these are passed to the computer.

UPLINK MESSAGE LABELS

Label 1	Label 2
O System Entry	O System Entry
E MSG for Printer	Q Other Messages
T Resynch Real Time Clock	
Q Other Messages	

DOWNLINK MESSAGE LABELS

Label 1	Label 2
O System Entry	O System Entry
E MSG for Printer	Q Other Messages
R Request for Special General Poll	
Q Other Messages	

MODE CHARACTER

MODE

1 Transparent Text (echo test)

2 Normal Text

3 Normal Text (echo test)

H Transparent text

D System Entry

Message Labels and Mode Characters