DEPARTMENT OF GEOLOGY
SCHOOL OF SCIENCES AND HEALTH PROFESSIONS
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA

TECHNICAL REPORT GSTR-84-5

DEVELOPMENT AND OPERATION OF A REAL-TIME DATA ACQUISITION SYSTEM FOR THE NASA-LaRC DIFFERENTIAL ABSORPTION LIDAR

By

Carolyn Butler

Submitted by Earl C. Kindle, Principal Investigator

Progress Report
For the period January 1, 1983 to December 31, 1983

Prepared for the
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23665

Under
Research Grant NCCI-28
Edward Browell, Technical Monitor
Chemistry and Dynamics Branch

OLD DOMINION UNIVERSITY RESEARCH FOUNDATION

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DEVELOPMENT AND OPERATION OF A REAL-TIME DATA ACQUISITION SYSTEM FOR THE NASA/LANGLEY RESEARCH CENTER DIFFERENTIAL ABSORPTION LIDAR

By
Carolyn Butler

INTRODUCTION

This report documents work performed under Research Grant NCCI-28 toward the improvement of computer hardware and software of the NASA Multipurpose Differential Absorption Lidar (DIAL) system. The NASA DIAL system is undergoing development and experimental deployment at NASA/Langley Research Center (LaRC) for the remote measurement of atmospheric trace gas concentrations from ground and aircraft platforms. A viable DIAL system was developed capable of remotely measuring O3 and H2O cpncentrations from an aircraft platform. Test flights of the DIAL system were sucessfully performed onboard the NASA/Goddard Flight Center Electra aircraft from 1980-1983 (ref.1).

The work performed on this project resulted in improved capabilities of the DIAL Data Acquisition System (DAS). This included purchase of new computer hardware and its subsequent integration, and implementation of improved computer software. The original DIAL DAS has been documented in ODU Technical Report GSTR-81-8 (ref. 2). A transitional system which was to be field tested during a November 1983 flight to Barbados as part of the Atlantic Boundary Layer Experiment (ABLE) was documented in ODU Technical Report GSTR-83-5. This system included the previously used PDP 11/34 plus a newly purchased LSI 11/23. The ABLE project was postponed after one test flight in the vicinity of Wallops Island, Va. This test proved the flight worthiness of the new LSI. It was therefore agreed to proceed with the DIAL DAS modifications. The latest modification replaces the PDP 11/34 with a second LSI 11/23. This document is designed to be an operational manual for the current system. Hardware and peripheral device registers are briefly outlined only as an aid in debugging any DAS problems which may arise.

AIRBORNE DIAL SYSTEM

The airborne lidar system uses the DIAL technique for the remote measurement of atmospheric gas profiles. This technique determines the average gas concentration over some selected range interval by differencing the backscatter signals for laser wavelengths tuned on and off the molecular absorption line of the gas under investigation. Two DIAL wavelengths are transmitted with a 100 usec temporal separation. Simultaneously, measurements of aerosol backscatter at multiple wavelengths can be made by transmitting unused (non-doubled) energy from the DIAL system pump lasers. The aerosol measurements are single wavelength returns. A coaxial receiver system is used to collect and optically separate the DIAL and aerosol returns. Photomultipler tubes (PMT) detect the backscattered laser returns after optical filtering, and the analog signals from these tubes are digitized and stored on high-speed magnetic tape.

The lasers can be fired at 1, 5, or 10 Hz. Current objectives are to transmit up to four wavelengths at 10 Hz. The DIAL data will be collected by two PMT's to achieve greater range of measurement. One PMT will be gated on early for near-field data and the other will be gated on where signal levels of the first PMT start getting low. An aerosol backscatter return of a visible wavelength (from the off-line) can be collected by a third PMT. A second aerosol backscatter return at 1.06 u (from the on-line) can be detected by a photodiode. Present software allows up to four digitizers to be used with no more than 4096 words saved in the computer (10 MHz sampling interval). Of the 4096 words alloted per buffer, at least 20 are reserved for shot header information (shot number, navigation information, energy monitors, etc.) so a safe estimate of the number of words to record per return is obtained by dividing 4000 words per buffer by the total number of returns. If there are six returns to be digitized then no more than 650 words per return should be stored (range of 9.75 km from laser platform). This software limitation can be exceeded in one channel only at the expense of decreasing the number of stored words from another digitizer channel.

DATA ACQUISITION SYSTEM

The NASA multipurpose DIAL DAS is currently housed in half a double rack (see figure 1) with digitizers, control electronics and photomultiplier tube (PMT) power supplies occupying the other half. This configuration is a tremendous improvement over the previous two separate double racks for DIAL DAS and control electronics. The advantage in space reduction is obvious. It was also discovered that a one rack system considerably reduced 60 Hz noise on signal lines between the PMT's and the computer digitizers.

The DIAL DAS is based upon two Digital Equipment Corporation (DEC) LSI 11/23 processors. Each LSI has 128K words of 16-bit memory. The overall flow chart for the DIAL DAS is shown in figure 2. In general, all data acquisition and storage is performed by the LSI on the left (LSI #1), with all data display and analysis are performed by the LSI on the right (LSI #2). LSI #1 does have one data analysis function. On command, LSI #1 will generate a real-time gray scale of any return at one shot per second on the Tri-log T100.

LSI #1 acts as the master computer through which the operator communicates with LSI #2. The operator communicates with the master's software through a modified Ann Arbor keyboard (the Ann Arbor CRT has been replaced by one of the dual Panasonic monitors; the Ann Arbor interface board is mounted in a separate box). Operator input to LSI #1 is to a Plessey PM-DLV11J serial line interface with four serial line ports (the fourth port being the console input). The first serial port on LSI #1 is used to communicate to the console input port on an identical PM-DLV11J on LSI #2.

Data is presented to the operator on either the Panasonic

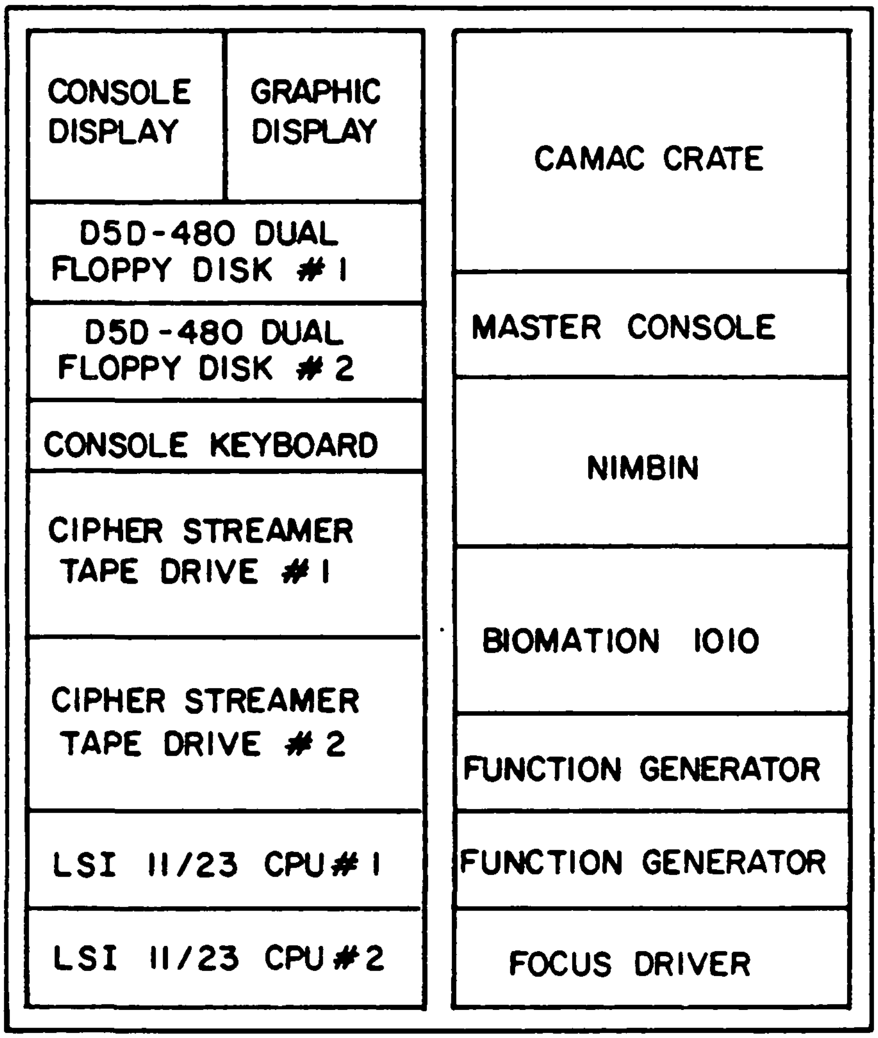


Figure 1. Schematic drawing of the DIAL DAS as configured on March 28, 1984

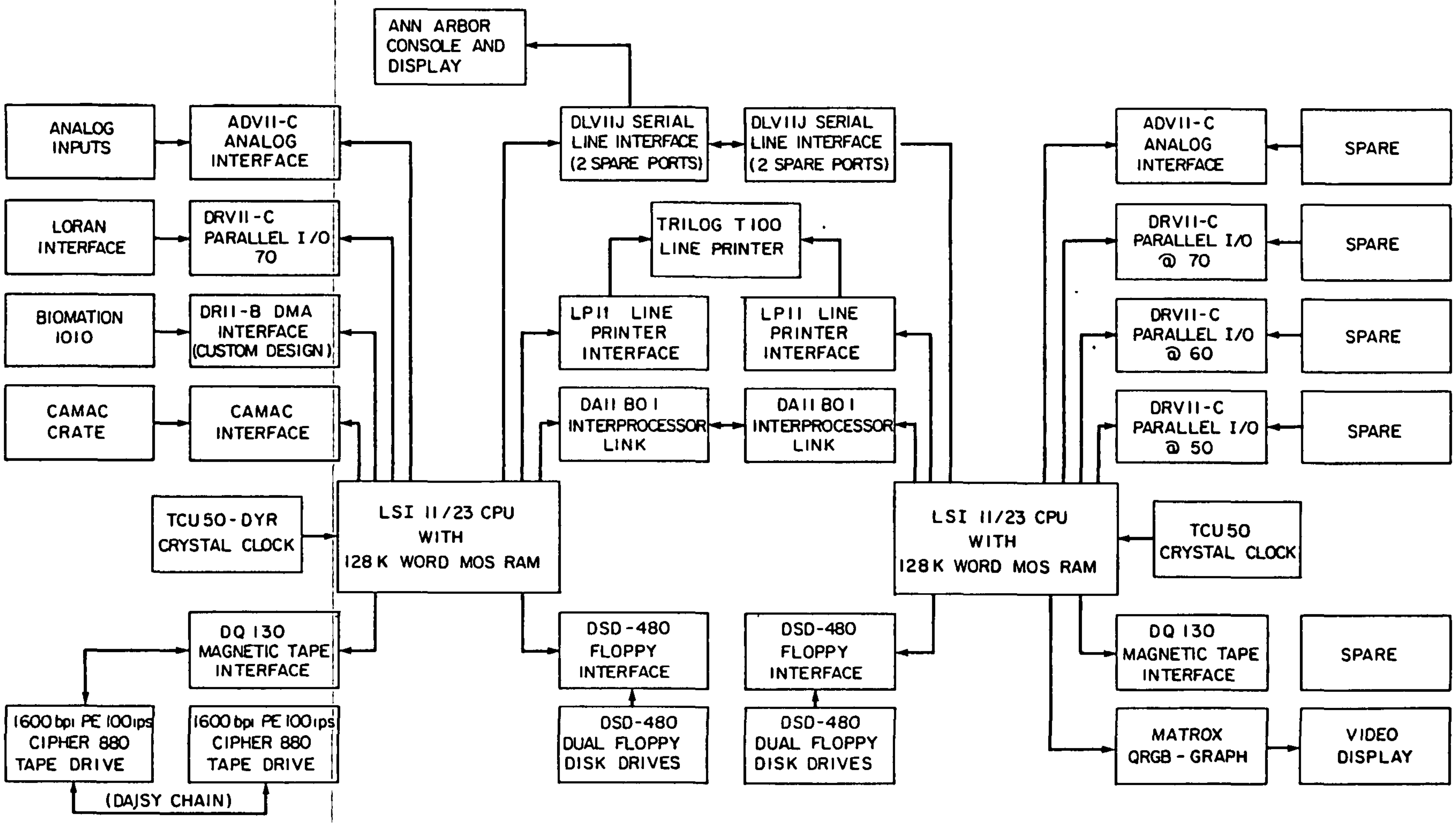


Figure 2. Computer devices flow chart

video monitor through the Matrox QRGB-Graph controller and/or the system line printer Trilog T100. Hard copy images of the video graphics display may be obtained through Polaroid photography or through a software copy command to the Trilog (with four size options). The DSD-480 dual floppy disk units (double sided and double density capabilities although not presently configured for either option) are used for storage and retrieval of program information on both LSI's. The DIAL data is stored real-time using one of two Cipher F880 magnetic tape units on 731.5 m (2400 ft) reels of 1.27 cm (.5 inch) wide magnetic tape. Two tape units are required so that continuous data is stored while one unit is rewinding. Tape speeds and densities are as follows:

25 ips @1600 bpi (PE; IBM and ANSI compatible)
100 ips @1600 bpi (PE; IBM and ANSI compatible)
50 ips @3200 bpi (PE; not IBM or ANSI compatible)

A Dilog DQ130 provides Cipher interface with the LSI 11/23.

The acquisition of data is accomplished using four Transiac Model 2012 waveform digitizers. One Biomation Model 1010 is also available as a back-up. The Transiacs are manually programmable for digitization of analog signals into 12-bit memory of selectable record lengths (2048 words are stored for DIAL applications). The internal memories of these digitizers are made available to the LSI 11/23 through a Kinetics Systems Direct Memory Access (DMA) interface board. The Biomation 1010 is manually programmable for digitization of analog signals into a 2048 word by 10-bit memory. Its memory is passed to the computer through a DMA interface of custom design (see ref. 2). Due to the bulkiness of the Biomation and its constant need to be re-calibrated , this unit will eventually be phased out of the DIAL DAS as more confidence is gained in the Transiacs.

Sixteen Analog-to-Digital Conversion (ADC) single ended inputs (or eight differential) are available to the system through an ADV11-C board. Unipolar inputs can range from 0V to 10V and bipolar inputs from -10V to +10V. Data can be converted with programmable gains of 1,2,4, or 8 times the input voltage. In addition, there are four DRV11-C modules (one in LSI #1 and three in LSI #2) available for parallel interfacing of TTL digital signals.

SYSTEM CONFIGURATION AND CONNECTION

Data on system component size, weight, and power consumption requirements are given in table 1. A drawing of the two controller box distributions is shown in figure 3.

One advantage to going with a two computer system is that one computer can be dedicated to data acquisition while the second is dedicated to data analysis, thus allowing for much more real-time processing of the data. An additional advantage is hardware backup. Should one LSI fail, then the other computer can be used as a totally independent data acquisition system with limited real-time display capabilities. In fact, the boards have been configured inside each LSI (figure 3) so that minimal changes would be necessary for fall back to a one computer system.

1	M 8186 CPU	DSD-480 FLOPPY INTERFACE
2	DA11 BOI INTERPROCESSOR LINK	
3	DQ130 MAG TAPE INTERFACE	
4	CAMAC INTERFACE	
5	DR11-B BIOMATION INTERFACE	
6	DR11-C @ 70	ADV11-C
7	LP 11	DLV11-J
8	M8059 MEMORY (128K)	TCU 50-DYR

1	M 8186 CPU	DSD-480 FLOPPY INTERFACE
2	DA11 BOI INTERPROCESSOR LINK	
3	DQ 130 MAG TAPE INTERFACE	
4	MATROX QRGB-GRAPH	
5	DR 11-C @ 50	DR11-C @ 60
6	DR 11-C @ 70	ADV11-C
~~7~~	~~LP11~~	~~DLV11-J~~
8	M 8059 MEMORY (128K)	TCU 50

Figure 3. Internal computer configurations

Table 1. DIAL DAS component specifications for size, weight, and power requirements.

DIAL DAS COMPONENT	Height (in)	Weight (lb)	Power (amp @ 115 Vac)
Magnetic tape drive (2)	8.75	80	3
LSI 11/23 (2)	5.5		
DSD-480 floppy disk (2)	5.5	60	2.6
Panasonic dual monitors	8.75		
Console keyboard	3.0		
Line printer	16.5 x 30 x 24.25	185	7
Biomation 1010	7.0	40	1.1
Camac crate	12.5	75	
Transiac 2012 (each)			

Table 2a shows connections from the two LSI's. LSI #2 houses five spare boards which need not be connected to anything at present. Table 2b shows various other connections that need be made in order to get the DAS up and running. Table 3 lists the necessary connections to the digitizers. The first item on 2b is a "daisy chain" connection between the two Cipher tape drives. The Cipher 880 manual shows no twist for these cables but we found a half twist was necessary to make the tape drives function properly. Also, Cipher #1 must not be terminated and Cipher #2 must have its unit number changed to two to make this configuration work.

The Ann Arbor keyboard/display has functioned reliably and yields good quality characters. The display, however, is large and bulky. A VK-170 (DEC) keyboard kit was tried but the lettering was poor and characters were often thrown out to the screen at random. A new keyboard kit is being investigated but for now the Ann Arbor keyboard and its interface board are being used. The interface board is mounted in a separate box with a power cable running to a specially built port in the Biomation 1010 for its 5V power supply.

If one of the two computers should fail, the functioning unit should be re-configured to look like LSI #1 with the exception of the Matrox board occupying the slot of the DA11BOI Interprocessor Link. When using only one computer most boards are duplicated except the Camac interface, the DR11-B Biomation interface, and the TCU 50-DYR. A second Camac interface board will probably be purchased. The Biomation will be eliminated eventually from the system but in the mean time, if its interface should fail, one could fall back on using only the Transiacs. If the TCU 50-DYR fails, time of day can be obtained from the TCU 50 board. Different software is required, however, as the two TCU boards do not operate in the same manner. Table 4 sums up corrective action for failure of various components.

Table 2a. DAS component interconnections.

LSI #1 Board	Connector Type	Destination
DSD-480 floppy interface	26p flat cable	DSD-480 #1
DA11BOI interprocessor link	dual 50p flat cables	LSI #2 DA11BOI (P1→P2;P2→P1)
DQ130 magtape interface	dual 50p flat cables	Cipher #1 (J1→P2;J2→P1)
Camac crate interface	p flat cable	Camac crate
DR11-B Biomation interface	dual 40p flat cables	Biomation I/O
	24p flat cable	Biomation
DRV11-C general purpose interface	dual 40p flat cables	Nav interface
ADV11-C ADC		ADC BNC panel
LP11 line printer controller	36p flat cable	Trilog T100
DLV11-J serial line interface	2p EIA (port 4)	Ann Arbor
	2p EIA (port 1)	LSI #2 DLV11 (port 4)

LSI #2 Board	Connector Type	Destination
DSD-480 floppy interface	26p flat cable	DSD-480 #2
DA11BOI interprocessor link	dual 50p flat cables	LSI #1 DA11BOI
DQ130 magtape interface	dual 50p flat cables	spare
Matrox QRGB-Graph	75 BNC cable	Panasonic #2
LP11 line printer controller	36p flat cable	Trilog T100
DLV11-J serial line	2p EIA (port 4)	LSI #1 DLV11 (port 1)

Table 2b. Other interconnections.

Source	Connector Type	Destination
Cipher #1	50p dual flat cables (half twist)	Cipher #2 (P1→P1;P2→P2)
Ann Arbor interface	p flat cable	keyboard Panasonic #1 Biomation

Table 3. Digitizer connections.

Biomation	Internal 50Ω	Transiac	Internal 50Ω
Arm	N	------	
Trigger	N	Trigger	N
Time Base	N	Time Base	Y
Input	N	Input	Y
------		Amp Input	Y

Available Connections for Digitizers

Lase-Coherent trigger
Master Control trigger
T-0 markers (positive)
T-0 markers (negative)
Diode clippers

Table 4. Component failure procedures.

Component	Action	Software
LSI Chassis	one computer DIAL DAS	BACKUP
CPU	"	"
Floppy Disk Interface	"	"
Interprocessor Link	"	"
Serial Link	"	"
Memory	"	"
Mag-tape Interface	replace with spare board	MASTER & SLAVE
DRV11-C	"	"
ADV11-C	"	"
Matrox	"	"
TCU-50DYR	replace with TCU-50	TCU50 & SLAVE
Camac Interface	use only Biomation	MASTER & SLAVE
Biomation Interface	use only Transiacs	MASTER & SLAVE

It is not always easy to determine where a problem is occurring. The DIAL DAS programs have been written to provide error messages when detection is possible through software techniques. These messages and appropriate action will be detailed in a later section. The following section is provided to help identify problems with peripheral devices.

PERIPHERAL PROGRAMMING INFORMATION

Table 5 is a summary of the base registers, trap vectors and priority levels for all the peripheral devices associated with the two LSI computers. The components marked with an asterisk are spare boards with switch registers set as shown.

Table 5. Base addresses for registers used by peripheral devices.

Device	Base Address	Trap Vector	Priority
LSI #1			
Floppy Disk	777170	264	BR4
Interprocessor Link	772410	124	
Mag-tape Interface	772520	224	BR5
Camac Interface	777550	400	
Biomation Interface	772430	120	
DRV11-C @70	767770	300	
ADV11-C	770400	340	
Line Printer Controller	777514	200	
Serial Link (Console)	777560	60	
Serial Link (to LSI #2)	776500	320	
TCU 50-DYR	760770		
LSI #2			
Floppy Disk	777170	264	BR4
Interprocessor Link	772410	124	
*Mag-tape Interface	772520	224	BR5
Matrox	764400		
*DRV11-C @50	767750		
*DRV11-C @60	767760		
*DRV11-C @70	767770		
*ADV11-C	770400		
Line Printer Controller	777514	200	
Serial Link	777560	60	
*TCU 50	760770		

On the following pages each of these peripheral devices will be discussed in a little more detail. The intention here is to provide only enough information to determine if a particular device is functioning properly and for more involved programming requirements references are given for each item.

DSD 480 Floppy Disk System

The DSD 480 is a double sided, double density flexible disk system which is RX02 compatible with RT-11 V3B. However, since the existing DIAL computer system is using RT11 V3 internal switches were set to make it RX01 compatible (single sided, single density). The floppy disk registers are outlined below.

RXICS	@ 777170	command and status register
RXIDB	@ 777172	data buffer register

RXICS
@ 777170

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ERROR	INIT	XBA17	XBA16	RX02		SIDE SEL	DEN	TRAN REQ	IE	DONE	UNIT SEL	FCN3	FCN2	FCN1	GO

ERROR	Error detected.
INIT	Initialize the DSD 480.
XBA17,XBA16	Extended address bits.
RX02	RX02 system identification bit.
SIDE SEL	Side select: =1 for side 0; =0 for side 1.
DEN	Density of the function encoded in FCN1-FCN3.
TRAN REQ	Transfer request flag.
IE	Allows DONE to interrupt.
DONE	Operation completed.
UNIT SEL	Drive unit select.
FCN3-FCN1	Function select: 000 fill buffer 001 empty buffer 010 write sector 011 read sector 100 set media density 101 read status 110 write deleted data sector 111 read error code
GO	Execute the function.

RXIES
@ 777172

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
				NXM	WC OVFL	SIDE SEL	UNIT SEL	DRV RDY	DEL DATA	DRV DEN	DEN ERR	PWR LO	INIT DN	SD 1 RDY	CRC

NXM	Non-existent memory error.
WC OVL	Word count overflow.
SIDE SEL	Indicates side selected during last operation.
UNIT SEL	Indicates unit selected during last operation.
DRV RDY	Drive ready -- disk installed and ready to go.
DEL DATA	Deleted data -- indicates deleted data address mark was found on last operation.
DRV DEN	Density of diskette.
DEN ERR	Diskette density did not match DEN.
PWR LO	Power failure in the controller/drive subsystem.
INIT DN	Initialize done.

SD 1 RDY	Set for double sided diskette when ready.
CRC	Cyclic redundancy error.

<u>Interprocessor Link (DA11BOI)</u>

The Interprocessor Link provides a means of transferring data through DMA between two LSI 11/23 processors. This is the device used by the DIAL DAS software to transfer a data record from LSI #1 to LSI #2 to be processed and plotted.

WCNT	@ 772410	word count
ADDR	@ 772412	bus address
STATUS	@ 772414	control/status
DATA	@ 772416	data buffer

STATUS @ 772414

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ERROR	NEX	ATTN	MAINT	IN IR	IN DIR	IN MODE	CYCLE	READY	IE	XBA17	XBA16	OUT IR	OUT DIR	OUT MODE	GO

ERROR	Set by NEX, ATTN from the other computer or by bus address overflow.
NEX	Non-existent memory.
ATTN	Reads ATTN from the other computer.
MAINT	Maintenance.
IN IR	Input interrupt request. Reads status of the OUT IR from the other computer.
IN DIR	Input direction. Reads status of OUT DIR from the other computer.
IN MODE	Input mode. Reads status of OUT MODE from other computer.
CYCLE	Initiates a DMA transfer when the generating DA11BOI is both the requested computer and the transmitter. When CYCLE and GO are both set, an immediate bus cycle is executed.
READY	Must be cleared before a block transfer can be done.
IE	Allows READY, IN IR or ERROR to cause interrupt.
XBA17,XBA16	Extended memory bits.
~~OUT IR~~	~~Causes IN IR and READY in the other computer.~~
OUT DIR	During block transfer: =0 for transmitter; = 1 for receiver. Must be opposite of IN DIR.
OUT MODE	Output mode: =0 for DMA; =1 for program mode.
GO	Executes.

<u>Cipher F880 Interface (Dilog DQ130)</u>

Two Cipher F880 tape drives are available for storage of data. This allows for continuous data acquisition when one drive is rewinding. The two units are cabled together by a "daisy chain" configuration and interfaced to the LSI 11/23 through a Dilog DO130 tape coupler. Tape density is determined by a button on each Cipher unit and tape speed is software selectable. The fast speed (100 ips) or streamer mode requires a longer repositioning time if the tape motion stops during read or write operations. The DIAL DAS software must stack data records in extended memory during repositioning times to take advantage of the streamer mode. Tests showed that for 4096 word buffers and 10 Hz DIAL data, 11 or 12 records would get stacked during repositioning. The interface registers are outlined below.

MTS	@ 772520	status
MTC	@ 772522	command
MTBRC	@ 772524	byte/record counter
MTCMA	@ 772526	current memory address
MTD	@ 772530	data buffer
MTRD	@ 772532	tape read lines

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MTS @ 772520	ILL COM	EOF		PAR ERR	BGL	EOT	RLE		NXM	SELR	BOT	7 CH	SDWN	WRL	RWS	TUR

ILL COM	Occurs if (a) a new instruction is issued before last one has finished, (b) no write ring when told to write, (c) a command to unit whose SELR is 0, or (d) SELR becomes 0 during tape operation.
EOF	Set when end of file is detected during tape operation.
PAR ERR	Parity error.
BGL	Bus grant late.
EOT	End of tape marker detected.
RLE	Record length error -- detected during read operations if tape record is too long.
NXM	Non-existent memory.
SELR	Indicates unit addressed is on-line.
BOT	Beginning of tape.
7 CH	Set to indicate 7-channel tape unit.
SDWN	Will accept new command during settle down as long as it is in the same direction.
WRL	Write lock set if no write ring is on tape.
RWS	Rewind status set when rewind command given, cleared at BOT.
TUR	Tape unit ready is cleared by GO and function occurs.

MTC
@772522

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ERROR			PWR CLR		STREAMER	US1	US0	READY	IE	XBA17	XBA16	FCN3	FCN2	FCN1	GO

ERROR	Set by bits 7-15 of the status register.		
PWR CLR	Clears the control unit and tape units.		
STREAMER	Selects streamer mode.		
US1,US0	Selects unit number for MTS operation.		
READY	Control unit ready.		
IE	Interrupt enable.		
XBA17,XBA16	Extended memory bits.		
FCN3-FCN1	Function bits (with GO set):		
	000	(1)	Off line
	001	(3)	Read
	010	(5)	Write
	011	(7)	Write EOF
	100	(11)	Space Forward
	101	(13)	Space Reverse
	110	(15)	Write with Extended Interrecord Gap
	111	(17)	Rewind
GO	When set, begins operation defined by function.		

<u>Transiac 2012 Interface (Kinetics 2920-Z2B bus adaptor)</u>

The Transiac 2012 digitizers are interfaced to the LSI 11/23 through a Kinetics 3920 Crate Controller and a Kinetics Bus Adaptor board. The interface is versatile in that any unit in the Camac crate can be addressed by its slot number. The function codes will be defined by the type of hardware being used in that slot. Since this interface is presently being used only for the Transiac digitizers, only those function codes will be listed here. The interface has four directly addressable registers plus an additional 6 registers addressed by offsets.

DLO	@ 777550	data low	(RA2 = 0, RA1 = 0)
LLO		lam low	(RA2 = 0, RA1 = 1)
MAR		memory address	(RA2 = 1, RA1 = 0)
DMACSR		DMA control/status	(RA2 = 1, RA1 = 1)
DHI	@ 777552	data high	(RA2 = 0, RA1 = 0)
LHI		lam high	(RA2 = 0, RA1 = 1)
WCR		word count	(RA2 = 1, RA1 = 0)
EMA		extended memory	(RA2 = 1, RA1 = 1)
NAF	@ 777554	station/function	
CACSR	@ 777556	control/status	

NAF
@ 777554

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ASCAN	SLOT4	SLOT3	SLOT2	SLOT1	SLOT0	SA4	SA3	SA2	SA1	SA0	FCN4	FCN3	FCN2	FCN1	FCN0

ASCAN	Enables the crate controller to increment the Camac address on completion of a Dataway Cycle.
SLOT0-SLOT4	Station or slot number of Camac device.
SA0-SA4	Sub-address of Camac device (not used with Transiacs.)
FCN0-FCN4	Function code defined by user device.

Transiac Function Codes

0	00000	Read front panel switch settings. Sets Q = 1.
1	00001	Read status of overtemperature indicator.
2	00010	Read data sequentially from memory. The N+1 word (N = record length) will return Q = 0.
10	01000	Tests LAM and returns Q = 1 if ready for readout. Must be preceded by funtion 32 (110010).
11	01001	Resets to sampling mode--all previous data is written over. Q = 1 returned.
12	01010	Clears LAM. Q = 1 returned.
13	01011	Computer generated sampling clock. Sets Q = 1.
30	11000	Disables LAM and switches from readout mode to display mode. Sets Q = 1.
31	11001	Generates stop trigger. Sets Q = 1.
32	11010	Enables LAM -- enables unit for readout. Sets Q = 1.
33	11011	Enables offset measurement logic. Sets Q = 1.

CACSR
@ 777556

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ON-LINE	L-SUM	NO-Q	NO-X		N>23	RA2	RA1	DONE	IE	SET Z	SET C	SET INH	READ INH		GO

ON-LINE (R)	True when 3920 is powered and on-line.
L-SUM (R)	True if any LAM is set in crate (causes interrupt).
NO-Q (R/W)	Updated by 3920 during every Dataway Cycle.
NO-X (R/W)	Updated by 3920 during every Dataway Cycle.
N>23 (R)	During address scan operations, indicates the slot number has been incremented past 23.
RA2,RA1 (R/W)	Used to select registers defined above.
DONE (R)	True when 3920 has completed a progammed control operation (i.e. non-DMA).
IE (R/W)	When set, allows L-SUM to cause interrupt.
SET Z (W)	Dataway initialize.
SET C (W)	Dataway clear (does not affect registers).

SET INH (R/W) Sets state of Dataway inhibit line.
READ INH (R) Reflects status of Dataway inhibit line.
GO (W) Starts 3920 operation defined in NAF and DMACSR.

DMACSR
@ 777550
RA2 = 1
RA1 = 1

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ERROR	NXM	TMO					16/24	DMA DONE	DMA IE	A17	A16		M2	M1	SUS

ERROR (R) Set by NXM, NO-X, N/23, or TMO; cleared by INIT or GO.
NXM (R) DMA transfer to non-existent memory attempted.
TMO (R) Time-out condition during Q-Repeat DMA mode (mode 3).
16/24 (R/W) Specifies 16 or 24 bit data transfers (16-bit = 1).
DMA DONE (R) Set when DMA operation is done.
DMA IE (R/W) Enables DMA DONE to interrupt.
A17,A16 (R/W) Extended memory bits used with MAR during DMA.
M2,M1 (R/W) Specify mode when GO of CACSR is set.

mode 0 programmed transfer
mode 1 Q-stop/stop on word count
mode 2 address scan
mode 3 Q-repeat/stop on word count

SUS (R/W) Set to suspend DMA operation.

<u>Biomation 1010 Interface (custom designed DR11-B)</u>

The Biomation Model 1010 Transient Digitizer Interface is custom designed using the DR11-B Direct Memory Access (DMA) method for fast data transfer to CPU memory. This custom interface allows for sequential communication with up to 8 Biomation 1010 units operating in parallel. The DR11-B module registers are outlined below.

DRWC	@ 772430	word count (2's complement)
DRBA	@ 772432	buffer address
DRST	@ 772434	control and status
DRDB	@ 772436	data register

DRST
@ 772434

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ERROR	NEX	ATTN	MAINT	REL	DOG	FLAG	CYCLE	READY	IE	XBA17	XBA16	FCN3	FCN2	FCN1	GO

ERROR (R) Set by NEX, ATTN, interlock error or bus address overflow. Sets READY and causes interrupt if IE. Cleared by clearing all error conditions.
NEX (R/W) Non-existent-memory sets error bit. Cleared by

	INIT or by program.
ATTN (R)	Set by 0 to 1 transition of REL or DOG. Set and cleared only by user device.
MAINT (R/W)	Maintenance. Used to enable execution of diagnostic programs. Cleared by INIT.
REL (DSTATA)	Indicates that new data is ready in Biomation memory.
DOG (DSTATB)	Indicates that Biomation is in digital output mode.
FLAG (DSTATC)	Indicates that Biomation has gated data to DRDB.
CYCLE (R/W)	If set when GO is issued, enables an immediate bus cycle. Cleared by INIT or start of bus cycle.
READY (R)	Indicates that the DR11-B is able to accept a new command. If ATTN, NEX and ERROR are cleared, then READY can be cleared by setting DRST=3. READY can then be reset by ATTN or by sending SATTN.
IE (R/W)	Interrupt enable. Allows READY or ERROR to interrupt.
XBA17 (R/W)	Extended bus address (bit 17).
XBA16 (R/W)	Extended bus address (bit 16).
FCN3	When set, enables add-to-memory function.
FCN2	When set, inhibits normal address increments to CPU.
FCN1	When set, enables program controlled transfers to DRDB.
GO	Causes DR11-B to signal user device that a command has been issued. Clears READY.

DRDB
@ 772436

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ADD2	ADD1	ADD0									SATTN	CLR	EXT EWR	OSR	DOR

ADD0, ADD1, ADD2	Biomation 1010 address (set inside units).
SATTN	This command resets ATTN when set from 0 to 1 with FCN1 set.
CLR	Clears ATTN and REL when set from 0 to 1 with FCN1 set.
EXT EWR	When set from 0 to 1 with CLR and FCN1=1, then an EWR pulse is sent to the Biomation.
OSR	When set from 0 to 1 with FCN1=1, causes the Biomation to exit DOG mode.
DOR	When set from 0 to 1 with FCN1=1, causes the Biomation to enter dog mode.

The Biomation address bits are latched in the interface when FCN1 is cleared. Since only one Biomation is presently being used those bits are all set to zero. When FCN1 is set, then the address lines are active and can be changed under program control.

Operation examples for the Biomation 1010 are outlined below:

1. Detection of new raw data:
   (a) Clear all conditions which will set READY.
   (b) Clear READY by initiating a dummy DMA operation; viz,

DRST=3.

(c) READY will remain clear until set by REL, DOG or SATTN.

2. Select Biomation by setting ADDO, ADD1 and ADD2 to 0 with FCN1=1.
3. Send DOR to force unit into DOG mode. DOR clears ATTN and REL, and ATTN is reset when DOG goes from 0 to 1.
4. After DOG is set, the unit is ready to transfer data into CPU memory.
   (a) Set DRWC to 2's complement of number words to be transferred.
   (b) Set DRBA to address of data buffer to be used.
   (c) Put DR11-B into DMA mode (FCN1=0) with FCN2 and FCN3 set as desired.
   (d) Initiate data transfer by setting GO. READY will come true when data transfer is completed.
   (e) When finished with data transfers, send OSR command to get Biomation out of DOG. Note that it may take as much as 1 ms before DOG is removed.
   (f) Alternatively, the unit may be forced out of DOG by sending EWR after 2049 words have been transferred. This procedure can be used to assure integrity of data transfers (i.e., that no words have been skipped or multiply transferred).

<u>Parallel Line Interface Module (DRV11-C)</u>

This module acts as an interface between the LSI 11/23 and a peripheral device. The DIAL DAS presently uses one of these modules to pass data from the LORAN or INS interface to the computer. There are three spare DRV11-C modules in LSI #2 which are not being used.

DRSR	@ 767770	control/status
DRO	@ 767772	output buffer
DRI	@ 767774	input buffer

DRSR
@ 767770

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
REQ B								REQ A	IEB	IEA				CSR1	CSR0

REQ B	Set by user device and causes interrupt if IEB set.
REQ A	Set by user device and causes interrupt if IEA set.
IEB	Interrupt enable for REQ B.
IEA	Interrupt enable for REQ A.
CSR1	User defined function -- if linked to another DRV11-C causes REQ B.
CSR0	User defined function -- if linked to another DRV11-C causes REQ A.

Analog-to-Digital Converter (ADV11-C)

Sixteen Analog-to Digital Conversion single ended inputs (or eight differential) are available to the DIAL DAS through an ADV11-C board. Unipolar inputs can range from 0V to 10V and bipolar inputs from -10V to +10V and can be stored with programmable gains of 1, 2, 4, or 8 times the input voltage.

ADST	@ 770400	control/status
ADBF	@ 770402	data buffer

ADST @ 770400

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ERROR	ERR IE			ADD3	ADD2	ADD1	ADD0	A/D DONE	IE	RTC	EXT TRIG	GS1	GS0		GO

ERROR	Caused by doing a GO when A/D DONE is set or A/D still in progress.
ERR IE	Allows ERROR to interrupt.
ADD3-ADDO	Channel address.
A/D DONE	Set when A/D done, cleared by reading A/D data buffer.
IE	Interrupt enable.
RTC	Enables real-time-clock input to start A/D conversion.
EXT TRIG	When set allows external trigger to start A/D.
GS1-GSO	Gain select: 00=1, 01=2, 10=4, 11=8.
GO	Starts an A/D conversion -- cleared after starting.

Line Printer Controller (MLSI-LP11)

The LP11 provides the interface between the LSI 11/23 computers and the TRILOG T100 printer. Each computer has its own interface board and care must be taken to cable up the desired computer to the Trilog. Eventually, we hope to have either a software instruction or a manual switch to select which computer's output to send to the Trilog.

LPS	@ 777514	status
LPB	@ 777516	data buffer

LPS @ 777514

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ERROR								READY	IE						

Teletype (Plessey PM-DLV11J Serial Line Interface)

The Plessey PM-DLV11J is a 4-channel asynchronous serial line interface between the LSI 11/23 bus and standard I/O devices. On LSI #1 one port is used to communicate with the teletype and another port is used to communicate with a second PM-DLV11J interface on LSI #2. Baud rates on both boards have been wire-wrapped for 9600 baud.

From LSI #1 port #1 to LSI #2 port #4:

RCSR	@ 776500	receiver control/status	(port 1)
RBUF	@ 776502	receiver buffer	(port 1)
XCSR	@ 776504	transmitter control/status	(port 1)
XBUF	@ 776506	transmitter buffer	(port 1)

From LSI #1 to console device:

RCSR	@ 777560	receiver control/status	(port 4)
RBUF	@ 777562	receiver buffer	(port 4)
XCSR	@ 777564	transmitter control/status	(port 4)
XBUF	@ 777566	Transmitter buffer	(port 4)

RCSR
@ 776500
@ 777560

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
								DONE	IE						

DONE	Set when entire word has been received and is ready for transmission.
IE	When set, allows DONE to cause interrupt.

RBUF
@ 776502
@ 777562

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ERROR	OVER RUN	FRAME	PAR ERR					DAT7	DAT6	DAT5	DAT4	DAT3	DAT2	DAT1	DAT0

ERROR	Set by bits 14,13, or 12.
OVER RUN	Set when previous character was not completely read prior to receiving a new character.
FRAME	Set when no valid stop bit for character.
PAR ERR	Parity error.
DAT7-DATO	Received data bits.

XCSR
@ 776504
@ 777564

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
								READY	IE						BREAK

READY — Set when XBUF is ready to receive another character.
IE — Enables READY to cause interrupt.
BREAK — When set, causes a continuous space level to be transmitted.

XBUF
@ 776506
@ 777566

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
								DAT7	DAT6	DAT5	DAT4	DAT3	DAT2	DAT1	DAT0

DAT7-DAT0 — Transmitter data bits.

Timing Control Unit (TCU-50 and TCU-50 DYR)

These two timing control units are similar in that they are both crystal clocks that continue to operate even after the computer has been powered down. The TCU-50 has month, day, hours, minutes and seconds while the TCU-50 DYR also has year, day of week as well as .1, .01 and .001 seconds. The two clocks are set and read differently so both are outlined below. The TCU-50 DYR is used in LSI #1 while the TCU-50 resides in LSI #2 but is not currently being used by the DIAL DAS -- it is maintained for back-up purposes.

TCU-50:

MNTH/DAY
@ 760770

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
				MONTH	MONTH	MONTH	MONTH				DAY	DAY	DAY	DAY	DAY

HR/MIN
@ 760772

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
			HOUR	HOUR	HOUR	HOUR	HOUR			MINUTE	MINUTE	MINUTE	MINUTE	MINUTE	MINUTE

SECND
@ 760774

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
										SECOND	SECOND	SECOND	SECOND	SECOND	SECOND

STATUS
@ 760776

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
M/D SET	H/M SET							READY							

M/D SET   Month/day being set -- fast clock on.
H/M SET   Hour/minute being set -- fast clock on when 1.
READY   TCU ready.

TCU-50 DYR:

DATA
@ 760770

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
								DAT7	DAT6	DAT5	DAT4	DAT3	DAT2	DAT1	DAT0

DAT7-DAT0   Read/write data bits. When reading a counter or latch register, the bits are 2 BCD numbers packed in 8 binary bits (eg. 23 = 00010011 = 0001 0011 = 13).

CTRL
@ 760772

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
			IE	WRT	CLK/RAM	RS9	RS8	RS7	RS6	RS5	RS4	RS3	RS2	RS1	RS0

IE   Interrupt enable if switch SW3-1 is on.
WRT   Write enable -- allows writing to the clock or RAM registers.
CLK/RAM   If this bit is 0, then bits 0-4 select one of the 32 clock registers. If 1, then bits 0-9 select one of the 1024 CMOS RAM registers.
RS9-RS0   Register select:

00000	counter - .001 secs
00001	counter - .1 and .01 secs
00010	counter - secs
00011	counter - mins
00100	counter - hours
00101	counter - day of week
00110	counter - day of month

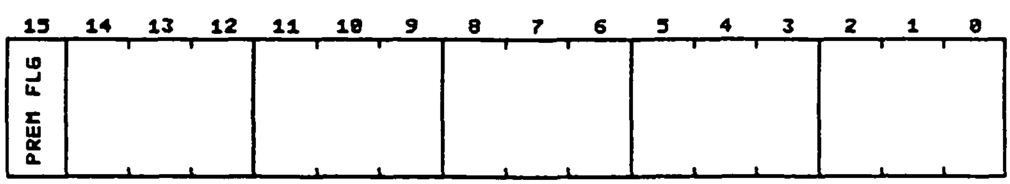
00111	counter - month
01000	latch - .001 secs
01001	latch - .1 and .01 decs
01010	latch - secs
01011	latch - mins
01100	latch - hours
01101	latch - day of week
01110	latch - day of month
01111	latch - months
10000	interrupt status register (R)
10001	interrupt control register (W)
10100	status bit
10101	GO command
10110	standby interrupt

Matrox QRGB-GRAPH Controller

The Matrox QRGB-GRAPH controller is a color graphics interface for use with RGB monitors. Contained in a PROM is a color look-up table which has been modified by Norman McCrae for gray-scale operations. I have written general purpose software routines to be used with the Matrox board and these are printed out in Appendix I. There are 512 x 512 pixels available but due to some flaw in the design of the Matrox board the software only uses 256 pixels in the Y direction. There are 11 directly accessed registers plus 14 CRTC registers that are indirectly accessed through an address register (VECT) and data port (CRT5). The CRTC registers will not be discussed here -- they are used only for initialization procedures and their use can be found in the Matrox manual. Not all mnemonics for the directly accessible registers will be defined in this report as they are not used in the DIAL DAS software.

XREG		@ 764400	X coordinate (10 bits)
YREG		@ 764402	Y coordinate (10 bits)
DATA		@ 764404	data register (4 bits)
ST1	(R)	@ 764406	preset memory status
CTR1	(W)	@ 764406	zoom/pan control
ALP	(R)	@ 764410	auxiliary light pen register
CTR3	(W)	@ 764410	color map select
CTR4		@ 764412	write plane enable
ST2	(R)	@ 764414	vertical blanking status
~~VECT~~	~~(W)~~	~~@ 764414~~	~~CRTC address/vector register~~
CTR5		@ 764416	CRTC data register/preset control

ST1
@ 764406



PREM FLG	If 1, memory is being preset or frame grab in progress.

CRT1 @ 764406

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
YZOOM 1	YZOOM 0	XZOOM 2	XZOOM 1	XZOOM 0	XPAN 2	XPAN 1	XPAN 0	ALTMAP	BLINKEN	FGC	DMA	IRQUEN	VDO BUS	CLIPEN	WRCPL

YZOOM1-YZOOMO	Y-zoom: 00 = 1, 01 = 2, 10 = 4
XZOOM2-XZOOMO	X-zoom: 111 = 1, 110 = 2, 101 = 3, 100 = 4, 011 = 5, 010 = 6, 001 = 7, 000 = 8
XPAN2-XPANO	Horizontal display pan delay.
ALTMAP	Selects A or B color-look-up table.
BLINKEN	When set, blinks display.
FGC	Continuous frame grab (not used).
DMA	When 1, the display memory can be accessed by DMA.
IRQUEN	Interrupt enable.
VDO BUS	Video bus enable when 0.
CLIPEN	Clipping enabled when 1.
WRCPL	Data at X,Y is complemented when 1.

VECT @ 764414

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
			WRT AUTO	DEC Y	DEC X	INC Y	INC X	CRTC 7	CRTC 6	CRTC 5	CRTC 4	CRTC 3	CRTC 2	CRTC 1	CRTC 0

WRT AUTO	When 0, data in DATA is automatically written to X,Y when DATA is loaded.
DEC Y	When 1, auto-decrement of Y is in effect.
DEC X	When 1, auto-decrement of X is in effect.
INC Y	When 1, auto-increment of Y is in effect.
INC X	When 1, auto-increment of X is in effect.
CRTC7-CRTCO	Address of CRTC register (used only at start-up).

CRT5 @ 764416

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PRESET	FGS					DISS	DISM	DATA7	DATA6	DATA5	DATA4	DATA3	DATA2	DATA1	DATA0

PRESET	When 1, the part of display memory appearing on the screen is preset to the value in DATA.

FGS	Frame grab control.
DATA7-DATA0	Data port to and from the CRTC registers.

DIAL DAS SOFTWARE

The DIAL DAS Operating System (OS) software consists of two programs which run simultaneously on the two LSI computers. The program on LSI #1 is called "MASTER" and is dedicated to data transfer and storage. The LSI #2 program is called "SLAVE" and is responsible for data analysis and display. The user communicates with both programs through LSI #1 which passes data buffers and display options to LSI #2 as necessary. During real-time experimental situations, the MASTER program gathers digitized laser signals from the Transiac 2012's and the Biomation 1010. It also gathers laser energies, temperatures, and pressure altitude from the ADV11-C (analog-to-digital converter), time of day from the TCU-50 DYR, and position information from the Loran or INS navigation devices. Data acquisition is interrupt driven by the Lase Coherent Trigger into the Transiacs and Biomation. If the Biomation is used, then the interrupt occurs when the Biomation is ready to transfer data. Otherwise, the Transiacs determine the interrupt. After the data is packed into one continuous , the buffer is written to magnetic tape. If LSI #2 has finished processing the previous laser shot, the new data buffer is transferred to LSI #2 from LSI #1 through a DMA interprocessor link. The display rate in real-time depends on the amount of data to be plotted and on the complexity of the data analysis to be performed. For example, at 5 Hz laser firing, 2048 words of raw data from one unit (no analysis) will be viewed every third shot. Real-time profiles of ozone or water vapor concentrations are updated every fifth shot. These displays of raw and processed DIAL information allow for real-time system optimization as well as flight path decisions during flight operations.

Data transfer operations from the digitizing units (2048 words each) are readily accomplished within the minimum 100 ms operation time envelope between laser firings. Not all of the words from each unit are saved in computer memory, but each unit is completely read to obtain the proper sequence of device responses or error conditions. Software commands are available which control the starting point and number of words for data storage for each signal return. The maximum buffer size is presently set at 4096 words. The combined data stored from all the digitizers in use plus the shot header information must not exceed 4096 words.

Getting Started

Since the teletype is interfaced to LSI #1, a short program is available on each of the system diskettes which allows the user to communicate directly with LSI #2. Once LSI #1 is booted, type "R LSI2" to access LSI #2. Thereafter, each character is sent through the serial line interface to LSI #2. To exit, hit the "BREAK" key -- this returns the user to ODT (on line debug-technique) on LSI #1.

To run the MASTER and SLAVE programs, LSI #2 must start out in ODT. This allows program MASTER to boot LSI #2 and run program SLAVE. The procedure to start up the MASTER/SLAVE programs is outlined below. System diskettes with the RT11 monitor on them have blue labels. The diskettes with the programs "MASTER" and "SLAVE" have yellow labels.

1. Place system diskettes (blue) in drive 0 of both disk drives.
2. Place MASTER (yellow) in drive 1 of LSI #1 and SLAVE (yellow) in drive 1 of LSI #2.
3. Boot LSI #1 by typing: 173000g
4. Run program MASTER by typing: RUN MASTER
5. MASTER will load and in turn call SLAVE. LSI #2 is ready when "MATROX" is visible on the video display. LSI #1 is ready when the default banner record is printed out on the console display.
6. You are now under the DIAL DAS OS. Anything you type in from now on will be interpreted by program MASTER. To return to the monitor use the instruction KILL. To return to ODT hit the BREAK key.
7. To erase one character hit the "backspace" key. To erase a whole line hit the DEL key.
8. Valid instructions are listed in the section "Keyboard Commands".
9. If LSI #1 bombs, halt both computers and start back at step 4.
10. If LSI #2 bombs to ODT (indicated by "@"), then type BOOT. If LSI #2 bombs to Monitor (indicated by RT-11 error message), type SLAVE.

The user now has the capability to fully control data buffering and recording, as well as many other aspects of data analysis and display. A sample user dialogue is given in Appendix II. Comments are made on each line to describe what the user is doing (those preceded by two hyphens) or what action the computer is taking (comments in parentheses).

Data Acquisition

Data acquisition is controlled by hardware switches on the digitizing units and by keyboard commands. On the Biomation 1010 there is a pre-trigger delay dial which causes the unit to store a certain number of words prior to the trigger in increments of 10 words. On the Transiac 2012 a knob setting selects the number of pre-trigger samples in increments of 256 words. A certain number of pre-trigger samples are desirable (about 10 to 20) to provide a good window for the trigger marker but certainly not all 256 of the Transiac pre-trigger words need be saved. There is also the case where a unit is used to digitize only an offline return which occurs 100 usecs (or 1000 words) after that unit was triggered. The first 100 usecs of data must be read by the program, but only the data from the second 100 usecs need be saved. The instruction " STORE U1,U2,U3,U4" determines the starting word for each unit at which data is to be saved. For those units storing two returns (both online and offline), the first return is saved starting at Ui and the second return is saved starting at Ui + 1000, i = 1, 2, 3, OR 4. The number of words saved for each unit is determined by the instruction "POINTS U1,U2,U3,U4". An example of data acquisition will be given at the end of the section "Keyboard Commands".

Real-Time Data Display

All data processing and display to the video screen are performed by the SLAVE program on LSI #2. LSI #1 is reserved for data transfer from the digitizers, for magnetic tape operations, and for console keyboard communications. However, on request, LSI #1 will produce real-time hard copy gray scales at 1 Hz (i.e. only one shot plotted per second). On LSI #2, four basic modes for DIAL data display are available, each with a variety of display options. On the right hand side of the screen, inputs from the ADV11-C can be viewed. The DIAL DAS command language allows the user to input a slope and intercept to convert each digitized voltage to a meaningful unit (see section "Keyboard Commands"). If the slope of any channel is set to 0 then no conversion is attempted and voltage is displayed directly. For labeling purposes, the program assumes that the ADV11-C inputs and the conversion constants are defined as follows:

ADV11-C Channel	Input	Label	Units
1	aircraft altitude	ALT	ft
2	dewpoint temperature	DPT	^oC
3	temperature	T	^oC
4	total temperature	TT	^oC
5	online pump laser energy	NP	MJ
6	offline pump " "	FP	MJ
7	online UV " "	NUV	MJ
8	offline UV " "	FUV	MJ
9	visible " "	VIS	MJ
10	infra-red " "	IR	MJ

Conversion constants must be input as integers. Each slope and intercept is represented by an integer mantissa and corresponding exponent of 10. These four words per conversion channel are stored in the banner record. The user also has options to update the plot side of the screen (left) by itself, update the ADV11-C side (right) by itself, or both sides at the same time (ADCDAT command).

The different display options are summarized below. Each display mode has a number of default options associated with it. These are summarized in table 6. The default values can be changed by various keyboard commands. Display options are available for background subtraction, range-square correction, overlaying data of different digitizers, scale and more. Each display option can be activated or de-activated in real-time to observe signal features in the most useful format.

Raw Data (MODE1)

This is the most fundamental display mode which presents raw data from each of the digitizing units as it exists in computer memory (figure 4). The abscissa represents word sequence in

7/22/81 21:29:54

FILE # 10

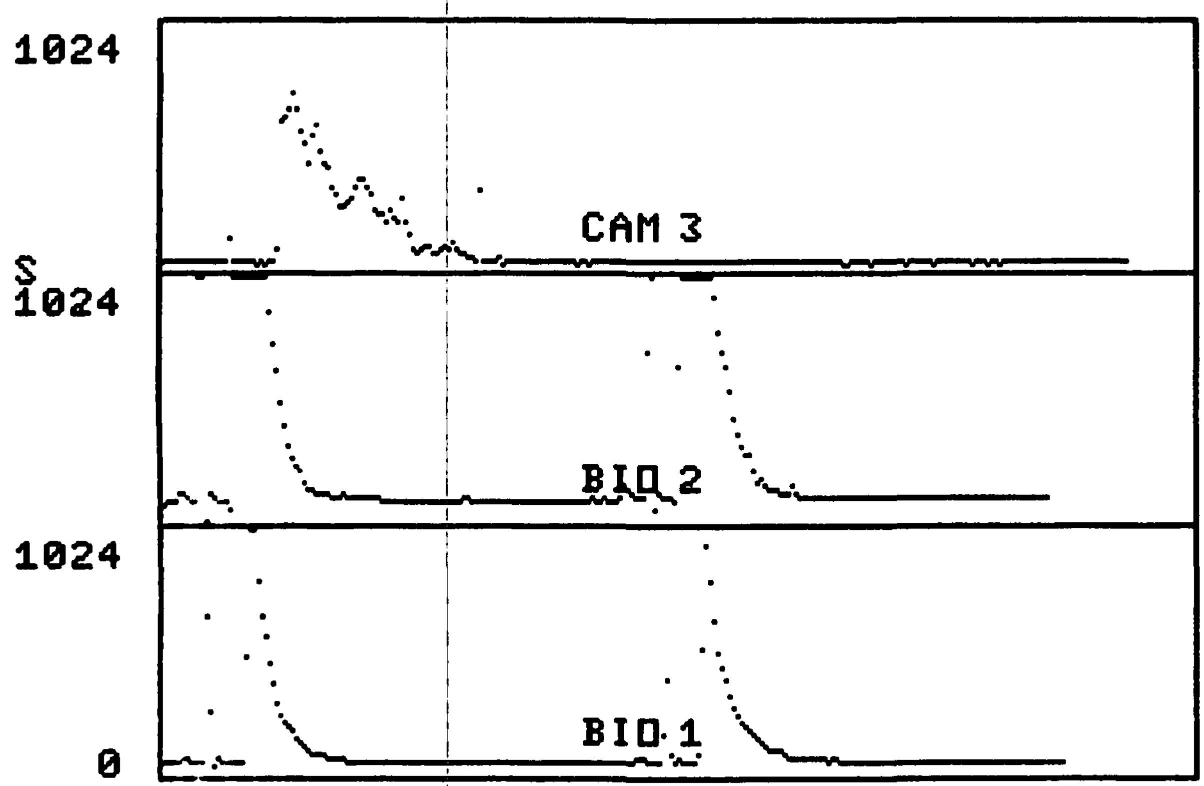
SHOT # 325

LAT 3540.8N

LON 7616.3W

ADV11-C DATA

1.	ALT	(FT)	13000.
	ALT	(M)	3962.5
2.	DPT	(C)	3.5191
3.	T	(C)	3.5191
4.	TT	(C)	3.5191
5.	NP	(V)	0.352
6.	FP	(V)	0.352
7.	NUV	(V)	0.352
8.	FUV	(V)	0.352
9.	VIS	(V)	0.352
10.	IR	(V)	0.352



TRIGGERS

Figure 4. Example of MODE1 display

memory while the ordinate is adjusted to present the 12-bit signal magnitude with variable magnification. The one word instruction "MODE1" calls up all the options listed as defaults in table 6.

Table 6. Default plotting parameters.

PARAMETER	MODE1	MODE2	MODE3	GRYSCL
unit select	all	all	UNIT1	UNIT2
y-axis scale	0-4096	0-4096	0-800	150m/tic
x-axis scale	all data	150m/tic	150m/tic	---
background word	600	600	600	600
trigger search	no	yes	yes	yes
smooth	no	105m	105m	no
average shots	no	no	100	no
range cell	---	---	210m	---
gas exponent	---	---	-10	---
shift toa	---	no	no	---
display ADV11-C	yes	no	no	no

<u>Online/Offline Overlay (MODE2)</u>

A second display mode presents the raw data signals in an overlapped format. As shown in figure 5, the online and offline UV signals are overlayed when the data is tagged as a DIAL type measurement. The top profile in figure 5 presents an aerosol return which is a single wavelength measurement at 600nm. By default, each of these returns have been smoothed over 105m and plotted as a function of range , each tic mark representing 1 usec. Each data shot is plotted in this mode starting after the PMT gate delay. In this mode a search is also performed for a trigger position to line up each of the returns with respect to the laser firings. This trigger position word number is displayed on the right hand side of the screen. The user specifies the trigger ordinate level to be used for each digitizer unit along with the number of words it is nominally delayed. The lase-coherent trigger markers are electronically ~~delayed 14 words from the actual laser firing but a breakthrough~~ pulse occurs at the same word as the laser firing.

Figure 6 shows the effect of activating the background subtraction and range squared options on the profile in figure 5 in MODE2.

<u>Concentration Profiles (MODE3)</u>

This display mode presents the gas concentration mixing ratios as a function of altitude or range calculated from the DIAL signal pair (figure 7). For each DIAL return, the background signal level is integrated over a 3 usec interval after the ground return. The starting point of this integration is

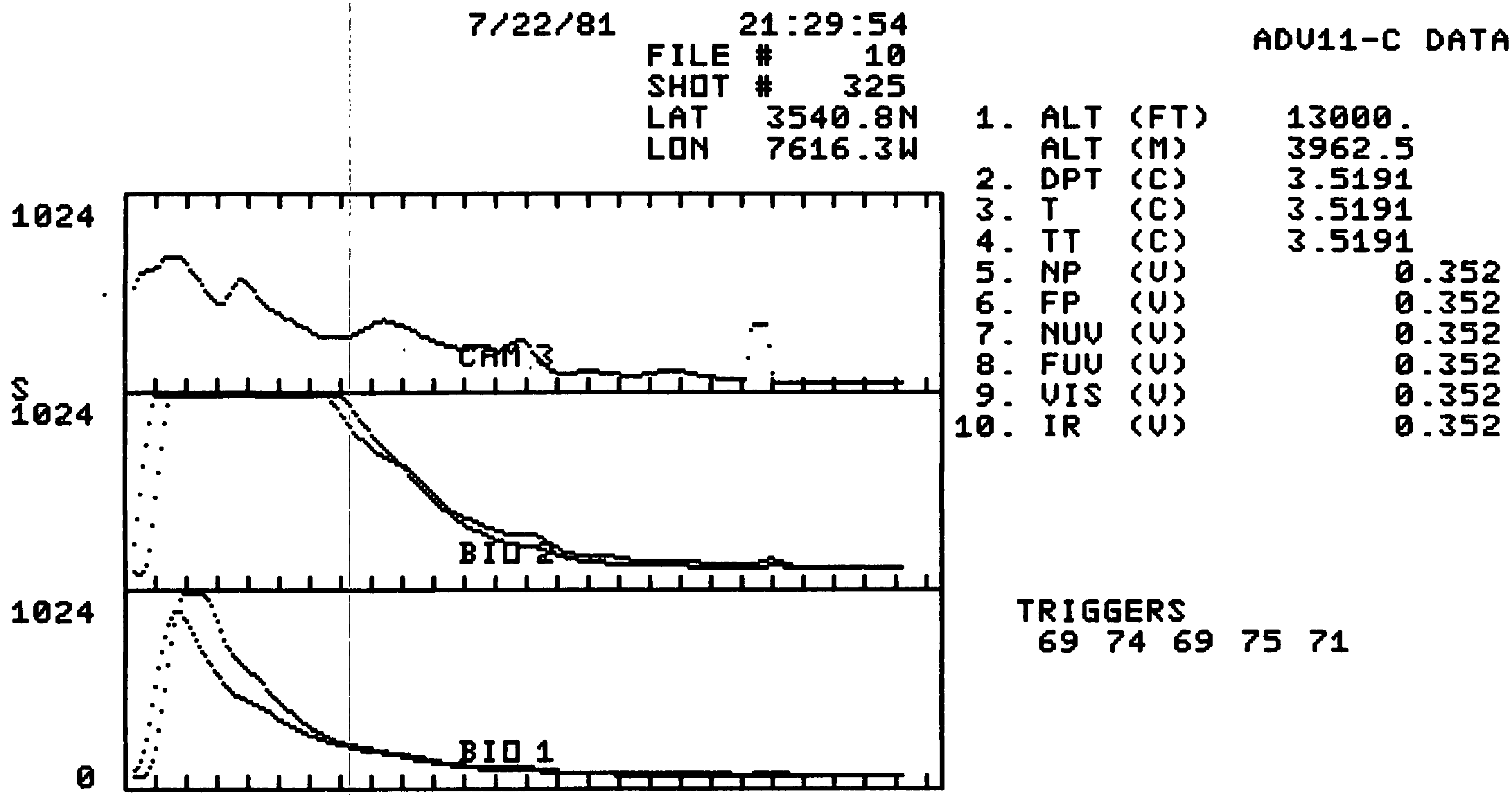


Figure 5. Example of MODE2 display

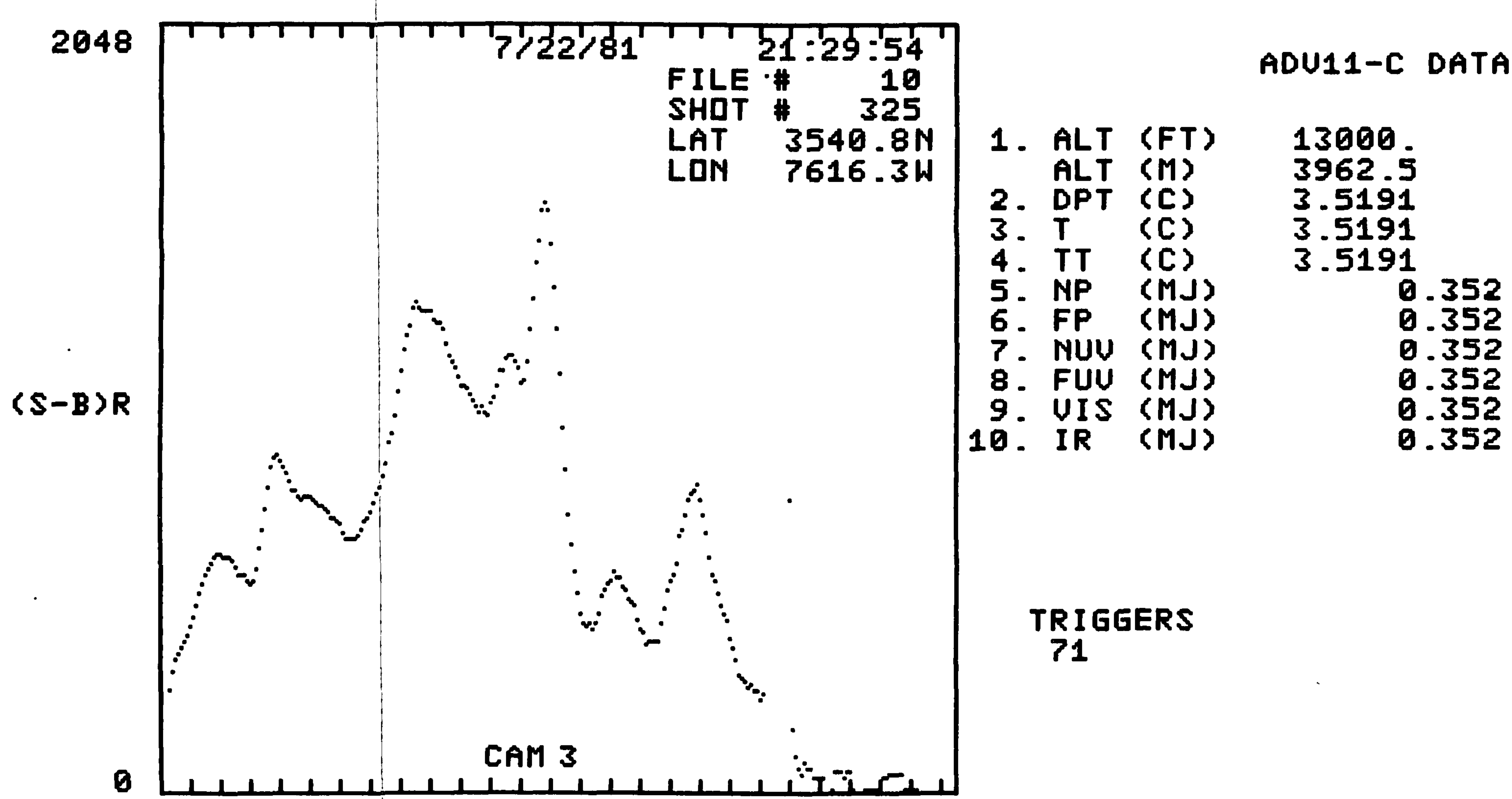


Figure 6. MODE2 display with background subtraction and range-squared options in effect

selected by the command "BGWORD". This average background is subtracted from the return signal, and the resulting data is then smoothed with a running mean over the specified range interval (see "SMOOTH"). This smoothing technique does not introduce errors only for those atmospheric conditions where the aerosol scattering is not changing rapidly along the DIAL measurement path. The DIAL equation (ref. 1) is evaluated using the smoothed lidar returns over a specified range cell size, usually 210 m. Ozone mixing ratios are determined by dividing each range cell concentration by the corresponding standard atmospheric number density at that altitude. A correction factor of 6.7 ppb is subtracted from the ozone mixing ratio to compensate for Raleigh extinction differences between 286 and 300 nm. Water vapor mixing ratios are determined by dividing each range cell by the standard number density at sea level since the product of the water vapor absorption cross section at line center and the atmospheric number density is independent of pressure. Each DIAL signal pair produces a mixing ratio profile. Any number of DIAL measurements can be averaged together to improve the profile statistics at the expense of increased horizontal integration for the measurement. The standard deviation for the resulting averaged profile is computed at increments equivalent to the range cell size and displayed on the mixing ratio profile.

Gray-Scale Display (GRYSCL)

A 16 level gray scale display format is available for presentation of the spatial distribution of aerosol scattering (figure 8). In processing the aerosol lidar return, the background signal level is subtracted from the lidar-plus-background signal and the geometrical range squared lidar signal dependence is eliminated. The resulting lidar backscatter profile is indicative of the distribution of aerosols along the lidar line-of-sight. The vertical resolution of the aerosol data is 15 m. The nominal horizontal resolution is 10 m for aircraft operation at a 10 Hz repetition rate. The backscatter signal level is converted into a 16 level gray scale display line where stronger scattering is indicated by higher brightness on the monitor or a darker dot pattern on the printed version of the display. Sequential gray scale lines are used to construct a real-time picture of the aerosol vertical distribution along the Electra flight path. Each of the gray scale displays can contain 300 individual or integrated aerosol profiles. At a laser pulse repetition rate of 1 or 10 Hz, the 300 individual profiles correspond to a nominal horizontal traverse of 30 or 3 km, respectively. This horizontal scale assumes a nominal ground speed of 100 m/sec for the Electra aircraft. The gray scale format shows the terrain profile, and it clearly identifies the distribution of aerosols in the boundary layer and the free troposphere.

Hard Copy Gray-Scale (GRYLOG)

This option represents the same type of display as described for "GRYSCL"; however, it is done on the Trilog T-100 and does

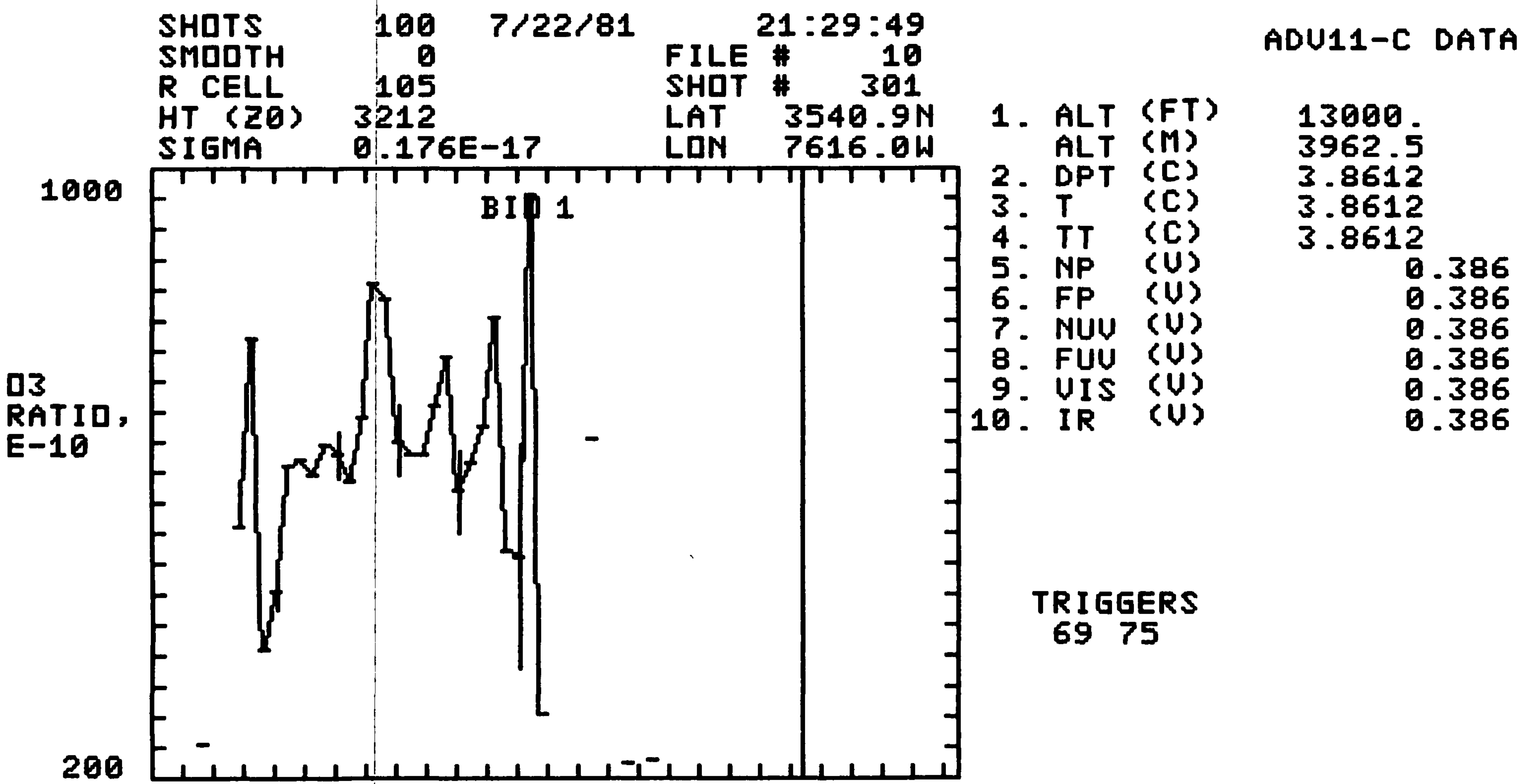


Figure 7. Example of MODE3 display (100 shots averaged)

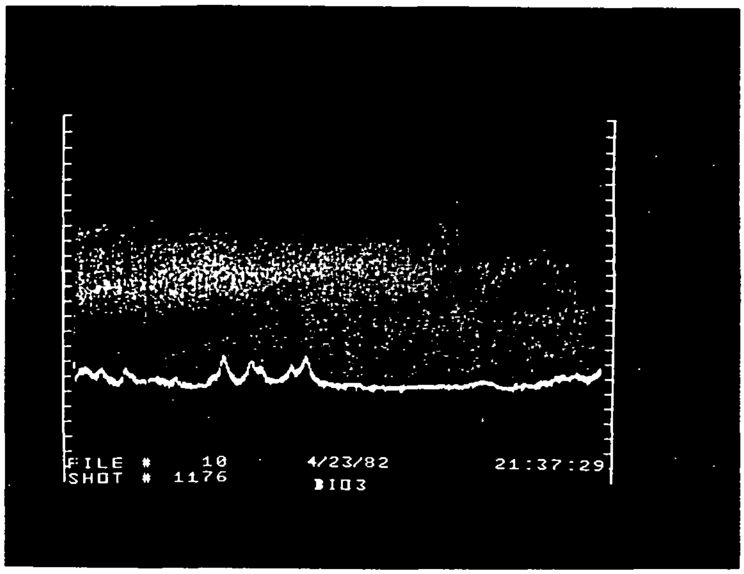


Figure 8. Example of GRYSCL

not affect the display options chosen for the video screen. When this option is activated, the current banner record and GRYLOG plotting paramaters are printed followed by a 10 shade gray scale display of relative aerosol concentrations. No matter what the laser frequency, only one shot per second is plotted. Time, latitude and longitude are printed at each minute marker (figure 9). The hard copy continues until turned off with the instruction "GRYOFF" or whenever any of the GRYLOG plotting parameters are changed. The user must re-start the "GRYLOG" after changing plotting parameters. This allows the new plotting parameters to be printed so that an updated record is always available.

Magnetic Tape Storage and Format

The DIAL data is stored in real-time using one of two Cipher tape drives. This allows for constant recording of data while one unit is rewinding. The data is recorded at 100 ips in "streamer" mode. Streamer mode is the only method we found to record the 4K blocks of DIAL data at 10 Hz operation. The disadvantage of streamer mode is that if the tape unit does not get a new instruction within a small period of time it requires a long repositioning time. The DIAL DAS software was written so that each data transfer from the digitizers is stored in a consecutive block of extended memory -- up to 23 blocks are available. Once transfer to the top block (@ 740000) is done data transfer continues to the bottom block (@ 200000). When a request is made to commence recording data, the first available block is transferred to tape as soon as the tape has repositioned. During repositioning time other data blocks have been stored in memory and these are queued as they come along. As soon as the tape is again ready it is given the next queued block to record. This procedure produces a streaming operation with minimal need to reposition. Tests show that 4k blocks are written to tape at 10 Hz with upto 10 blocks getting queued, at 5 Hz 5 blocks get queued and at 1 Hz no blocks get queued.

Data is written using 1600 bpi PE magnetic tape format on 2400-ft reels of .5 in wide magnetic tape. Each data storage file begins with a 256 word banner record (16 bits per word) with DIAL DAS information as shown on table 7. The data from each laser shot is packed into one large record on magnetic tape (data ~~from all digitizer units are packed into one single buffer).~~ Each data record begins with a 20 word shot header of information required on a shot-by-shot basis. This includes time, shot number, latitude, longitude and 10 channels of the ADV11-C data. The number of words in the header is currently 20 but this number can be changed with the instruction "HDRPTS". Table 8 shows the structure of a typical data record. At the end of the tape or at the end of the information stored on that tape there are 2 file marks (EOF) to denote end of information.

While recording data, if one tape drive reaches an end of tape marker then it will automatically back up two records, write two EOF's, start rewinding the tape, and start recording a new file on the alternate tape drive.

```
     BANNER RECORD
TAPE=     5   FILE=    10   HEADER WORDS= 10   DATE=  7/22/82

ALT=      13000   UP/DOWN=  0   SAMP FRE=   10   PRE-TRIG=   70
REP RATE=     5   ABS COEF=  176E-20
UNIT   WRDS  RTRNS        START   BASE    TRIG    DELAY   SPECIES   TO DELAY
   1    700      2            0      0 )  100        5       O3            0
   2    800      2            0      0 )  200        5       O3            0
   3   1000      1         1000   1023 (  900        5       VIS           0
UNIT 1 = BID 1
UNIT 2 = TRANSIAC  2
UNIT 3 = TRANSIAC  6
AR11 CONVERSION CONSTANTS
CHAN     SLOPE    OFFSET
   1  1 0      0 13E+05
   2  20       -50
   3  10       -10
   4  20       -50
  PLOTTING PARAMETERS
UNIT   3    RET  1    ADRS OFSET       6000    # WORDS  1000    DELAY   5
SCALE     -7    OFFSET      0   BGWORD   600    INDEX    1   AVERAGE     1
```

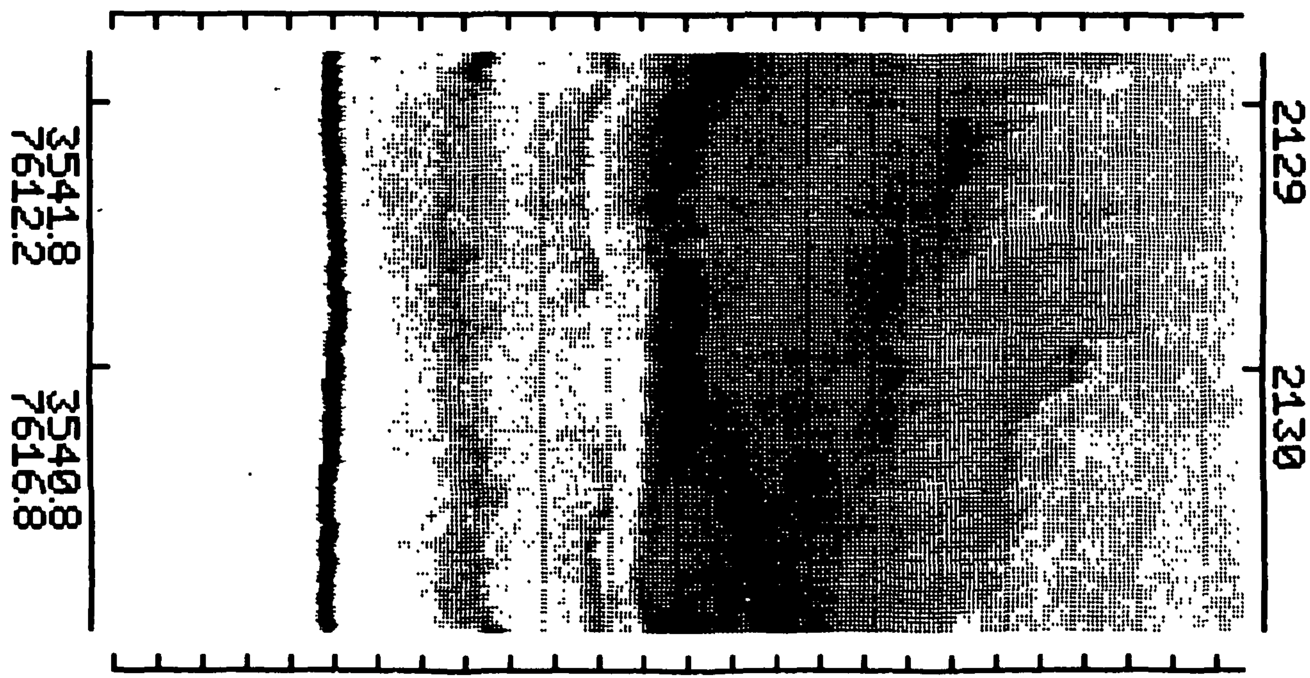


Figure 9. Example of GRYLOG

Table 7. Banner record word assignments (dimensioned 256).

Word	Description
1	banner record format
2	tape #
3	file #
4	# words in shot header
5	date
6	plane altitude (feet)
7	up/down mode (0=down; 1=up)
8	sampling frequency (MHz)
9	laser fire word #
10	laser rep rate (Hz)
11	absorption coefficient (mantissa)
12	absorption coefficient (exponent)
13-16	spares
17	words/return unit 1
18	words/return unit 2
19	words/return unit 3
20	words/return unit 4
21	# returns unit 1
22	# returns unit 2
23	# returns unit 3
24	# returns unit 4
25	starting storage word unit 1
26	starting storage word unit 2
27	starting storage word unit 3
28	starting storage word unit 4
29	baseline unit 1
30	baseline unit 2
31	baseline unit 3
32	baseline unit 4
33,34	direction and magnitude of trigger marker unit 1
35,36	direction and magnitude of trigger marker unit 2
37,38	direction and magnitude of trigger marker unit 3
39,40	direction and magnitude of trigger marker unit 4
41	post-trigger delay (usecs) unit 1
42	post-trigger delay (usecs) unit 2
43	post-trigger delay (usecs) unit 3
44	post-trigger delay (usecs) unit 4
45	species identifier (RAD50) unit 1
~~46~~	~~species identifier (RAD50) unit 2~~
47	species identifier (RAD50) unit 3
48	species identifier (RAD50) unit 4
49	trigger marker delay (words) unit 1
50	trigger marker delay (words) unit 2
51	trigger marker delay (words) unit 3
52	trigger marker delay (words) unit 4
53-64	spares
65	ADV11-C channel 1 slope (mantissa)
66	ADV11-C channel 1 slope (exponent)
67	ADV11-C channel 1 intercept (mantissa)
68	ADV11-C channel 1 intercept (exponent)
69-104	same as above 4 words for channels 2-10

Table 8. Data record structure for shot buffers.

Word #	Description
1	shot number
2	# shots in buffer
3-4	time of day
5-6	unused
7	latitude (low order)
8	latitude (high order)
9	longitude (low order)
10	longitude (high order)
11	altitude
12	dew point temperature
13	temperature
14	total temperature
15	online pump energy
16	offline pump energy
17	online UV energy
18	offline UV energy
19	visible energy
20	infrared energy

The above constitutes the existing shot header. After this data the record buffer will contain the data stored from the various digitizers. The banner record whose values were defined in table 7 (iban) determines the storage of data:

if L=iban(4),M1=iban(17),M2=iban(18),M3=iban(19),M4=iban(20)
N1=iban(21),N2=iban(22),N3=iban(23),N4=iban(24)
then the data is located in the buffer as follows

start word #	end word #	contents
1	L	shot header
L+1	L+M1*N1 = K1	Unit 1 data
k1+1	k1+M2*N2 = K2	Unit 2 data
K2+1	k2+M3*N3 = k3	Unit 3 data
K3+1	k3+M4*N4	Unit 4 data

KEYBOARD COMMANDS

After the start-up procedure outlined above, all further keyboard input is interpreted by the program MASTER. A complete set of legal commands are listed on the following pages. A single character of operator input can be erased by means of the BACKSPACE (←) key. An entire line can be erased using the DEL key. The DIAL DAS OS is brought on-line with predefined option defaults. Data transfer from the digitizers can be initiated immediately if these defaults are suitable by means of the START command. Once START has been entered the program is interrupt-driven by the digitizers and certain paramaters should not be changed. Commands that change these parameters are listed in the section "Stop Mode Commands" and can be used only after STOP has been entered. Also included in the "Stop Mode Commands" are instructions which affect program control such as reading data back from tape or listing out the contents of a shot. One other category included in this section are those commands which deal with the interaction of the two LSI's. These commands can only be issued in stop mode to prevent the computers from getting out of sync. Error messages are detailed in Appendix III.

In the following list of commands, the variables U1, U2, U3, and U4 are used to refer to input parameters for digitizer units #1, #2, #3, and #4 respectively. If the Biomation 1010 is to be used it will be unit #1 by default. The Transiacs can be used in any order which is determined by the command CAMACS whose input parameters list the station numbers of each unit in the sequence in which they are to be read.

Stop Mode Commands

1. Digitizer Storage Commands:

POINTS	U1,U2,U3,U4	# points/return for each unit
RETRNS	U1,U2,U3,U4	# returns for each unit
STORE	U1,U2,U3,U4	store from this word for each unit
BIOS		use the Biomation as first digitizer
NOBIOS		do not use Biomation
CAMACS	I,J,K,L	station # for Transiacs to be used

2. Play-Back Commands:

LSTBNR		print out current banner record
LSTPLT		print out current plotting options
COPY	I	copy CRT to Trilog (sizes: I=1-4)
PRINT		plot buffer is printed out on Trilog
LIST	I,J	print data buffer from word I to J if I<0 print buffer in memory if I>0 read buffer from tape
PLOT	I	plot I shots from tape if I=-1 plot from memory

3. LSI #2 Program Control Commands:

BOOT		boot LSI #2 then run program SLAVE

SLAVE		run program SLAVE on LSI #2

Start or Stop Mode Commands

1. Program Control Commands:

START	start data transfer from digitizers
STOP	stop data transfer
RESTRT	clears interrupts and issues a macro RESET command which returns all units to their status at power-up time
KILL	kill program MASTER and return to Monitor
SHTSET	reset shot counter to zero

2. Banner Record Input:

FORMAT	I	format # (=2 presently)
TAPE	I	tape #
FILE	I	file #
HDRPTS	I	reserve I words in shot header
UPDOWN	I	I=0 down-looking; I=1 up-looking
PULFRE	I	pulse repetition frequency (Hz)
SAMFRE	I	sampling rate (MHz)
HEIGHT	I	plane altitude (ft)
PRETRG	I	# words stored before trigger marker
ABSCOF	I,J	absorption coefficient I*10**J (atm-cm)-1
TODLY	U1,U2,U3,U4	# words offset between marker and actual laser firing
DELAY	U1,U2,U3,U4	usecs after trigger to start of return
GASES	U1,U2,U3,U4	3-letter gas identifier (AER,O3,H2O)
BASLIN	U1,U2,U3,U4	base line for returns
TRGLEV	aU1,bU2,cU3,dU4	trigger marker level where a,b,c,d can be = or < or >

3. ADV11-C Calibration Constants:

CHAN1	I,J,K,L	channel 1	slope (I*10**J) and intercept (K*10**L)
CHAN2	"	channel 2	"
CHAN3	"	channel 3	"
CHAN4	"	channel 4	"
CHAN5	"	channel 5	"
CHAN6	"	channel 6	"
CHAN7	"	channel 7	"
CHAN8	"	channel 8	"
CHAN9	"	channel 9	"
CHAN10	"	channel 10	"

4. Magnetic Tape Commands:

CIPHER	I	cipher unit # (I=1 or 2)
RECORD		write banner and start recording
BANNER		write banner
ENDFIL		write EOF and stop recording
REWIND		rewind tape to BOT
SKPEOI		skip to 2 consecutive EOF's

FNDFIL	I	search for file I (forward only)
SKPFIL	I	skip forward I files
BAKFIL	I	skip backward I files
SKPREC	I	skip forward I records
BAKREC	I	skip backward I records

5. Plotting Options Commands:

PLTMOD	I	select plot mode I (I=0 for no display)
MODE1		raw data display
MODE2		on/off line overlay display
MODE3		concentration calculation display
PLTGRY	I	plot gray scale if I=1
GRYSCL		CRT aerosol gray scale display
UNIT1		display unit #1 data only
UNIT2		display unit #2 data only
UNIT3		display unit #3 data only
UNIT4		display unit #4 data only
ONLINE		show on-line return only
OFFLINE		show off-line return only
RETURN	U1,U2,U3,U4	plot return # for each unit (both=7)
SCALE	I	plot scale factor where scale=2**I (see note #2)
YMAX	I	display range interval (see note #2)
LITER		causes gray scale to be one scale lighter
DARKER		causes gray scale to be one scale darker
OFFSET	I	offset x-axis by I
CLEAR	I	clear CRT (0=no clear;1=data only;15=all)
OVRLAY	I	overlay data from different units if I=1
BGWORD	I	at word I after start of return, average 30 words for a background value
SUBBAK	I	subtract background if I=1
RNGCOR	I	range correct if I=1
SMOOTH	I	smooth data over I meters (max 105m)
PLTAVG	I	average I shots in display
INDEX	I	index of I through data buffer (if I=0 program computes index necessary to fit data on screen)
PIXPNT	I	I pixels plotted per data point
ADCDAT	I	I = 0 update plot and ADV11-C data I = 1 update plot only I = 2 update ADV11-C only
RNGCEL	I	use range cell of I meters
GASEXP	I	concentrations in parts *10**I
SHFTOA	I	shift TOA marker by I words

6. Trilog Gray-Scale Commands:

GRYLOG	start real-time gray scale on Trilog
GRYOFF	stop real-time gray scale on Trilog

The following commands are identical in function as those listed in the previous section but the "@" preceding each command directs the action to the gray-scale display on the Trilog.

@UNIT1	@UNIT2	@UNIT3	@UNIT4	@RETURN
@SCALE	@LITER	@DARKER	@OFFSET	@BGWORD
@INDEX	@PLTAVG			

Trigger Markers

It has been found that it is extremely important ot precisely line up the on and off line returns. Even a one word offset can cause oscillations in the concentration profiles. Therefore, there are several commands available to tell the program how to find a trigger marker. The trigger markers provided by the lase-coherent time base are electronically delayed from the actual laser firing so that any noise due to flash lamp firing will not mask the markers. These markers are the most accurate so they are used for the DIAL type returns. There are no trigger markers available for the one-wavelength returns so either flash lamp noise, or a breakthrough spike as the signal hits the aircraft window, or in the case of the 1.06 return where the diode detector is always on the return itself can be used to line up these returns with the DIAL returns. These types of markers occur at the time of laser firing. The first step is to determine at what word number the actual laser firing occurs. This can be done by looking at any one of the three types mentioned above which are not electronically delayed. The LIST instruction is used to display the word values in computer memory. When the word number of the laser fire has been noted it is entered with the command LASFIR. The next step is to tell the program whether a delayed type marker is to be used or one which occurs at laser firing. This is done with the command TODLY (this delay must be entered for each digitizer unit being used). The lase-coherent markers are presently delayed by 14 words (1.4 usecs) from the laser firing. The final step is to specify the actual level for the trigger with the command TRGLEV. Again, each digitizer unit will have its own trigger marker level. The trigger level is entered as less than (<), greater than (>), or equal to (=) some value (eg. < 0, > 900, = -2048).

The trigger search routine looks for the trigger marker in the 11 words centered around where it expects to find one as specified by the inputs LASFIR and TODLY. For example, LASFIR is set for 6, TODLY is 14, and TRGLEV is =2048 then the trigger search routine expects to find a value of 2048 between word 15 and word 25 of the online return and between POINTS + 15 and POINTS + 25 for the offline. If a value is found before that window or no value is found at all within the 11 words searched then the data shot is not included in the concentration calculation. MODE2 display does a trigger search on each return so inputs can be checked by displaying MODE2. The valid trigger words are displayed in the lower righthand side of the screen as they are found. Invalid markers are denoted by an asterisk.

One more word of caution. The occurrence of the trigger marker in the data stream can be altered by switch settings on the digitizers as well as by the command STORE. The Biomation 1010 has a pre-trigger dial which can be changed in increments of

10 words (@ 10 MHz) and the Transiacs have a pre-trigger dial which increments by 256 words (for 2048 word record length). To allow for an ample window for the trigger marker the Biomation dial should be set at no more than 2.03 (2030 words stored after the trigger and 18 words before) and the Transiac should be set at 1/8 (1892 words stored after the trigger and 256 words before). When the data from the digitizers is transferred into computer memory for storage to magnetic tape, the operator has the option of selecting where to begin storage with the instruction STORE. This is especially useful with the Transiacs since so many pre-trigger words are digitized or for any unit when only the second return need be saved (such as the visible aerosol measurement). A STORE value of 234 for the Transiac places the laser firing at word 6 in the data stream and the trigger marker at word 20. If only the second laser return were to be saved on a Transiac then a STORE value of 1234 might be used (the extra 1000 to skip the first 100 usecs). Figure 10 shows digitizer memory as compared to computer memory for the keyboard commands as follows:

```
STORE  0,1230,230,230
POINTS 500,500,500,500
RETRNS 1,1,2,2
LASFIR 10
TODLY 0,0,14,14
```

A possible set of trigger levels for this set up might be:

```
TRGLEV >512,<0,<0,>0
```

Scaling

The scale factor "I" for MODE1, MODE2 and MODE3 is such that

displayed range interval = 256 * (2 ** -I)/(2 ** N-1)

where N = # digitizers in use.

So if a range interval of 4096 is desired with 4 units, the scale factor must be -7. An easier instruction to use is YMAX I which automatically scales the data for you so that your resulting range interval is equal to or the next power of two less than the input value I. For the gray-scales the scale factor must reduce range corrected signals to values between 0 and 15. This scale is typically -8 (i.e. S*R*R * 2 ** -8 < 16). The instructions LITER and DARKER will either increment or decrement the scale factor by one.

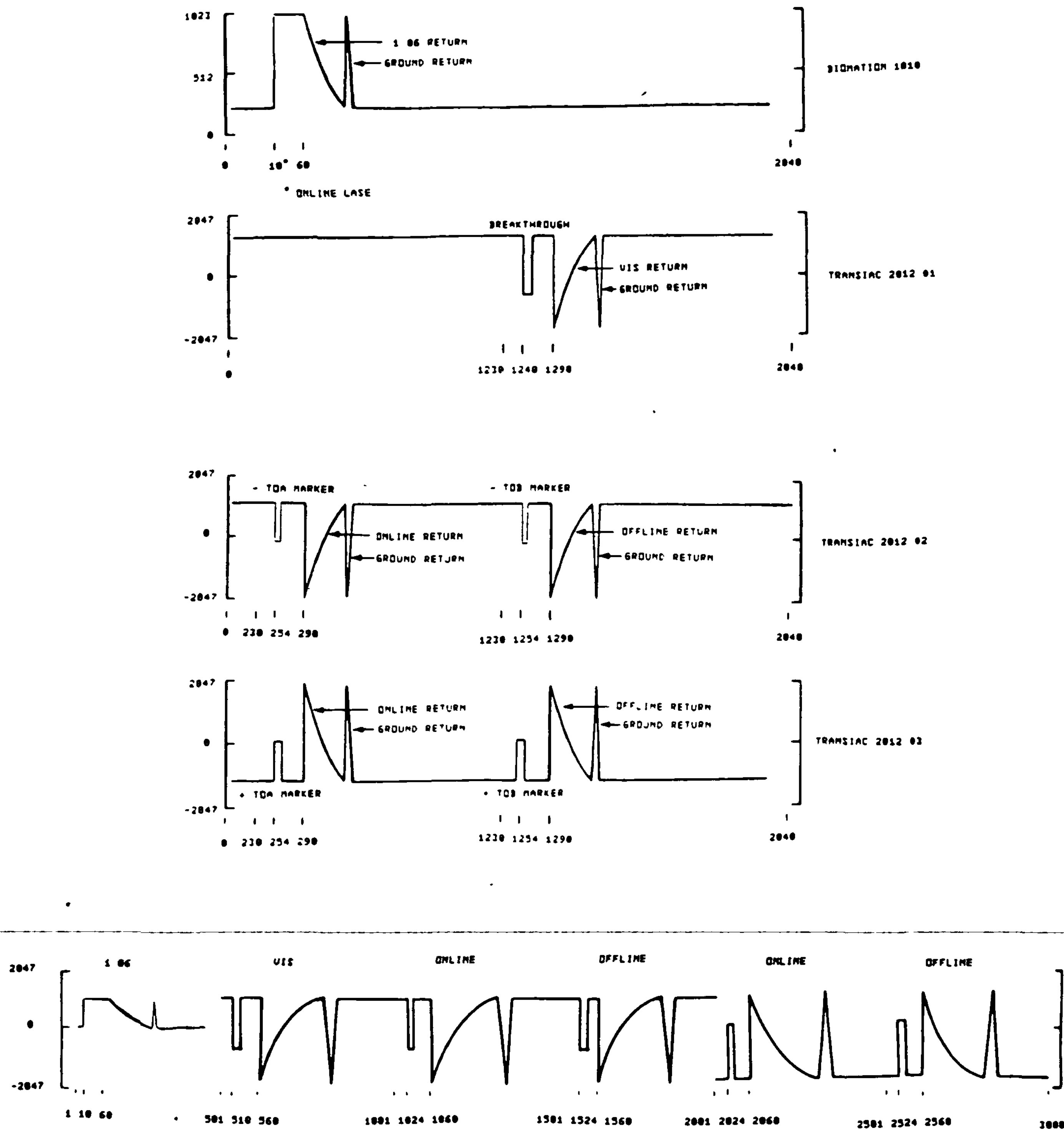


Figure 10. Example of digitizer memory as compared to saved buffer memory

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APPENDIX I

MATROX UTILITY ROUTINES

```
MATROX  MACRO V03 01 21-FEB-84 PAGE 1

                                                 TITLE MATROX
          164400                      B0=164400
          164402                      B2=164402
          164404                      B4=164404
          164406                      B6=164406
          164410                      B10=164410
          164412                      B12=164412
          164414                      B14=164414
          164416                      B16=164416
                                      ,       CALL LRESET       INITIALIZATION ROUTINE (512 X 256 PIXELS)
                                      ,       THIS ROUTINE INITIALIZES SUCH THINGS AS HORIZONTAL AND VERTICAL
                                      ,       DISPLAYED PIXELS, SYNCH POSITION, SYNCH WIDTH, MODE CONTROL
                                      ,       AND SCAN LINE -- SEE MATROX MANUAL FOR DETAILS
                                      ,       THE ROUTINE WILL CLEAR THE SCRREN AND PRINT "MATROX" IN THE
                                      ,       TOP LEFT CORNER
 000000   012701  000242'             LRESET  MOV     #PARAM,%1
 000004   012767  037442  164406              MOV     #37442,B6       ,CTR1 IS INITIALIZED--VIDEO ENABLED,
 000012   012767  037442  164406              MOV     #37442,B6       ,SINGLE DENSITY,NO DMA,NO FRAME GRAB,
                                                                      ,NO PRESET, XPAN=0, XZOOM=1,YZOOM=1
 000020   005067  164410                      CLR     B10             ,CTR3 INITIALIZED--COLOR MAP #1 SELECTED
 000024   005067  164412                      CLR     B12             ,CTR4 INITIALIZED--ALL BIT PLANES ENABLED
 000030   005067  000232                      CLR     SBL             ,SAVE BIT PLANES
                                      ,
 000034   012702  000012                      MOV     #10 ,%2         ,THIS LOOP SETS THE CRTC REGISTERS
 000040   012700  010000                      MOV     #10000,%0       ,ACCORDING TO THE TABLE "PARAM"
 000044   010067  164414              LRESO.  MOV     %0,B14
 000050   012167  164416                      MOV     (%1)+,B16
 000054   005200                              INC     %0
 000056   077206                              SOB     %2,LRESO
 000060   012767  010014  164414              MOV     #10014,B14      ,STARTING ADDRESS IS ROW 0
 000066   005067  164416                      CLR     B16
 000072   012767  010015  164414              MOV     #10015,B14      ,STARTING ADDRESS IS COLUMN 0
 000100   005067  164416                      CLR     B16
 000104   004767  000200                      JSR     %7,ERO          ,ERASE SUBROUTINE
 000110   004767  000174                      JSR     %7,ERO
 000114   012767  000001  000470              MOV     #1,X1           ,DISPLAY "MATROX" IN TOP LEFT CORNER
 000122   012767  000001  000466              MOV     #1,Y1
 000130   012702  000006                      MOV     #6,%2
 000134   012767  000017  000460              MOV     #017,ITY
 000142   012700  000154'                     MOV     #MX,%0
 000146   004767  001006                      JSR     %7,LTO          ,PRINT CHARACTER ROUTINE
 000152   000207                              RTS     %7
                                      ,
 000154      115     101     124      MX       ASCIZ /MATROX/
 000157      122     117     130
 000162      000
                                               EVEN
                                      ,
                                      ,       CALL MRESET (SBL)   WRITE ENABLE BIT PLANES
 000164   005725                      MRESET   TST    (%5)+
 000166   012700  000017                      MOV     #17,%0
 000172   017501  000000                      MOV     @(%5),%1
 000176   040100                              BIC     %1,%0
 000200   010067  000062                      MOV     %0,SBL
 000204   016767  000056  164412              MOV     SBL,B12
 000212   000207                              RTS     %7
```

```
                                        .         CALL LTABLE (I)  COLOR MAP SELECTION
                                        .         IF I=0  BLACK/WHITE
                                        .         IF I=1  GRAY SCALE
000214  005725                          LTABLE    TST     (%5)+
000216  005775  000000                            TST     @(%5)
000222  001403                                    BEQ     LTAB0
000224  005067  164410                            CLR     B10
000230  000207                                    RTS     %7
000232  012767  000001  164410  LTAB0             MOV     #1,B10
000240  000207                                    RTS     %7
                                        .
000242  000112  000100  000077  PARAM              WORD 112,100,077,066,042,07,041,041,06,07
000250  000066  000042  000007
000256  000041  000041  000006
000264  000007
000266  000000                  SBL                WORD 0
                                        .
                                        .         CALL ERASE (I)  CLEAR SCREEN ROUTINE (I=PLANES TO BE CLEARED)
000270  005725                  ERASE             TST     (%5)+
000272  012700  000017                            MOV     #17,%0
000276  017501  000000                            MOV     @(%5),%1
000302  040100                                    BIC     %1,%0
000304  010067  164412                            MOV     %0,B12
000310  005067  164404          ER0               CLR     B4
000314  012767  010037  164414                    MOV     #10037,B14
000322  012767  101000  164416                    MOV     #101000,B16
000330  012767  037442  164406                    MOV     #37442,B6
000336  005767  164406          ER1               TST     B6              ,PRESET MEMORY FLAG
000342  002775                                    BLT     ER1
000344  016767  177716  164412                    MOV     SBL,B12
000352  000207                                    RTS     %7
                                        .
                                        .         CALL LINE (X1,Y1,X2,Y2,ITY)   DRAW A LINE ROUTINE
                                        .         DRAWS STRAIGHT HORIZONTAL OR VERTICAL LINES
                                        .         ITY=INTENSITY (GRAY SCALE) OR BIT PLANE (BLACK/WHITE)
                                        .         X,Y ARE DEFINED IN TERMS OF A BOTTOM LEFT ORIGIN OF 0,0
                                        .         HOWEVER, MATROX DEFINES TOP LEFT AS 0,0 SO ALL INPUTS
                                        .         ARE CONVERTED
000354  005725                  LINE              TST     (%5)+
000356  013567  000230                            MOV     @(%5)+,X1
000362  013567  000230                            MOV     @(%5)+,Y1
000366  013567  000222                            MOV     @(%5)+,X2
000372  013567  000222                            MOV     @(%5)+,Y2
000376  017567  000000  000216                    MOV     @(%5),ITY       , INTENSITY
000404  005467  000206                            NEG     Y1
000410  005467  000204                            NEG     Y2
000414  066767  001520  000174                    ADD     YMAX,Y1         ,YMAX= # PIXELS IN Y DIRECTION (255)
000422  066767  001512  000170                    ADD     YMAX,Y2
000430  005000                                    CLR     %0
000432  026767  000154  000154                    CMP     X1,X2           ,THE FOLLOWING COMPARES DETERMINE WHICH
000440  001417                                    BEQ     L2              ,BITS TO SET FOR AUTO INCREMENT
000442  002407                                    BLT     L1              ,OR AUTO DECREMENT IN THE X AND Y
000444  052700  000004                            BIS     #4,%0           ,DIRECTIONS
000450  016702  000136                            MOV     X1,%2
000454  166702  000134                            SUB     X2,%2
000460  000431                                    BR      L4
000462  052700  000001          L1                BIS     #1,%0
```

```
000466  016702  000122                    MOV     X2,%2
000472  166702  000114                    SUB     X1,%2
000476  000422                            BR      L4
000500  026767  000112  000112  L2        CMP     Y1,Y2
000506  001416                            BEQ     L4
000510  002407                            BLT     L3
000512  052700  000010                    BIS     #10,%0
000516  016702  000074                    MOV     Y1,%2
000522  166702  000072                    SUB     Y2,%2
000526  000406                            BR      L4
000530  052700  000002          L3        BIS     #2,%0
000534  016702  000060                    MOV     Y2,%2
000540  166702  000052                    SUB     Y1,%2
000544  016767  000042  164400  L4        MOV     X1,B0
000552  016767  000040  164402            MOV     Y1,B2
000560  016767  000036  164404            MOV     ITY,B4
000566  000300                            SWAB    %0
000570  052700  000037                    BIS     #37,%0
000574  010067  164414          L5        MOV     %0,B14
000600  077203                            SOB     %2,L5
000602  012767  010000  164414            MOV     #10000,B14
000610  000207                            RTS     %7
                                ,
000612  000000                  X1         WORD 0
000614  000000                  X2         WORD 0
000616  000000                  Y1         WORD 0
000620  000000                  Y2         WORD 0
000622  000000                  ITY        WORD 0
                                ,
                                ,         CALL VECTOR (X1,Y1,X2,Y2,ITY) DRAW A VECTOR ROUTINE
                                ,         SAME AS LINE ROUTINE BUT FOR VECTORS -- NOT AS FAST

000624  005067  164414          VECTOR     CLR    B14
000630  005725                            TST     (%5)+
000632  013567  177754                    MOV     @(%5)+,X1
000636  016767  001276  177752            MOV     YMAX,Y1
000644  163567  177746                    SUB     @(%5)+,Y1
000650  013567  177740                    MOV     @(%5)+,X2
000654  016767  001260  177736            MOV     YMAX,Y2
000662  163567  177732                    SUB     @(%5)+,Y2
000666  013567  177730                    MOV     @(%5)+,ITY
                                ,
000672  016702  177716                    MOV     X2,%2
000676  166702  177710                    SUB     X1,%2
000702  016703  177712                    MOV     Y2,%3
000706  166703  177704                    SUB     Y1,%3
000712  020302                            CMP     %3,%2
000714  001430                            BEQ     VECT1
000716  103415                            BLO     VECT0
                                ,
000720  005000                            CLR     %0
000722  010201                            MOV     %2,%1
000724  072127  000006                    ASH     #6,%1
000730  071003                            DIV     %3,%0           ,STEP X IN %0
000732  012701  000100                    MOV     #100,%1         ,STEP Y
000736  005703                            TST     %3
000740  002026                            BGE     VECT3
```

```
000742  005400                           NEG     %0
000744  005401                           NEG     %1
000746  005403                           NEG     %3
000750  000422                           BR      VECT3
                                 ,
000752  005000                   VECT0   CLR     %0
000754  010301                           MOV     %3,%1
000756  072127  000006                   ASH     #6,%1
000762  071002                           DIV     %2,%0
000764  010001                           MOV     %0,%1          ,STEP Y
000766  012700  000100                   MOV     #100,%0        ,STEP X
000772  010203                           MOV     %2,%3          ,N
000774  000410                           BR      VECT3
                                 ,
000776  012701  000100           VECT1   MOV     #100,%1
001002  005703                           TST     %3
001004  002001                           BGE     VECT2
001006  005401                           NEG     %1
001010  012700  000100           VECT2   MOV     #100,%0
001014  010203                           MOV     %2,%3
                                 ,
001016  016767  177570  164400   VECT3   MOV     X1,B0
001024  016767  177566  164402           MOV     Y1,B2
001032  016767  177564  164404           MOV     ITY,B4
                                 ,
001040  016702  177546                   MOV     X1,%2
001044  016704  177546                   MOV     Y1,%4
001050  072427  000006                   ASH     #6,%4
001054  072227  000006                   ASH     #6,%2
001060  060002                   VECT4   ADD     %0,%2
001062  060104                           ADD     %1,%4
001064  010205                           MOV     %2,%5
001066  072527  177772                   ASH     #-6,%5
001072  010567  164400                   MOV     %5,B0
001076  010405                           MOV     %4,%5
001100  072527  177772                   ASH     #-6,%5
001104  010567  164402                   MOV     %5,B2
001110  016767  177506  164404           MOV     ITY,B4
001116  077320                           SOB     %3,VECT4
001120  000207                           RTS     %7
                                 ,
                                 ,       CALL LTEXT(X1,Y1,ITY,N,ARRAY)  PRINT TEXT ROUTINE
                                 ,       X1,Y1 ARE TOP LEFT POSITION OF FIRST CHARACTER
                                 ,       ITY = INTENSITY (GRAYSCALE) OR BIT PLANE (BLACK/WHITE)
                                 ,       N = # CHARACTERS
                                 ,       ARRAY= ARRAY OF N ASCII CHARACTERS
001122  005725                   LTEXT   TST     (%5)+
001124  013567  177462                   MOV     @(%5)+,X1
001130  013567  177462                   MOV     @(%5)+,Y1
001134  005467  177456                   NEG     Y1
001140  066767  000774  177450           ADD     YMAX,Y1
001146  013567  177450                   MOV     @(%5)+,ITY
001152  005725                           TST     (%5)+
001154  013502                           MOV     @(%5)+,%2      ,#CHARACTERS
001156  012500                           MOV     (%5)+,%0       ,CHARACTER ARRAY
001160  112001                   LT0     MOVB    (%0)+,%1
001162  042701  177600                   BIC     #177600,%1
```

```
001166  162701  000040                  SUB     #40,%1          ,VALID ASCII CODES START AT 040
001172  070127  000005                  MUL     #5,%1           ,CALCULATE ADDRESS OFFSET IN CHARACTER
001176  062701  001326'                 ADD     #LETTER,%1
001202  005067  000116                  CLR     IPIX
                                                                ,TABLE-- EACH DEFINED BY 5 BYTES
001206  016767  177400  164400  LT1.    MOV     X1,B0
001214  066767  000104  164400          ADD     IPIX,B0
001222  016767  177370  164402          MOV     Y1,B2
001230  012703  000001                  MOV     #1,%3           ,MASK
001234  012704  000007                  MOV     #7,%4           ,7 PIX HIGH
001240  005005                  LT2     CLR     %5
001242  130311                          BITB    %3,(%1)
001244  001402                          BEQ     LT3
001246  016705  177350                  MOV     ITY,%5
001252  010567  164404          LT3     MOV     %5,B4
                                ,       MOV     #1037,B14
001256  005267  164402                  INC     B2
001262  006303                          ASL     %3
001264  077413                          SOB     %4,LT2
001266  105721                          TSTB    (%1)+           ,NEXT COLUMN
001270  005267  000030                  INC     IPIX
001274  026727  000024  000005          CMP     IPIX,#5
001302  002741                          BLT     LT1
001304  062767  000007  177300          ADD     #7,X1
001312  077256                          SOB     %2,LT0
001314  012767  010000  164414          MOV     #10000,B14
001322  000207                          RTS     %7
                                ,
001324  000000                  IPIX      WORD 0
001326     000     000     000  LETTER    BYTE 0,0,0,0,0            ,SPACE
001331     000     000
001333     000     000     137            BYTE 0,0,137,0,0          ,'
001336     000     000
001340     000     007     000            BYTE 0,7,0,7,0            ,"
001343     007     000
001345     024     177     024            BYTE 24,177,24,177,24     ,#
001350     177     024
001352     044     052     177            BYTE 44,52,177,52,22      ,$
001355     052     022
001357     143     023     010            BYTE 143,23,10,144,143    ,%
001362     144     143
001364     066     111     126            BYTE 66,111,126,40,120    ,&
001367     040     120
001371     000     000     007            BYTE 0,0,7,7,0            ,'
001374     007     000
001376     000     034     042            BYTE 0,34,42,101,0        ,(
001401     101     000
001403     000     101     042            BYTE 0,101,42,34,0        ,)
001406     034     000
001410     012     004     037            BYTE 12,4,37,4,12         ,*
001413     004     012
001415     010     010     076            BYTE 10,10,76,10,10       ,+
001420     010     010
001422     000     000     120            BYTE 0,0,120,60,0         ,,
001425     060     000
001427     010     010     010            BYTE 10,10,10,10,10       ,-
001432     010     010
```

```
    267 001434   000   000   100      BYTE 0,0,100,100,0            ,
        001437   100   000
    268 001441   140   020   010      BYTE 140,20,10,4,3            ,/
        001444   004   003
    269 001446   076   121   111      BYTE 76,121,111,105,76        ,0
        001451   105   076
    270 001453   104   102   177      BYTE 104,102,177,100,100      ,1
        001456   100   100
    271 001460   142   121   121      BYTE 142,121,121,111,106      ,2
        001463   111   106
    272 001465   041   101   111      BYTE 41,101,111,125,42        ,3
        001470   125   042
    273 001472   030   024   022      BYTE 30,24,22,177,20          ,4
        001475   177   020
    274 001477   107   105   105      BYTE 107,105,105,105,71       ,5
        001502   105   071
    275 001504   074   112   111      BYTE 74,112,111,111,61        ,6
        001507   111   061
    276 001511   001   161   011      BYTE 1,161,11,5,3             ,7
        001514   005   003
    277 001516   066   111   111      BYTE 66,111,111,111,66        ,8
        001521   111   066
    278 001523   106   111   111      BYTE 106,111,111,51,36        ,9
        001526   051   036
    279 001530   000   000   102      BYTE 0,0,102,102,0            ,
        001533   102   000
    280 001535   000   000   122      BYTE 0,0,122,62,0             ,,
        001540   062   000
    281 001542   000   010   024      BYTE 0,10,24,42,101           ,<
        001545   042   101
    282 001547   024   024   024      BYTE 24,24,24,24,24           ,=
        001552   024   024
    283 001554   000   101   042      BYTE 0,101,42,24,10           ,>
        001557   024   010
    284 001561   002   001   121      BYTE 2,1,121,11,6             ,^
        001564   011   006
    285 001566   000   000   000      BYTE 0,0,0,0,0                ,@ (NOT DEFINED)
        001571   000   000
    286 001573   174   012   011      BYTE 174,12,11,12,174         ,A
        001576   012   174
    287 001600   101   177   111      BYTE 101,177,111,111,66       ,B
        001603   111   066
    288 001605   076   101   101      BYTE 76,101,101,101,42        ,C
        001610   101   042
    289 001612   177   101   101      BYTE 177,101,101,42,34        ,D
        001615   042   034
    290 001617   177   111   111      BYTE 177,111,111,111,111       E
        001622   111   111
    291 001624   177   011   011      BYTE 177,11,11,11,1           ,F
        001627   011   001
    292 001631   076   101   111      BYTE 76,101,111,111,171       ,G
        001634   111   171
    293 001636   177   010   010      BYTE 177,10,10,10,177          H
        001641   010   177
    294 001643   000   101   177      BYTE 0,101,177,101,0          ,I
        001646   101   000
    295 001650   040   100   100      BYTE 40,100,100,100,77        ,J
```

```
    001653  100     077
    001655  177     010     024        BYTE 177,10,24,42,101         ;I
    001660  042     101
    001662  177     100     100        BYTE 177,100,100,100,100      ;L
    001665  100     100
    001667  177     002     004        BYTE 177,2,4,2,177            ;M
    001672  002     177
    001674  177     002     004        BYTE 177,2,4,10,177           ;N
    001677  010     177
    001701  177     101     101        BYTE 177,101,101,101,177      ;O
    001704  101     177
    001706  177     011     011        BYTE 177,11,11,11,6           ;P
    001711  011     006
    001713  076     101     121        BYTE 76,101,121,41,136        ;Q
    001716  041     136
    001720  177     011     031        BYTE 177,11,31,51,106         ;R
    001723  051     106
    001725  042     105     111        BYTE 42,105,111,121,42        ;S
    001730  121     042
    001732  001     001     177        BYTE 1,1,177,1,1              ;T
    001735  001     001
    001737  077     100     100        BYTE 77,100,100,100,77        ;U
    001742  100     077
    001744  037     040     100        BYTE 37,40,100,40,37          ;V
    001747  040     037
    001751  177     040     020        BYTE 177,40,20,40,177         ;W
    001754  040     177
    001756  143     024     010        BYTE 143,24,10,24,143         ;X
    001761  024     143
    001763  003     004     170        BYTE 3,4,170,4,3              ;Y
    001766  004     003
    001770  141     131     111        BYTE 141,131,111,115,103      ;Z
    001773  115     103
                                       EVEN
                                  ;
                                  ;    CALL PLOT (STEP,DATA,NPTS,X0,Y0,SHFY,OFSET,IT\)
                                  ;    PLOTS POINTS IN A DATA BUFFER
                                  ;    Y = (DATA(I) + OFSET) * (2**SHFY) + Y0
                                  ;
    001776  005725              PLOT   TST     (%5)+
    002000  013567  000130             MOV     @(%5)+,STP
    002004  012500                     MOV     (%5)+,%0
    002006  013502                     MOV     @(%5)+,%2        ;# DATA PTS
    002010  013567  164400             MOV     @(%5)+,B0        ;X0
    002014  016704  000120             MOV     YMAX,%4
    002020  163504                     SUB     @(%5)+,%4        ;Y0
    002022  013503                     MOV     @(%5)+,%3        ;SHIFT
    002024  013567  000106             MOV     @(%5)+,OFSET
    002030  013567  176566             MOV     @(%5)+,ITY
    002034  012001              PLOT0  MOV     (%0)+,%1
    002036  066701  000074             ADD     OFSET,%1
    002042  072103                     ASH     %3,%1
    002044  005401                     NEG     %1
    002046  060401                     ADD     %4,%1
    002050  010167  164402             MOV     %1,B2
    002054  016705  000054             MOV     STP,%5
```

```
002062  016767  176534  164404  PLOT1   MOV     ITY,B4
002070  005267  164400                  INC     B0
002074  005305                          DEC     %5
002076  003371                          BGT     PLOT1
002100  022705  177776                  CMP     #-2,%5
002104  003002                          BGT     PLOT2
002106  077226                          SOB     %2,PLOT0
002110  000410                          BR      PLOT4
002112  016705  000016          PLOT2   MOV     STP,%5
002116  005305                          DEC     %5
002120  005720                  PLOT3   TST     (%0)+
002122  005302                          DEC     %2
002124  003402                          BLE     PLOT4
002126  077504                          SOB     %5,PLOT3
002130  077237                          SOB     %2,PLOT0
002132  000207                  PLOT4   RTS     %7
002134  000000                  STP      WORD 0
002136  000000                  DFSET    WORD 0
002140  000377                  YMAX     WORD 255
                                .
                                         ENABL LC
                                .       CALL IMAGE (DX,DY,DATA,NPTS,X0,Y0,Z0,SHFZ,OFSET)
                                .       DRAWS A VERTICAL GRAY SCALE VERSION OF A DATA BUFFER
                                .       Z=(DATA + OFSET) *2**SHFZ + Z0
                                .

002142  005725                  IMAGE   TST     (%5)+
002144  005725                          TST     (%5)+           .DX ALWAYS 0
002146  005725                          TST     (%5)+           .DY ALWAYS -1
002150  012500                          MOV     (%5)+,%0        .DATA BUFFER
002152  013502                          MOV     @(%5)+,%2       .NPTS
002154  013567  164400                  MOV     @(%5)+,B0       .X
002160  013504                          MOV     @(%5)+,%4       .Y
002162  005404                          NEG     %4
002164  066704  177750                  ADD     YMAX,%4
002170  010467  164402                  MOV     %4,B2
002174  013503                          MOV     @(%5)+,%3       .Z0
002176  013504                          MOV     @(%5)+,%4       .SCALE
002200  013505                          MOV     @(%5)+,%5       .OFSET
002202  012001                  IM0     MOV     (%0)+,%1
002204  060501                          ADD     %5,%1
002206  072104                          ASH     %4,%1           .SHIFT
002210  060301                          ADD     %3,%1
002212  022701  000017                  CMP     #17,%1
002216  003002                          BGT     IM1
002220  012701  000017                  MOV     #17,%1
002224  005701                  IM1     TST     %1
002226  002001                          BGE     IM2
002230  005001                          CLR     %1
002232  010167  164404          IM2     MOV     %1,B4
002236  012767  001000  164414          MOV     #1000,B14
002244  077222                          SOB     %2,IM0
002246  000207                          RTS     %7
                                .
                                .       CALL COPY (DENS)        COPY SCREEN TO TRILOG ROUTINE
                                .       DENS=SIZE OF COPY (1-4)  IF DENS IS POSITIVE, ONLY THE
                                .       FIRST 320 PIXELS OF THE SCREEN ARE COPIED   IF NEGATIVE,
```

```
                                          .       ALL 512 PIXELS (X-AXIS) ARE COPIED
002250  005725                            COPY    TST     (%5)+
002252  013567  000402                            MOV     @(%5)+,DENS
002256  005767  000376                            TST     DENS
002262  003005                                    BGT     PR0
002264  005467  000370                            NEG     DENS
002270  012701  001000                            MOV     #512.,%1
002274  000402                                    BR      PR1
002276  012701  000500                    PR0     MOV     #320 ,%1
002302  012767  010000  164414            PR1     MOV     #10000,B14          .INHIBIT AUTO INC
002310  005067  164400                            CLR     B0
002314  012767  000400  176274            PR2     MOV     #256 ,Y1
002322  012703  000053                            MOV     #43.,%3
002326  070367  000326                            MUL     DENS,%3        .TOTAL WORDS/LINE = 256/6 *DENS
002332  010300                                    MOV     %3,%0
002334  011504                                    MOV     (%5),%4
002336  012702  000100                    PR3     MOV     #100,%2
002342  012703  000001                            MOV     #1,%3
002346  022767  000002  000304                    CMP     #2,DENS
002354  001002                                    BNE     PR3A
002356  012703  000003                            MOV     #3,%3
002362  022767  000003  000270            PR3A    CMP     #3,DENS
002370  001002                                    BNE     PR3B
002372  012703  000007                            MOV     #7,%3
002376  022767  000004  000254            PR3B    CMP     #4,DENS
002404  001002                                    BNE     PR4
002406  012703  000017                            MOV     #17,%3
002412  005367  176200                    PR4     DEC     Y1
002416  002446                                    BLT     PR6
002420  016767  176172  164402                    MOV     Y1,B2
002426  105767  164404                            TSTB    B4
002432  001401                                    BEQ     PR5
002434  050302                                    BIS     %3,%2
002436  022767  000004  000214            PR5     CMP     #4,DENS
002444  001406                                    BEQ     PR5A
002446  072367  000206                            ASH     DENS,%3
002452  032703  000100                            BIT     #100,%3
002456  001755                                    BEQ     PR4
002460  000425                                    BR      PR6
002462  022703  000017                    PR5A    CMP     #17,%3
002466  001003                                    BNE     PR5B
002470  012703  000060                            MOV     #60,%3
002474  000746                                    BR      PR4
002476  022703  000060                    PR5B    CMP     #60,%3
002502  001014                                    BNE     PR6
002504  010214                                    MOV     %2,(%4)
002506  005300                                    DEC     %0
002510  012702  000100                            MOV     #100,%2
002514  032724  000060                            BIT     #60,(%4)+
002520  001402                                    BEQ     PR5C
002522  052702  000003                            BIS     #3,%2
002526  012703  000074                    PR5C    MOV     #74,%3
002532  000727                                    BR      PR4
002534  010224                            PR6     MOV     %2,(%4)+
002536  005300                                    DEC     %0
002540  003402                                    BLE     PR6A
002542  000167  177570                            JMP     PR3
```

```
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002546  004767  000016   PR5A   JSR   %7,LPW
002552  005301                  DEC   %1
002554  003404                  BLE   PR7
002556  005267  164400          INC   B0
002562  000167  177526          JMP   PR2
002566  000207           PR7    RTS   %7
                         .
002570  011504           LPW    MOV   (%5),%4
002572  016700  000062          MOV   DENS,%0
002576  012703  000053   LPW1   MOV   #43 ,%3
002602  070367  000052          MUL   DENS,%3
002606  011504                  MOV   (%5),%4
002610  012402           LPW2   MOV   (%4)+,%2
002612  004767  000026          JSR   %7,LPW0
002616  077304                  SOB   %3,LPW2
002620  012702  000005          MOV   #5,%2          .END LINE WITH 5
002624  004767  000014          JSR   %7,LPW0
002630  012702  000012          MOV   #12,%2         .CARRIAGE RETURN
002634  004767  000004          JSR   %7,LPW0
002640  077022                  SOB   %0,LPW1
002642  000207                  RTS   %7
002644  105737  177514   LPW0   TSTB  @#177514
002650  100375                  BPL   LPW0
002652  010237  177516          MOV   %2,@#177516
002656  000207                  RTS   %7
                         .
002660  000000           DENS    WORD 0
        000001                   END
```

```
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SYMBOL TABLE

B0      = 164400        IM2      002232R      LT1      001206R      PLOT2    002112R      PR6A     002546R
B10     = 164410        IPIX     001324R      LT2      001240R      PLOT3    002120R      PR7      002566R
B12     = 164412        ITY      000622R      LT3      001252R      PLOT4    002132R      SBL      000266R
B14     = 164414        LETTER   001326R      L1       000462R      PR0      002276R      STP      002134R
B16     = 164416        LINE     000354RG     L2       000500R      PR1      002302R      VECTOR   000624RG
B2      = 164402        LPW      002570R      L3       000530R      PR2      002314R      VECT0    000752R
B4      = 164404        LPW0     002644R      L4       000544R      PR3      002336R      VECT1    000776R
B6      = 164406        LPW1     002576R      L5       000574R      PR3A     002362R      VECT2    001010R
COPY      002250RG      LPW2     002610R      MRESET   000164RG     PR3B     002376R      VECT3    001016R
DENS      002660R       LRESET   000000RG     MX       000154R      PR4      002412R      VECT4    001060R
ERASE     000270RG      LRES0    000044R      OFSET    002136R      PR5      002436R      X1       000612R
ER0       000310R       LTABLE   000214RG     PARAM    000242R      PR5A     002462R      X2       000614R
ER1       000336R       LTAB0    000232R      PLOT     001776RG     PR5B     002476R      YMAX     002140R
IMAGE     002142RG      LTEXT    001122RG     PLOT0    002034R      PR5C     002526R      Y1       000616R
IM0       002202R       LT0      001160R      PLOT1    002062R      PR6      002534R      Y2       000620R
IM1       002224R

  ABS     000000       000
          002662       001
ERRORS DETECTED    0

VIRTUAL MEMORY USED    323 WORDS  ( 2 PAGES)
DYNAMIC MEMORY AVAILABLE FOR  66 PAGES
DK MATROX,LP MATROX=DK MATROX
```

APPENDIX II

SAMPLE DIAL DAS DIALOGUE

```
@173000G                                -- BOOT LSI #1

RT-11SJ   V03-02                           (LSI COMES UP IN RT11 SJ MONITOR)

 ASSIGN DX1  DK                            (DX1 IS TARGET DISK DRIVE)

 RUN RTSET                                 (SET RT11 DATE FROM TCU-50 DYR)

 DATE                                      (PRINT DATE)

24-FEB-84                                  (DATE PRINTED HERE IF "RTSET" IS ON DX1)

 RUN MASTER                             -- RUN "MASTER"
@173000G                                   (LSI #1 SENDS LSI #2 A BOOT COMMAND)

RT-11SJ   V03-02                           (LSI #2 COMES UP IN RT11 SJ MONITOR)

 ASSIGN DX1  DK                            (DX1 IS TARGET DISK ON LSI #2)
 RUN SLAVE                                 (LSI #1 TELLS LSI #2 TO RUN PROGRAM "SLAVE")
                                           (LSI #1 PRINTS OUT RESIDENT BANNER RECORD)
     BANNER RECORD
TAPE=     0   FILE=     0   HEADER WORDS= 10   DATE=  2/24/84

ALT=          0   UP/DOWN=   1   SAMP FRE=   10   LASE FIRE AT   10
REP RATE=    5   ABS COEF=  180E-20
UNIT   WRDS  RTRNS     START   BASE    TRIG    DELAY   SPECIES   TO DELAY
   1    500     2         0       0  =   0        5        O3          0
UNIT 1 = BIO 1
ADV11-C CONVERSION CONSTANTS
CHAN     SLOPE   OFFSET
   1    1 0      -1000


?BIOS                                   -- USE THE BIOMATION AS FIRST DIGITIZER
?CAMACS 2,6,10                          -- USE THE TRANSIACS IN SLOTS 2, 6, AND 10
?POINTS 500,500,500,500                 -- STORE 500 POINTS/RETURN IN EACH UNIT
?RETRNS 1,1,2,2                         -- STORE 1 RETURN FROM UNITS 1 AND 2, STORE 2 RETURNS FROM 3 AND 4
?STORE 0,1230,230,230                   -- START DATA STORAGE FROM DIGITIZERS AT THESE WORDS
?BASLIN 0,2047,2047,-2047               -- BASE-LINE OF EACH DIGITIZER
?DELAY 0,5,5,5                          -- GATE TURN ON DELAY (USECS) AFTER LASER FIRE
?LASFIR 10                              -- LASER FIRES AROUND WORD 10
?TODLY 0,0,14,14                        -- UNITS 3 & 4 USE TO MARKERS WHICH ARE DELAYED BY 14 WORDS
?TRGLEV =1023,(0,(0,)0                  -- TRIGGER MARKERS MUST BE THESE LEVELS TO QUALIFY
?HDRPTS 20                              -- THERE WILL BE 20 WORDS OF SHOT HEADER INFORMATION
?GASES 106,VIS,O3,O3                    -- IDENTIFIES TYPE OF MEASUREMENT FOR EACH UNIT
?ABSCOF 176,-20                         -- ABSORPTION COEFFICIENT TO BE USED FOR O3 CALCULATIONS
?HEIGHT 13000                           -- PLANE ALTITUDE IN FEET
?UPDOWN 0                               -- INDICATES DOWN-LOOKING MODE
?CHAN2 20,0,-50,0                       -- SECOND ADV11-C CHANNEL WILL BE 20 * VOLTS - 50
?CHAN3 1,1,1,1                          -- THIRD CHANNEL WILL BE 10 * VOLTS - 10
?LSTBNR                                 -- LIST OUT NEW BANNER RECORD


     BANNER RECORD
TAPE=     0   FILE=     0   HEADER WORDS= 20   DATE=  2/24/84

ALT=      13000   UP/DOWN=   0   SAMP FRE=   10   LASE FIRE AT   10
REP RATE=    5   ABS COEF=  176E-20
UNIT   WRDS  RTRNS     START   BASE    TRIG    DELAY   SPECIES   TO DELAY
   1    500     1         0       0  =1023       0       106          0
   2    500     1      1230    2047  (   0        5       VIS          0
   3    500     2       230    2047  (   0        5        O3         14
   4    500     2       230   -2047  )   0        5        O3         14
UNIT 1 = BIO 1
UNIT 2 = TRANSIAC  2
UNIT 3 = TRANSIAC  6
UNIT 4 = TRANSIAC 10
ADV11-C CONVERSION CONSTANTS
CHAN     SLOPE   OFFSET
   1    1 0      -1000
   2    20       -50
   3    10        10
?START                                  -- START DATA TRANSFER FROM DIGITIZERS
```

APPENDIX III

DIAL DAS ERROR MESSAGES

TTY ERROR	Teletype input error or attempt to use STOP mode command while transferring data.
BIO ERROR	Biomation transfer error -- check to see that arm, trigger and time base are properly connected.
CAMAC: DMA XFER ERROR	Transiac transfer error -- check to see that triggers and time bases for all units being used are properly connected.
CAMAC: NO-Q NOT SET	"
CAMAC: LAMS NOT SET	"
CAMAC: LAMS NOT CLEARED	"
MT: QUEUE EXCEEDS 22	Mag tape streamer queue cannot keep up.
MT: ILLEGAL COMMAND	Occurs if (a) a new instruction is issued before last one has finished, (b) no write ring when told to write, (c) tape unit is off-line or becomes off-line.
MT: END OF FILE	
MT: CYCLICAL REDUNDANCY	
MT: PARITY ERROR	
MT: BUS GRANT LATE	
MT: END OF TAPE	If data is being recorded when EOT is detected, an alarm sounds, 2 EOF's are written, the tape starts rewinding, and data is transferred to the second tape drive.
MT: RECORD LENGTH ERROR	
MT: BAD TAPE ERROR	
MT: NON-EXISTENT MEMORY	
MT: ERROR?	This is an unrecognizable tape error.
MT: TAPE UNIT OFF-LINE	
MT: NEED WRITE RING	
MT: ACTION COMPLETE	
MEMORY SWAP ERROR	This could occur when swapping in extended memory -- but has not so far.
NAV INTERFACE NOT RESPONDING	This usually means that the Loran interface is not hooked up.
170400 (ADV11-C) NOT THERE	This occurs if the ADV11-C board is not resident.