DEPARTMENT OF GEOLOGICAL SCIENCES
COLLEGE OF SCIENCES
OLD DOMINION UNIVERSITY
NORFOLK, VA 23508

TECHNICAL REPORT GSTR-88-1

THEORY AND OPERATION OF THE REAL-TIME
DATA ACQUISITION SYSTEM FOR THE NASA-LaRC
DIFFERENTIAL ABSORPTION LIDAR (DIAL)

By
Carolyn Butler

Submitted by Dr. Randall Spencer, Principal Investigator

Final Report
For the period January 1, 1986 to December 31, 1987

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

Under
Research Contract F33615-86-C-3230
Dr. Edward Browell, Technical Monitor
Chemistry and Dynamics Branch

January 1988

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Submitted by the
Old Dominion University Research Foundation
P. O. Box 6369
Norfolk, Virginia 23508

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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 concentrations from an aircraft platform. Experiments involving the DIAL system were successfully performed onboard the NASA/Goddard Flight Center Electra aircraft from 1980-1987 (ref. 1) and the NASA/Ames DC-8 in 1987.

The DIAL Data Acquisition System (DAS) has undergone a number of improvements over the past few years. Due to the participation of the DIAL in the Global Tropospheric Experiment (GTE), modifications and improvements of the system have been tested and used both in the laboratory environment as well as in the air. The DIAL system, in fact, was the primary system for two experiments in 1987. In the Spring the system was flown on the Electra for 5 weeks over the Amazon for the Amazon Boundary Layer Experiment and in the Fall the system was flown on the DC-8 for stratospheric work during the Ozone Hole experiment.

This report is designed to be used as an operational manual for the DIAL DAS. Many changes were performed on the system during the 1986-1987 time frame. In previous years the system was able to look either above or below the aircraft but not in both directions simultaneously. A change could be made from nadir to zenith operation in a matter of hours on the ground. The major improvement to the system in 1986 was the ability to transmit and receive all wavelengths above as well as below the aircraft. The impact on the data system was to double the amount of data being recorded. In terms of data tapes, this would have meant we would fill up a tape in less than ten minutes at 5 Hz operation. It was decided that for the most part we did not need the 5 Hz horizontal resolution so the digitizers were modified to enable them to perform internal hardware averaging of successive laser shots. The software was incorporated into the DIAL DAS to program the digitizer averaging memories to select either single shot or 5 shot averages or a combination of both (this will be discussed in more detail in a later section).

The DC-8 which was used for the ozone hole experiment, has only an up-looking window at present. Since the ozone depletion was occurring at altitudes higher than the aircraft could fly we were only interested in zenith transmission. Therefore, the DIAL system was temporarily re-configured to transmit all wavelengths (with some redundancy) in the zenith mode. Since most of the
DIAL work is done in the troposphere, the emphasis in this report will be on our zenith/nadir configuration as performed on the Electra.

The other major improvement to the DIAL system in 1986 was the ability to output real-time color maps of the ozone distribution (as we have been doing with the aerosols for the last few years). Since both LSI 11/23's were already very busy performing the existing data acquisition and real-time analysis, a third processor was added to the system to handle the ozone computations for the color maps. Also, the LSI 11/23 processors were replaced by LSI 11/73 processors with the floating point accelerators to speed up existing computations.

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 300 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. Two coaxial receiver systems are used to collect and optically separate the DIAL and aerosol returns. Photomultiplier tubes (PMT) and photodiodes detect the backscattered laser returns after optical filtering, and the analog signals from these tubes are digitized, averaged and stored on high-speed magnetic tape.

The lasers can be fired at 1, 5, or 10 Hz. Current operations are to transmit four wavelengths above the aircraft and four wavelengths below the aircraft: an on-line UV and off-line UV for DIAL ozone measurements; an IR aerosol wavelength; and a visible aerosol wavelength. The nadir UV returns are both detected by the same PMT with 300 usec separation and the zenith UV returns are similarly collected by another PMT. The visible wavelengths are collected by two more PMT's and the two IR returns are detected by separate photodiodes. So we have a total of 8 returns detected by 4 PMT's and 2 diodes. The nadir IR return comes from the on-line laser while the zenith IR comes from the off-line laser so there is a 300 usec separation between the two returns. This allows us to sum the two returns with an analog switch (designed by R. J. Allen) prior to being digitized by only one digitizer. The visible returns are obtained in the same manner and digitized by just one digitizer. Present software allows up to four digitizers to be used with no more than 8192 words saved in the computer (10 MHz sampling interval). Of the 8192 words allotted per buffer, at least 40 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 8100 words per buffer by the total number of returns. However, for the nadir returns we
are usually only interested in the data return to the ground plus an additional area past the ground return for background purposes. The zenith returns, on the other hand, are not limited by ground returns so are of interest for a much greater range. So we typically record more data words of the zenith returns than we do of the nadir returns.

DATA ACQUISITION SYSTEM

The 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 set-up is advisable in that it eliminates the occurrence of ground loops between the PMT's and the digitizers. The DIAL DAS is based upon two Digital Equipment Corporation (DEC) LSI 11/73 processors and one MDB JFEP-11 front-end processor. 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), while 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 color scale representation of range resolved data with averaging on the ACT II. The JFEP-11 is housed in LSI #2 and has 256K words of memory of which 128K words can be shared with the host computer. The JFEP-11 does the DIAL calculation to obtain an ozone profile, performs a running average on some number of profiles and returns that average to LSI #2 for color scale representation on a second ACT II printer.

LSI #1 acts as the master computer through which the operator communicates with LSI #2 and the JFEP-11. 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. The second port is used to communicate to the JFEP-11 through the SLU (serial line unit) also housed in LSI #2.

Data is presented to the operator on either the Panasonic video monitor through the Matrox ORGB-Graph controller and/or the system color printers (Act II). Hard copy images of the video graphics display may be obtained through Polaroid photography or through a software copy command to the second ACT II (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
Figure 1. DIAL DAS component configuration in aircraft rack.
Figure 2. Computer devices flow chart.
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 D0130 provides Cipher interface with the LSI 11/73.

The acquisition of data is accomplished using four Transiac Model 2012S waveform digitizers (each with a 4100 averaging memory). The Transiacs are manually programmable for digitization of analog signals into 12-bit memory of selectable record lengths (the settings are typically 4096 for DIAL applications) and selectable record averages. The internal memories of these digitizers are made available to the LSI 11/73 through a Kinetics Systems Direct Memory Access (DMA) interface board. In addition, there are four DRV11-C modules in LSI #1 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 fail back to a one computer system.

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

<table>
<thead>
<tr>
<th>DIAL DAS COMPONENT</th>
<th>Height (in)</th>
<th>Weight (lb)</th>
<th>Power (amp @ 115 Vac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetic tape drive (2)</td>
<td>8.75</td>
<td>80</td>
<td>1</td>
</tr>
<tr>
<td>LSI 11/73 (2)</td>
<td>5.5</td>
<td>35</td>
<td>4</td>
</tr>
<tr>
<td>DSD-480 floppy disk (2)</td>
<td>5.5</td>
<td>60</td>
<td>1.5</td>
</tr>
<tr>
<td>Panasonic dual monitors</td>
<td>8.75</td>
<td>27</td>
<td>.5</td>
</tr>
<tr>
<td>Console keyboard</td>
<td>3.0</td>
<td>7</td>
<td>.5</td>
</tr>
<tr>
<td>Camac crate (full)</td>
<td>12.5</td>
<td>105</td>
<td>12</td>
</tr>
<tr>
<td>Act II Printer (HxWxD) (2)</td>
<td>8.2 x 22 x 17.9</td>
<td>40</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>569</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M 8192 CPU</td>
<td>DSD-480 FLOPPY INTERFACE</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>--------------</td>
<td>--------------------------</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>DAII BOI INTERPROCESSOR LINK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>DQ 130 MAG TAPE INTERFACE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>CAMAC INTERFACE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>DRVII-C @ 70</td>
<td>DRVII-C @ 60</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>DRVII-C @ 50</td>
<td>DRVII-C @ 40</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>LP II</td>
<td>DLVII-J</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>M8059 MEMORY (128K)</td>
<td>TCU 50-DYR</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3. Internal computer configurations.
Table 2a shows connections from the two LSI's. LSI #2 houses 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.

Table 2a. DAS component interconnections.

<table>
<thead>
<tr>
<th>LSI #1 Board</th>
<th>Connector Type</th>
<th>Destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSD-480 floppy interface</td>
<td>26p flat cable</td>
<td>DSD-480 #1</td>
</tr>
<tr>
<td>DA11B0I interprocessor link</td>
<td>dual 50p flat cables</td>
<td>LSI #2 DA11B0I (P1=P2=F1=P2)</td>
</tr>
<tr>
<td>D0130 magtape interface</td>
<td>dual 50p flat cables</td>
<td>Cipher #1 (J1=P2=J2=P1)</td>
</tr>
<tr>
<td>Camac crate interface</td>
<td>50p flat cable</td>
<td>Camac crate A/D interface (N. McRae design)</td>
</tr>
<tr>
<td>DRV11-C digital interface (@50)</td>
<td>40p flat cable (customized)</td>
<td>Energy monitor (R. Allen design)</td>
</tr>
<tr>
<td>DRV11-C digital interface (@60)</td>
<td>40p flat cable (customized)</td>
<td>Nav interface (N. McRae design)</td>
</tr>
<tr>
<td>DRV11-C digital interface (@70)</td>
<td>40p flat cable (customized)</td>
<td></td>
</tr>
<tr>
<td>LP11 line printer controller</td>
<td>36p flat cable</td>
<td>Act II printer</td>
</tr>
<tr>
<td>DLV11-J serial line interface</td>
<td>2p EIA (port 4)</td>
<td>Ann Arbor</td>
</tr>
<tr>
<td></td>
<td>2p EIA (port 1)</td>
<td>LSI #2 DLV11 (port 4)</td>
</tr>
<tr>
<td></td>
<td>2p EIA (port 2)</td>
<td>JFEP-11 SLU</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LSI #2 Board</th>
<th>Connector Type</th>
<th>Destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSD-480 floppy interface</td>
<td>26p flat cable</td>
<td>DSD-480 #2</td>
</tr>
<tr>
<td>DA11B0I interprocessor link</td>
<td>dual 50p flat cables</td>
<td>LSI #1 DA11B0I</td>
</tr>
<tr>
<td>Matrox QRGB-Graph</td>
<td>75 Ω BNC cable</td>
<td>Panasonic #2</td>
</tr>
<tr>
<td>LP11 line printer controller</td>
<td>36p flat cable</td>
<td>Act II printer</td>
</tr>
<tr>
<td>DLV11-J serial line</td>
<td>2p EIA (port 4)</td>
<td>LSI #1 DLV11 (port 1)</td>
</tr>
<tr>
<td>JFEP-11 SLU</td>
<td>2p EIA</td>
<td>LSI #2 DLV11 (port 2)</td>
</tr>
<tr>
<td>JFEP-11</td>
<td>50p flat cable</td>
<td>JFEP-11 SLU</td>
</tr>
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</table>
Table 2b. Other interconnections.

<table>
<thead>
<tr>
<th>Source</th>
<th>Connector Type</th>
<th>Destination</th>
</tr>
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<tbody>
<tr>
<td>Cipher #1</td>
<td>50p dual flat cables (half twist)</td>
<td>Cipher #2</td>
</tr>
<tr>
<td>Ann Arbor interface</td>
<td>26p flat cable</td>
<td>keyboard</td>
</tr>
<tr>
<td></td>
<td>BNC cable</td>
<td>Panasonic #1</td>
</tr>
<tr>
<td></td>
<td>power cable</td>
<td>Power supply</td>
</tr>
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</table>

Table 3. Impedences for digitizer connections.

<table>
<thead>
<tr>
<th>Transiarc</th>
<th>Internal 50Ω</th>
</tr>
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<tbody>
<tr>
<td>Trigger</td>
<td>N</td>
</tr>
<tr>
<td>Time Base</td>
<td>Y</td>
</tr>
<tr>
<td>Input</td>
<td>Y</td>
</tr>
<tr>
<td>Amp Input</td>
<td>Y</td>
</tr>
</tbody>
</table>

Available Connections for Digitizers

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

But we found a half twist was necessary to make the tape drives function properly. Also, the manual says that only the last unit in the chain should be terminated but we have found that when this is done you cannot turn off one unit (to clear an error) without affecting the other so both our units are terminated. 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 an external power supply (drawn from LSI #1 chassis).
The NASA multipurpose DIAL DAS has been developed toward optimizing the following:

1. Speed. The DIAL DAS must be able to digitize and store 8192 words at up to 10 Hz rates as well as retrieve other information such as navigation, laser energies, and meteorological data. All this data must be read into computer memory (possibly averaged) and then recorded to magnetic tape prior to the next laser fire. To accomplish this, DMA (direct memory access) devices were chosen. Timing tests show that it takes about 16 msecs to store 2000 words from the Transiac 2012 digitizer. To record the data, streamer tape speeds are a necessity (for 8192 words and 10 Hz). Since tape units take about 3 minutes to rewind, two streamer tape drives are necessary to avoid interruptions in the data.

2. Size. Since the LaRC DIAL system is mainly an airplane platform system, size is a major consideration in DAS hardware. The current DIAL DAS is half the size of what it was five years ago with more than three times the computer capability.

3. Program control. Some experimenters prefer the type of computer system which, once started, runs itself with no operator intervention necessary. The DIAL DAS is not that kind of system and, in fact, requires this report and some hands-on experience to operate. The advantage to this type of software is that it allows the experimenter to have maximum control over real-time data acquisition and display. Near instantaneous modifications can be made to both using the commands detailed in the section "Keyboard Commands".

4. Data display. There are three purposes to the DIAL DAS data display. When starting out on a mission a fast refresh plotting capability is needed to align and optimize returns. When a dial or a mirror is turned we need near instantaneous display of that adjustment. As the mission proceeds we need the capability to monitor our returns but the refresh cycles are not so important. At this time, however, we need the capability to do some processing of the data to determine ozone and relative aerosol concentrations. We cannot expect to do all necessary corrections to the data in a real-time situation, so the software has been written to do as much as possible in the one second refresh time allotted. As an example, ozone concentrations can be calculated but the aerosol correction is not performed. Hard-copy color maps of aerosol concentrations have been extremely useful in DIAL missions in determining aerosol layers and subsequent flight altitudes in and around those layers. The third purpose to the data display is diagnostics. There are times when we need to look at the returns in a number of different ways in order to determine why we are getting errors in our concentrations. If the problem turns out to be something like mis-alignment, the beams can be re-aligned and the data for the mission can be salvaged.

The DIAL DAS has four data display capabilities. The CRT keyboard monitor can be used to list out raw data, the current
banner record (a record consisting of experimental parameters) or the current plotting options. The second CRT monitor is used for plotting data returns in a number of viewing modes. There are also two color printers, one which is used to generate real-time aerosol concentrations in a 3-D type display and the other is used to generate real-time ozone concentrations in a similar display mode. The second printer can also be used to copy any CRT display. The advantage of having all these display modes is two-fold: (1) maximum control over experiment objectives, and (2) hard-copy data format for post-mission debriefings. The disadvantage is that the DIAL DAS software is long (requires most of the 128K word memory on both computers) and involved (not easily interpreted by other programmers).

Ideally, it would be desirable to see all the data inputs at any processing level on a shot by shot basis but this is usually not possible in a real-time situation. As an example, we used to have two modes of calculating ozone concentrations for CRT display. One mode does a shot-by-shot calculation averaging in each successive concentration. This allows the user to see an updating and converging average and when the specified averaging interval is complete error bars are also shown. To perform the ratios and logarithms each time requires considerable CPU time (about .8 seconds on the LSI 11/73). The other mode averages all the on-line returns and all the off-line returns and does only one DIAL calculation at the end of the specified averaging interval. In this mode, the screen remains empty during the averaging process and no error bars can be calculated, however, the computation is done in about half the time. In real-time situations there is a trade-off between time required to generate a display versus being able to view the data in the most informative way. With hardware averaging of DIAL returns, we are able to achieve concentration averages using the first method at rates equivalent to that of the second method. The second method is no longer available as an option.

The DIAL DAS display modes will be covered in more detail in the section entitled "Real-Time Data Display" and refresh times are cited for each example shown.
PERIPHERAL PROGRAMMING INFORMATION

Table 4 is a summary of the base registers and trap vectors for all the peripheral devices associated with the two LSI computers. The magtape interface is the only device at BR7 -- the highest priority interrupt. The components marked with an asterisk are spare boards with switch registers set as shown.

Table 4. Base addresses for registers used by peripheral devices.

<table>
<thead>
<tr>
<th>Device</th>
<th>Base Address</th>
<th>Trap Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floppy Disk</td>
<td>777170</td>
<td>264</td>
</tr>
<tr>
<td>Interprocessor Link</td>
<td>772410</td>
<td>124</td>
</tr>
<tr>
<td>Mag-tape Interface</td>
<td>772520</td>
<td>224</td>
</tr>
<tr>
<td>Camac Interface</td>
<td>777550</td>
<td>400</td>
</tr>
<tr>
<td>*DRV11-C @40</td>
<td>767740</td>
<td></td>
</tr>
<tr>
<td>DRV11-C @50</td>
<td>767750</td>
<td></td>
</tr>
<tr>
<td>DRV11-C @60</td>
<td>767760</td>
<td></td>
</tr>
<tr>
<td>DRV11-C @70</td>
<td>767770</td>
<td>300</td>
</tr>
<tr>
<td>Line Printer Controller</td>
<td>777514</td>
<td>200</td>
</tr>
<tr>
<td>Serial Link (Console)</td>
<td>777560</td>
<td>60</td>
</tr>
<tr>
<td>Serial Link (to LSI #2)</td>
<td>776500</td>
<td>320</td>
</tr>
<tr>
<td>Serial Link (to JFEP-11)</td>
<td>776510</td>
<td>330</td>
</tr>
<tr>
<td>TCU 50-DYR</td>
<td>760770</td>
<td></td>
</tr>
<tr>
<td>Floppy Disk</td>
<td>777170</td>
<td>264</td>
</tr>
<tr>
<td>Interprocessor Link</td>
<td>772410</td>
<td>124</td>
</tr>
<tr>
<td>Matrox</td>
<td>764400</td>
<td></td>
</tr>
<tr>
<td>Line Printer Controller</td>
<td>777514</td>
<td>200</td>
</tr>
<tr>
<td>Serial Link</td>
<td>777560</td>
<td>60</td>
</tr>
<tr>
<td>*TCU 50</td>
<td>760770</td>
<td></td>
</tr>
<tr>
<td>LSI 11/73 Memory Management Registers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Page Descriptor</td>
<td>772300</td>
<td></td>
</tr>
<tr>
<td>Page Address</td>
<td>772340</td>
<td></td>
</tr>
<tr>
<td>Memory Management 0</td>
<td>777572</td>
<td></td>
</tr>
<tr>
<td>Memory Management 3</td>
<td>772516</td>
<td></td>
</tr>
</tbody>
</table>

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

ERROR Error detected.
INIT Initialize the DSD 480.
XBA17,XBA16 Extended address bits.
RXO2 RXO2 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

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.

13
SD 1 RDY Set for double sided diskette when ready.
CRC Cyclic redundancy error.

Interprocessor Link (DIALB01)

The Interprocessor Link provides a means of transferring data through DMA between two LSI 11/73 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

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<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERROR</td>
<td>NEX</td>
<td>ATTN</td>
<td>MAINT</td>
<td>IN IR</td>
<td>IN DIR</td>
<td>IN MODE</td>
<td>CYCLE</td>
<td>READY</td>
<td>IN</td>
<td>IN</td>
<td>IN</td>
<td>OUT</td>
<td>OUT</td>
<td>OUT</td>
<td>OUT</td>
</tr>
</tbody>
</table>

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 DIALB01 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.

Cipher F880 Interface (Dilig D0130)

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 11/73 through a Dilog DQ130 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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Address</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTS</td>
<td>772520</td>
<td>status</td>
</tr>
<tr>
<td>MTC</td>
<td>772522</td>
<td>command</td>
</tr>
<tr>
<td>MTBRC</td>
<td>772524</td>
<td>byte/record counter</td>
</tr>
<tr>
<td>MTCMA</td>
<td>772526</td>
<td>current memory address</td>
</tr>
<tr>
<td>MTD</td>
<td>772530</td>
<td>data buffer</td>
</tr>
<tr>
<td>MTRD</td>
<td>772532</td>
<td>tape read lines</td>
</tr>
</tbody>
</table>

ILL --> 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.

EDT --> 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.
Set by bits 7-15 of the status register.

Clears the control unit and tape units.

Selects streamer mode.

Selects unit number for MTS operation.

Control unit ready.

Interrupt enable.

Extended memory bits.

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

When set, begins operation defined by function.

**Camac Interface (Kinetics 2920-22B bus adaptor)**

The Transiac 2012S digitizers are interfaced to the LSI 11/73 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.

<table>
<thead>
<tr>
<th>Address</th>
<th>Description</th>
<th>Function Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLO</td>
<td>777550</td>
<td>data low</td>
</tr>
<tr>
<td>LLO</td>
<td>777550</td>
<td>lam low</td>
</tr>
<tr>
<td>MAR</td>
<td>777550</td>
<td>memory address</td>
</tr>
<tr>
<td>DMACSR</td>
<td>777552</td>
<td>DMA control/status</td>
</tr>
<tr>
<td>DHI</td>
<td>777552</td>
<td>data high</td>
</tr>
<tr>
<td>LHI</td>
<td>777552</td>
<td>lam high</td>
</tr>
<tr>
<td>WCR</td>
<td>777552</td>
<td>word count</td>
</tr>
<tr>
<td>EMA</td>
<td>777554</td>
<td>extended memory</td>
</tr>
<tr>
<td>NAF</td>
<td>777554</td>
<td>station/function</td>
</tr>
<tr>
<td>CACSR</td>
<td>777556</td>
<td>control/status</td>
</tr>
</tbody>
</table>

(RA2 = 0, RA1 = 0)

(RA2 = 0, RA1 = 1)

(RA2 = 1, RA1 = 0)

(RA2 = 1, RA1 = 1)

(RA2 = 0, RA1 = 0)

(RA2 = 0, RA1 = 1)

(RA2 = 1, RA1 = 0)

(RA2 = 1, RA1 = 1)
NAF
@ 777554

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-SA3 Sub-address of Camac device (not used with Transiaccs.)

FCN0-FCN4 Function code defined by user device.

Transiack Function Codes

F(0)*A(0) Reads LAM register and record length.
F(1)*A(0) Reads number of sweeps completed.
F(2)*A(0) Reads signal averaged data. Cannot be executed until signal averaging disabled.
F(8)*A(0) Tests LAM and returns 0 = 1 if ready for readout.
F(9)*A(0) Resets module; clears averaging memory to zero; enables averaging memory.
F(10)*A(0) Resets LAM.
F(16)*A(0) Sets the record length register.
F(16)*A(1) Writes address of the first data word to be read from averaging memory (must be executed twice). A record length of 4K is selected by 100(octal) in DLO register.
F(17)*A(0) Sets the sweep register.
F(24)*A(0) Disables LAM.
F(24)*A(1) Disables averaging and generates a LAM.
F(26)*A(0) Enables LAM to become active on dataway.
F(26)*A(1) Enables averaging.
Z,C Clear and reset; same as F(9)*A(0).

C ACSR
@ 777556

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 programmed control
IE (R/W)  operation (i.e. non-DMA).
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.

\[
\begin{array}{cccccccccc}
\text{DMACSR} & @ 777550 & \text{RA}2 & = & 1 & \text{RA}1 & = & 1 \\
\end{array}
\]

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.

\[
\begin{array}{cccccccc}
\text{mode 0} & \text{programmed transfer} & \text{mode 1} & Q\text{-stop/stop on word count} & \text{mode 2} & \text{address scan} & \text{mode 3} & Q\text{-repeat/stop on word count} \\
\end{array}
\]

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

Parallel Line Interface Module (DRV11-C)

This module acts as an interface between the LSI 11/73 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, one to transfer digital laser energy readings and one to transfer temperature and altitude information from aircraft systems. The X represents 5, 6 or 7 depending on which DRV11-C is being addressed.

DRSR  @ 7677X0  control/status

DRO  @ 7677X2  output buffer

DRI  @ 7677X4  input buffer

\[
\begin{array}{cccccccccc}
\text{DRSR} & @ 7677X0 & \text{DRSR} & \text{DRO} & \text{DRI} \\
\end{array}
\]

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
      DRVII-C causes REQ B.
CSR0 User defined function -- if linked to another
      DRVII-C causes REQ.

Analog-to-Digital Converter (ADVII-C)

Sixteen Analog-to-Digital Conversion single ended inputs
(or eight differential) are available to the DIAL DAS through an
ADVII-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.
This board is not being used in the system presently.

ADST  @ 770400  control/status
ADBF  @ 770402  data buffer

<table>
<thead>
<tr>
<th>15</th>
<th>14</th>
<th>13</th>
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<tr>
<td>ERROR</td>
<td>ER</td>
<td>ERR</td>
<td>IE</td>
<td>ADD1</td>
<td>ADD2</td>
<td>ADD3</td>
<td>ADD4</td>
<td>ADD5</td>
<td>ADD6</td>
<td>ADD7</td>
<td>ADD8</td>
<td>A/D DONE</td>
<td>IE</td>
<td>IE</td>
<td>IE</td>
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</tbody>
</table>

ERROR  Caused by doing a GO when A/D DONE is set or A/D
still in progress.
ERR IE  Allows ERROR to interrupt.
ADDS-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-GS0  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 11/73
computers and the ACT II printers. Each computer has its own
interface board.

LFS  @ 777514  status
LPB  @ 777516  data buffer

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<tr>
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<tr>
<td>ERROR</td>
<td>RE</td>
<td>READY</td>
<td>IE</td>
<td>IE</td>
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</table>
Teletype (Flessey PM-DLV11J Serial Line Interface)

The Flessey PM-DLV11J is a 4-channel asynchronous serial line interface between the LSI 11/73 bus and standard I/O devices. On LSI #1 one port is used to communicate with the teletype, a second port is used to communicate with a second PM-DLV11J interface on LSI #2 and a third port is used to communicate with the JFEP-11 through its SLU board. Baud rates on both boards have been wire-wrapped for 9600 baud.

From LSI #1 port #1 to LSI #2 port #4 (X=0) and from LSI #1 port #2 to JFEP SLU (X=1):

- **RCSR** @ 7765X0 receiver control/status
- **RBUF** @ 7765X2 receiver buffer
- **XCSR** @ 7765X4 transmitter control/status
- **XBUF** @ 7765X6 transmitter buffer

From LSI #1 port #4 to console device:

- **RCSR** @ 777560 receiver control/status
- **RBUF** @ 777562 receiver buffer
- **XCSR** @ 777564 transmitter control/status
- **XBUF** @ 777566 Transmitter buffer

### Diagram

From **RCSR** @ 776500, @ 776510, @ 777560:

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

From **RBUF** @ 776502, @ 776512, @ 777562:

- **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.
**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.

---

**XCSR**
- @ 776504
- @ 776514
- @ 777564

---

**DAT7-DATO**
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

---

**HR/MIN**
- @ 760772
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 DR:  

DATA  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  

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
The Matrox RGB-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 to draw axes, point plots, vector plots and draw characters. 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.

<table>
<thead>
<tr>
<th>Register</th>
<th>Address</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XREG</td>
<td>@ 764400</td>
<td>X coordinate (10 bits)</td>
</tr>
<tr>
<td>YREG</td>
<td>@ 764402</td>
<td>Y coordinate (10 bits)</td>
</tr>
<tr>
<td>DATA</td>
<td>@ 764404</td>
<td>data register (4 bits)</td>
</tr>
<tr>
<td>ST1 (R)</td>
<td>@ 764406</td>
<td>preset memory status</td>
</tr>
<tr>
<td>CTR1 (W)</td>
<td>@ 764406</td>
<td>zoom/pan control</td>
</tr>
<tr>
<td>ALP (R)</td>
<td>@ 764410</td>
<td>auxiliary light pen register</td>
</tr>
<tr>
<td>CTR3 (W)</td>
<td>@ 764410</td>
<td>color map select</td>
</tr>
<tr>
<td>CTR4</td>
<td>@ 764412</td>
<td>write plane enable</td>
</tr>
<tr>
<td>ST2 (R)</td>
<td>@ 764414</td>
<td>vertical blanking status</td>
</tr>
<tr>
<td>VECT (W)</td>
<td>@ 764414</td>
<td>CRTC address/vector register</td>
</tr>
<tr>
<td>CTR5</td>
<td>@ 764416</td>
<td>CRTC data register/vector/preset control</td>
</tr>
</tbody>
</table>
PREM FLG
If 1, memory is being preset or frame grab in progress.

CRT1
@ 764406

YZOOM1-YZOOM0
Y-zoom: 00 = 1, 01 = 2, 10 = 4
XZOOM2-XZOOM0
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.

IRQEN
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

WRT AUTO
When 0, data in DATA is automatically written to X,Y when VECT 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-CRTC0
Address of CRTC register (used only at start-up).

CRTS
@ 764416
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.

**JFEP-11 Front-End Processor**

The JFEP-11 is a front-end processor using a J-11 chip which plugs into a Q-bus backplane. It has 256K words of dual ported memory which may be accessed through the Q-bus. The Q-bus may only access 128K of the J-11 memory at a time. The lower range or upper range of J-11 memory is selected through a bit in the Q-bus CSR. Programs for the JFEP-11 are developed, compiled and linked on the LSI computers. To load a JFEP-11 program, the program is loaded into the memory of the LSI #2 with the lower range of J-11 memory selected. To run the program on the JFEP-11, LSI #1 communicates with ODT on the J-11 board by loading the program counter register (R7) with the starting address of the J-11 program then sending a "P" which is the ODT command to proceed at the address pointed to by the program counter.

The DIAL DAS uses the JFEP-11 to perform a running average on the ozone profiles either above or below the aircraft. In order to do the running average, all shots must be maintained in memory so that one may be subtracted off the front end when a new one is added to the existing average. This requires all the memory available on the JFEP-11.

These registers are not presently used in the DIAL DAS software and are included because they will probably be used in future revisions.

@ 762004 (Q-Bus)         Q-Bus CSR
@ 777740 (J11-Bus)       J11-Bus CSR

**Q-Bus CSR**

| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|---|
| $SS$ | STOP/RESTART J-11 through power fail mode. Cleared by writing a zero or power fail acknowledged. | MEM SEL | Selects lower memory when clear, upper memory when 1. | DMA ENA | Enables DMA transfers to Q-bus | DPM DIS | Disables the dual ported memory from the Q-bus. | VECT | J11 vector address which gets shifted by one when sent to the J11 bus, thereby, doubling address in these bits. | JINT REQ | Generates a J11 interrupt request. |
DMA ENA  When set, Q-bus has enabled DMA transfers. Read only.
UBACK  When clear, J11 can access Q-bus DMA controller.
GBQ  Grab the Q-bus for transfers between the J11 and Q-bus.
EVT  Used to enable the EVENT line time clock.
REQ DMA  Requests control of the DMA logic.
VECT  Vector address for the Q-bus, shifted by one.
QINT REQ  Used to generate an interrupt request to the Q-bus.

LSI 11/23 Memory Management Registers

There are many registers internal to the LSI CPU's which will not be discussed here. The registers described below are all concerned with memory management and are included in this document because they are used extensively in the DIAL DAS software. Only the bits that are used will be defined here.

- PDR  @ 772300  page descriptor
- PAR  @ 772340  page address
- MMRO  @ 777572  memory management register 0
- MMR3  @ 772516  memory management register 3

BYP CAC  Bypass cache.
PLF  Page length field.
PAF  Page address field. Address to be relocated. The actual address that is relocated is the PAF+00. A 200 PAF represents an address of 20000.
Enable relocation when set to 1.

Enable 22-bit addressing.
DIAL DAS SOFTWARE

The DIAL DAS Operating System (OS) software consists of three programs which run simultaneously on the two LSI processors and the JFEP-11 processor. 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 program on the JFEP-11 is called J11 and does the DIAL calculation on an on-line and off-line pair then performs a running average of these profiles. The user communicates with all three programs through LSI #1 which passes data buffers and display options to LSI #2 and the JFEP-11 as necessary. Figure 4 shows the interconnection among the three programs running on the three processors. During real-time experimental situations, the MASTER program gathers digitized laser signals from the Transiac 2012S’s. It also gathers laser energies through a DRV11-C interface, temperatures and pressure altitude through a second DRV11-C interface, time of day from the TCU-50 DYH, and position information from the Loran or INS navigation devices through a third DRV11-C. Data acquisition is interrupt driven by the Laser Coherent Trigger into the Transiacs. After the data is packed into one continuous buffer, the record 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 on-line and off-line pair to be processed is sent to the JFEP-11 through J11 dual ported memory on LSI #2. The CRT 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, 8192 words of raw data from one unit (no analysis) will be viewed every fourth 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. Display rates on the two ACT II printers are governed by operations on their respective processors. The range-squared aerosol color maps are performed by LSI #1 and we typically do a 15 shot average (or 3 seconds) before plotting so there is plenty of time to catch each shot, i.e. a 15 shot average represents 3 uninterrupted seconds of data. On the other hand, when we use LSI #2 and the JFEP-11 to perform our running average of ozone plots to the color printer, plotting time (which is done by LSI #2) must be shared with CRT data display and analysis. Depending on the complexity of CRT display, a 60 shot running average may represent a 2 minute or more display in time.

Data transfer operations from the digitizing units are readily accomplished within the minimum 100 ms operation time envelope between laser firings. The laser-coherent time base is designed to key the digitizers to sample for 136.3 usecs (1363 words) of the on-line lase then to go into a "sleep" mode until the off-line lase at which time it restarts the sampling (ref. 3). This avoids the necessity of digitizing long records to acquire the on-line return followed by the off-line return 300 usecs later. Since both sampling intervals are triggered by the
Figure 4. DIAL DAS program interconnections.
actual firing of the lasers through optical sensors, there is more stability of word alignment between the on and off-line returns. Software commands are available which control the starting points and number of words for data storage for each signal return. The maximum buffer size is presently set at 8192 words. The combined data stored from all the digitizers in use plus the shot header information must not exceed 8192 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 LS12" to access LSI #2. Thereafter, each character is sent through the serial line interface to LSI #2. Similarly, there is a program on each system diskette called JFEP-11 to communicate with ODT on the JFEP-11.

Jumpers have been selected on both LSI's to boot up from disk to RT-11 on power up. To run the MASTER and SLAVE programs, LSI #2 must start out in RT-11. This allows program MASTER to 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. Make sure both systems are running RT-11 by pushing the DC ON buttons on both chassis then waiting for the RUN lights to come on and stay lit.
4. Run program MASTER by typing: RUN MASTER
5. MASTER will load and in turn call SLAVE. LSI #2 is ready when "MATORX" 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, start back at step 3.
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.
11. If the display on LSI #2 stops updating, use the SYNC command.

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 at the end of the section "Keyboard Commands". Comments are made on each line to describe what the user is doing (those preceded by two
Data Acquisition

Data acquisition is controlled by hardware switches on the digitizing units and by keyboard commands. On the Transiac 2012S a knob setting selects the number of pre-trigger samples in increments of 1/8 of the total record (a selected record length of 4096 words would have pre-trigger increments of 512). 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 512 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 some time after that unit was triggered. Only the data from the second return 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 U1 and the second return is saved starting at U1 + 1363, i = 1, 2, 3, or 4. The number of words saved of the first return for each unit is determined by the instruction "WORDS1 U1, U2, U3, U4". Similarly, "WORDS2 U1, U2, U3, U4" specifies the number of words to store of the second return of each unit. The separation between the on and off-line returns has varied from one mission to another so the command "WAKEUP I" can be used to change the value from 1363 to a suitable value. The word number for the "wake up" can be determined by listing out words of the online return and off-line return, determining where the trigger markers are and then adding or subtracting from the existing value to make the two trigger words fall at the same word.

The laser shots can be internally averaged by the Transiac 2012S and 4100. Hardware averaging is a necessity at 10 Hz operations for buffers of 8192 words. The number of shots to average can be selected by the command "DATAVG U1, U2, U3, U4". Each unit should be set to average the same number of shots except when in "STACK" or "TWEAK" modes. The maximum number of shots that can be averaged without overflowing the 16-bit integer is 15. Thus far, we have used a 5 shot (or 1 Hz) averaging option. For most cases, the 1 Hz resolution is more than adequate for our experimental objectives but at times there is a need to obtain a finer resolution of the visible aerosol data. Rather than an increasing storage rates of all digitizing units to a 5 Hz resolution (thereby increasing the amount of data stored by a factor of 5) a special set-up is provided for where the last unit to be sampled can be stacked in memory at the end of the buffer at a different rate than the other three units. There are two restrictions on the use of this procedure. The stacked unit must be the last unit and the resolution of the stacked data must be 5 Hz. Thus, for a 5 Hz laser repetition rate the command "DATAVG 5, 5, 5, 1" and for a 10 Hz rate, the command "DATAVG 10, 10, 10, 2" are valid stacking set-ups (see figure 5). An example of data acquisition will be given at the
Figure 5. Stacked data buffer format.
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 color representation of range resolved profiles on the Act II printer. On LSI #2, four basic modes for DIAL data display are available, each with a variety of display options. At the same time several other pieces of information can be shown on the right hand side of the screen. Altitude, temperature data, and laser energies from the DRV11-C interfaces can be viewed. Certain hook-up conventions must be observed for the DRV11-C input in order to get default conversion constants and labeling to correspond:

<table>
<thead>
<tr>
<th>DRV11-C Channel (@50)</th>
<th>Input</th>
<th>Label</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>aircraft altitude</td>
<td>ALT</td>
<td>ft</td>
</tr>
<tr>
<td>2</td>
<td>dewpoint temperature</td>
<td>DPT</td>
<td>C</td>
</tr>
<tr>
<td>3</td>
<td>temperature</td>
<td>T</td>
<td>C</td>
</tr>
<tr>
<td>4</td>
<td>total temperature</td>
<td>TT</td>
<td>C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DRV11-C Channel (@60)</th>
<th>Input</th>
<th>Label</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>online UV</td>
<td>UVN</td>
<td>MJ</td>
</tr>
<tr>
<td>2</td>
<td>offline UV</td>
<td>UVF</td>
<td>MJ</td>
</tr>
<tr>
<td>3</td>
<td>online IR</td>
<td>IRN</td>
<td>MJ</td>
</tr>
<tr>
<td>4</td>
<td>offline IR</td>
<td>IRF</td>
<td>MJ</td>
</tr>
<tr>
<td>5</td>
<td>online VIS</td>
<td>VISN</td>
<td>MJ</td>
</tr>
<tr>
<td>6</td>
<td>offline VIS</td>
<td>VISF</td>
<td>MJ</td>
</tr>
</tbody>
</table>

The DIAL DAS command language allows the user to input a slope and intercept to the banner record for each DRV11-C channel to convert the digitized counts to the units shown above. Conversion constants must be input as integers. So 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 right side by itself, or both sides at the same time (UPDATE command).

When the data is being hardware averaged by the digitizers, update of the CRT display is limited to the effective rate of the averaged data. In some cases, a faster update may be necessary so a "TWEEK I" command has been included where unit I will bypass internal averaging to allow for tweaking or optimizing of signals from that unit. To return to normal operations type
The different display options are summarized on the next page. Each display mode has a number of default options associated with it. These are summarized in Table 5. The default values can be changed by various keyboard commands. Display options are available for background subtraction, range-square correction, over-laying data of different digitizers, scale and more. Each display option can be activated or deactivated in real-time to observe signal features in the most useful format.

Table 5. Default plotting parameters (tropospheric set-up).

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>MODE 1</th>
<th>MODE 2</th>
<th>OZONE</th>
<th>COMMAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>unit select</td>
<td>all</td>
<td>all</td>
<td>UNIT1</td>
<td>UNIT</td>
</tr>
<tr>
<td>y-axis scale</td>
<td>0-4096</td>
<td>0-4096</td>
<td>0-800</td>
<td>SCALE</td>
</tr>
<tr>
<td>x-axis scale</td>
<td>all data</td>
<td>150m/tic</td>
<td>150m/tic</td>
<td>INDEX</td>
</tr>
<tr>
<td>background word</td>
<td>550</td>
<td>550</td>
<td>550</td>
<td>BGWOrd</td>
</tr>
<tr>
<td>background window</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>BGWIND</td>
</tr>
<tr>
<td>smooth</td>
<td>no</td>
<td>no</td>
<td>300m</td>
<td>SMOOTH</td>
</tr>
<tr>
<td>average shots</td>
<td>no</td>
<td>no</td>
<td>300</td>
<td>PLTAVG</td>
</tr>
<tr>
<td>range cell</td>
<td>---</td>
<td>---</td>
<td>300m</td>
<td>RNGCEL</td>
</tr>
<tr>
<td>gas exponent</td>
<td>---</td>
<td>---</td>
<td>-10</td>
<td>GASEXP</td>
</tr>
<tr>
<td>atmospheric correction</td>
<td>---</td>
<td>yes</td>
<td>---</td>
<td>ATMCOR</td>
</tr>
<tr>
<td>Rayleigh correction</td>
<td>---</td>
<td>-6.7 ppb</td>
<td>---</td>
<td>RAYCOR</td>
</tr>
<tr>
<td>shift toa</td>
<td>---</td>
<td>no</td>
<td>no</td>
<td>SHFTOA</td>
</tr>
<tr>
<td>update right screen</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>UPDATE</td>
</tr>
</tbody>
</table>

Raw Data (MODE 1)

This is the basic display mode which presents raw data from each of the digitizing units as it exists in computer memory (figure 6). The abscissa represents word sequence in memory while the ordinate is adjusted to present the 12-bit signal magnitude with variable magnification. The one word instruction "MODE 1" calls up all the options listed as defaults in table 5.

Online/Offline Overlay (MODE 2)

A second display mode presents the raw data signals in an overlapped format. As shown in figure 7, the online and offline return signals from each unit are overlayed. Units 1 and 2 represent UV returns in the nadir and zenith directions respectively. Unit 3 shows the 1060nm aerosol returns -- the zenith and nadir returns have been summed with an analog switch to enable us to digitize with only one unit. Unit 4 shows the 600nm aerosol returns --again these returns have been summed. By default, each of these returns have been smoothed over 300m and plotted as a function of time, each tic mark representing 1 usec. Each data shot is plotted in this mode starting after
Figure 6. Example of MODE 1 display. Copied to ACT II printer with COPY -1 command.
Figure 7. Example of MODE 2 display.
the FMT 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 laser-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 8 shows the effect of activating the background subtraction and range squared options on the profile of UNIT1 in figure 7 (MODE 2). Display of the data in this mode allows us to more readily see the differences in the absorbed on-line return as compared to the off-line return. Figure 9, again shows the effect of activating the subtraction and range squared options. This time the on-line returns of units 3 and 4 have been selected and the overlay option is turned on. From this display we can easily see the response of the two different aerosol wavelengths used -- one being more sensitive to the molecular content of the atmosphere. The sequence of instructions to obtain figure 9 is as follows:

```
MODE 2
RETURN 0,0,1,1
OVRLAY 1
RNGCOR 1
YMAX 8192
```

**Gray-Scale Display (GRYSCD)**

A 16 level gray scale display format is available for presentation of the spatial distribution of aerosol scattering. 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
Figure 8. MODE 2 display with background subtraction and range-squared options in effect on DIAL pair of UNIT 1. Difference in slopes indicates absorption by ozone.
Figure 9. MODE 2 display of the online returns of units 3 and 4 with background subtraction, range-squared and overlay options in effect.
troposphere. Since the addition of the ACT II printers to the system, this operation is performed hardcopy and in color on one of the printers and rarely used as a CRT mode of display.

**Concentration Profiles (OZONE)**

This display mode presents the gas concentrations as a function of altitude or range calculated from the DIAL signal pair (figure 10). For each DIAL return, the background signal level is integrated over a specified interval. The starting point of this integration is selected by the command "BGWORD" and the number of words to average over is specified by "BGWIND". 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 300 m. Ozone concentrations are determined for each range cell and finally, the Rayleigh extinction is corrected for altitude and subtracted. The Rayleigh term is to compensate for extinction differences between the on and off lines. Each DIAL signal pair produces a concentration profile. Ozone profiles are plotted as concentrations for startospheric work and mixing ratios for tropospheric work. To obtain the mixing ratios, an approximation to the molecular number density is divided into the concentration at each range cell. 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 concentration profile.

The commands UNIT, BGWORD, BGWIND, RNGCEL, SMOOTH, PLTAVG, GASEXP can all be used to change the defaults to modify the display or to better improve the resulting calculations. These and others that can be used are listed in the section "Keyboard Commands". The command SHFTOA which applies only to ozone calculations is a diagnostic tool to shift one DIAL UV pair with respect to the other. This command will be further discussed in the section titled "DIAL Pair Alignment".

**Hard Copy Aerosol Color-Scale Map (MAPAER)**

This option represents the same type of display as described for "GRYSCL"; however, it is done in color on the ACT II printer. When this option is activated, the current banner record and MAPAER plotting parameters are printed followed by a 25 shade color scale display of relative aerosol concentrations. The color scale which follows the color spectrum is shown at the top of each plot. White is on the low end of the scale and black is on the high end. The user specifies a minimum value below which all data will appear as white ("WHITE") and a maximum value above
Figure 10. Example of OZONE display (300 shots averaged).
which all data will appear as black ("BLACK"). Data shots may be averaged (up to 15 shots) or plotted individually. Additionally, data may be vertically smoothed with a running average. The nadir data can be shifted for altitude variations using the information in the shot header if the ALTCOR option is used. During real-time operations the computer can plot about one profile a second (either averaged or individual). Time, latitude and longitude are printed at specified minute markers. The hard copy continues until turned off with the instruction "AEROFF" or whenever any of the MAPAER plotting parameters are changed. The user must re-start with "MAPAER" after changing plotting parameters. This allows the new plotting parameters to be printed so that an updated record is always available.

**Hard-Copy Ozone Color Scale Map (MAPUV)**

On and off-line pairs of data are sent to the JFEP-11 through the shared memory on LSI #2 and ozone concentrations similar to those discussed above (CRT display mode) are calculated. Each concentration profile up to some specified average is stored in the JFEP memory. When a total number of profiles for the average has been stored, a new profile will be added on to the end for one that is subtracted off the beginning to form a running average. All options discussed in the section concerning the CRT ozone display also apply to the hard-copy displays but must be preceded by the symbol *. Each single ozone profile can be shifted in the array to compensate for variations in aircraft altitude using the information in the shot header (nadir mode only). Additionally, cloud returns can be detected and computations will be performed as far as the cloud using the CLOUD I parameter. A value of CLOUD 2 will pick up weak clouds and a value of CLOUD 4096 will ignore clouds altogether.

Figure 11 shows sample aerosol and ozone color maps using the MAPAER and MAPUV commands.

**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 8K 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 11 blocks are available (for non-stack operation). Once transfer to the top block (@ 7400000) is done data transfer continues to the bottom block (@ 2000000). 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 will be 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
Figure 11. Photograph made of real-time aerosol (MAPAER) and ozone (MAPUV) color maps. Prints are 15% of original size.
operation with minimal need to reposition. Tests show that 4k blocks are written to tape at 10 Hz with up to 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 6. 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 shot header of information required on a shot-by-shot basis. This includes time, shot number, latitude, longitude, altitude, temperature data, and laser energies. The number of words in the header is currently 30 but this number can be changed with the instruction "HDRFTS". Table 7 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.
Table 6. Banner record word assignments (dimensioned 256).

<table>
<thead>
<tr>
<th>Word</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>banner record format</td>
</tr>
<tr>
<td>2</td>
<td>tape #</td>
</tr>
<tr>
<td>3</td>
<td>file #</td>
</tr>
<tr>
<td>4</td>
<td># words in shot header</td>
</tr>
<tr>
<td>5</td>
<td>date</td>
</tr>
<tr>
<td>6</td>
<td>plane altitude (feet) (x10 when value is negative)</td>
</tr>
<tr>
<td>7</td>
<td>up/down mode (0=down; 1=up)</td>
</tr>
<tr>
<td>8</td>
<td>sampling frequency (MHz)</td>
</tr>
<tr>
<td>9</td>
<td>laser fire word #</td>
</tr>
<tr>
<td>10</td>
<td>laser rep rate (Hz)</td>
</tr>
<tr>
<td>11</td>
<td>absorption coefficient (mantissa)</td>
</tr>
<tr>
<td>12</td>
<td>absorption coefficient (exponent)</td>
</tr>
<tr>
<td>13</td>
<td>wakeup value</td>
</tr>
<tr>
<td>14-16</td>
<td>spares</td>
</tr>
<tr>
<td>17</td>
<td>words/return #1 unit 1</td>
</tr>
<tr>
<td>18</td>
<td>words/return #1 unit 2</td>
</tr>
<tr>
<td>19</td>
<td>words/return #1 unit 3</td>
</tr>
<tr>
<td>20</td>
<td>words/return #1 unit 4</td>
</tr>
<tr>
<td>21</td>
<td>words/return #2 unit 1</td>
</tr>
<tr>
<td>22</td>
<td>words/return #2 unit 2</td>
</tr>
<tr>
<td>23</td>
<td>words/return #2 unit 3</td>
</tr>
<tr>
<td>24</td>
<td>words/return #2 unit 4</td>
</tr>
<tr>
<td>25</td>
<td>starting storage word unit 1</td>
</tr>
<tr>
<td>26</td>
<td>starting storage word unit 2</td>
</tr>
<tr>
<td>27</td>
<td>starting storage word unit 3</td>
</tr>
<tr>
<td>28</td>
<td>starting storage word unit 4</td>
</tr>
<tr>
<td>29</td>
<td>baseline unit 1</td>
</tr>
<tr>
<td>30</td>
<td>baseline unit 2</td>
</tr>
<tr>
<td>31</td>
<td>baseline unit 3</td>
</tr>
<tr>
<td>32</td>
<td>baseline unit 4</td>
</tr>
<tr>
<td>33</td>
<td>direction and magnitude of trigger marker unit 1</td>
</tr>
<tr>
<td>34</td>
<td>direction and magnitude of trigger marker unit 2</td>
</tr>
<tr>
<td>35</td>
<td>direction and magnitude of trigger marker unit 3</td>
</tr>
<tr>
<td>36</td>
<td>direction and magnitude of trigger marker unit 4</td>
</tr>
<tr>
<td>37</td>
<td>shots to accumulate unit 1</td>
</tr>
<tr>
<td>38</td>
<td>shots to accumulate unit 2</td>
</tr>
<tr>
<td>39</td>
<td>shots to accumulate unit 3</td>
</tr>
<tr>
<td>40</td>
<td>shots to accumulate unit 4</td>
</tr>
<tr>
<td>41</td>
<td>post-trigger delay (usecs) unit 1</td>
</tr>
<tr>
<td>42</td>
<td>post-trigger delay (usecs) unit 2</td>
</tr>
<tr>
<td>43</td>
<td>post-trigger delay (usecs) unit 3</td>
</tr>
<tr>
<td>44</td>
<td>post-trigger delay (usecs) unit 4</td>
</tr>
<tr>
<td>45</td>
<td>species identifier (RAD50) unit 1</td>
</tr>
<tr>
<td>46</td>
<td>species identifier (RAD50) unit 2</td>
</tr>
<tr>
<td>47</td>
<td>species identifier (RAD50) unit 3</td>
</tr>
<tr>
<td>48</td>
<td>species identifier (RAD50) unit 4</td>
</tr>
<tr>
<td>49</td>
<td>trigger marker delay (words) unit 1</td>
</tr>
<tr>
<td>50</td>
<td>trigger marker delay (words) unit 2</td>
</tr>
<tr>
<td>51</td>
<td>trigger marker delay (words) unit 3</td>
</tr>
<tr>
<td>52</td>
<td>trigger marker delay (words) unit 4</td>
</tr>
<tr>
<td>53-64</td>
<td>spares</td>
</tr>
</tbody>
</table>
ALT and TEMP calibration constants for channels 1-10
4 words per channel (slope mantissa, slope exponent, intercept mantissa, intercept exponent)

Energy monitor calibration constants for channels 1-6
4 words per channel (same as ADV11-C constants above)

Table 7. Data record structure for shot buffers.

<table>
<thead>
<tr>
<th>Word #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>shot number</td>
</tr>
<tr>
<td>2</td>
<td>stack/nostack indicator (i=stacked)</td>
</tr>
<tr>
<td>3-4</td>
<td>time of day</td>
</tr>
<tr>
<td>5-6</td>
<td>unused</td>
</tr>
<tr>
<td>7</td>
<td>latitude (low order)</td>
</tr>
<tr>
<td>8</td>
<td>latitude (high order)</td>
</tr>
<tr>
<td>9</td>
<td>longitude (low order)</td>
</tr>
<tr>
<td>10</td>
<td>longitude (high order)</td>
</tr>
<tr>
<td>11</td>
<td>pressure altitude</td>
</tr>
<tr>
<td>12</td>
<td>radar altitude</td>
</tr>
<tr>
<td>13</td>
<td>dew point temperature</td>
</tr>
<tr>
<td>14</td>
<td>surface temperature</td>
</tr>
<tr>
<td>15</td>
<td>total temperature</td>
</tr>
<tr>
<td>16</td>
<td>Gregory Ozone</td>
</tr>
<tr>
<td>17-20</td>
<td>spare DRV11-C channels</td>
</tr>
<tr>
<td>21</td>
<td>online UV energy</td>
</tr>
<tr>
<td>22</td>
<td>offline UV energy</td>
</tr>
<tr>
<td>23</td>
<td>online IR energy</td>
</tr>
<tr>
<td>24</td>
<td>offline IR energy</td>
</tr>
<tr>
<td>25</td>
<td>online visible energy</td>
</tr>
<tr>
<td>26</td>
<td>offline visible energy</td>
</tr>
<tr>
<td>27-30</td>
<td>spare energy monitor channels</td>
</tr>
<tr>
<td>31</td>
<td># shots averaged unit 1 (same as IBAN(37))</td>
</tr>
<tr>
<td>32</td>
<td># shots averaged unit 2 (same as IBAN(38))</td>
</tr>
<tr>
<td>33</td>
<td># shots averaged unit 3 (same as IBAN(39))</td>
</tr>
<tr>
<td>34</td>
<td># shots averaged unit 4 (same as IBAN(40))</td>
</tr>
<tr>
<td>35</td>
<td># interrupts received from unit 1</td>
</tr>
<tr>
<td>36</td>
<td># interrupts received from unit 2</td>
</tr>
<tr>
<td>37</td>
<td># interrupts received from unit 3</td>
</tr>
<tr>
<td>38</td>
<td># interrupts received from unit 4</td>
</tr>
<tr>
<td>39-40</td>
<td>spares</td>
</tr>
</tbody>
</table>

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 6 (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
if data is stacked, there will follow another 4*(M4+N4) words of unit 4 data (see figure 5).

Decoding Information

This section provides information necessary to decode and convert various information in the banner (IBAN) and shot header (IBUF).

DATE

<table>
<thead>
<tr>
<th>bit</th>
<th>14</th>
<th>10</th>
<th>9</th>
<th>5</th>
<th>4</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>month day year (binary)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To get the actual year, add 1972 to the value in bits 4-0.

TRIGGER MARKERS

IBAN(33)-IBAN(40)

The two high order bits indicate the logical operator: less than is signified by a value of 1; equal to by a value of 2, and; greater than by a value of 3. The lower 14 bits indicate the magnitude of the comparison to be made.

GAS SPECIES

IBAN(45)-IBAN(48)

Radix-50 values are stored, up to three characters per word, by packing them into single numeric values according to the formula:

\[(i \times 50 + j) \times 50 + k\]

where "i", "j", and "k" represent the octal code values:

Space 0
A-Z 1-32
0-9 36-47

TEMP and ALT

IBAN(65)-IBAN(104)
IBUF(11)-IBUF(20)

The banner record contains the conversion constants for the DRV11-C channels which are read in on a shot by shot basis and stored in the shot header.
counts = IBUF(10+ICH), where ICH = channel #
volts = counts * (10v/4095 counts)
and conversion to desired units is accomplished by:

volts*IBAN(65+I4)*10**IBAN(66+I4)+IBAN(67+I4)*10**IBAN(68+I4)
where I4 is 4 * (channel # -1).

ENERGY MONITOR DATA

IBAN(105)-IBAN(144)
IBUF(21)-IBUF(30)

As in the preceding data, the conversion constants are stored in
the banner record and the laser energies are stored on a shot by
shot basis in the shot header. The values in the header are
2's complement binary counts which have been calibrated to read
in millivolts. To convert to millijoules:

IBUF(20+ICH)*(IBAN(105+I4)*10**IBAN(106+I4))
+IBAN(107+I4)*10**IBAN(108+I4)
where ICH is the channel and I4 = 4 * (channel # -1).

NAVIGATION DATA

IBUF(7)-IBUF(10)

Latitude and longitude are each 2 16-bit word integers coded in
BCD. Bits 7-0 of the low order word are labels (latitude label
in hex is 10 and longitude is 90). The information is then
stored in bits 15-8 of the low order word and bits 13-0 of the
high order word with .1 min resolution. Bits 14 and 15 of the
high order word designate east, west, north or south.

Some examples:

IBUF(8) IBUF(7)
NB125.8 0000 1000 0001 0010 0101 1000 0001 0000
IBUF(10) IBUF(9)
W16637.8 1101 0110 0110 0111 0111 1000 1001 0000
E07654.1 0000 0111 0110 0101 0100 0001 1001 000

DIAL Pair Alignment

It has been found that it is extremely important to precisely
line up the on and off line returns. Even a one word offset
can cause oscillations in the concentration profiles. Therefore,
a discussion of data alignment follows. 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 should be to attempt to line up the on and off-line pair as
it is read in from the digitizers. Plug the trigger markers into
the first unit and note the word at which these occur in both the
on and off line returns. This is done by listing out the first 50 words of each return (e.g. LIST -1,50 and LIST -601,650). If there is any offset of the trigger markers, stop data transfer and adjust the WAKEUF value to line up the offline return with the online. For example, if the current WAKEUF value is 1363 and the offline trigger marker occurs one word earlier than the online trigger marker, a new WAKEUF of 1362 will properly align the returns. If there were no "jitter" in the timing of the two returns this would be all that would be necessary. The ABLE2B data was found to be very stable, in fact, no change was detected throughout the 6 weeks of the experiment. On the other hand, the Ozone Hole data showed three changes in the separation during the various flights. In order to eliminate any doubt, trigger search routines can be used to line up the returns on a shot by shot basis. To line up the UV DIAL pair, the software requires several inputs:

1. Determine and input the word number of the laser fire. This can most easily be done by transmitting the IR return and noting the word number of saturation (using the LIST -1, J command). Input the word number with the LASFIR I command.

2. Check the offset between the actual laser fire and the delayed trigger markers. This offset is currently 13 words or 1.3 usecs. Enter the number of words with the TODLY command.

3. With both the FMT returns and the trigger markers going into the digitizer make sure the trigger markers can still be discerned. If not, an adjustment of the light pipe may be necessary. The trigger levels must be specified for single shots so if data is being averaged in the digitizer you must either divide the level by the number of shots averaged or do a TWEAK operation on the digitizer unit. The trigger level is entered as less than (\textless{}), greater than (\textgreater{}), or equal to (\texttt{=}) some value (e.g. TRGLEV \textless{} 0, \textgreater{} 900, \texttt{=} -2048). Do not forget to return to normal data averaging when done using TWEAK 0.

The above three steps should be repeated for each digitizer unit with DIAL pairs. Data alignment of the single return aerosol data is not as critical but still important for comparisons with the DIAL data and accurate determination of aerosol layers. Actually, all data pairs (either DIAL or single aerosol returns) can be aligned using only one set of trigger markers since if there is any jitter between the online and offline laser timing it will be the same in each unit. Future plans are to include a trigger search during data transmission and to include these findings in the shot header.

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 7, TODLY is 13, 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 WORDS1 + 15 and WORDS1 + 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. MODE 2 display does a trigger search on each return so inputs can be checked by displaying MODE 2. 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 Transiacs have a pre-trigger dial which increments by 512 words (for 4096 word record length). To allow for an ample window for the trigger marker the Transiac should be set at 1/8 (3584 words stored after the trigger and 512 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 command is especially useful with the Transiacs since so many pre-trigger words need be digitized. It also helps to conserve on storage when the first return in the digitizer is of no interest and only the second return need be saved (such as the zenith operation measurements). It has also been found that sometimes one of the amplifiers will cause a one word offset of the entire data set. When this happens, a STORE value should be input to the program to bring that data set in line with the other units.

Figure 12 shows digitizer memory as compared to computer memory for the keyboard commands as follows:

STORE 490,490,490,490
WORDS1 650,1350,600,600
WORDS2 650,1350,1400,1400

The events shown at the top of the figure are defined in the following table:

<table>
<thead>
<tr>
<th>Event</th>
<th>Time (usec)</th>
<th>Word #</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>499</td>
</tr>
<tr>
<td>B</td>
<td>1.3</td>
<td>512</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>549</td>
</tr>
<tr>
<td>D</td>
<td>30</td>
<td>799</td>
</tr>
<tr>
<td>E</td>
<td>163.7 usecs</td>
<td>1861</td>
</tr>
<tr>
<td>F</td>
<td>300</td>
<td>1862</td>
</tr>
<tr>
<td>G</td>
<td>301.3</td>
<td>1875</td>
</tr>
<tr>
<td>H</td>
<td>305</td>
<td>1912</td>
</tr>
<tr>
<td>I</td>
<td>330</td>
<td>2162</td>
</tr>
</tbody>
</table>

The sample dialogue on the following page shows how to start the computer and run the DIAL DAS OS. This dialogue follows the typical sequence performed during actual flight experiments. Lines followed by comments preceded by two hyphens (--) are user inputs. Lines followed by comments in parentheses are computer responses. The use of some of the DIAL DAS OS commands are shown.
Figure 12. Example of digitizer memory as compared to saved buffer memory.
Sample DIAL DAS dialogue. The dialogue sequence on the following pages is typical of an actual flight experiment. The first two pages show the procedure to align the different returns with each other, which is not necessary to perform on each flight provided the returns are stable. The third page shows the commands necessary to display the returns for optimization, record to tape and perform color maps of aerosol and ozone.
SHOT = 372 AVG = 1
 0 1 2 3 4 5 6 7 8 9
1551 3904 3901 3908 3907 3909 3904 3906 3902 1296 3906
1561 3900 3901 3907 3908 3904 3906 3902 3906 3903 3909
1571 1530 1550 1493 1265 3906 3902 3903 3905 3901 3900
1250 --- TRIGGER MARKERS ON UNIT 2 ARE DELAYED 14 WORDS
?TRELY /3000 --- LOOK FOR LEVEL LESS THAN 3000
?THEK 3 --- RETURN UNIT 2 TO 5 SHOTS; TAKE SINGLE SHOTS UNIT 3
?LIST -3901.159M --- LIST UNIT 3/ONLINE FIRST 30 WORDS
SHOT = 462 AVG = 1
 0 1 2 3 4 5 6 7 8 9
3901 3900 3902 3907 3909 3901 3903 3909 3906 3900 0 0 1
3911 0 0 0 0 0 0 0 0 0 0 0 0
?LIST -6501.653M --- LIST UNIT 3/OFFLINE FIRST 30 WORDS
SHOT = 572 AVG = 1
 0 1 2 3 4 5 6 7 8 9
4501 3904 3901 3908 3907 3909 3904 3906 3902 3900 0 0 0
4511 0 0 0 0 0 0 0 0 0 0 0 0
4521 0 0 0 0 0 0 0 0 0 0 0 0
?TIDLY,0 --- WILL USE ACTUAL LASER FIRING AS MARKER (NO DELAY)
?TRELY /:0 --- WILL LOOK FOR SATURATION ON UNIT 3
(CAN THE POINT THE TRIGGERS ON UNIT 4 SHOULD BE CHECKED, SINCE WE HAVE ONLY 2 LIGHT PIPE OUTPUTS WHICH HAVE BEEN ALREADY BEEN USED ON UNITS 1 AND 2, AND NOT SUFFICIENT PEKCEL NOISE ON THE VISIBL TO USE AS A MARKER, WE MIGHT PROVISIONAL THE MARKERS OF UNIT 1 TO CHECK THE DATA)
?THEK 4 --- RETURN UNIT 3 TO 5 SHOTS; TAKE SINGLE SHOTS ON UNIT 4
?LIST -5901.593M --- LIST UNIT 4/OFFLINE FIRST 30 WORDS
SHOT = 505 AVG = 1
 0 1 2 3 4 5 6 7 8 9
5901 500 502 508 505 501 503 509 500 508 501
5911 500 503 506 502 500 501 509 501 502 1622
5921 1601 1604 1591 523 500 506 504 508 502 503
?LIST -6501.653M --- LIST UNIT 3/OFFLINE FIRST 30 WORDS
SHOT = 527 AVG = 1
 0 1 2 3 4 5 6 7 8 9
6501 504 501 508 507 509 504 500 502 500 509
6511 500 501 504 507 508 504 506 502 503 1609
6521 1530 1550 1493 526 526 526 542 548 545 591 500
?THEK 0 --- RETURN UNIT 4 TO 5 SHOTS
?TIDLY,0/16 --- MARKER IS DELAYED 16 WORDS
?TRELY /:640 --- MARKER MUST BE DELAYED 640
?STOP --- STOP DATA TRANSFER
?SUITE --- UNIT 4 IS TRIGGERING 1 WORD EARLY 50 BY STORING 1 WORD SOONER WE CAN LINE IT UP WITH OTHER UNITS
?START --- RESTART DATA TRANSFER
?INITIAT 15000 --- PLACE AIRCRAFT ALT IN MARKER
?LIST --- LIST OUT NEW MARKER RECORD
... MARKER RECORD ...
TAPE = 1 FILE: 0 HEADER WORDS: 40 DATE: 6/5/77
ALT = 15000 UP/DOWN: 0 SAMP FRE: 10 LIGER FIRE: 9
REP RATE: 5 A_8: CDF: 1318-26 UNWED:1363
UNIT WORDS UNDER START BASE DELAY SPECIES OUTMPS
1 600 600 600 600 0 > 600 5 03 5
2 1350 1350 409 409 < 3000 5 03 5
3 400 400 400 400 0 0 0 5 10 5
4 600 1400 409 409 < 600 5 03 5
A/D CONVERSION CONSTANTS
CHNl SLOPE OFFSET CHNl SLOPE OFFSET
1 1.000 1.000 1.000 1.000
2 15.0 -19.0 2 15.0 -19.0
3 33.0 -19.0 3 33.0 -19.0
4 20.0 -56.0 4 20.0 -56.0
0.0 0.0
?UNIT 1 --- DISPLAY MAIN UV BY ITSELF

53
<table>
<thead>
<tr>
<th>UNIT</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>2</td>
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<tr>
<td>6</td>
<td>1000</td>
</tr>
<tr>
<td>7</td>
<td>1000</td>
</tr>
</tbody>
</table>

**FILE Details:**
- **TAPE**: 1  
- **FILE**: 1  
- **HEADER WORDS**: 40  
- **DATE**: 6/5/77  
- **ALT**: 500  
- **UP/DOWN**: 1  
- **LAM IP**: 10  
- **LAMEN**: 10  

**UNIT Details:**
- **UNIT 1**: 13750  
- **UNIT 2**: 13750  
- **UNIT 3**: 4095  
- **UNIT 4**: 4095  

**CONVERSION CONSTANTS:**
- **CHAIN SLOPE**: 1.000  
- **OFFSET**: 0.000  
- **CHAIN SLOPE**: 0.000  
- **OFFSET**: 0.000  

**SETUP Conditions:**
- **UNIT**: 2  
- **UNIT**: 3  
- **UNIT**: 4  
- **UNIT**: 5  
- **UNIT**: 6  

**Additional Notes:**
- **Applicable settings and data for various units and conditions are detailed in the document.**
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 parameters 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 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. 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. Once the order has been established by the CAMACS command all other commands that have unit numbers as variables will follow that order.

Commands which have been changed or added since last year’s report are denoted by a plus symbol.

Stop Mode Commands

1. Digitizer Storage Commands:

+ WORDS1 U1, U2, U3, U4  # points/return #1 for each unit
+ WORDS2 U1, U2, U3, U4  # points/return #2 for each unit
STORE U1, U2, U3, U4  store from this word for each unit
CAMACS I, J, K, L  station # for Transiacs to be used
+ DATAVG U1, U2, U3, U4  # shots to sum before storage
LOLEG  calls for a number of defaults used during low altitude passes
HILEG  calls up a number of defaults used during high altitude passes
+ WAKEUP I  word separation in digitizer between first and second returns
2. Play-Back Commands:

PLOT I  plot I shots from tape
   if I=-1 plot from memory

3. LSI #2 Program Control Commands:

BOOT SLAVE  boot LSI #2 then run program 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
SYNC  RESET command which returns all units
to their status at power-up time
KILL   synchronize the two computers --used
      when monitor display fails to update
      kill program MASTER and return to Monitor
STACK  record in stacked format the last unit
       at 5 Hz rep rate
SHTSET reset shot counter to zero
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

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)--for altitudes
greater than 32000 use -I/10
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,03,H2O)
BASLINS 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 >
3a. Calibration Constants For Met Data:

ADCH1 I,J,K,L altitude slope (I*10**J) and intercept (K*10**L)
ADCH2 " altitude-radar "
ADCH3 " dewpoint "
ADCH4 " PRT temp "
ADCH5 " total temp "
ADCH6 " Gregory ozone "

3b. Conversion Constants For Laser Energy Data:

EMCH1 I,J,K,L channel 1 slope (I*10**J) and intercept (K*10**L)
EMCH2 " channel 2 "
EMCH3 " channel 3 "
EMCH4 " channel 4 "
EMCH5 " channel 5 "
EMCH6 " channel 6 "

4. Magnetic Tape Commands:

CIPHER I cipher unit # (I=1 or 2)
RECORD write banner and start recording
BANNER write banner
ENDFIL write EDF and stop recording
REWIND rewind tape to BOT
SKPEO 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:

TWEENK I sample and display unit I at rep rate
PLTMOD I select plot mode I (I=0 for no display)
MODE 1 raw data display
MODE 2 on/off line overlay display
OZONE ozone concentration display mode
WATER water vapor concentration display mode
PLTGRY I plot gray scale if I=1
GRYSCG CRT aerosol gray scale display
UNIT I display unit I data only
ONLINE show on-line return only
OFFLINE show off-line return only
BOTH show both on-line and off-line
RETURN U1,U2,U3,U4 plot return # for each unit (both=7)
SCALE I plot scale factor where scale=2**I
YMAX I display range interval (see note #2)
BLOWUP subtract background and blowup to scale=0
OFFSET I offset x-axis by I
CLEAR I clear CRT (O=no clear;1=data only;15=all)
OVRLAY I overlay data from different units if I=1
BGWORD I start word # for background average
BGWIND I  # words to average for background (window)
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)
FIXPNT I  I pixels plotted per data point
UPDATE I  I = 0 update plot and right screen
          I = 1 update plot only
          I = 2 update right screen only
RNGCEL I  use range cell of I meters
GASEXP I  concentrations in parts *10**I
SHFTOA I  shift TOA marker by I words
ATMCOR I  if I=1 correct concentrations for
          altitude change of standard atmosphere
          (this correction not necessary when
          the absorption cross-section is changing
          with altitude as well)
RAYCOR I  Rayleigh correction in same units as
          GASEXP above

6. Aerosol Color-Scale Commands:
+ MAFAE R  start real-time color map of aerosol
+ AEROFF   stop real-time color of aerosol
@EXPAND I  zoom factor (default is 3)
@WHITE I   minimum value of range corrected signal
            -- when it falls below this value it
            will be white
@BLACK I   maximum value of range corrected signal
            -- when it falls above this value it
            will be black
@ALTCOR I  aligns data such that pressure
            altitude ground is at third tic mark from
            bottom
NORMAL I   normalizes return by EO/E where EO
            is first shot energy computed for energy
            monitor channel I and E is the energy of
            that channel on each shot
@CUTOFF I  zero fill data if value greater than I
@MARKER   places a solid black line on plot
@RETURN I  plot the I return (either 1 or 2)
@LABEL I   place time and position every I minutes

The following commands are identical in function as those
listed in the previous section but the "@" preceding each command
directs the action to the color aerosol display on the Act II.
@UNIT @SMOOTH @BGWORD @BGWIND @INDEX @PLTAVG
7. Ozone Color-Scale Commands:

+ MAPUV                   start real-time color map of ozone
+ UVOFF                   stop real-time color of ozone
+ *WHITE                  minimum value of ozone
  -- when it falls below this value it will be white
+ *BLACK                  maximum value of ozone
  -- when it falls above this value it will be black
+ *ALTCOR                 aligns data such that pressure altitude ground is at third tic mark from bottom -- only works for nadir data
+ *LABEL                  place time and position every I minutes

The following commands are identical in function as those listed in the previous section but the "*" preceding each command directs the action to the color ozone display on the Act II.

*UNIT  *BGWORD  *BGWIND  *SMOOTH  *RNGCEL  *PLTAVG
*INDEX  *GASEXP  *SHFTOA  *ATMCOR  *RAYCOR
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