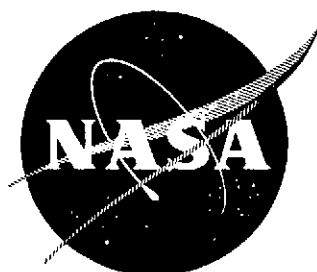


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SYSTEMATIC MONITORING AND EVALUATION OF M7 SCANNER PERFORMANCE AND DATA QUALITY

by

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FORMERLY WILLOW RUN LABORATORIES.
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16. Abstract This report presents the results of an investigation to provide the information required to maintain data quality of the Michigan M7 Multispectral scanner by systematic checks on specific system performance characteristics. Data processing techniques which use calibration data (called "standardization" runs) gathered routinely every mission have been developed to assess current data quality. Significant changes from past data quality are thus identified and attempts made to discover their causes. Procedures for systematic monitoring of scanner data quality are discussed. In the solar reflective region, calculations of NE Δ L (Noise Equivalent Change in Radiance) on a per-mission basis are compared to theoretical tape-recorder limits to provide an estimate of overall scanner performance. M7 signal/noise characteristics (from μ sec to days) are examined. In the thermal region, calculations of NE Δ T (Noise Equivalent Change in Temperature) are used to evaluate scanner performance after each mission. Techniques are developed using the hot, cold, and ambient temperature reference plates to determine if they are working properly. Finally, overall improvements in the processing of radiance calibration data are reported.					
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PREFACE

This report describes part of a comprehensive and continuing program of research concerned with advancing the state-of-the-art in remote sensing of the environment from aircraft and satellites. The research is being carried out for the National Aeronautics and Space Administration (NASA), Lyndon B. Johnson Space Center, Houston, Texas, by the Environmental Research Institute of Michigan (ERIM), formerly the Willow Run Laboratories of The University of Michigan. The basic objective of this multi-disciplinary program is to develop remote sensing as a practical tool to provide the planner and decision-maker with extensive information quickly and economically.

Timely information obtained by remote sensing can be important to such people as the farmer, the city planner, the conservationist, and others concerned with problems such as crop yield and disease, urban land studies and development, water pollution, and forest management. The scope of our program includes (1) extending the understanding of basic processes, (2) discovering new applications, developing advanced remote sensing systems, and improving automatic data processing to extract information in a useful form, and (3) assisting in data collection, processing, and analysis as well as in data verification via ground truth.

The research described herein was performed under NASA Contract NAS 9-9784, Task II, and covers the period from 1 February 1973 through 31 October 1973. Dr. Andrew Potter was Technical Monitor. The program was directed by R. R. Legault, Vice President of ERIM, J. D. Erickson, Principal Investigator and Head of the Information Systems and Analysis Department, and by R. F. Nalepka, Head of the Multispectral Analysis Section. The ERIM number for this report is 190100-23-T.

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CONTENTS

1. Introduction and Summary	7
1.1 Introduction	7
1.2 Summary	7
2. M7 Scanner Noise Characteristics	9
2.1 Low Frequency (Long-Term Signal Stability)	9
2.1.1 Program CALIB.	9
2.1.2 Standardization Runs	12
2.1.3 Establishment of Procedure for Weekly Monitoring	31
2.2 Intermediate Frequency (Several Hours)	31
2.2.1 Program DGNSTC.	31
2.2.2 Evaluation of Data Set	39
2.3 High Frequency (Minutes and Seconds)	46
3. Dark-Level Determination	49
4. M7 Radiance Calibration	55
4.1 Radiance Calibration	55
4.2 Techniques for Lamp Pulse Measurement	55
4.2.1 Summary of Techniques	55
4.2.2 Experimental Determination of Width Constant	59
4.3 Program LAMRAD.	62
4.4 Summary of Calibration Data	65
5. Monitoring of Thermal Data Quality	70
5.1 Program THERML.	70
5.2 Procedure for Checking Thermal Data Quality	71
5.3 NEAT	73
5.4 High and Low Frequency Thermal Noise	76
6. Conclusions and Recommendations	78
Appendix A: Program CALIB.	81
Appendix B: Program DGNSTC.	109
Appendix C: Radiance Calibration	128
Appendix D: Program LAMRAD.	130
Appendix E: Program THERML.	157
Reference	171
Distribution List	172

FIGURES

1. Lamp-Pulse Voltage Versus Reselm Position	11
2. Reference-Lamp Response for Nine Months	14
3. Computerized Reference-Lamp Response for Fifteen Months	16
4. Scanner Voltage Output Versus Time	45
5. Scanner Signals for Reselm Regions	50
6. Relative Positions of Sync and Radiation Sources	51
7. Mean-Level Method of Pulse-Voltage Calculation	58
8. Determining Pulse-Width Constants (K_w)	60
9. Relative Spectral Response of Aged Lamps	67
B.1. Lamp-Pulse Voltage Versus Reselm Position, Simplified	111

TABLES

1. Mission Numbers and Dates	30
2. S-Channel Equivalents for Program CALIB.	32
3. Data Form for Program CALIB.	33
4. Directions for Completing Data Forms for Program CALIB.	35
5. Completed Sample Data Form	36
6. Log of Eaton County, Michigan, Flightlines	40
7. Means and Standard Deviations of Dark Level and Lamp for Five Data Sets over Eaton County. $\lambda = 0.41-0.48 \mu\text{m}$	42
8. Means and Standard Deviations of Dark Level and Lamp for Five Data Sets over Eaton County. $\lambda = 0.55-0.60 \mu\text{m}$	43
9. Means and Standard Deviations of Dark Level and Lamp for Five Data Sets over Eaton County. $\lambda = 2.0-2.6 \mu\text{m}$	44
10. Dark Level Means and Standard Deviations for One Segment of Data over Eaton County	47
11. Summary of Dark Level Average Values for Different Spatial and Spectral Regions in a Single Scan Period	52
12. Summary of Dark Level Average Values for Different Spatial and Spectral Regions Averaged over 100 Scanlines	53
13. Dates of Spectral Radiance Calibration	56
14. Width Constants for a Single Radiance Calibration	61
15. Width Constants for Several Radiance Calibrations	63
16. Summary of Radiance Calibration Information for Channel C10	66
17. Relative Spectral Response Factor	69
18. Calculated Plate Temperature Compared to Measured Plate Temperature	72
19. Summary of NEAT Values over Time	75

SYSTEMATIC MONITORING AND EVALUATION OF M7 SCANNER PERFORMANCE AND DATA QUALITY

1

INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

The purpose of this study is to establish and monitor the performance of the multispectral scanner operated by ERIM as an aid in the processing of data gathered as part of NASA's Earth Resources Program. Our goal is not simply to perform radiance calibrations and provide quantitative measurements by which users can extract radiance information. Rather, it is to investigate the temporal variations and overall uncertainties in scanner performance characteristics in order to meet data processing and interpretation requirements. Those areas potentially most helpful in improving data processing capabilities are emphasized. Efforts are also being made to improve radiance calibration techniques (including more efficient data reduction).

1.2 SUMMARY

Many users of remote sensing data gathered by the M7 scanner system are interested in extending spectral classification and mapping capabilities from one flightline to another, even when such lines are flown days apart. Such a capability obviously offers tremendous savings in manpower (including ground truthing teams) as well as in data processing time. In most cases, however, attempts to recognize objects in one flightline using signatures and decision rules generated from another line (even with flightlines only several minutes apart) have been characterized by significant decreases in the percentages of objects correctly classified.

From the viewpoint of the data processor, it would be very helpful to know the magnitude of the scanner-associated signal variations one might expect during the course of a three- or four-hour mission. Information on longer-term signal variations covering three or four months would also be helpful. By knowing all the kinds of signal variations and their characteristics to be encountered over long periods of time—including scanner, atmospheric, and seasonal changes—the processor has a better chance of extending object classification capabilities from one flightline to another.

Toward answering the question of short- and long-term scanner signal variations, one of the approaches we used was to analyze the so-called "standardization" tests conducted periodically in the course of normal data collection over the past year and one-half. These tests were devised originally to indicate changes in system response. Forty tests, covering the periods 5 May 1972 to 25 January 1973 and 22 June to 12 August 1973, were analyzed with a program

called CALIB., which was written expressly for the purpose of calculating a set of statistics concerning the solar reflective reference sources of the M7 scanner. General characteristics of the M7 scanner are documented in [1]. Some of these statistics, plotted by the computer as graphs of mean signal voltage versus test date, showed that under normal circumstances, standard deviations of the mean lamp signal amounting to not more than 10% could be expected over several months and that in most cases the figure was less than 5%. A few instances of much larger changes were noted but these were under unusual circumstances, as we will discuss later.

Since these standardization tests are planned to serve as continuing indicators of scanner performance, a system for rapid, computerized data reduction was designed. Once implemented, this system will enable one-day retrieval of desired data on the performance characteristics as determined in the standardization tests.

Also completed during this study were three other programs designed to help determine the impact of scanner signal variation and calibration on data processing. One of these programs, THERML., provides a set of statistics on thermal reference sources as a function of time—much as the program CALIB. does in the solar reflective. NE Δ Ts* for the hot, cold, and ambient reference plates were calculated and compared as a function of time to qualitatively assess thermal data performance. In addition, a new technique for evaluating the accuracy of temperature calibration was perfected using THERML. output. Also, we made a quantitative analysis of the frequency content of the thermal channel by using the output of another program called DGNSTC. The results of this study indicated that a line-by-line dynamic temperature calibration was necessary to minimize errors resulting from noise. DGNSTC. was also used to determine the darkest region in the scanner's field-of-view and thus permit uniform baseline corrections for all processors of M7 data.

The last program, called LAMRAD., was written to automatically calculate M7 scanner radiance calibration constants for each spectral channel. New methods employed in this subroutine greatly improved the signal-to-noise ratio of the scanner signals as compared to old techniques. NE Δ Ls* (radiance) were also calculated by LAMRAD.

*Noise Equivalent Temperature Difference, defined later in Section 5.3.

M7 SCANNER NOISE CHARACTERISTICS (SOLAR REFLECTIVE REGION)

Noise figures for the M7 multispectral scanner (and, for that matter, any scanner) have much more value than just indicating system performance. It is true that noise level monitoring does help indicate overall system performance; but to data processing personnel, noise figures—especially the frequency content of the noise—can provide enlightening information as to which noise in the data is of sensor origin, and which results from other physical phenomena. Such significant discrimination must be achieved if optimal use is to be made of remotely sensed data. It is questionable at this stage in technique development, especially in data collected over agricultural areas, as to whether some of the signal variation problems encountered stem primarily from the scanner or from changes in the scene. In all probability, it is some combination of the two. The remainder of this section is aimed at classifying the different types of noise to be expected from the scanner. The noise is evaluated over different time intervals to help the data processor analyze specific problem areas, such as apparent effects during one scanline (high frequency noise) and during signature extensions (low frequency noise).

2.1 LOW FREQUENCY (LONG-TERM SIGNAL STABILITY)

Low frequency noise, as analyzed in this section, means signal variations in the M7 over a period on the order of days and weeks. During this length of time (days to even months), some changes in the optics, reference lamp spectral characteristics, and detector response are to be expected. Our main concern in observing such signal variations was to determine the frequency and amplitude of the changes as an indicator of system performance. Of secondary interest was the possibility that signature extension of data from one flight to the next several weeks later may be attempted in the near future.

2.1.1 PROGRAM CALIB.

The purpose of program CALIB. is to permit quick data handling and analysis of the standardization test performed routinely on most data-collection missions (see next section).

This program calculates the following set of statistics:

- (a) mean and standard deviation of the dark level (in absolute volts)
- (b) mean and standard deviation of the lamp pulse level (in volts relative to dark level)
- (c) mean and standard deviation of the middle reselm level in the lamp pulse (in volts relative to dark level)
- (d) mean and standard deviation of the position of the lamp pulse (average of 50% points in dark-level-corrected lamp pulses)

- (e) mean and standard deviation of the integral of the solar reference pulse (in volt-reselms relative to the dark level).

All voltages will have been initially adjusted to correct for any gain changes. A table of all five sets of statistics is printed out, as well as a plot of the mean voltage and standard deviation of (a), (b), and (c) above versus standardization run number. Since these standardization runs occur days or weeks apart, the plots effectively indicate the scanner response versus time relationship. One of the desirable features of this plot routine is the capability of storing previously calculated standardization data on a special tape data base for updating as new data are gathered. Hence, whenever CALIB. is run on a standardization data set (or sets), output from that last set (or sets) is plotted along with all previously acquired data. An updated history of scanner response over any desired length of time is available for immediate analysis—subject, of course, to keeping the standardization tests current. A procedure for achieving rapid data reduction and thus fast turn-around time for these tests is discussed later.

Other innovative features of the CALIB. program include new methods to calculate lamp and sky reference values.* A common method in the past was to obtain a histogram of the lamp pulse over all the scanlines in the data set. The reselm corresponding to the peak lamp voltage from the histogram was then chosen as the point on the pulse to use on all channels. Unfortunately, when skewing errors are present, a single reselm cannot describe the position of the pulse peak on all channels simultaneously. Also, if tape jitter is present, the position of the lamp peak will shift from line to line by nearly the amount of the jitter. For jitter of more than 1 or 2 reselms, a single reselm will not describe exactly the peak lamp voltage. One of the techniques being used in this program to determine the lamp pulse voltage level is given below (also see Fig. 1):

- (a) first, the maximum (MAX) magnitude of the lamp signal is found (this may, unfortunately, include noise spikes)
- (b) next, the reselms closest to $\text{MAX}/2$ are found (points X and Y defining the 50% points)
- (c) then, the middle reselm $\frac{X+Y}{2}$ is calculated
- (d) bounds on the area of the lamp plateau used for the level determination are then set on either side of $\frac{X+Y}{2}$; any odd number of reselms (called TOP) can be used; the plateau bounds are $\pm(\text{TOP}-1)/2$; TOP must be an odd number to permit symmetric bounds.

For purposes of our test, TOP was set at 5 reselms (although any reasonable width could have been used). The default case was also set at 5 reselms.

*A typical scanline is depicted in Section 3.

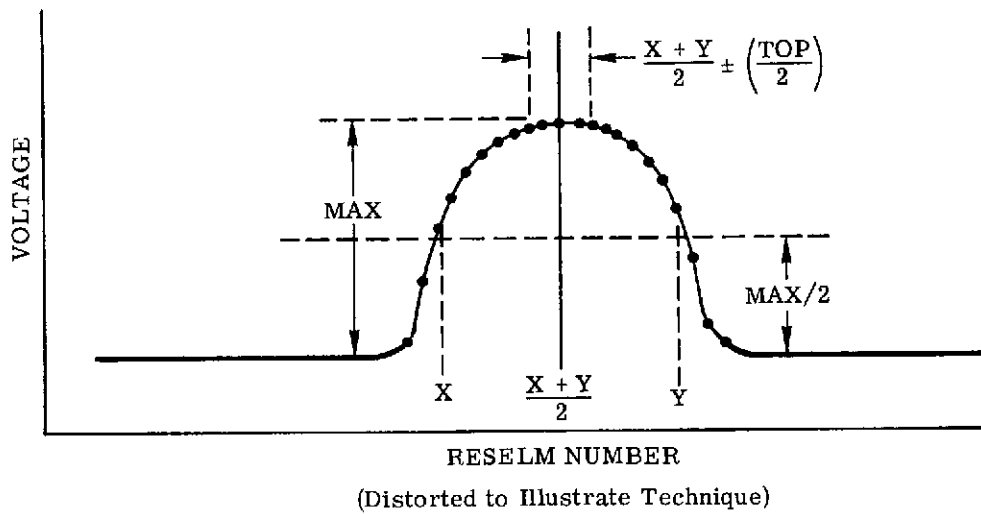


FIGURE 1. LAMP-PULSE VOLTAGE VERSUS RESELM POSITION

An advantage of the technique outlined above is that it is independent of any lamp jitter present in the data. Also, it can reveal the amount of jitter present by calculating the standard deviation of the middle lamp reselm $(X + Y)/2$ position. There are several disadvantages, however. It is subject to possible error resulting from large noise spikes in the flat area of the pulse. Calculations of the 50% points, if based on a noise spike maximum, would be wrong. Moreover, only a few data points per line (typically five) are available for statistical calculations. Hence the standard deviation is larger than need be. In addition, both of these disadvantages are compounded with the present scheme for determining lamp voltage levels. Such problems may be overcome, however, by means of a new technique using integration; it is outlined below for the sky reference, and will be analyzed in more depth in the section on program LAMRAD. The advantage of integrating is that many more points per line are available for statistical averaging. This greatly improves signal-to-noise, and noise spikes do not cause the problems they do in the present system.

The integration technique mentioned above was initiated primarily because of the geometrical constraints imposed on the present sky reference. The pulse shape from the scanner is triangular instead of nearly square—as the lamp pulse is. Hence, the maximum value of the signal is defined by at most one or two points; this makes it almost impossible to obtain an accurate measurement. With integration, the value of each and every dark-level-corrected reselm making up the pulse is summed. The resulting sum is a number proportional to the maximum or peak value (since the width of the pulse is fixed by the geometry of the sensor). Actually, a number close to the real maximum value can be obtained simply by dividing the integrated value by the half-width (or some other representative width).

In practice, the region integrated is much larger than the pulse itself. This allows for pulse movements by reason of tape or scanner jitter. Since all the values are dark-level corrected, any reselms falling outside the pulse but inside the integration region will contribute nothing to the integral. Note that tape and scanner jitter do affect the integral approach since tape speed variations cause some fluctuations in pulse width. However, the magnitude of error from jitter is considerably smaller than those errors associated with current methods of determining lamp pulse voltages. A complete, detailed description of the program CALIB (including a program listing) may be found in Appendix A.

2.1.2 STANDARDIZATION RUNS

During the time of this study, 40 standardization data sets, covering three distinct periods from 5 May 1972 to 25 January 1973, and a fourth from 22 June to 12 August 1973 were digitized and the data analyzed by the program CALIB. No data were digitized from 26 January through 21 June because of limited time and funds.

These standardization data sets were digitized so we would have a basis for comparing scanner response from one mission to the next. To achieve this, we adopted a standardized procedure for recording reference lamp voltage approximately once every mission. The procedure uses a fixed lamp current setting and fixed amplifier gains. Assuming no amplifier gain changes and no spectral or irradiance changes in the reference lamp (reasonable assumptions over several months), a shift in lamp voltage must indicate a change in overall system response. These changes, then, are basically the quantities being analyzed by the program CALIB.

As it turned out, fixed amplifier gains were not maintained over the time periods of interest. Changes in some system components required that different gains be used. For this reason, the gains were compensated for by CALIB. Shown in Fig. 2 are plots of lamp response versus time for each spectral channel available (except thermal) covering only the first three time periods mentioned above. The computer plots shown in Figs. 3(a - n) give a more detailed look at response for each channel. The overall time frame spanned in these detailed plots includes these three time periods plus a fourth which covers the most recent months of scanner operation. It should be noted that these response values are plotted against mission number. The date of each mission is indicated in Table 1. As mentioned, the data covers four main periods of scanner operation.

The first period covers the months of May and June 1972 which were bracketed between major scanner maintenance during the winter and performance tests the following July. As can be seen from the plots, absolute system response does vary somewhat during this period, although the standard deviation of the mean response goes from a maximum of 10% in channel C10 (0.46-0.49 μm) to only 3% in C6 (0.55-0.60 μm). It should be noted, however, that even though the overall response may have varied as much as 10% over a two-month interval, the variations observed over one-day intervals (by two missions flown on the same day or, at most, on the next day) showed variations typically on the order of 2% or less. Hence, evidence from past data indicates a high degree of short-term (and here we mean one day or less) stability.

Note from Fig. 2 that some degree of total spectral response shifts is indicated by the graph. For instance, all channels except C10 show a decrease in response between 4 May 1972 and 5 May 1972; likewise, a decrease between 11 May and 12 May 1972 is noted for most of the channels. It is obvious, however, that not all channels change in the same direction all the time. A major exception is channel C8, which had a PM tube replaced midway during this period—the change there is obvious.

The second period covered by this data set occurs during the months of July and August, 1973, at a time when the scanner was undergoing a series of bench performance checks. We discovered in these checks that the lamp housing containing the secondary radiance standard

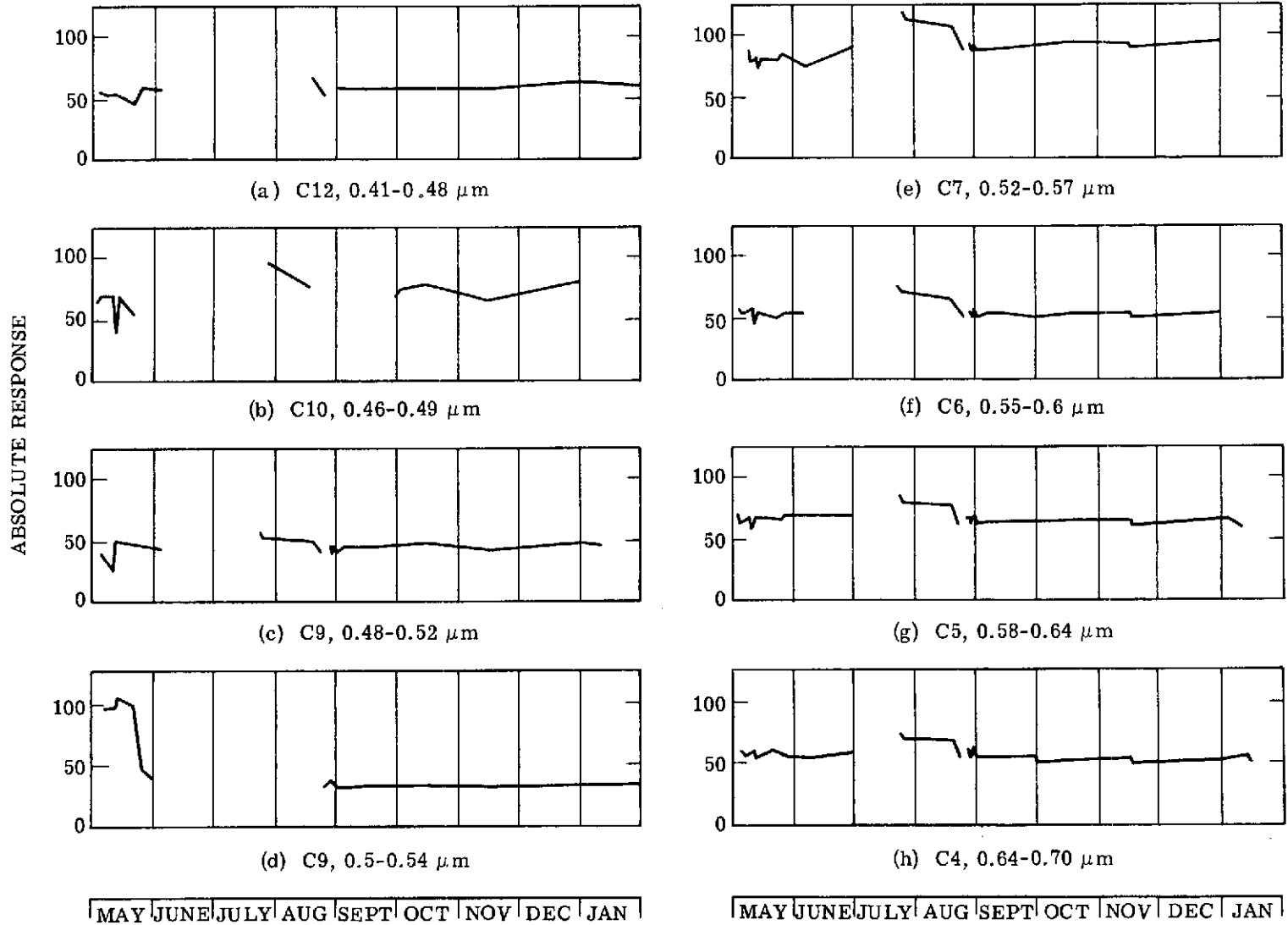


FIGURE 2. REFERENCE-LAMP RESPONSE FOR NINE MONTHS (Continued)

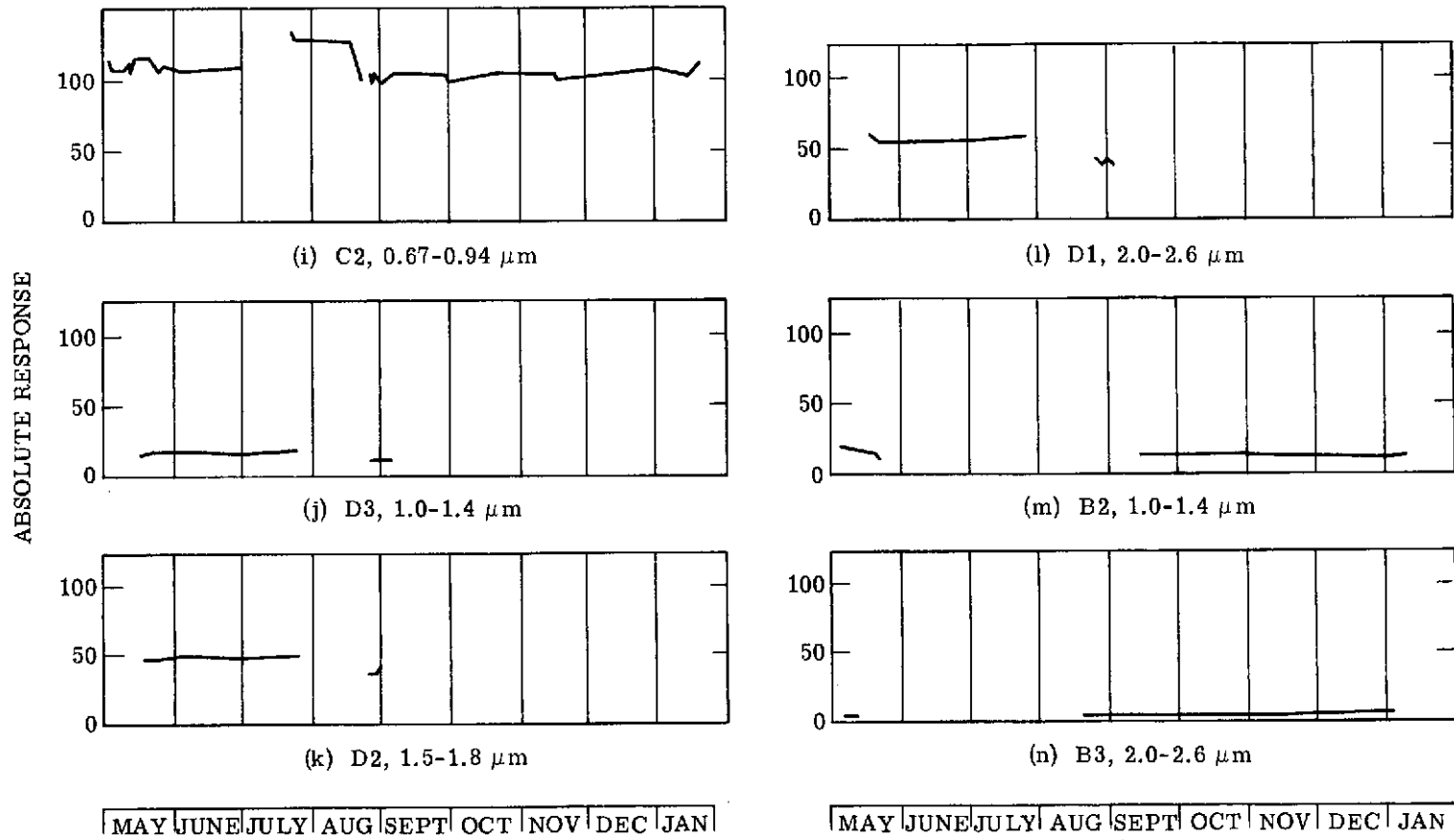


FIGURE 2. REFERENCE-LAMP RESPONSE FOR NINE MONTHS (Concluded)

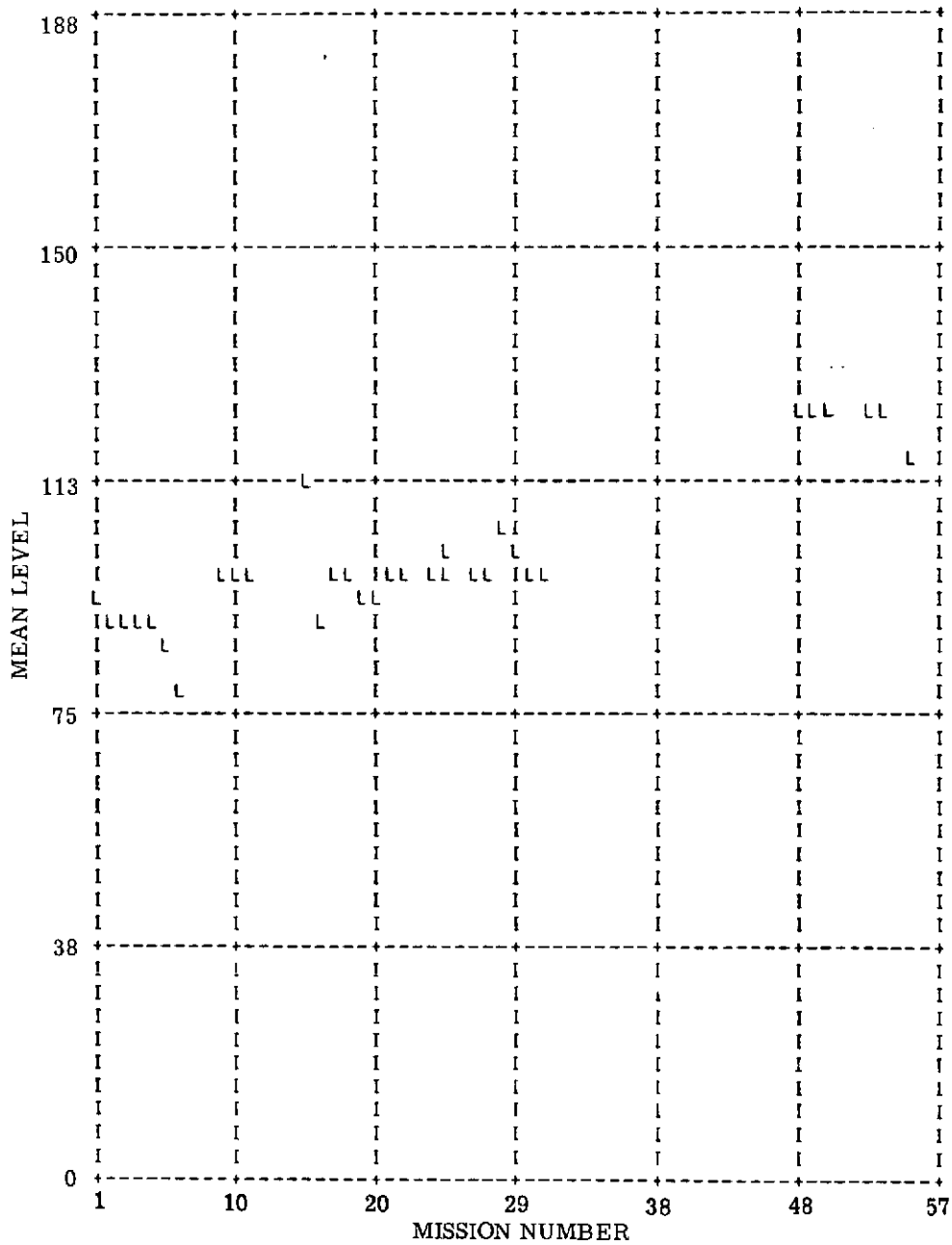

 (a) C12, 0.41-0.48 μm

FIGURE 3. COMPUTERIZED REFERENCE-LAMP RESPONSE FOR FIFTEEN MONTHS (Continued)

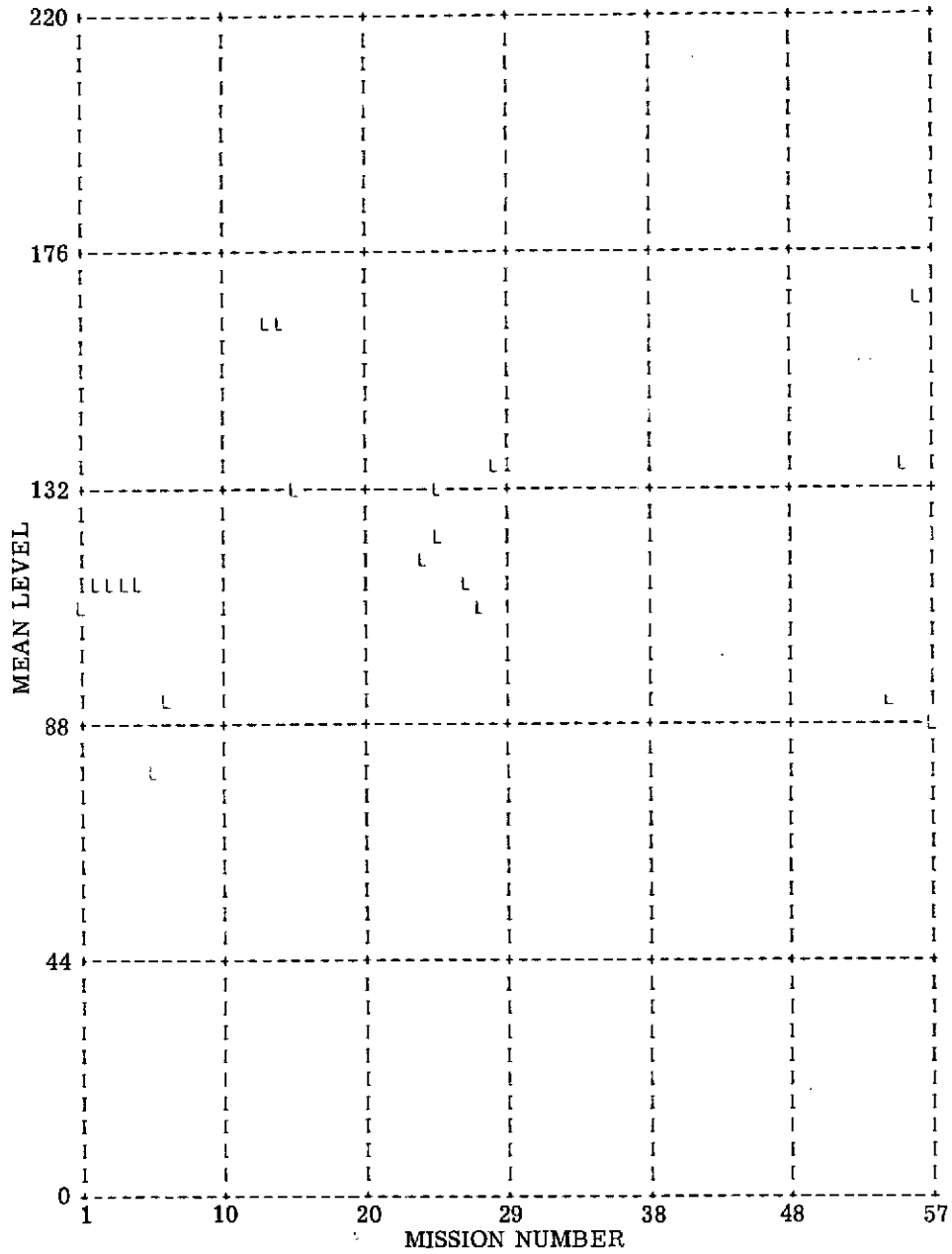

 (b) C10, 0.46-0.49 μm

FIGURE 3. COMPUTERIZED REFERENCE-LAMP RESPONSE FOR FIFTEEN MONTHS (Continued)

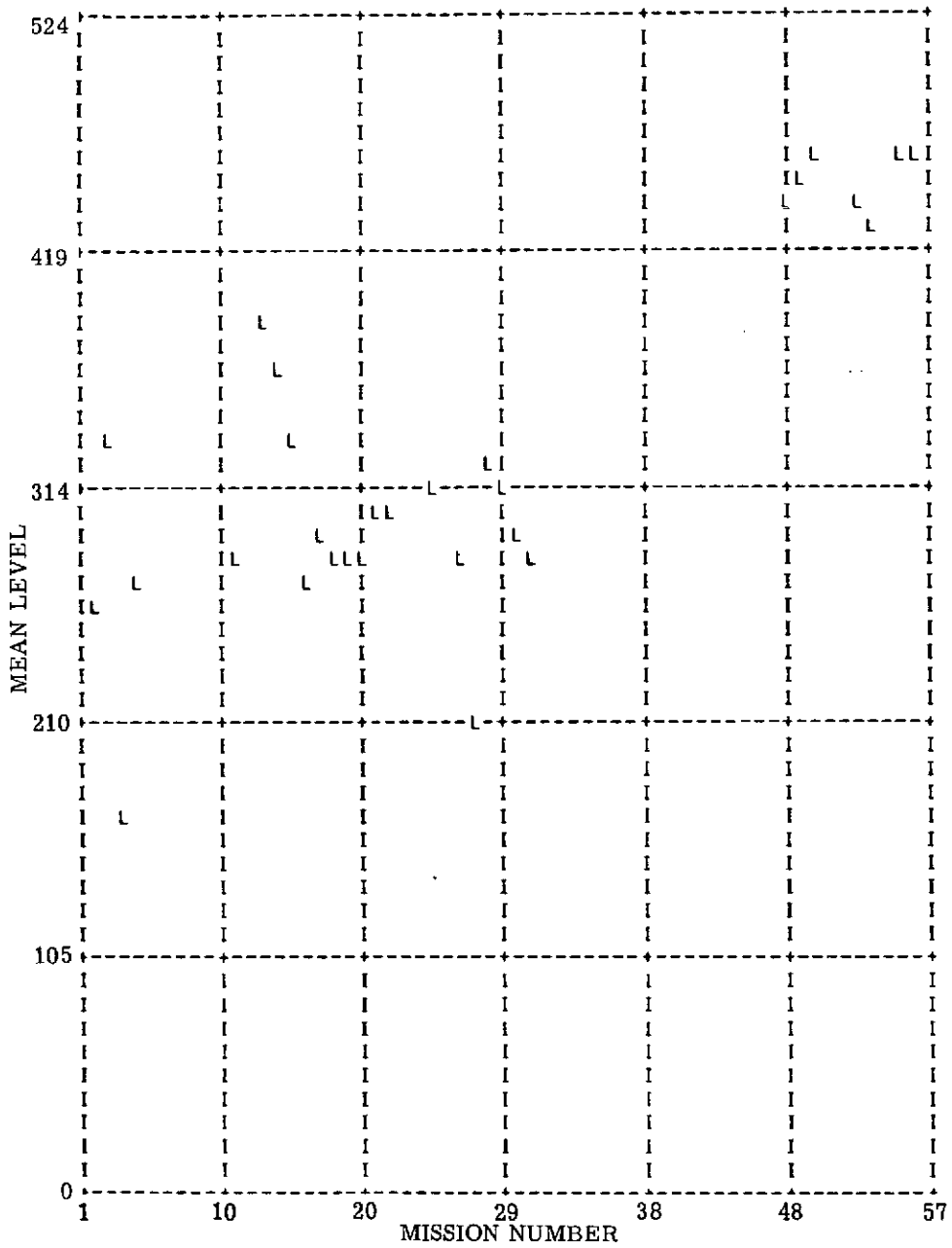
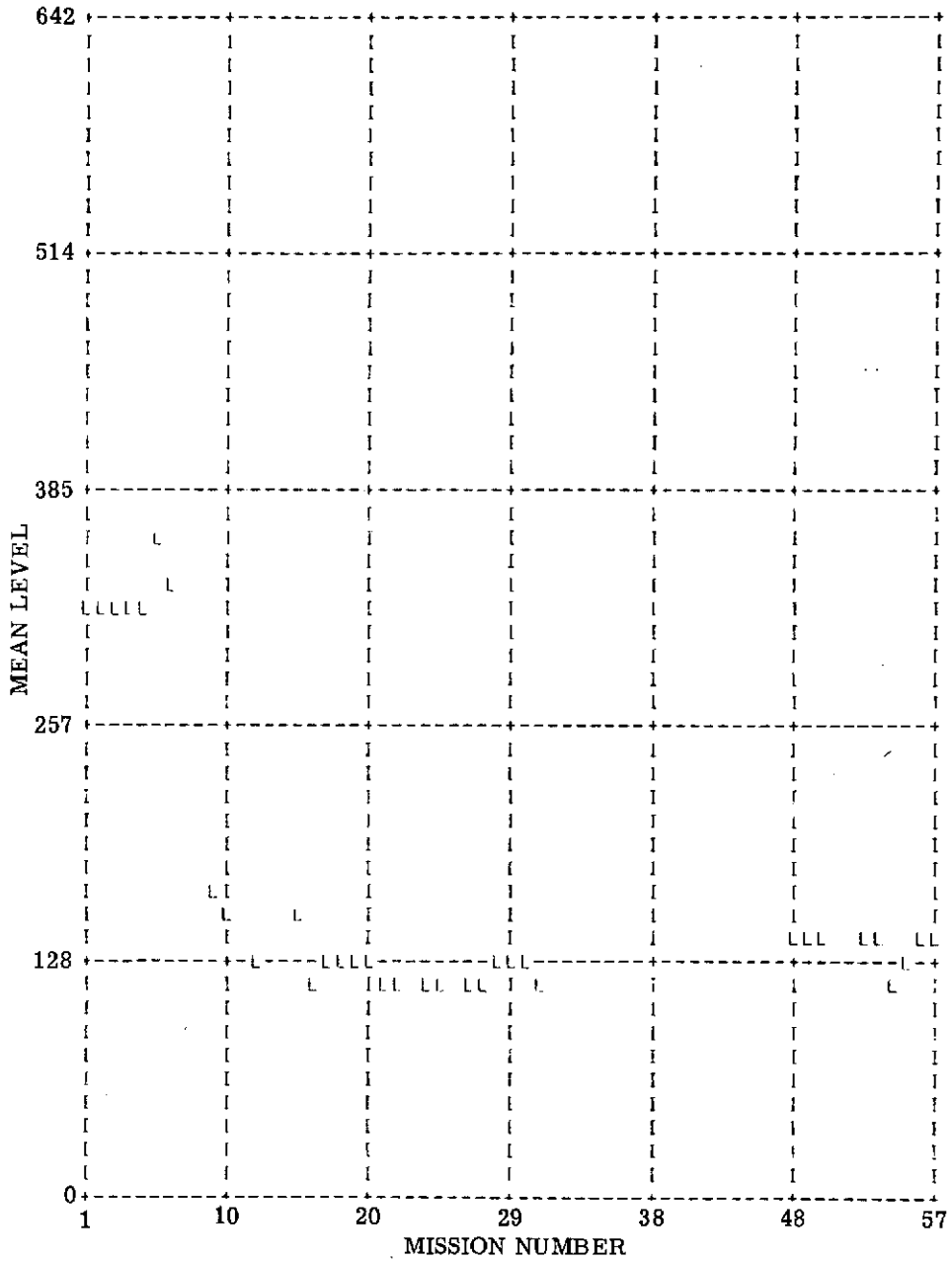

 (c) C9, 0.48-0.52 μm

FIGURE 3. COMPUTERIZED REFERENCE-LAMP RESPONSE FOR FIFTEEN MONTHS (Continued)



(d) C8, 0.50-0.54 μm

FIGURE 3. COMPUTERIZED REFERENCE-LAMP RESPONSE FOR FIFTEEN MONTHS (Continued)

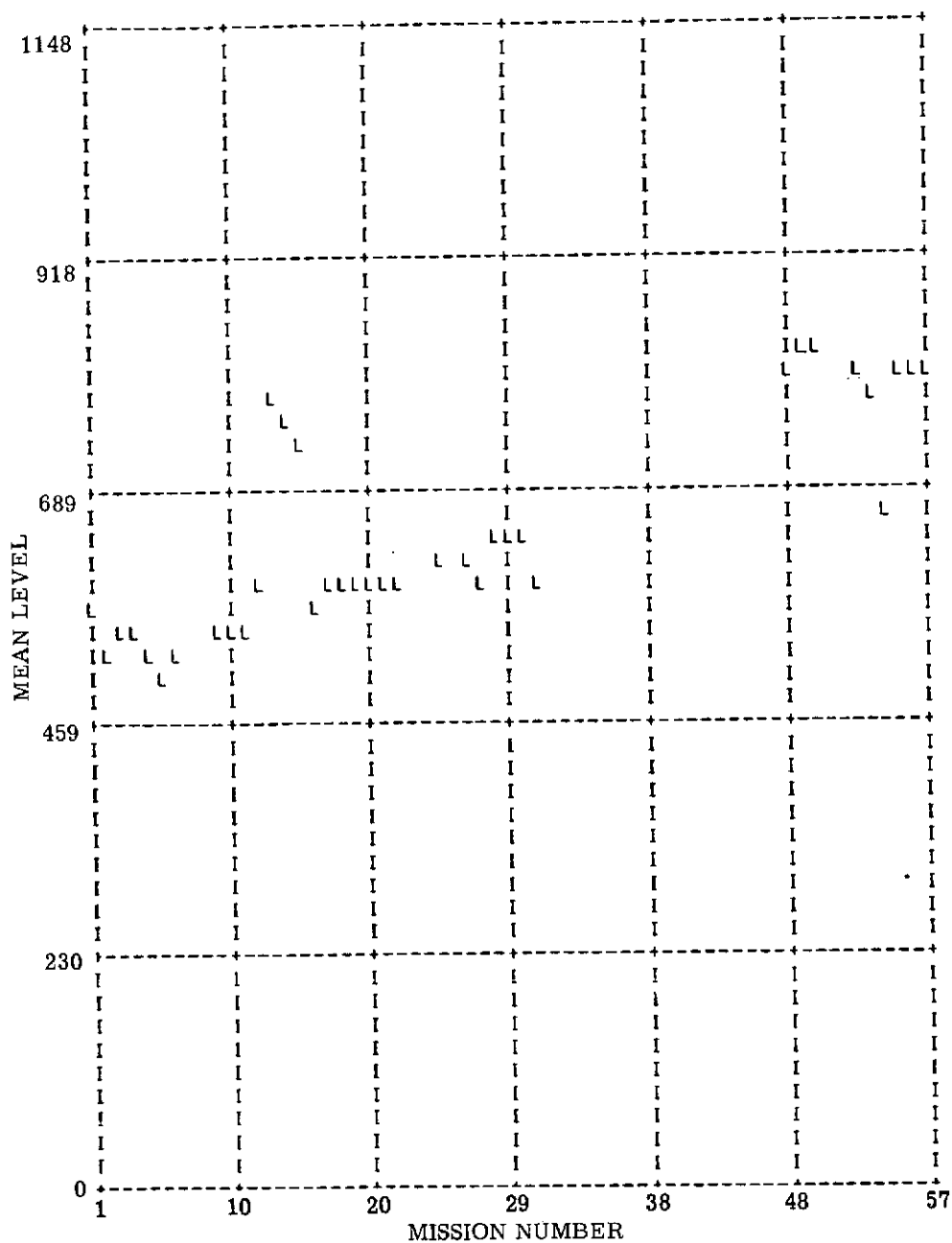

 (e) C7, 0.52-0.57 μm

FIGURE 3. COMPUTERIZED REFERENCE-LAMP RESPONSE FOR FIFTEEN MONTHS (Continued)

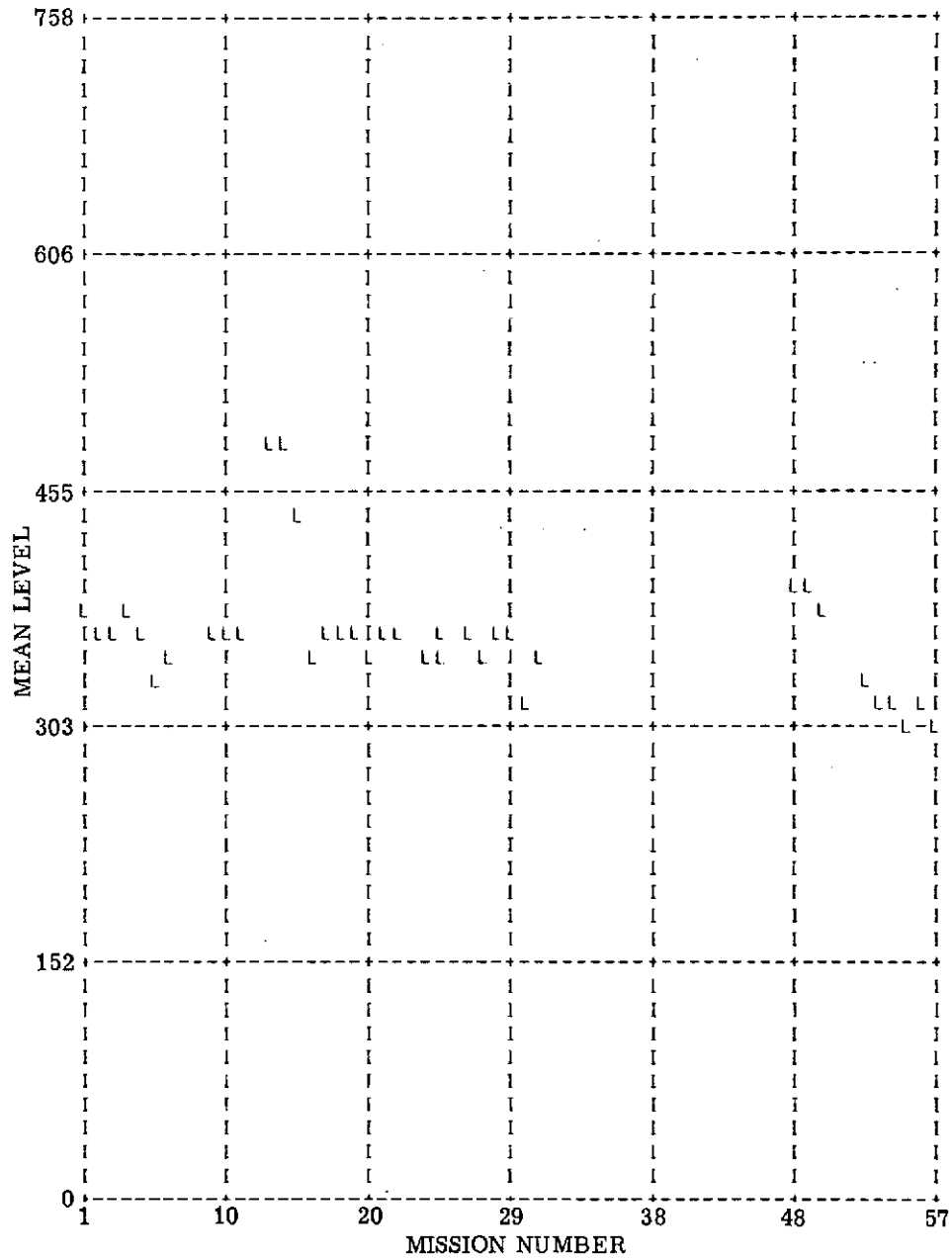
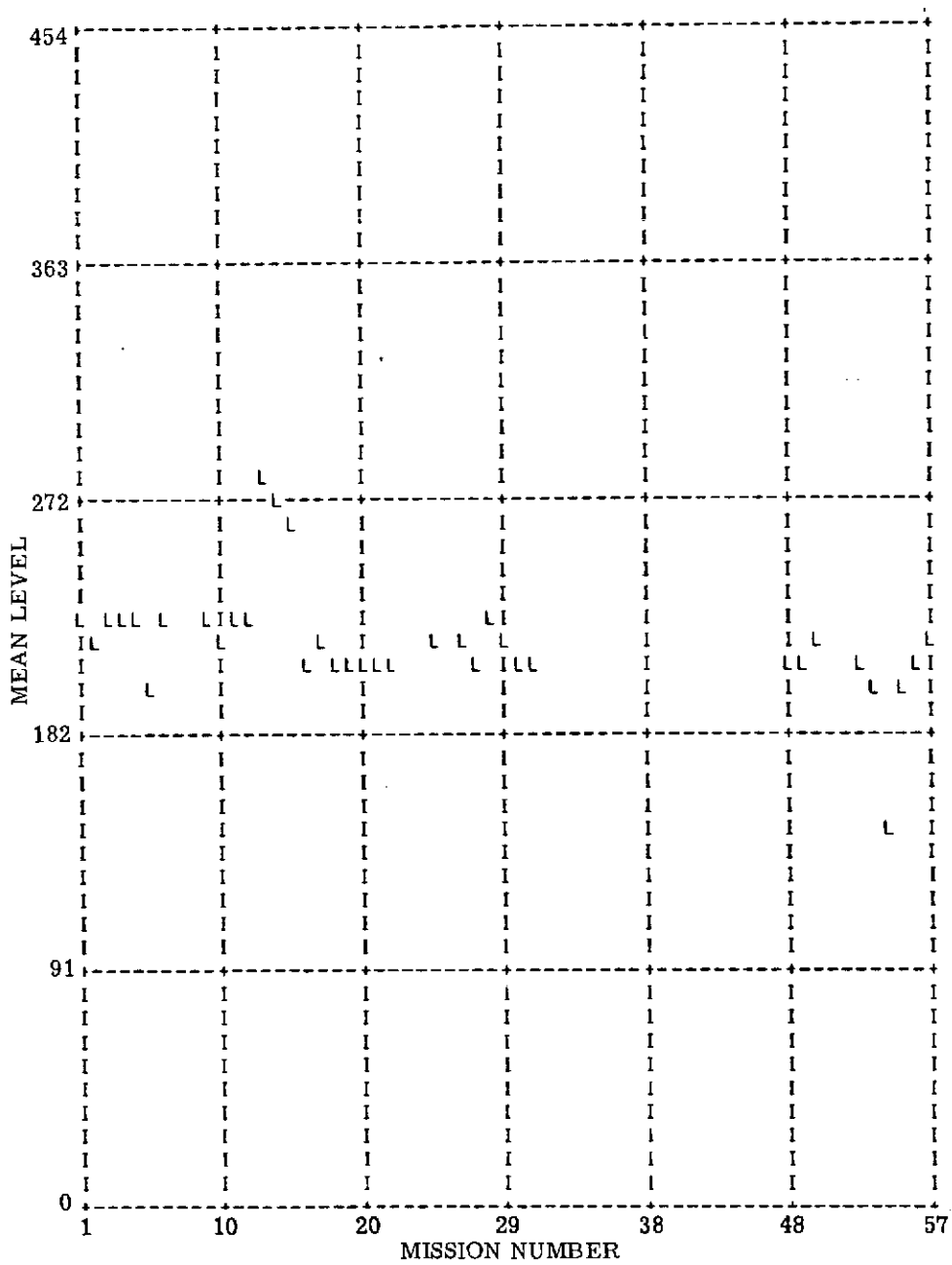
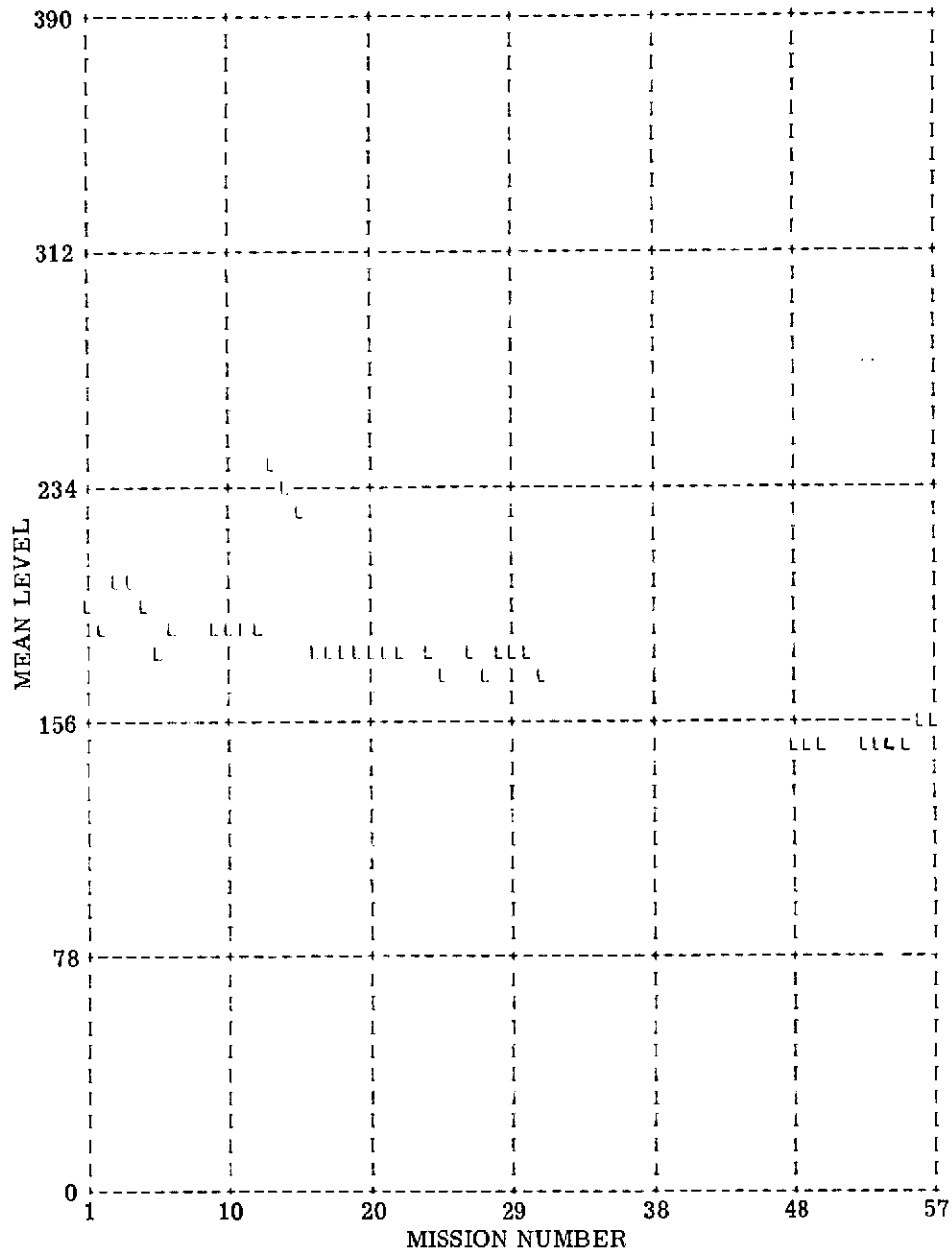

 (f) C6, 0.55-0.60 μm

FIGURE 3. COMPUTERIZED REFERENCE-LAMP RESPONSE FOR FIFTEEN MONTHS (Continued)



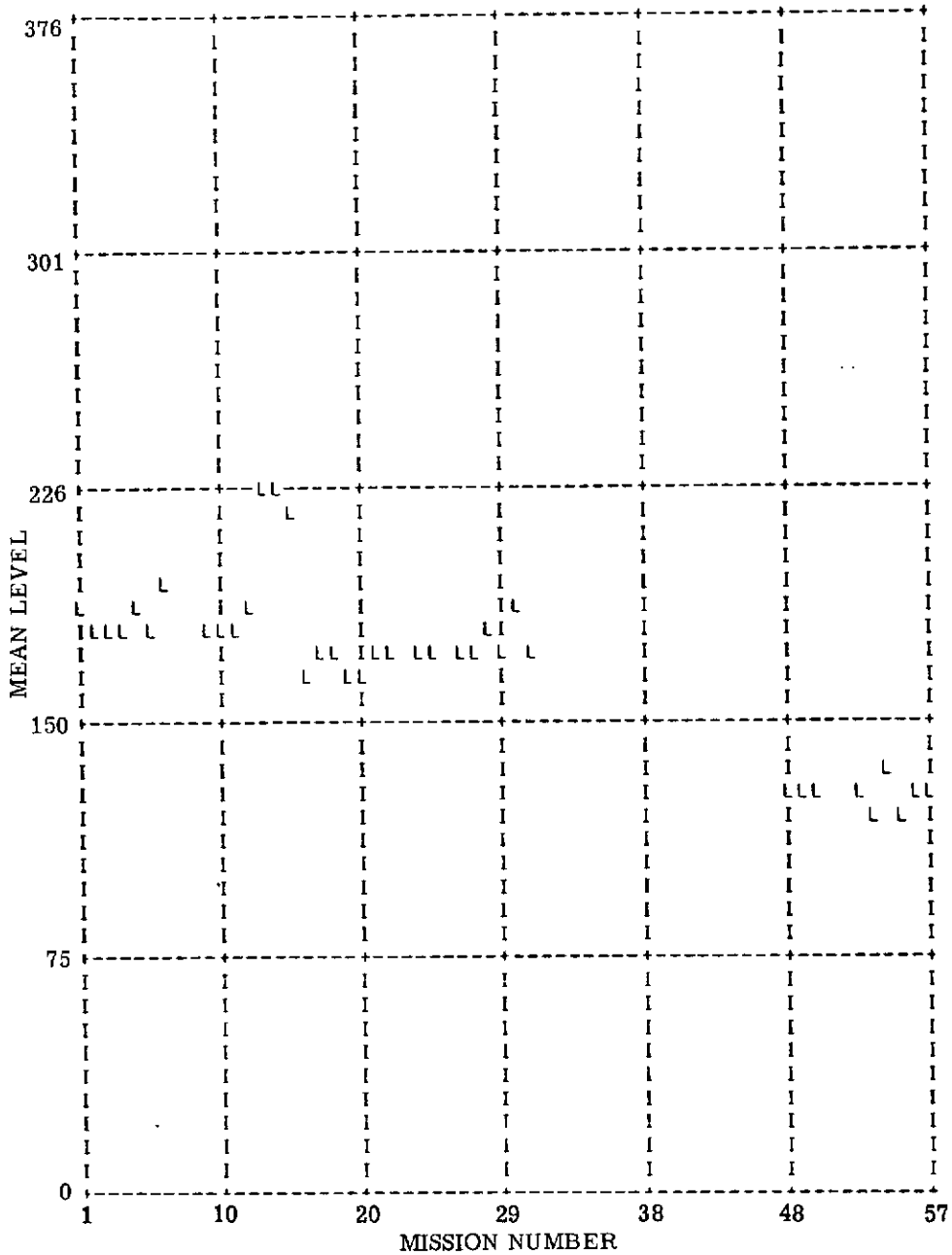
(g) C5, 0.58-0.64 μ m

FIGURE 3. COMPUTERIZED REFERENCE-LAMP RESPONSE FOR FIFTEEN MONTHS (Continued)



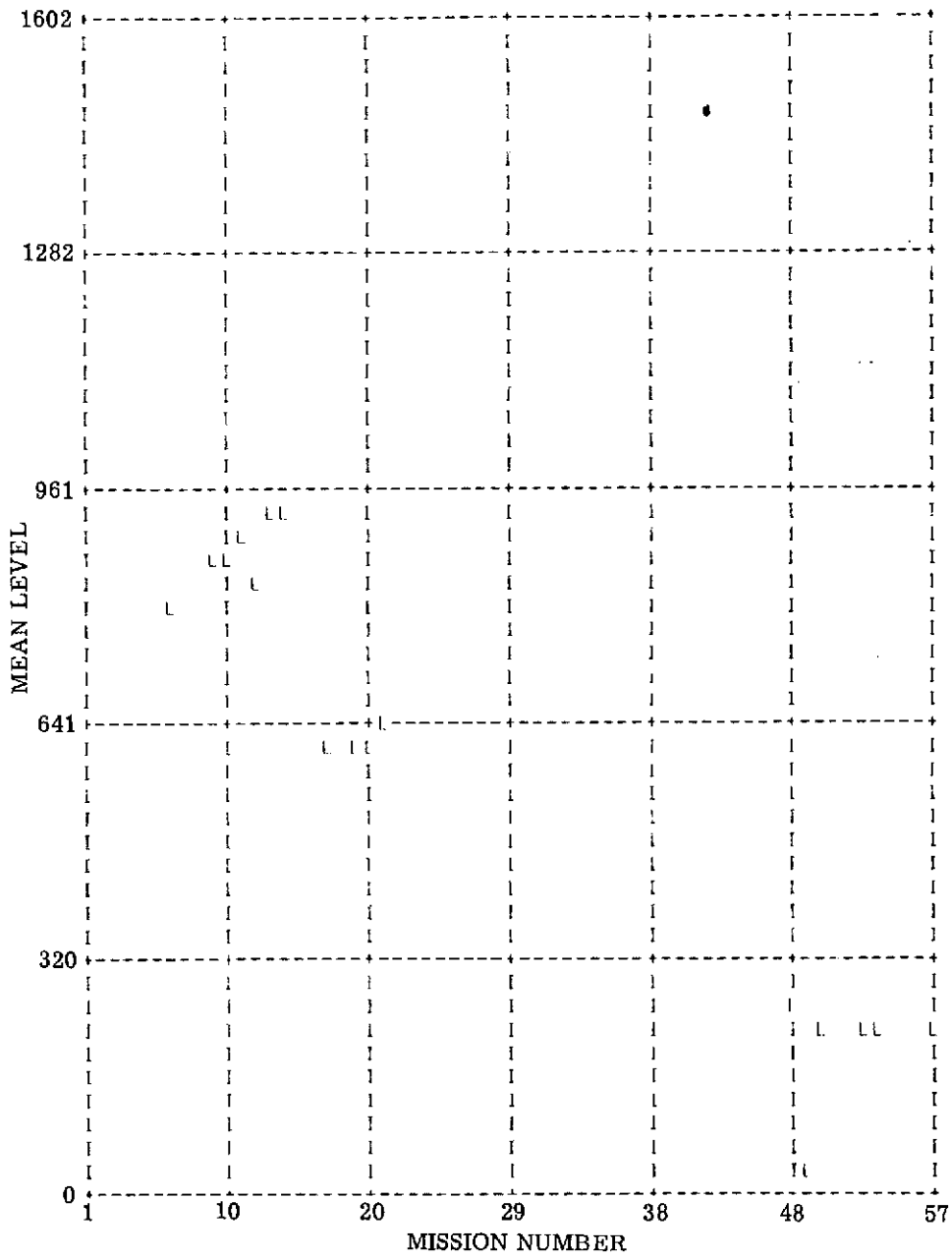
(h) C4, 0.62-0.70 μm

FIGURE 3. COMPUTERIZED REFERENCE-LAMP RESPONSE FOR FIFTEEN MONTHS (Continued)



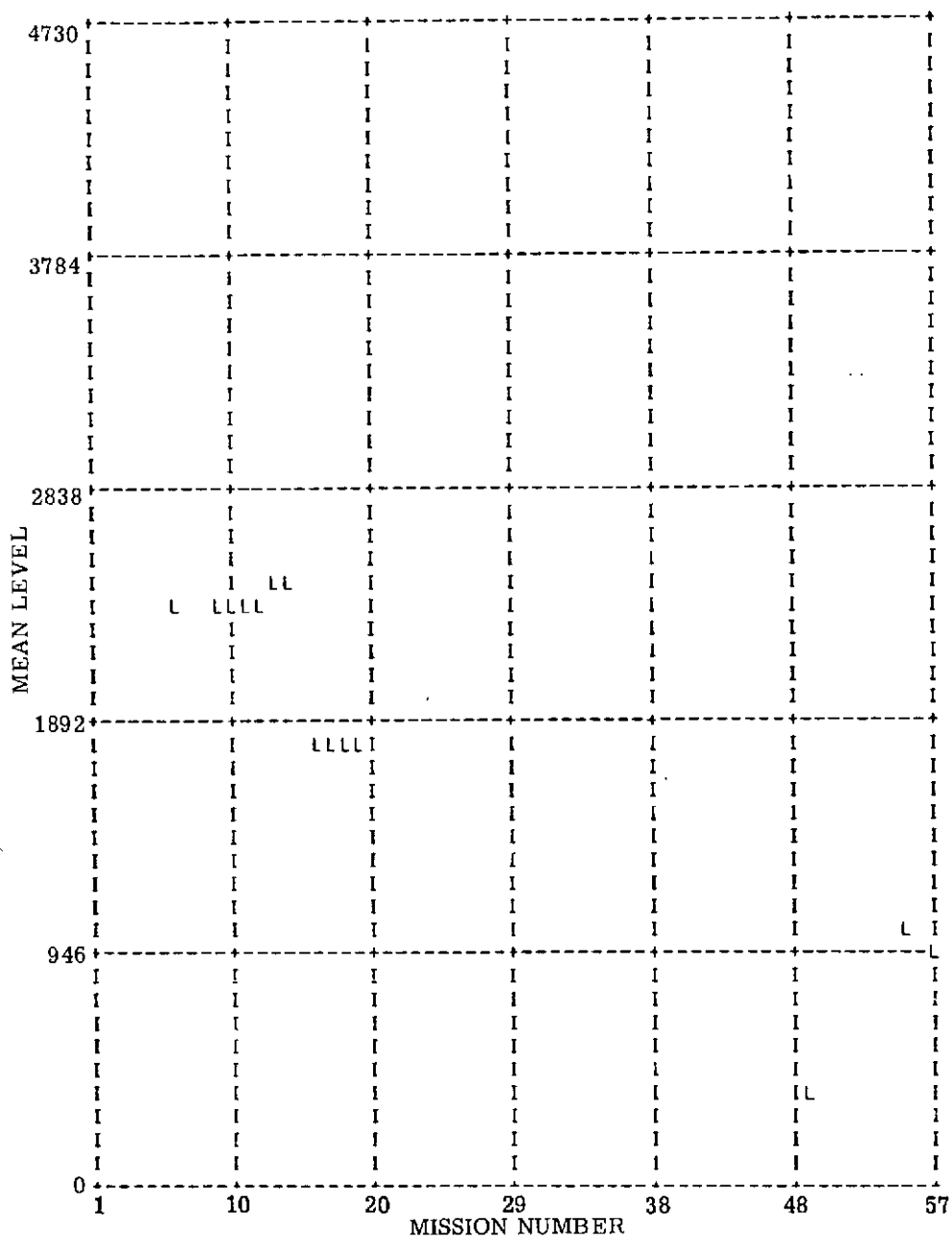
(i) C2, 0.67-0.94 μm

FIGURE 3. COMPUTERIZED REFERENCE-LAMP RESPONSE FOR FIFTEEN MONTHS (Continued)



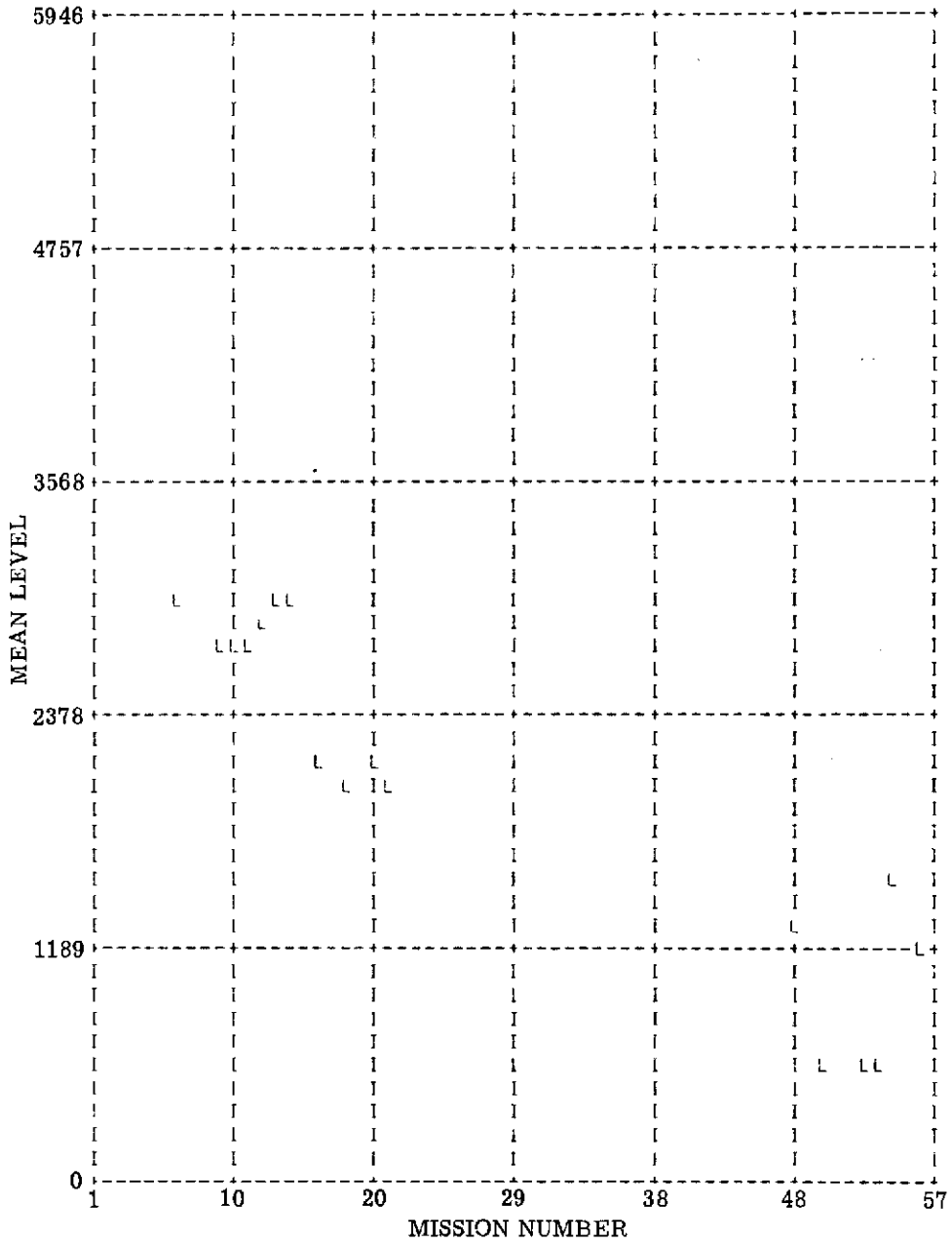
(j) D3, 1.0-1.4 μm

FIGURE 3. COMPUTERIZED REFERENCE-LAMP RESPONSE FOR FIFTEEN MONTHS (Continued)



(k) D2, 1.5-1.8 μm

FIGURE 3. COMPUTERIZED REFERENCE-LAMP RESPONSE FOR FIFTEEN MONTHS (Continued)



(1) D1, 2.0-2.6 μm

FIGURE 3. COMPUTERIZED REFERENCE-LAMP RESPONSE FOR FIFTEEN MONTHS (Continued)

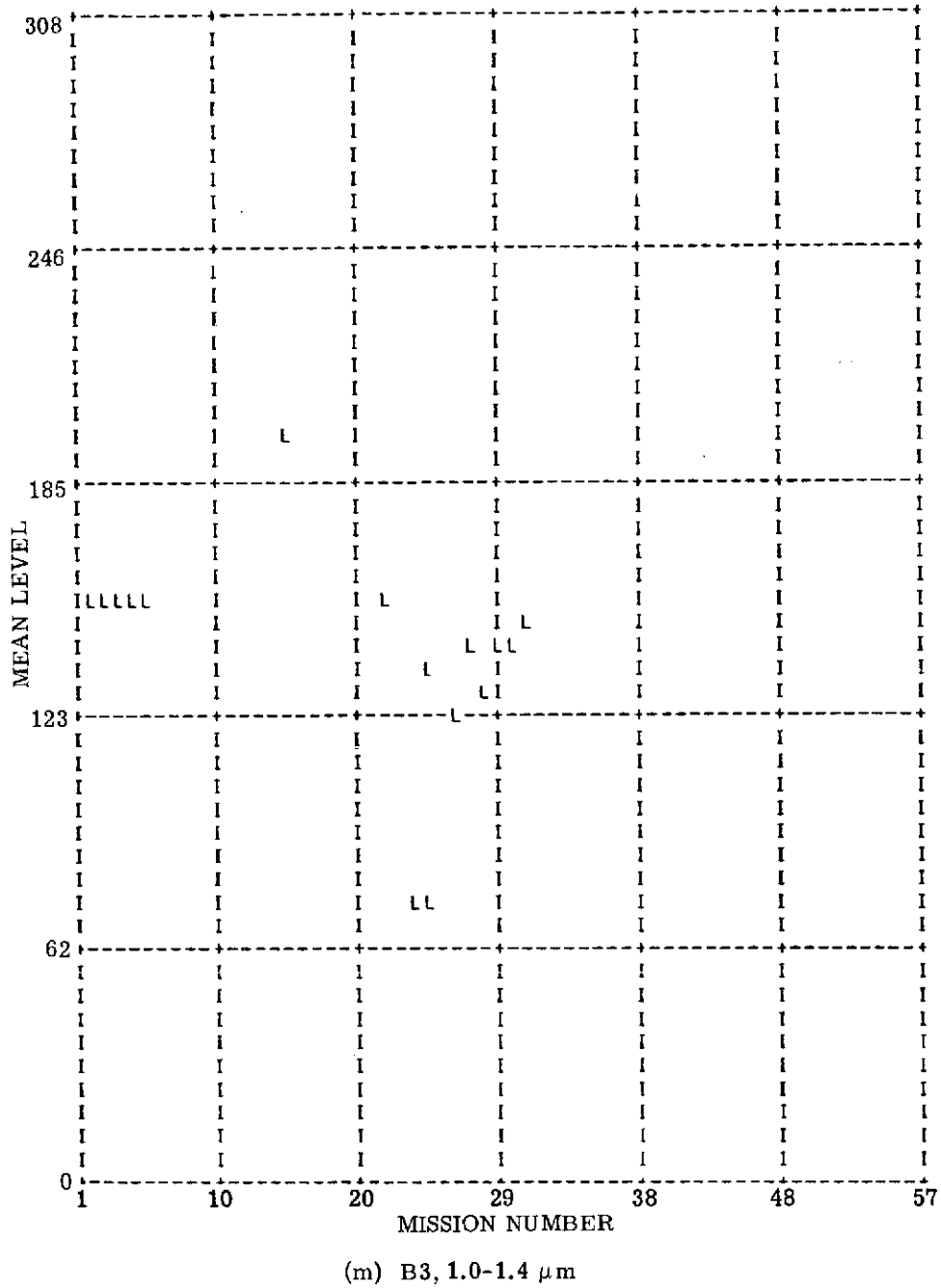
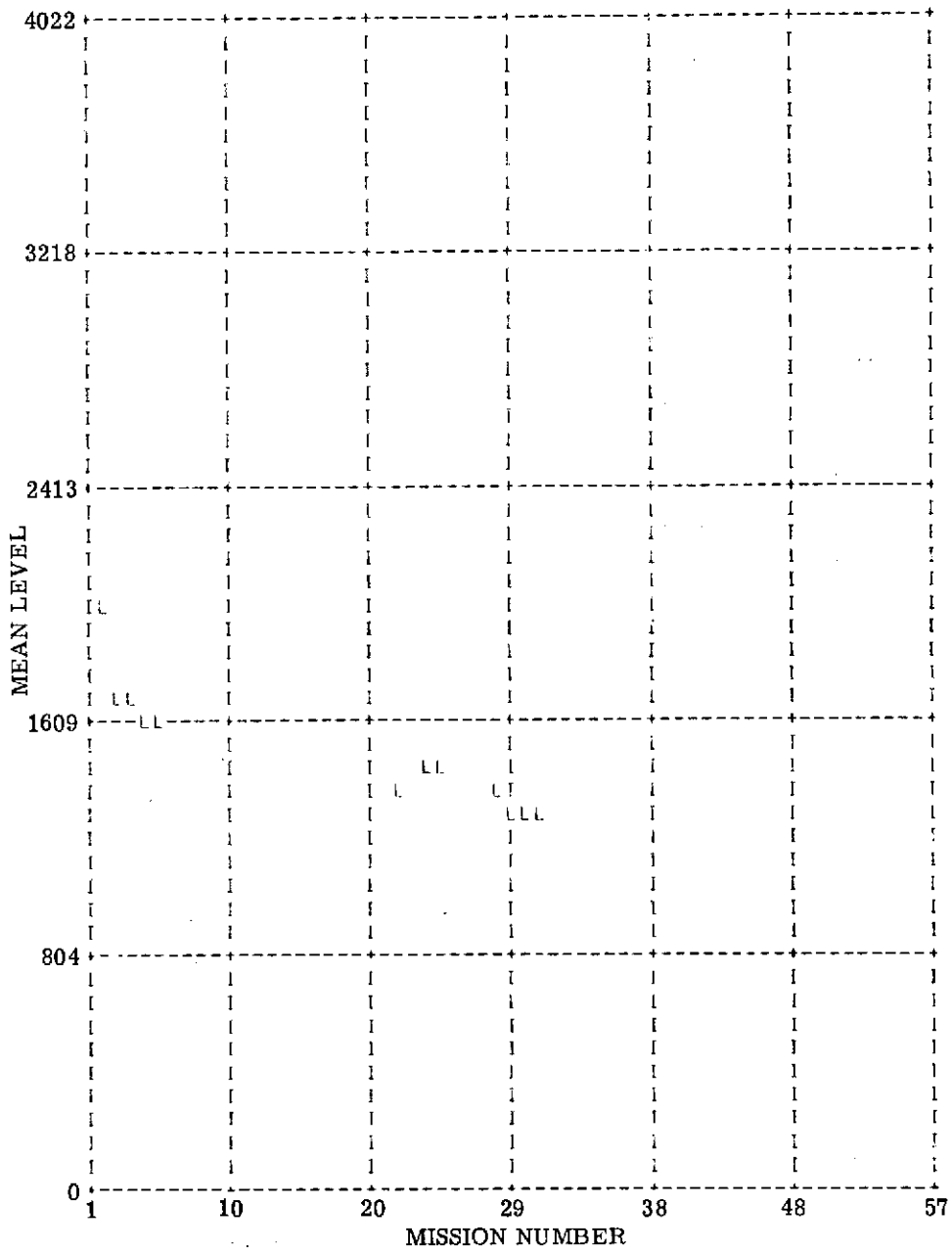


FIGURE 3. COMPUTERIZED REFERENCE-LAMP RESPONSE FOR FIFTEEN MONTHS (Continued)



(n) B2, 3.0-2.6 μm

FIGURE 3. COMPUTERIZED REFERENCE-LAMP RESPONSE FOR FIFTEEN MONTHS (Concluded)

TABLE 1. MISSION NUMBERS AND DATES

<u>Mission Number</u>	<u>Date</u>	<u>Mission Number</u>	<u>Date</u>
1	4 May 72	21	5 September 72
2	5 May 72	22	14 September 72
3	11 May 72	23	30 September 72
4	11 May 72	24	1 October 72
5	12 May 72	25	17 October 72
6	12 May 72	26	16 November 72
7	19 May 72	27	17 November 72
8	not available	28	2 January 73
9	25 May 72	29	10 January 73
10	25 May 72	30	12 January 73
11	5 June 72	31	25 January 73
12	6 June 72	48	22 June 73
13	23 July 72	49	25 June 73
14	24 July 72	50	3 July 73
15	18 August 72	51	5 July 73
16	25 August 72	52	6 July 73
17	28 August 72	53	7 July 73
18	29 August 72	54	4 August 73
19	29 August 72	55	5 August 73
20	30 August 72	56	10 August 73
		57	12 August 73

(quartz-iodine lamp) was subject to jarring and subsequent movement during scanner installation. This fact is obvious from the graphs; not only does the magnitude of signal change, but also the changes in overall system response correlate almost 100% between channels.

An effort was then made to prevent the lamp housing from being again inadvertently jarred. Subsequently, we decreased both the frequency of scanner installation and removal. This brings us into a third period covering the months of September 1972 through January 1973. Here the overall variation in system response is better than that observed in May and June, and the high correlation in changes between channels is evident. It is apparent from this signal correlation that the variations noted are primarily due to response changes such as dust collecting on the scanner mirror or secondary mirrors and lens. This also explains why the short-time response (one day or less) is usually much more stable than the long-time response.

Because a lack of time prevented processing all the data, a period of five months was skipped to permit the data from the most recent mission to be compared to data acquired earlier. During April 1973 the lamp housing was modified substantially to permit better viewing by the scanner mirror; also, a 45-watt bulb was installed in place of the original 100-watt bulb. Because of the spectral differences in the smaller lamp, some change in absolute magnitude of the signals is to be expected. In general, the variations in lamp voltages are similar to those observed with the 100-watt bulb. Except for channel C10 which, for some unknown reason, indicated excessive variation, scanner signals over a two-month span were stable to within an average of 10%. Day-to-day stability tends to be typically better than 2%.

2.1.3 ESTABLISHMENT OF PROCEDURE FOR WEEKLY MONITORING

To facilitate a quick computer turn-around of this CALIB output for the standardization tests, a system was initiated for analog-to-digital conversion of the data and operation of the CALIB program on the data. CALIB channel equivalents appear in Table 2. The idea was to minimize the time and cost of constructing the stability history of the M7 scanner. Forms were designed which, when properly filled out, will allow for complete data reduction. Table 3 represents the two forms that, when filled in, will permit complete automatic data processing by the program CALIB. Since the standardization tapes are digitized in a set procedure, no operator intuition is required. Directions for filling out the forms are detailed in Table 4. A sample form, filled out with comments explaining what was done, is shown in Table 5.

2.2 INTERMEDIATE FREQUENCY SCANNER SIGNAL NOISE (MINUTES TO HOURS)

2.2.1 PROGRAM DGNSTC.

The purpose of this program is to perform a more detailed analysis of possible noise problems with the M7 scanner system—specifically, higher frequency problems. To facilitate this,

TABLE 2. S-CHANNEL EQUIVALENTS FOR PROGRAM CALIB.

$\Delta\lambda$ * (μm)	Detector Notation	S-Channel (for "CALIB.")
0.41 - 0.48	C12	16
0.46 - 0.49	C10	15
0.48 - 0.52	C9	14
0.50 - 0.54	C8	13
0.52 - 0.57	C7	12
0.55 - 0.60	C6	11
0.58 - 0.64	C5	10
0.62 - 0.70	C4	9
0.67 - 0.94	C2	8
1.0 - 1.4	D3	7
1.5 - 1.8	D2	6
2.0 - 2.6	D1	5
1.0 - 1.4	B3	4
2.0 - 2.6	B2	3
0.33 - 0.38	E1	2
0.71 - 0.73	F1	1

*Note: These wavelengths are currently valid for the given detector notation. In general, however, care must be taken in associating a particular band with a detector notation.

TABLE 3. DATA FORM FOR PROGRAM CALIB.

GX28-7927-6 U/M 050*
Printed in U.S.A.

IBM

FORTRAN Coding Form

PROGRAM	PUNCHING INSTRUCTIONS	GRAPHIC	PAGE OF
PROGRAMMER	DATE	PUNCH	CARD ELECTRO NUMBER*

STATEMENT NUMBER	FORTRAN STATEMENT	IDENTIFICATION SEQUENCE
1	MODEI = \$START\$ * <i>Do not punch</i>	1
2	CHANNEL = 13, TAPE = \$OLD\$, FILMAX = *	2
3	INBIN = , UNIT = , FILE = , NSA = , , , , , *	3
4	FDATE(1) = , , , , , MISSION = , , , , , *	4
5	COMMENT(1) = \$ * * * * *	5
6	MPXMUX = , SCHAN = , AIRCHN = *	6
7	MPXMUX = , SCHAN = , AIRCHN = *	7
8	MPXMUX = , SCHAN = , AIRCHN = *	8
9	MPXMUX = , SCHAN = , AIRCHN = *	9
10	MPXMUX = , SCHAN = , AIRCHN = *	10
11	MPXMUX = , SCHAN = , AIRCHN = *	11
12	MPXMUX = , SCHAN = , AIRCHN = *	12
13	MPXMUX = , SCHAN = , AIRCHN = *	13
14	MPXMUX = , SCHAN = , AIRCHN = *	14
15	MPXMUX = , SCHAN = , AIRCHN = *	15
16	MPXMUX = , SCHAN = , AIRCHN = *	16
17	MPXMUX = , SCHAN = , AIRCHN = *	17
18	MPXMUX = , SCHAN = , AIRCHN = *	18
19	FILE = , NSA = , , , , , , , *	19

SPECIFY ONLY AS MANY "MPXMUX" CARDS AS THERE ARE CHANNELS ON THE TAPE. CROSS OUT "MPXMUX" CARDS NOT USED.

33

*A standard card form. IBM electro 688157. It is available for punching statements from this form. **Number of forms per pad may vary slightly.

TABLE 3. DATA FORM FOR PROGRAM CALIB.

GX28-7327-6 U/M 050**
Printed in U.S.A.

IBM

FORTRAN Coding Form

PROGRAM	DATE	PUNCHING INSTRUCTIONS	GRAPHIC PUNCH	PAGE OF
PROGRAMMER				CARD ELECTRO NUMBER

LINE	STATEMENT NUMBER	FORTRAN STATEMENT	IDENTIFICATION SEQUENCE																																																																												
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
	1	FILE =	DO NOT																																																																												
	2	NSA =																																																																													
	3	FDATE(1) =	PUNCH																																																																												
	4	MISSEN =	73-80																																																																												
	5	COMMENT(1) = \$																																																																													
	6	MPXMUX =																																																																													
	7	SCNAN =																																																																													
	8	AIRCHN =																																																																													
	9	MPXMUX =																																																																													
	10	SCNAN =																																																																													
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34

Disregard unless last file has been entered (cross out)

*A standard card form, IBM electro 808157, is available for punching statements from this form.

** Number of forms per pad may vary slightly.

TABLE 4. DIRECTIONS FOR COMPLETING DATA FORMS FOR PROGRAM CALIB.

Card 1: Supply only if beginning a second or following file set (See last instruction)

Card 2: Supply FILMAX (see Table 5)

Card 3: Supply INBIN, UNIT, FILE, NSA (see Table 5)

Card 4: Supply F DATE, MISSION #, (see Table 5)

Card 5: Supply COMMENT or TITLE (see Table 5)

Card 6-18: Fill out

(1) Multiplex channel => (MPXMUX, order of channels on digital tape, usually consecutively numbered 1-X)

(2) SCHAN => see chart #1

(3) AIRCHAN => Match previously numbered MPXMUX to original channels ("tape channels")

Fill out as many of the 18 channel blanks as needed, then cross out remaining blanks!

Card 19: Supply as in line 3 above (only FILE & NSA, see Table 5)

Card 20: Supply new FILE and NSA # (Table 5)

Card 21: Supply FILE DATE and MISSION # (Table 5)

Card 22: COMMENT (Table 5)

Card 23-35: Fill out as in 6-18 above

Card 36: Fill out as in 19 above

At this point repeat 19-36 above as needed to cover all files to be entered (flights).

After last file (last line 19 completed) has been entered — proceed

Last Card: MODE 1 = \$FINAL\$ * (Enter as shown)

For new file, set start at CARD #1 and supply MODE information as indicated.

TABLE 5. COMPLETED SAMPLE DATA FORM

Card 1	
MODE(1) = \$START\$ *(ASTERISK)	(Not used in this sample because there is only one file set.) Asterisk signifies End of Instruction; it is used after last entry on card.
Card 2	
CHANNL = 13 DEFAULT = 13	Maximum number of channels to be analyzed in any one file. (May process fewer than maximum) $1 \leq \text{CHANNL} \leq 13$
FILMAX = 8 DEFAULT = 1	Maximum number of files to be processed. $\text{FILMAX} \geq 1$ (1 file/flight) (Plot drops files entered out of sequence. Ex: 1, 2, 4, 8, 10, 7. 7 is dropped.)
LAMTOP = 5 DEFAULT = 5	Number of data points at top of lamp pulse to be used in calculations $0 \leq \text{LAMTOP} \leq \text{LAMPE} - \text{LAMPB} + 1$ see card 4 (If $\text{LAMTOP} < 5$, lamp bounds LAMPE AND LAMPB must be narrowed.)
TAPE = \$NEW\$ DEFAULT = \$OLD\$	\$NEW\$ = No tape data exists. Present data are used as base and put on tape TBASE 1. \$OLD\$ = Tape base exists (by DEFAULT = 799), and is merged with processed data (data base compilation at 799). \$PRINT\$ = Recall of precompiled data from last MISSIONX. MISSION must be specified. Only 3 statements needed: PRINT = \$PRINT\$ MISSION = X MODE = \$FINAL\$
MISSION = 12 DEFAULT = 0	Only for a preceding instruction of \$PRINT\$. Number of mission up to which the accumulated data is plotted and tabulated (including above-specified mission data).
TBASE 1 = 799 DEFAULT = 799	Used for a preceding instruction of \$NEW\$ (BIN number of tape).
TBASE 2 = 800 DEFAULT = 800 *(ASTERISK)	BIN number of tape from another data base End of Instruction
Card 3	
INBIN = 777 DEFAULT = -1	BIN number of <u>input</u> tape to be mounted (never = 0); if = -1, no mounts.
UNIT = 4 DEFAULT = NONE	Logical unit number of tape drive on which input tape is mounted (only 2, 3, 4, 8, 9)
FILE = 1 DEFAULT = 0	File on input tape to be processed; if < 1, no positioning.

TABLE 5. COMPLETED SAMPLE DATA FORM (Continued)

NSA	= 1	Starting line number
	= 225	Ending line number
	= 1	Line number increment
	= 1	Starting point number
	= 358	Ending point number
	= 1	Point number increment
DEFAULT	= 0	
*(ASTERISK)		End of Instruction
Card 4		
FDATE (1)	= 05, 25, 73	Date of flight associated with file
DEFAULT	= 00, 00, 00	3 variables → FDATE (1) - mo - $0 \leq (1) \leq 12$
		FDATE (2) - dy - $0 \leq (2) \leq 31$
		FDATE (3) - yr - $0 \leq (3) \leq 99$
MISSION	= 12	Number of mission associated with file being
DEFAULT	= 0	entered. MISSION ≥ 0
LAMPB	= 10	Number of reselm denoting beginning of lamp
DEFAULT	= 10	pulse (Note: <u>DEFAULT</u>)
		LAMPB \geq NA (see "NSA," card number 3)
LAMPE	= 60	Number of reselm denoting the end of lamp pulse
DEFAULT	= 60	(Note: <u>DEFAULT</u>)
		LAMPE \leq NB (see "NSA," card number 3)
DARKB	= 185	Number of reselm denoting the beginning of dark
DEFAULT	= 185	signal (Note: <u>DEFAULT</u>)
		DARKB \geq NA
DARKE	= 225	Number of reselm denoting the end of dark signal
DEFAULT	= 225	(Note: <u>DEFAULT</u>)
		DARKE \leq NB
SØLARB	= 310	Number of reselm denoting the beginning of solar
DEFAULT	= 310	signal (Note: <u>DEFAULT</u>)
		SØLARB \geq NA
SØLARE	= 355	Number of reselm denoting the end of the solar
DEFAULT	= 355	signal (Note: <u>DEFAULT</u>)
		SØLARE \leq NB
Card 5		
COMMNT (1)	= \$\$9,	Any 48-character comment
	BLACK HILLS, 0745, \$	to be printed as given between \$ signs
	*(ASTERISK)	End of Instruction. (Includes cards 4 & 5.)
Card 6		
MPXMUX	= 1	Number of multiplexer channel
		$1 \leq$ MPXMUX ≤ 13
SCHAN	= 8	Number of spectral channel MPXMUX represents
		(See chart)
		$0 \leq$ SCHAN ≤ 16 ; if = 0, MPXMUX is ignored in processing.

TABLE 5. COMPLETED SAMPLE DATA FORM (Concluded)

AIRCHN = 8 *(ASTERISK)	Number of aircraft channel that MPXMUX represents End of Instruction
Card 7	
MPXMUX = 2 SCHAN = 9 AIRCHN = 13 *(ASTERISK)	End of Instruction
Card 8	
MPXMUX = 3 SCHAN = 10 AIRCHN = 6 *(ASTERISK)	End of Instruction
Card 9	
MPXMUX = 4 SCHAN = 11 AIRCHN = 5 *(ASTERISK)	End of Instruction
Card 10	
MPXMUX = 5 SCHAN = 12 AIRCHN = 4 *(ASTERISK)	End of Instruction
Card 11	
MPXMUX = 6 SCHAN = 13 AIRCHN = 3 *(ASTERISK)	End of Instruction
Card 12	
MPXMUX = 7 SCHAN = 15 AIRCHN = 2 *(ASTERISK)	End of Instruction
Card 13	
MPXMUX = 8 SCHAN = 16 AIRCHN = 1 *(ASTERISK)	End of Instruction
Cards 14-18	For this example, MPXMUX cards 14 through 18 were not needed.
Card 19	
File = 1 NSA = 1, 225, 1, 1, 358, 1 *(ASTERISK)	NSA is same as card 3. End of Instruction
Last Card	
MODE (1) = \$FINAL\$ †	Close files.

† NOTE: When a "Data Set" is closed (file set started with FILMAX card and finished with MODE1 = \$FINAL\$), further program operation requires all cards and steps to be repeated.

For a series of files within a data set, you only need the following:

- (1) FILE, NSA
- (2) FDATE, MISSON
- (3) COMMNT
- (4) MPXMUX, SCHAN, AIRCHN

LAST, FILE, NSA
Repeat

the program has been made as general as possible and designed for rapid execution. It provides a technique to measure the effect of varying scan rate or tape recorder speed on digitized data. Although the statistics do not point to the cause of the apparent speed change, they do show that a change has occurred in the system and how drastic it might be.

The user is also able to determine the mean and standard deviation (1) of the signal level within any specified area, and (2) of the signal level of another area relative to the first. For example, when used with the lamp reference source, the user can measure changes in lamp radiance relative to a dark area within the scanner. In addition, plots of both these means and standard deviations versus scanline number may be obtained. With these plots, the user will be able to observe the detailed quality of changes in the signal level of an area in the scanline along the flight path. For instance, the user could look for cyclical fluctuations in an ambient area.

A measure of speed changes in the system is accomplished by analyzing some fixed-position signal in the scanline such as the lamp reference pulse. The mean position of the middle of the lamp pulse is measured relative to the beginning sync pulse for each scanline. The standard deviation from this mean shows how much jitter there is in the digitized image of the lamp pulse.

Differing only in output detail, the other two facilities of the program do virtually the same thing. One feature simply determines the mean and standard deviation of the signal level (either absolute or relative to another area) in a specified area of the scanline over the entire data set. The other feature calculates the mean and standard deviation of the signal level (either absolute or relative to another area) in a specified area of each scanline. Plots are made of these statistics versus the scanline number from which they were calculated. Appendix B includes a complete description of the program DGNSTC.

2.2.2 EVALUATION OF DATA SET

Measurements were made on M7 scanner data to determine, quantitatively, the intermediate frequency noise (or drift) that one might encounter in processing multispectral scanner data over short periods of time. The particular data set chosen for this study was obtained over Eaton County, Michigan, on 25 August 1972, as part of the ERTS underflight program. This mission was chosen specifically because it satisfied two requirements: (1) it had been obtained recently enough to qualify the scanner configuration and performance as being typical of the present system; and (2) it contained several long (12-minute) data passes encompassing a total period of approximately one hour—this enabled us to obtain a near-continuous measurement of the short-term drift over a manageable time period.

A total of five passes covering one hour and twelve minutes (see Table 6) were analyzed by DGNSTC. Since five full 12-minute data runs would require a prohibitive amount of processing,

TABLE 6. LOG OF EATON COUNTY, MICHIGAN, FLIGHTLINES

<u>Line</u>	<u>Date</u>	<u>GMT Start</u>	<u>GMT Stop</u>	<u>Altitude (1000 ft)</u>	<u>Aircraft Heading (deg)</u>
1	25 August 72	16:20:30	16:30:00	5	360
2	25 August 72	16:41:00	16:51:00	5	180
3	25 August 72	16:54:30	17:06:00	5	360
4	25 August 72	17:09:00	17:18:30	5	180
5	25 August 72	17:22:00	17:37:30	5	360

five segments of data (equally spaced from beginning to end) were digitized for each run. Each segment required 15 seconds of actual data collection time out of the original 12-minute run. Only a region of the dark level (base line) and the lamp was observed. Output from the program DGNSTC. was obtained on this data; the results are summarized in Tables 7, 8, and 9 ($\lambda = 0.41-0.48, 0.55-0.60, \text{ and } 2.0-2.6 \mu\text{m}$, respectively).

Only three spectral channels were analyzed since a considerable amount of computer time was still required for processing each channel. It should be noted here that the data were averaged (smoothed) over four lines before processing; hence, the noise figures (expressed as a standard deviation) listed in the tables do not represent the values on the original analog tape. It can be shown that smoothing n -lines has the effect of decreasing the noise by \sqrt{n} . Therefore, the actual noise values on tape are twice those indicated in the tables (smoothing over four lines). The values were left unchanged, though, because much of the computer processing being done uses the concept of smoothing to reduce noise. Hence, these values are directly related to current techniques.

The mean value shown in Tables 7, 8, and 9 for the dark level and lamp pulse are the averages of the means obtained from the region of interest in each line. The standard deviations are the deviations of the mean of each line about the average mean for the whole segment. For the dark level, the region digitized was midway between the reference lamp pulse and the sky reference pulse (see Fig. 4). As the tables indicate, in the solar-reflective region the value of the dark level per line (averaged over 25 points) deviates only 0.1% from the mean dark level value for the whole 72-minute data set. In the near-IR region where the dark level is adjusted manually before each run via dc-offset pots, the deviation is a remarkably small 0.3%. Note that the deviation over the whole 72-minute set is no larger than that for the 12-minute runs.

The values shown for the reference lamp were calculated in a similar manner. The region used for averaging the lamp signal was 15 points wide and covered dark levels on both sides of the pulse. The average value obtained for the lamp is analogous to integration of the pulse and not to the peak value. Standard deviations of the lamp pulse varied from 2.3% of the mean in the blue channel (noisiest channel) to 1.3% in the near-IR.

In general, then, when smoothing four lines and averaging 15-25 points per line, the standard deviation of a signal from line-to-line (assuming a constant input) will generally not exceed 2.5% (worst case) of the mean value over all lines collected in a period of time as long as one hour and twelve minutes. Of course, in many cases, smoothing between lines and averaging in a line is not possible. For this instance, statistical theory leads us to a standard deviation that will be $\sqrt{4} \times \sqrt{15}$ larger than that obtained when smoothing over four lines and averaging over 15 points per line. Hence, the standard deviation from line to line with no averaging of any kind would be as follows:

TABLE 7. MEANS AND STANDARD DEVIATIONS OF
 DARK LEVEL AND LAMP FOR FIVE DATA SETS
 OVER EATON COUNTY. $\lambda = 0.41-0.48 \mu\text{m}$

Line No.	Segment No.	Dark Level		Lamp	
		\bar{x}	σ	\bar{x}	σ
1	1	140.18	0.16	13.45	0.22
	2	140.05	0.15	13.30	0.20
	3	140.07	0.16	13.34	0.20
	4	140.40	0.22	13.35	0.50
	5	140.32	0.21	13.47	0.46
	AVE	140.20	0.18	13.38	0.34
2	1	139.29	0.19	13.52	0.37
	2	139.50	0.21	13.28	0.55
	3	139.63	0.20	13.15	0.50
	4	139.80	0.19	13.10	0.33
	5	139.83	0.18	13.15	0.25
	AVE	139.61	0.19	13.24	0.41
3	1	140.82	0.18	13.15	0.28
	2	140.86	0.18	13.18	0.26
	3	140.90	0.16	13.21	0.25
	4	140.87	0.17	13.11	0.23
	5	140.91	0.15	13.15	0.21
	AVE	140.87	0.17	13.16	0.25
4	1	140.91	0.16	13.15	0.22
	2	140.92	0.17	13.15	0.23
	3	140.90	0.14	13.14	0.17
	4	145.02	0.15	13.34	0.21
	5	145.03	0.14	13.64	0.18
	AVE	142.56	0.15	13.28	0.20
5	1	145.21	0.17	13.46	0.32
	2	145.16	0.19	13.35	0.29
	3	145.17	0.19	13.40	0.29
	4	145.21	0.18	13.37	0.34
	5	145.22	0.18	13.35	0.34
	AVE	145.19	0.18	13.39	0.32
Mean Total		141.69	0.18	13.29	0.31
Percent Deviation		0.1%		2.3%	

TABLE 8. MEANS AND STANDARD DEVIATIONS OF DARK LEVEL AND LAMP FOR FIVE DATA SETS OVER EATON COUNTY. $\lambda = 0.55-0.60 \mu\text{m}$

Line No.	Segment No.	Dark Level		Lamp	
		\bar{x}	σ	\bar{x}	σ
1	1	144.05	0.15	37.01	0.19
	2	143.90	0.15	36.74	0.23
	3	143.91	0.15	36.73	0.21
	4	143.92	0.18	36.82	0.25
	5	143.95	0.18	36.82	0.25
	AVE	143.95	0.16	36.82	0.23
2	1	144.05	0.15	36.74	0.20
	2	144.09	0.16	36.77	0.23
	3	144.07	0.16	36.63	0.20
	4	144.04	0.15	36.50	0.20
	5	144.01	0.15	36.61	0.21
	AVE	144.05	0.15	36.65	0.21
3	1	143.93	0.15	36.67	0.20
	2	143.91	0.15	36.58	0.21
	3	143.91	0.16	36.54	0.25
	4	143.86	0.15	36.60	0.26
	5	143.87	0.15	36.65	0.27
	AVE	143.90	0.15	36.61	0.24
4	1	143.93	0.14	36.62	0.25
	2	143.88	0.16	36.43	0.25
	3	143.83	0.15	36.36	0.25
	4	143.89	0.16	36.49	0.44
	5	143.90	0.14	36.77	0.29
	AVE	143.89	0.15	36.53	0.31
5	1	144.02	0.13	36.77	0.22
	2	143.97	0.14	36.43	0.22
	3	143.97	0.14	36.53	0.22
	4	144.01	0.14	36.62	0.22
	5	144.05	0.15	36.76	0.26
	AVE	144.00	0.14	36.62	0.23
Mean Total		143.96	0.15	36.65	0.24
Percent Deviation		0.1%		0.7%	

TABLE 9. MEANS AND STANDARD DEVIATIONS OF DARK LEVEL AND LAMP FOR FIVE DATA SETS OVER EATON COUNTY. $\lambda = 2.0-2.6 \mu\text{m}$

Line No.	Segment No.	Dark Level		Lamp	
		\bar{x}	σ	\bar{x}	σ
1	1	160.24	0.42	47.89	0.65
	2	159.00	0.40	47.60	0.57
	3	159.74	0.39	47.46	0.61
	4	159.15	0.39	47.55	0.58
	5	160.48	0.40	47.03	0.91
	AVE	159.72	0.40	47.51	0.66
2	1	163.13	0.43	47.28	0.58
	2	163.53	0.40	47.37	0.61
	3	163.43	0.46	47.22	0.57
	4	163.77	0.35	47.07	0.52
	5	164.55	0.35	47.16	0.59
	AVE	163.68	0.40	47.22	0.57
3	1	163.87	0.35	47.18	0.53
	2	163.29	0.37	47.16	0.54
	3	163.64	0.32	47.17	0.60
	4	162.75	0.37	47.26	0.54
	5	161.93	0.34	47.21	0.45
	AVE	163.10	0.35	47.20	0.53
4	1	162.79	0.44	47.17	0.59
	2	163.62	0.35	47.03	0.67
	3	163.93	0.38	47.16	0.57
	4	165.28	0.47	47.00	0.63
	5	165.19	0.37	47.28	0.52
	AVE	164.16	0.40	47.13	0.60
5	1	164.81	0.53	47.15	0.66
	2	164.29	0.61	47.08	0.83
	3	163.51	0.52	47.02	0.66
	4	163.07	0.37	47.00	0.55
	5	162.92	0.38	47.13	0.60
	AVE	163.72	0.49	47.08	0.67
Mean Total		162.88	0.41	47.23	0.61
Percent Deviation		0.3%		1.3%	

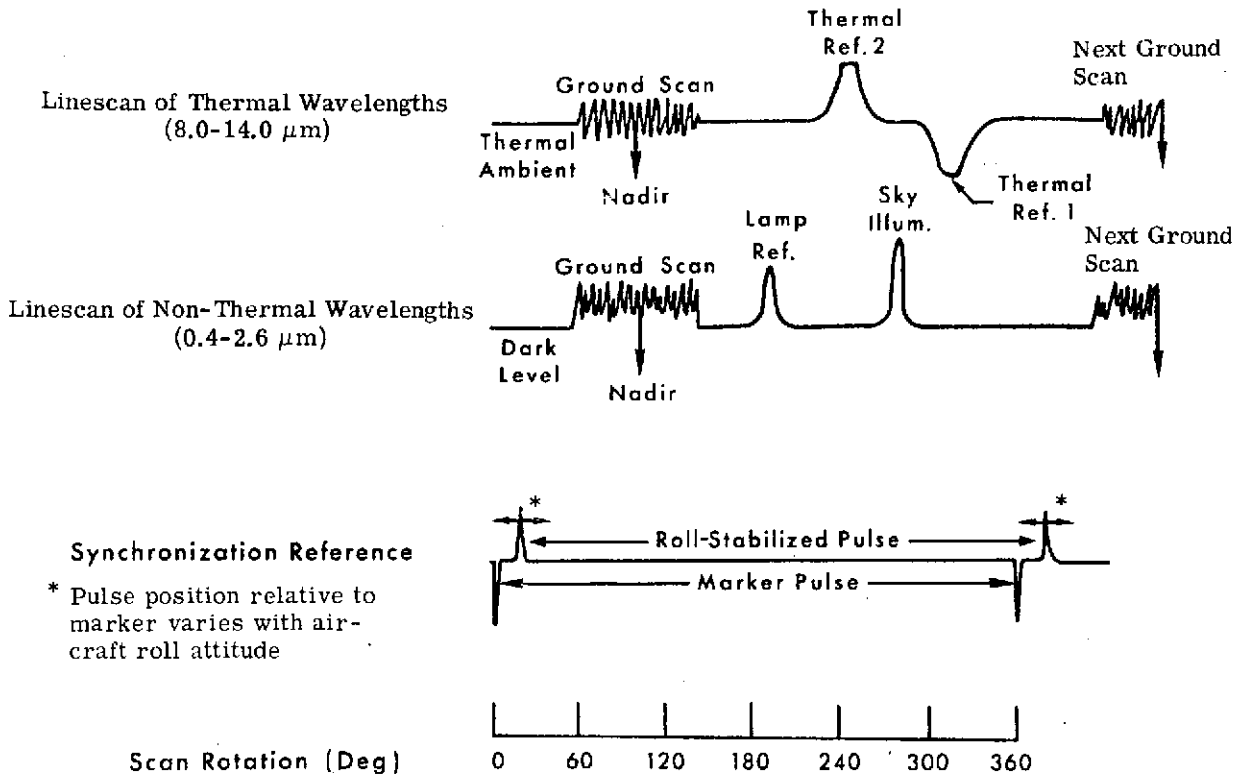


FIGURE 4. SCANNER VOLTAGE OUTPUT VERSUS TIME

$$\begin{aligned} \text{standard deviation}_{\text{no average}} &= \sqrt{4} \times \sqrt{15} \times 2.3\% (\lambda = 0.41-0.48 \mu\text{m}) \\ &= 17.8\% (\text{worst case}) \end{aligned}$$

This would be the variation, line-to-line, about the mean value over all lines expected in a scanner signal obtained from a single resolution element over a data run 12 to 72 minutes in length.

2.3 HIGH FREQUENCY NOISE CHARACTERISTICS (SECONDS-TO-MINUTES)

Thus far, noise measurements have been made on M7 scanner data to determine the signal variation to be expected over months, days, and hours. This kind of information is valuable in terms of analyzing signature extension capabilities over various time periods. Another aspect to the noise problem is the higher frequency noise that occurs within a single scanline. Knowledge of this noise (which is akin to NE Δ L) would permit the data processor, for example, to evaluate the potential for resolving the spectra of two similar objects. But, before discussing the actual measurement of this noise, several prefatory comments should be made about the M7 system in general.

As in the thermal channel (discussed later), the noise observed in solar-reflective channels is almost always tape-recorder-limited; that is, the dynamic range of the tape recorder (Mincom PC-500) is almost always less than the dynamic range of signals encountered in viewing the terrain (including detector and amplifier noise). This recorder dynamic range is 39.5 dB, peak-to-peak, which results in a maximum signal-to-noise ratio (S/N) of 89:1. This assumes that the entire range of the recorder is being used and that the signal is indeed tape-recorder-limited (true most of the time). The one possible exception occurs when the highest gains are used over low reflecting objects such as water or during low sun-angle situations. In this case, detector or preamplifier noise becomes the limiting factor.

With this maximum signal-to-noise ratio in mind, data were analyzed over Run 1 of the same mission discussed in Section 2.2. The average dark level values (in bins) over 195 lines and 25 pts/line for each of the five segments are recorded in Table 10. Also tabulated is the average standard deviation per line ($\bar{\sigma}_{\text{line}}$) for each of the segments and their deviations ($\sigma_{\bar{\sigma}}$). The same wavelengths discussed earlier were also studied here. The most important thing to note from these data is that in the solar-reflective region the noise in a single scanline (denoted by $\bar{\sigma}_{\text{line}}$) is indeed equal to the tape recorder limit.

To see this, one must be aware that in digitizing the data the maximum number of bins available to cover the full dynamic range of the recorder is 512. Since the average dark level (0.41-0.48 μm) is at 140.20, the number of bins available to the recorder for a maximum signal

TABLE 10. DARK LEVEL MEANS AND STANDARD DEVIATIONS
 FOR ONE SEGMENT OF DATA OVER EATON COUNTY

λ	Run No.	Segment No.	Dark Level		
			\bar{x}_{Line}	$\bar{\sigma}_{\text{Line}}$	$\frac{\sigma}{\bar{\sigma}}$
0.41-0.48 μm	1	1	140.18	0.39	0.12
		2	140.05	0.35	0.14
		3	140.07	0.39	0.11
		4	140.40	0.46	0.08
		5	140.32	0.45	0.09
		AVE	140.20	0.41	0.11
0.55-0.60 μm	1	1	144.05	0.38	0.13
		2	143.90	0.38	0.12
		3	143.91	0.40	0.13
		4	143.92	0.40	0.11
		5	143.95	0.39	0.13
		AVE	143.95	0.39	0.12
2.0-2.6 μm	1	1	160.24	1.43	0.43
		2	159.00	1.36	0.32
		3	159.74	1.37	0.34
		4	159.15	1.37	0.32
		5	160.48	1.36	0.46
		AVE	159.72	1.38	0.38

input is $512 - 140.20 = 371.80$. Hence, the corresponding signal-to-noise ratio is $907.8 : 1$ ($371.8 \div 0.41$). In obtaining the data, however, 100 points were averaged to arrive at the figures shown in Table 10. Therefore, the noise in each line (with no averaging) is actually $\sqrt{100}$ higher than indicated. This reduces the S/N to $90.8:1$. The corresponding values for the other two channels are as follows:

for $\lambda = 0.55-0.60 \mu\text{m}$, $S/N = 94.4$

$\lambda = 2.0-2.6 \mu\text{m}$, $S/N = 25.5$

The near infrared channel does not appear to be tape-recorder-limited, although the cause of the noise is at this time unknown.

3

DARK-LEVEL DETERMINATION

One of the more seemingly insignificant decisions made by processors of multispectral data is the choice of a baseline region for dark-level correction. There are several regions of darkness viewed by the rotating scan mirror in one 360° swing, and in the past it has been more or less an arbitrary choice by the processor as to which region to use. One of the goals of the study was to determine if all these baseline regions were indeed equally dark and, if not, what region was optimal.

Data were examined from a flight flown on 20 March 1973, at 15:30 GMT, over Washtenaw County specifically to locate an optimal dark level region. Only five spectral channels were digitized so that maximum spatial resolution could be obtained. The entire scanline was not digitized because of gate limitations on the analog-to-digital equipment; nearly 1000 sample points out of a possible 1333 (at 4.7 $\mu\text{r}/\text{sample}$ and 80K samples/sec) were obtained. The 300 and some points not digitized are located in the region between the sky reference and the fixed sync (see Fig. 6). Included in this area are the hot plate and UV reference lamp. It is possible that this area contains a region of even darker base line than that determined from the remainder of the data; since the present system cannot digitize data in this area, however, it will be neglected here.

Shown in Figure 5 is a plot of signal (in bins) versus reselm location for a single scanner line. The discrete level fluctuations in the data are the results of quantization into bins of voltage levels on the analog tape during the analog-to-digital conversion process. Each bin is equal to 0.01953 volt. Tables 11 and 12 contain the tabulated results of a statistical analysis performed on nine regions of the base line data (see Fig. 6). Table 11 shows the mean (in bins) and standard deviation for all five channels and one scanline. Table 12 gives the same figures averaged over 100 scanlines. As the tables show, the best region for dark level correction is the area just before the beginning of the video (Region I). In terms of physical location inside the scanner housing, this region corresponds to a blackened area 80° from nadir. Unfortunately, under severe aircraft roll conditions, the roll-corrected sync pulse can move into this region. During turbulent weather, then, Region I should not be used.

However, an alternative is to use Regions VIII or IX, which have values very near to that of Region I. These areas are part of one broad region located between the reference lamp and the sky reference. The blackened cold-plate thermal reference is included in this area. The pulse located at reselm number 715 is an SCR noise spike which comes from a solid state DC-to-AC inverter used to supply 110 V, 60 Hz to the equipment. This noise spike will always be found somewhere in the data (at least for the present), although efforts are being

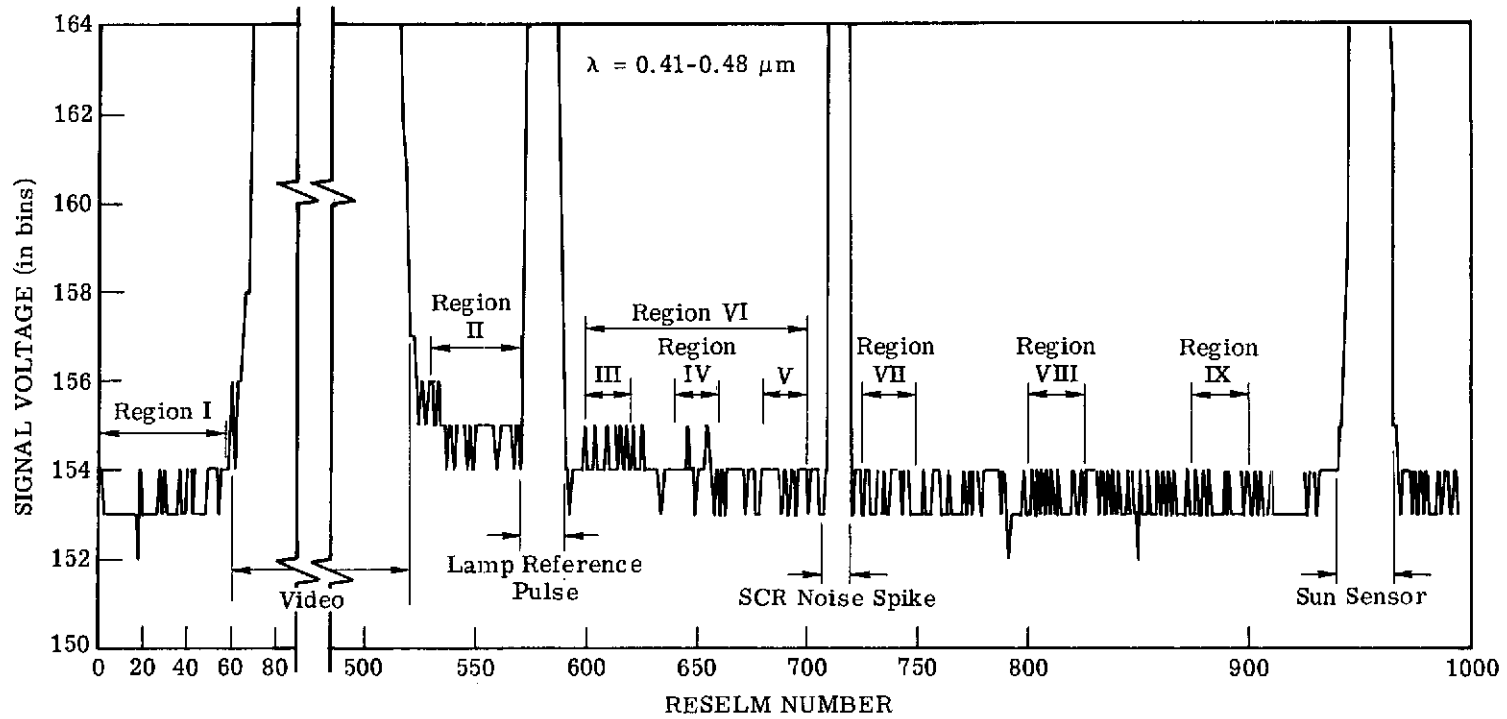


FIGURE 5. SCANNER SIGNALS FOR RESELM REGIONS

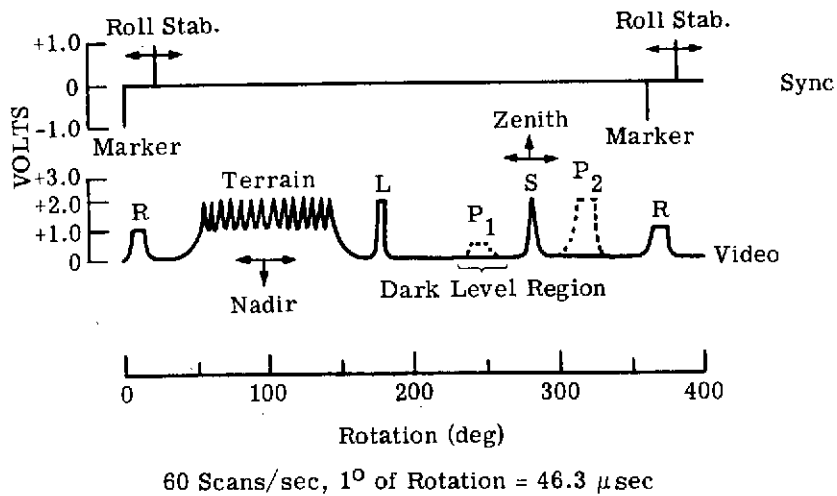
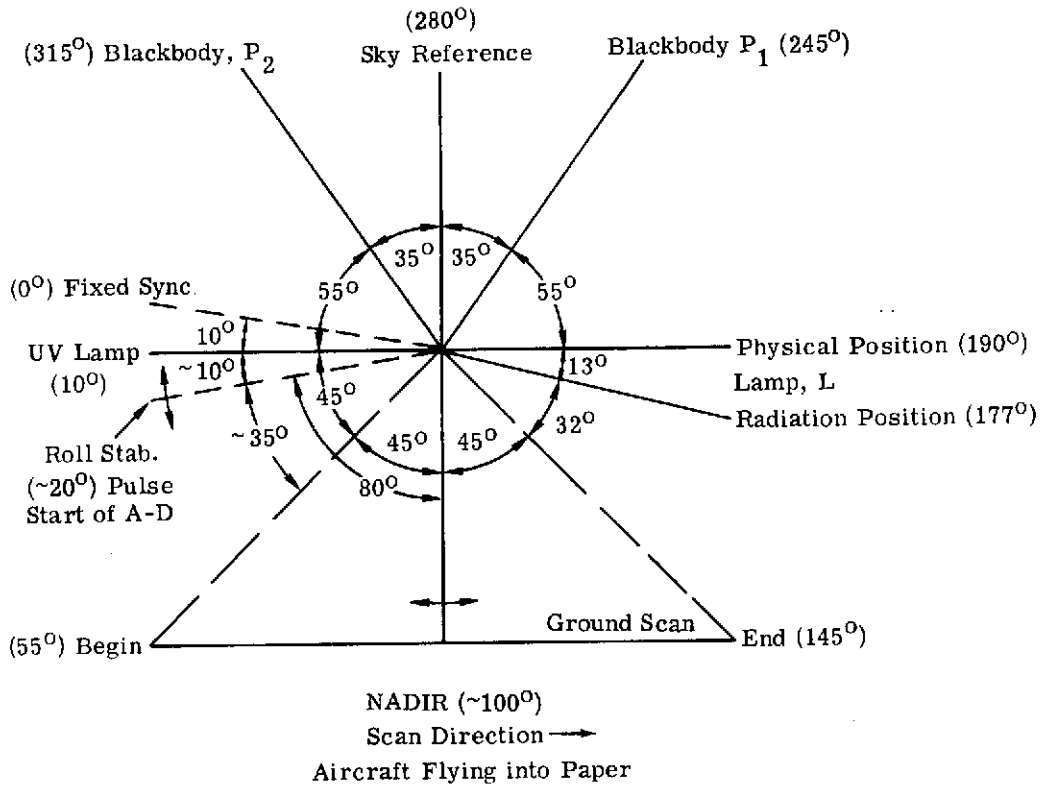


FIGURE 6. RELATIVE ANGULAR POSITIONS OF SYNC AND RADIATION SOURCES

TABLE 11. SUMMARY OF DARK LEVEL AVERAGE VALUES FOR DIFFERENT SPATIAL AND SPECTRAL REGIONS IN A SINGLE SCAN PERIOD. Average values are in bins (1 bin = 0.01953 V). Numbers in parentheses are normalized values.

REGION	LOCATION	$\lambda = 0.41-0.48 \mu\text{m}$		$\lambda = 0.50-0.54 \mu\text{m}$		$\lambda = 0.58-0.64 \mu\text{m}$		$\lambda = 0.67-0.94 \mu\text{m}$		$\lambda = 1.0-1.4 \mu\text{m}$	
		\bar{x}	σ	\bar{x}	σ	\bar{x}	σ	\bar{x}	σ	\bar{x}	σ
		(0.41-0.48)		(0.50-0.54)		(0.58-0.64)		(0.67-0.94)		(1.0-1.4)	
I	I-58	153.31 (1.000)	0.50	150.81 (1.000)	0.66	149.05 (1.000)	0.47	149.17 (1.000)	0.53	154.60 (1.000)	1.22
II	530-570	154.83 (1.010)	0.49	152.37 (1.010)	0.53	150.80 (1.012)	0.40	155.17 (1.040)	0.49	156.54 (1.013)	0.50
III	600-620	154.43 (1.007)	0.49	151.86 (1.007)	0.47	150.52 (1.010)	0.50	154.29 (1.034)	0.45	155.24 (1.004)	0.43
IV	640-660	153.95 (1.004)	0.49	151.67 (1.006)	0.56	150.00 (1.006)	0	153.28 (1.028)	0.45	155.24 (1.004)	0.43
V	680-700	153.81 (1.003)	0.39	151.33 (1.003)	0.47	149.95 (1.006)	0.21	152.57 (1.023)	0.49	155.05 (1.003)	0.21
VI	600-700	154.01 (1.005)	0.52	151.60 (1.005)	0.55	150.16 (1.007)	0.39	153.35 (1.028)	0.77	155.22 (1.004)	0.44
VII	725-750	153.56 (1.002)	0.57	151.22 (1.003)	0.42	149.70 (1.004)	0.46	150.44 (1.009)	0.50	154.59 (1.000)	0.49
VIII	800-825	153.38 (1.000)	0.49	151.08 (1.002)	0.47	149.58 (1.004)	0.49	150.00 (1.006)	0.28	154.42 (1.000)	0.49
IX	875-900	153.42 (1.001)	0.49	150.92 (1.001)	0.47	149.29 (1.002)	0.45	149.73 (1.004)	0.52	154.19 (0.997)	0.39

TABLE 12. SUMMARY OF DARK LEVEL AVERAGE VALUES FOR DIFFERENT SPATIAL AND SPECTRAL REGIONS
 AVERAGED OVER 100 SCANLINES. Average values are in bins (1 bin = 0.01953 V).

REGION	$\lambda = 0.41-0.48 \mu\text{m}$		$\lambda = 0.50-0.54 \mu\text{m}$		$\lambda = 0.58-0.64 \mu\text{m}$		$\lambda = 0.67-0.94 \mu\text{m}$		$\lambda = 1.0-1.4 \mu\text{m}$	
	\bar{x}	σ	\bar{x}	σ	\bar{x}	σ	\bar{x}	σ	\bar{x}	σ
	(0.41-0.48)		(0.50-0.54)		(0.58-0.64)		(0.67-0.94)		(1.0-1.4)	
I	152.47	0.62	150.01	0.56	148.36	0.38	149.07	0.43	153.77	1.06
II	153.61	0.53	151.18	0.49	149.71	0.33	154.23	0.40	155.30	0.43
VIII	152.58	0.54	150.13	0.48	148.60	0.34	149.60	0.33	153.54	0.39
IX	152.50	0.55	150.06	0.48	148.52	0.34	149.44	0.36	153.68	0.39

made to move it to an area of insignificance. For this reason, a standard region to use for dark level correcting is the one between regions VIII and IX which corresponds to the position of the cold plate. Since the SCR noise spike is always kept out of the hot and cold plate regions, there need be no worry about this pulse affecting the dark level value. From the standpoint of time, this dark level region occurs 1.326 msec before the sky reference. Any width up to approximately 30 reselms (4.7 mr/sample) can be used. It is expected that all data digitized in the future will use this region for dark level correction.

M7 RADIANCE CALIBRATION

4.1 RADIANCE CALIBRATION

Eleven radiance calibration tapes have been generated since the M7 scanner was first put into service in June 1971. Their dates are listed in Table 13. Until now, only a portion of these had been digitally analyzed—using a variety of techniques. In order to understand more fully the changes that have occurred in these calibration data sets and to simplify the data reduction procedure, the program LAMRAD. was written. Designed to handle M7 scanner radiance tapes exclusively, this program calculates the radiance calibration constants (as a function of lamp current) used to provide radiance information for multispectral processing. A complete derivation and explanation of the procedure used to calibrate the M7 scanner is given in Appendix C. In summary, the radiance of a target on the ground is given by

$$L_T(\lambda) = \left(\frac{V_T}{V_L} \right) \left(\frac{V'_L}{V_{\text{ref}}} \right) \left(\frac{\rho_{\text{ref}} E_{\text{QI}}(\lambda)}{\pi} \right)$$

where $L_T(\lambda)$ = radiance of target, assuming a Lambertian surface, for each channel

V_T = voltage of target on ground

V_L = peak lamp voltage during target data collection

V'_L = peak lamp voltage during calibration

V_{ref} = voltage off reference panel during calibration

$E_{\text{QI}}(\lambda)$ = spectral irradiance of quartz-iodine lamps

ρ_{ref} = directional reflectance of reference panel

It is the quantity

$$K_{\text{CAL}}(\lambda) = \frac{V'_L}{V_{\text{ref}}} \frac{\rho_{\text{ref}} E_{\text{QI}}(\lambda)}{\pi}$$

that is calculated by the program LAMRAD.

4.2 TECHNIQUES FOR LAMP PULSE MEASUREMENTS

4.2.1 SUMMARY OF TECHNIQUES

Critical to the equation above for $K_{\text{CAL}}(\lambda)$ are the values of V'_L and V_L . This is true because V'_L and V_L , of all the terms in that equation, are by far the most difficult to measure consistently. In general, V_L is represented by a narrow pulse that on occasion can exhibit jitter equal to its pulse width. This makes it very difficult for the data processor to measure its peak value.

TABLE 13. DATES OF SPECTRAL
RADIANCE CALIBRATION

<u>Calibration No.</u>	<u>Date</u>
1	20 August 71
2	6 June 72
3	7 June 72
4	16 June 72
5	12 July 72
6	5 September 72
7	24 January 73
8	26 January 73
9	3 April 73
10	5 June 73
11	6 August 73

One of the tasks of this study was to attempt to improve the technique for measuring this voltage.

Thus far, two methods have been developed for calibrating the signal pulse of the lamp in the M-7 scanner using the program LAMRAD. Both methods result in a voltage value for the peak of the signal. One method, called the "mean level method" and used exclusively up until this time, has certain drawbacks which a second method, called the "integral method," will hopefully eliminate.

The mean level method of determining signal height (voltage) is calculated in the following way (refer to Fig. 7). The program will first select the point on the pulse curve which has the curve's peak voltage "P" and then determine at which reselms the half-value of P (P/2) intersects the curve. There will always be only two intersections: one at the pulse rise and one at the pulse drop. This is dictated simply by the shape of the curve. The two reselm locations mentioned will be called x and y, respectively. The program will then average these values and determine another reselm value $(x + y)/2$. At this point, LAMRAD. will determine the voltage of the curve at the point $(x + y)/2$ and take the average voltage of it and other consecutively preselected reselms on either side of $(x + y)/2$. Figure 7, for example, shows only two reselms selected on either side of $(x + y)/2$ and averaged to obtain the mean level. Thus far, this has been the configuration used in LAMRAD. The curve values taken at the reselm points and then divided by $(N + 1)$ gives the mean level. The general equation for the mean level is:

$$\left(\sum_{Z=0}^N \left(\frac{x+y}{2} \right) - \frac{N}{2} + Z \right)$$

where Z may have only integral values and N can only be even. This is to insure that no fractional reselm values will exist and that one may select equal numbers of reselm samples on either side of the $(x + y)/2$ reselm, thus allowing for a balanced mean. This method of calculating a mean voltage height of the pulse has some drawbacks, one of which is illustrated by the abnormally skewed curve in Fig. 7. If the curve should happen to be shaped oddly, the value for the height could be off true as shown. Another problem comes up in determining how many reselms to average on either side of $(x + y)/2$. We want to average as much of the pulse top as possible without going off the sides (the drop and rise usually occur within a reselm or so). Once this value is calculated, signal shift cannot be tolerated because a shift of a reselm or two would give values at the bottom of the curve, resulting in a "height" far below what actually exists.

The second means of determining signal level is the "integral method." As the title suggests, this method involves determining the area under the pulse in calculating the pulse height. With this method, instead of trying to pinpoint where the pulse and its peak will appear

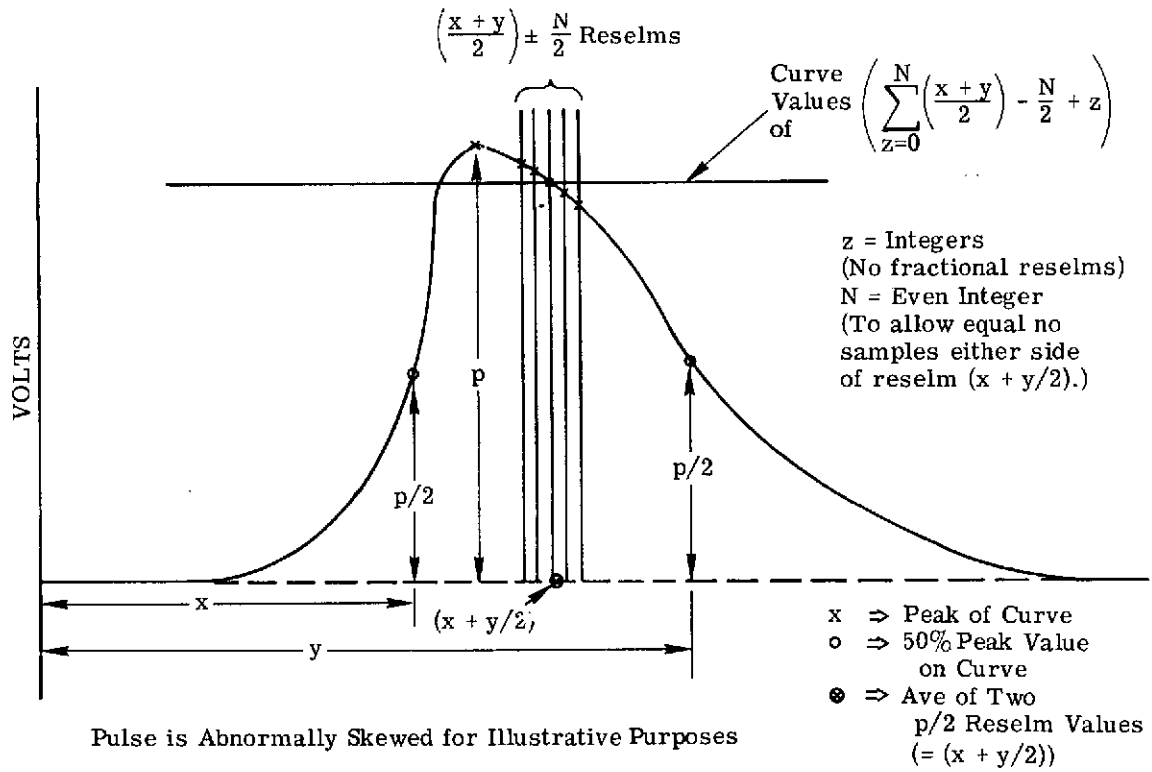


FIGURE 7. MEAN-LEVEL METHOD OF PULSE-VOLTAGE CALCULATION

(reselm limits), one may integrate the curve within wide limits (to allow for reselm position shift) and then divide the area value by an experimentally predetermined pulse "width constant" to obtain the mean value of the signal. The "width constant," which is a value determined over a period of time, is continually updated to offer accurate calibration values at any time. The "width constant" is simply determined by dividing the integrated area by the height of the pulse, as calculated in the first method (see Fig. 8).

Certain conditions must exist if this system of lamp calibration is to offer a more accurate way of determining signal value. If the shape of the pulse radically changes, the "width constant" will be inaccurate, producing incorrect lamp voltage values (although restrictions on pulse shape change are certainly no more imposing than in the "mean level method"). Generally, the only time the signal can change shape is after some type of movement has occurred within the lamp or its housing (observed experimentally). In this case, the width constant must be re-calculated to give accurate pulse voltages again. The "width constant" must be a time-weighted mean to avoid the accuracy problems encountered in determining the signal voltage by the "mean level method." Finally, the integral limits must be set far enough apart so that the integral will accurately tolerate the pulse shift that the "mean level method" was incapable of handling. The integral limits should be set such that the curve closely approaches zero at those points.

4.2.2 EXPERIMENTAL DETERMINATION OF WIDTH CONSTANT

LAMRAD. has been executed for several calibration runs. The "Lamp Mean" and the "Lamp Integral Mean" were among the data calculated by the program. By taking the values of the lamp integral mean and dividing by their respective lamp mean values, we obtained a width constant. After looking at the width constants resulting from some seven calibration runs, we then came to several conclusions.

First, the wavelength band in which the signal was observed had an effect on the width constant. For all thermal values ($1.0\mu\text{m}$ and above), the width constant varied so radically and the deviations were so great that no real attempt was made to obtain a width constant for them. The remaining width constants calculated for the various detector bandwidths had such small deviations between themselves that we could divide them into just two groups. One group used the signals emitted from all detectors operating in the $0.41\text{--}0.52\mu\text{m}$ range, while the other group contained all signals in the $0.50\text{--}0.94\mu\text{m}$. As Table 14 reveals, deviations of width constants within these two groups for any one run are on the order of 0.8%. Therefore, two width constants should be calculated, one for each of the two groups. These two values are calculated at the bottom of Table 14.

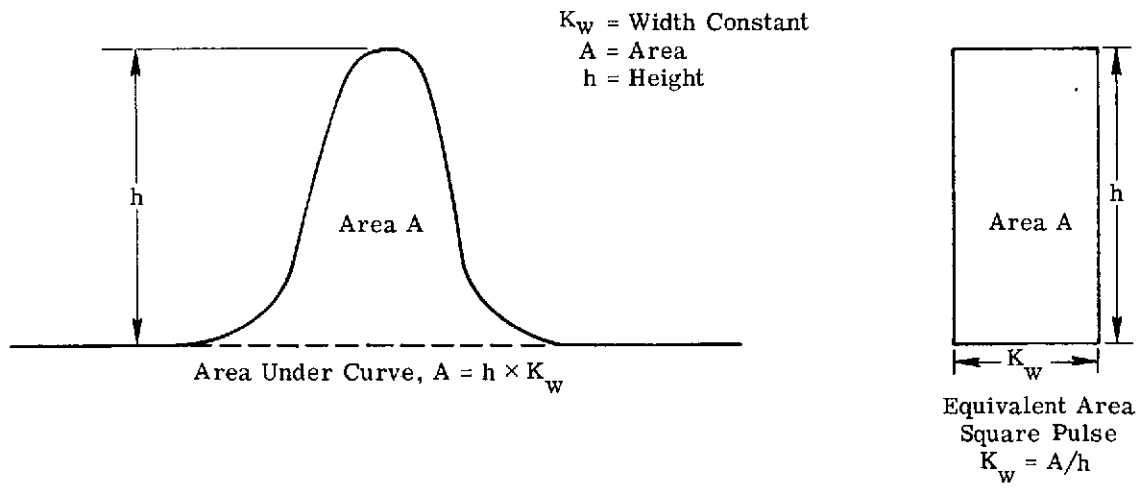


FIGURE 8. DETERMINING PULSE-WIDTH CONSTANTS (K_w)

TABLE 14. WIDTH CONSTANTS FOR A SINGLE RADIANCE CALIBRATION. (Calculated with 4.5-6.0 amp lamp current only)

Detector Bandwidths (μm)			
0.41 - 0.48	16.0837	GROUP 2	GROUP 2a
0.46 - 0.49	16.3078		
0.48 - 0.52	16.3747	GROUP 2	GROUP 2b
0.50 - 0.54	16.5327		
0.52 - 0.57	16.5803	GROUP 1	Mean = 16.4269 \pm 0.1537
0.55 - 0.60	16.5558		(Notice: worse deviation than either Group 1 or 2 alone)
0.58 - 0.64	16.5238	GROUP 1	Mean = 16.5127 \pm 0.0750
0.62 - 0.70	16.3501		
0.67 - 0.94	16.5335	GROUP 1	Disregard (deviation too great)
1.0 - 1.4	22.7585		
1.5 - 1.8	17.0816		
Final Mean Width Constants (Runs 4-8) for Groups 1 and 2 using currents of 4.5 A and greater			
GROUP 1	0.41 - 0.48	}	Mean = 16.3458 \pm 0.0445
	0.46 - 0.49		
	0.48 - 0.52		
GROUP 2	0.50 - 0.54	}	Mean = 16.5719 \pm 0.0554
	0.52 - 0.57		
	0.55 - 0.60		
	0.58 - 0.64		
	0.62 - 0.70		
	0.67 - 0.94		

Secondly, the width constant does not really remain very constant until calculated for lamp signals using 4.5 amps or more of current. Width constants calculated for signals using only 3.5 or 4.0 amps varied greatly. One way these signals might be made more useful is by increasing the gain at the time of calibration, instead of leaving the gain constant as is usually done. An increased signal gain may be able to bring the pulse level far enough out of the noise to allow more accurate calibrations to be made. Thus far, all experimental width constant data and their deviations have been calculated using lamp currents of only 4.5 amps and greater.

Lastly, as previously mentioned, changes in signal shape will affect the value of the width constant (the ratio of lamp integral mean to lamp mean will change). Also, the only way in which the signal shape can change is if there is some type of alteration made in lamp position (such as might result in housing movement). Between calibrations #8 and #9, a change was made affecting the position of the lamp's housing; the expected changes in width constants also occurred and are compared in Table 15. (Only signals in three spectral bands were analyzed.) New width constants must be calculated for calibration runs after #8. Calibration #9 gives an indication of what these values might be, but more data are needed to determine a good mean width constant for these new calibrations.

4.3 PROGRAM LAMRAD.

As mentioned earlier, the primary purpose of this program is to calculate a set of statistics from the calibration data set on the M7 scanner. These statistics are used to determine the radiance of the lamp reference source at various current levels. The statistics calculated by this program are:

- (1) the mean peak levels of the lamp and panel pulses (see Appendix C) relative to some specified dark area
- (2) the mean integrals of the lamp and panel pulses after dark-level normalization and pulse width adjustment
- (3) the standard deviations of the adjusted integrals of the lamp and panel pulses
- (4) the mean of the ratio of the adjusted lamp integral to the adjusted panel integral multiplied by a unique factor for each spectral channel
- (5) the standard deviation of the integral ratio
- (6) the mean integral of the lamp and panel pulses after dark-level normalization
- (7) the mean pulse widths for the lamp and panel pulses

TABLE 15. WIDTH CONSTANTS FOR SEVERAL RADIANCE CALIBRATIONS.
 (Means for currents of 4.5-6.5 amps, 3 bandwidths only)

Detector Bandwidths (μm)	CALIB. 4-8	CALIB. 9	Comment
0.41 - 0.48	16.2830 ± 0.1975 (1.21%)	17.0864 ± 0.2040 (1.94%)	Note greater width constants in all cases for CALIB. No. 9 (across-the-line change in pulse shape)
0.55 - 0.60	16.5530 ± 0.0885 (0.535%)	16.7218 ± 0.048 (0.287%)	
0.67 - 0.94	16.6314 ± 0.1435 (0.863%)	16.8995 ± 0.081 (0.479%)	

Before the lamp or panel pulses are used, the mean level of some specified dark area from the previous scanline is subtracted from each reselm level. This removes the effect of a varying dark level on pulse levels and allows comparisons between runs. It is assumed that the dark level does not vary significantly between any two consecutive scanlines. This assumption has been valid for all the data sets examined to date.

The mean peak level of the lamp pulse and panel pulse is determined by selecting a few reselms at the top of each in every requested scanline. Then the sets of lamp pulse and panel pulse reselms are averaged. These two means are saved for later use. The reselms for the lamp pulse are selected by determining the two reselm numbers of the reselm levels closest to half the maximum height of the pulse. These reselm numbers are averaged and two reselms on either side of this middle reselm are selected. The reselms for the panel pulse are selected in a similar manner, except that the two reselms nearest 80% of the maximum height of the pulse are used. (This 80% value was used instead of the 50% value because the panel pulse is flatter than the lamp pulse and does not drop below 50% of its maximum height.)

The mean integral levels of the lamp and panel pulses are calculated by performing an integration (using Simpson's 1/3 Rule) on the lamp pulse and panel pulse in each scanline after normalization to dark level. The lamp integral is then divided by a unique pulse width (in reselms) for each spectral channel. The number that results is no longer an area measurement (in quasi-volt-reselms); instead, it is a level measurement (in quasi-volts). The panel pulse is subjected to a similar process. All the adjusted integrals for the lamp pulse and panel pulse are averaged to obtain their respective means. The standard deviations of the two pulses from their respective means are then calculated. The mean integral ratio is calculated by dividing the adjusted mean lamp integral by the adjusted mean panel integral and then multiplying by the appropriate factor for each spectral channel. The program then goes back and calculates the integral ratio for each scanline and determines the standard deviation from the mean integral ratio for the data set.

The program now performs pulsewidth calculations. The normalized lamp integral is obtained by multiplying the adjusted mean lamp integral by the pulsewidth constant used to adjust it originally. This returns the level measurement to an area measurement. This normalized lamp-pulse integral is then divided by the mean lamp level determined earlier. In this manner, the area measurement is converted to an equivalent-square-wave width (in reselms). The adjusted mean panel integral is transformed in a similar manner.

The advantages of performing pulse-width calculations by integration instead of by the mean level method are summarized below:

- (1) The integration process usually results in lower standard deviations than those achieved with mean levels.

- (2) The integration process is faster and simpler than determining 50% or 80% points, selecting reselms, and calculating the mean level.
- (3) Changes in calculated pulsewidth provide a way to determine if changes had occurred in the shape of the pulse and how drastic they might be (assuming the specified pulsewidth is a valid representation of the expected pulsewidth).

A detailed description of the program LAMRAD. is included in Appendix D.

4.4 SUMMARY OF CALIBRATION DATA

All eleven radiance calibration sets were digitized and processed by LAMRAD. Although the volume of data generated is too large to be included in this report, a sample of the information obtained is listed in Table 16 for channel C10 (0.46-0.49 μm). As can be seen, the calibration constants $K_{\text{CAL}}(\lambda)$ have undergone two major, discrete changes associated with modifications to the system. These modifications include new amplifiers and lamp current controls (between CALIB. Nos. 1 and 2) and a different wattage lamp (between CALIB. Nos. 8 and 9). Even without these modifications, variations of up to 50% in $K_{\text{CAL}}(\lambda)$ are observed. It is apparent that more frequent radiance calibrations are needed if the changes observed between measurements are to be lowered.

The NE Δ Ls calculated for this channel were obtained using the panel noise and the following relation:

$$\text{NE}\Delta\text{L} = \frac{L \times 2\sigma_L}{V_L^i}$$

where L = radiance at lamp current i

σ_L = standard deviation at panel signal in bins (includes factor of 2 because of smoothing over 4 lines)

V_L^i = panel voltage in bins

From these values, it is seen that the high frequency noise measured on the reference panel also varies somewhat from one calibration date to the next. However, there is no apparent relationship between the changes in the value of $K_{\text{CAL}}(\lambda)$ and noise. In fact, two of the least noisy signals (CALIB. Nos. 9 and 10) show the greatest change in K_{CAL} .

One possible explanation for the change observed in the evaluation of $K_{\text{CAL}}(\lambda)$ is the aging of the reference lamps. A change in spectral character, which has been noted in aging quartz-iodine lamps, could indeed cause the differences in calibration constants. To measure this, the constants $K_{\text{CAL}}(\lambda)$ from several calibration data sets were normalized to the value at channel C2 (0.67-0.94 μm) and the results plotted (see Fig. 9). As can be seen, with the

TABLE 16. SUMMARY OF RADIANCE CALIBRATION INFORMATION FOR CHANNEL C10 ($\lambda = 0.46-0.49 \mu\text{m}$, 10% points)

CALIB. NO.	Date	Mean Dark Level (bins)	Mean Panel Level (bins)	$K_{\text{Cal}}(\lambda) @ 6.0A$ ($\mu\text{W-cm}^{-2}\text{-ster}^{-1}\text{-}\mu\text{m}^{-1}$)	% Deviation	NEAL ($\mu\text{W-cm}^{-2}\text{-ster}^{-1}\text{-}\mu\text{m}^{-1}$)	Lamp Width (reselms)	Panel Width (reselms)
1	20 August 71	147.84	11.87	12,945	3.4	54.9	13.87	7.82
2	6 June 72	147.66	26.62	5071	2.1	37.2	16.50	7.92
3	7 June 72	148.73	24.44	5116	2.1	61.2	16.32	7.98
4	16 June 72	153.44	22.64	5572	1.9	33.4	16.59	7.95
5	12 July 72	147.99	16.43	6867	2.5	53.2		7.40
6	No	C10	values					
7	No	C10	values					
8	26 January 73	161.33	18.61	4880	3.0	63.1	16.73	7.66
9*	3 April 73	148.25	26.58	2982	1.6	25.0	16.83	8.09
10*	5 June 73	147.49	27.54	2299	2.6	35.6	7.68 [†]	7.76
11*	6 August 73	149.05	19.33	2111	2.4	54.0	8.10 [†]	8.08

*45-Watt reference lamp.

[†] Due to slightly different A to O procedure.

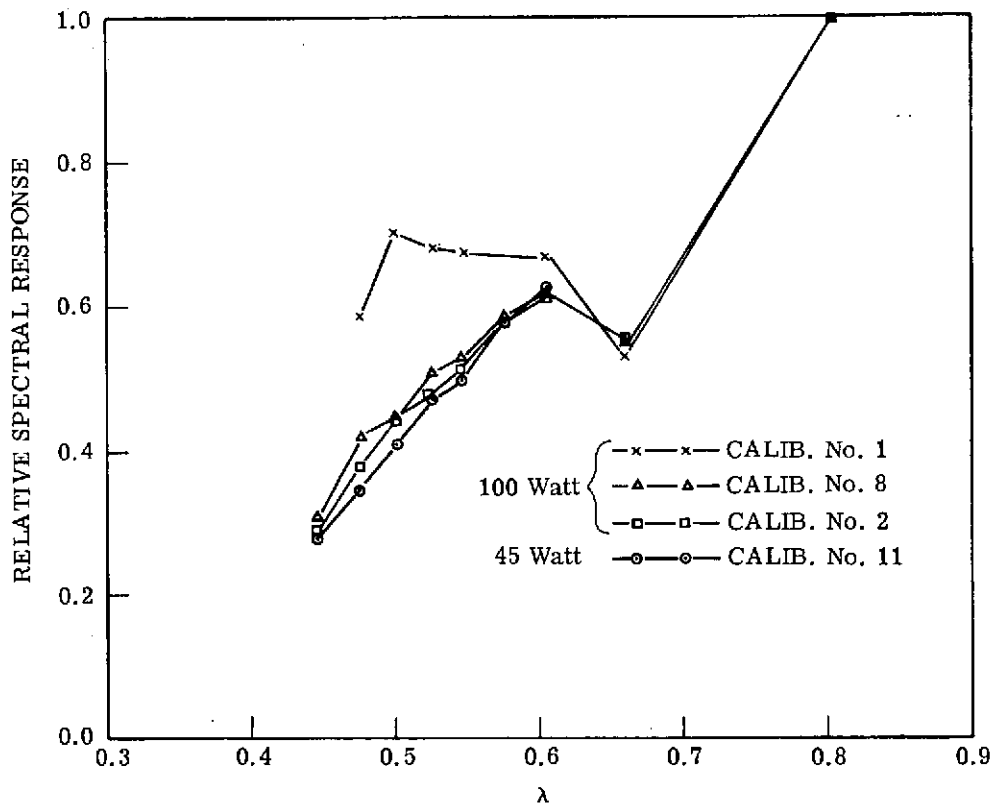


FIGURE 9. RELATIVE SPECTRAL RESPONSE OF AGED LAMPS.
Lamps set at 6.0 amps.

exception of calibration No. 1, the spectral character of the system has remained nominally constant. However, changes of 10% in some spectral bands are present, noticeably in channels C10 (0.46-0.49 μm) and C9 (0.48-0.52 μm). Calibration No. 1 does not bear any resemblance to the rest of the data except in the red region, even though the lamp was identical to those used in later runs. Since this data set was obtained with the old M5 scanner electronics (the new electronics were installed six months after the scanner itself), it is possible that the observed curve is attributable to the different spectral throughputs rather than changes in the lamp.

In still another evaluation of spectral system response, data from the panel measurements for all eleven calibration runs were used to calculate a relative response factor given by the following:

$$\text{Response}_{\lambda} \text{ factor} = \frac{L_{\lambda} \times \Delta_{\lambda} \times G}{V_{\text{panel},\lambda}}$$

where L_{λ} = radiance on panel at current i and wavelength λ

Δ_{λ} = bandpass of spectral channel

G = electronic gain

$V_{\text{panel},\lambda}$ = voltage obtained from panel

A list of these values is given in Table 17. In almost all the solar-reflective channels, the scanner spectral response has varied less than 10% during the course of 1 and 1/2 years of radiance calibration. The two exceptions in the solar-reflective region are channel C12 (0.41-0.48 μm), which shows a variation of 22%, and channel C8 (0.50-0.54 μm), which has a 16% variation. Barring one strange value which occurred during calibration No. 5, channel C12 would have only a 7% variation. CALIB. No. 1 is excluded from this analysis as it obviously exhibits characteristics quite different from the rest.

The variations observed in the near-IR region tend to be larger than in the shorter wavelength region, averaging approximately 15 to 20%. Considering the nature of these detectors and their associated preamps, however, this larger deviation is not surprising. In general, the response factor shows that the overall system has not significantly changed its response in almost two years of operation.

TABLE 17. RELATIVE SPECTRAL RESPONSE FACTOR

$$\text{Response}_\lambda = \frac{L_\lambda \times \Delta_\lambda \times G_{\min}}{V_{\text{panel } \lambda}}$$

Channel	* Calibration No.											Deviation (percent)	Mean (2-11)
	1	2	3	4	5	6	7	8	9	10	11		
C12	—	0.086	0.088	0.088	0.035 [†]	0.089	0.102	0.098	0.095	0.096	0.109	22 7	0.0886 (0.0191) 0.0954 (0.0068)
C10	0.189	0.046	0.051	0.053	0.050	—	—	0.053	0.044	0.047	0.053	7	0.0496 (0.0033)
C9	0.163	0.028	0.026	0.025	0.026	0.025	0.030	0.028	0.025	0.022	0.023	9	0.0258 (0.0023)
C8	0.104	0.061	0.060	0.060	0.070	0.078	0.095	0.085	0.077	0.084	0.091	16	0.0761 (0.0123)
C7	0.068	0.022	0.022	0.022	0.022	0.021	0.023	0.022	0.021	0.020	0.020	4	0.0215 (0.0009)
C6	—	0.042	0.042	0.042	0.043	0.041	0.050	0.047	0.045	0.043	0.056	10	0.0451 (0.0045)
C5	0.215	0.094	0.097	0.095	0.097	0.094	0.102	0.100	—	0.096	0.097	3	0.0969 (0.0025)
C4	0.498	—	—	0.143	0.141	0.137	0.151	0.145	0.143	0.148	—	3	0.1440 (0.0042)
C2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0		1.0
D3	346.7	0.0160	0.0163	—	0.0147	0.0157	—	—	0.055	0.0183	—	78 7	0.0332 (0.0259) 0.0162 (0.0012)
D2	131.2	0.0076	—	0.0075	0.0051	—	—	—	0.0056	0.0066	0.0057	16	0.0064 (0.0010)
D1	—	0.0055	0.0081	0.0053	—	0.0061	—	—	0.0062	0.0071	0.0065	14	0.0064 (0.0009)
B3	—	—	—	—	—	—	0.058	0.055	—	—	—	3	0.0565 (0.0015)
B2	—	—	—	—	—	—	0.0050	0.0073	—	—	—	19	0.0062 (0.0012)

*Note: Measurements made with M-5 scanner electronics.

[†]Note: Appear to be erroneous.

MONITORING OF THERMAL DATA QUALITY

Users of thermal data from a scanner such as the M7 usually are interested more in the accuracy (deviation from true value) of the temperature measurements than in some of the other performance parameters such as NE Δ T or stability. This is because many investigators (especially at this stage in technique development) are attempting to extend limited ground-truth information on temperatures to much larger areas by the use of imagery obtained by aircraft or satellite. When measurement differences occur between these sources of data, not only does the extension of temperatures become difficult but the researcher must do a considerable amount of investigation to identify (or justify) the causes of the differences.

This is not to say that NE Δ T and long-term stability are not important parameters. Obviously, a system that cannot resolve, say, a 5 $^{\circ}$ C temperature difference would not be suitable for most applications involving small temperature ranges. Also, knowledge of NE Δ T is a good indicator of system performance in the thermal region. In most cases, though, the researcher will tolerate poorer temperature resolution (as long as it is not excessively poor) to gain exact temperature calibration.

It is not the objective of this study, however, to improve the method of thermal calibration. That is, while some new techniques concerning thermal data quality were analyzed, none specifically involved the method of calibrating the reference plates themselves. This study was addressed to the problems of maintaining some degree of confidence for a given thermal calibration and determining how often these thermal calibrations are needed. The remainder of this section presents the results of this investigation.

5.1 PROGRAM THERML.

As an aid in analyzing thermal data, the program THERML. was written. This program calculates a set of statistics for the hot reference plate, cold reference plate, and ambient plate similar to that which CALIB. calculates for the solar reflective data channels. The main difference is that no data-base tape for gathering a history of thermal response is available, nor can more than one channel of thermal data be processed at one time. Since the hot plate and cold plate are represented by fairly flat pulses, calculations to find the mid-point need not be performed on the pulses. Any width of flat area on the plates can be selected by specifying the beginning and ending reselm numbers of each of the plates. A default case does exist, however, for routine data reduction.

To implement this program, the user simply specifies the location of the cold plate, the hot plate, and ambient area within each scanline of a scene. The program then calculates the average level and standard deviation of the cold plate. The same thing is done for the hot

plate and the ambient area, except that the mean level and standard deviation are relative to the mean level of the cold plate from the previous scanline. This assumes that the mean level of the cold plate does not change significantly between any two scanlines of a scene. (This proved to be a valid assumption throughout all the data sets we analyzed.) These statistics are calculated for as many data sets as required.

After all the statistics have been calculated for the requested data sets, the program plots the means of the cold plate, the hot plate, and the ambient areas versus the data set numbers. The same thing is done for the standard deviations. These plots are followed by a table of all the statistics calculated. Together, these plots and the table provide the user with comparisons between data sets so that trends and discontinuities can be determined. Once the user has found that a trend has developed or a discontinuity has occurred, the causes can be analyzed more thoroughly via other techniques available to him. Detailed documentation of Program THERML is given in Appendix E.

5.2 PROCEDURE FOR CHECKING THERMAL DATA QUALITY

The M7 scanner has two thermo-electrically heated (or cooled)-plates which serve as temperature references for the determination of apparent temperatures at the entrance aperture of the scanner. These plates are checked periodically to ensure that the plate temperature (apparent temperature) versus thermistor resistance (thermistors are embedded in the plates) has not changed. Though it has been determined that in general these plates do not change their radiative characteristics much from one calibration to the next, individual plate failure has often occurred. Once repaired, these plates exhibit temperature characteristics identical to those observed before failure. It is primarily during these periods of plate failure, then, that uncertainties exist concerning plate calibration.

Plate failures are caused by changes in operating characteristics of the thermoelectric devices used to control plate temperature. Although no solution has yet been worked out to prevent plate failure, a technique for monitoring plate performance has been found. Shown in Table 18 is a list of calculated and actual ambient surface temperatures located inside the scanner housing for a number of missions during 1972 and 1973. The surface being viewed for this experiment was a plate (identical to the reference plates) installed in an unused portion of the scanner housing during the summer of 1972. Although this plate was unpowered by thermoelectric devices and left to drift with ambient temperatures, a precision thermistor was embedded in its center to permit temperature monitoring.

The data in Table 18 provide comparison between the ambient surface temperature of this plate as determined by the thermistor and the apparent temperature calculated by using the hot and cold reference plates. Although some difference can be expected since surface

TABLE 18. CALCULATED PLATE TEMPERATURE COMPARED TO MEASURED PLATE TEMPERATURE

Date	Calculated Ambient Temperature (°C)	Actual Surface Temperature (°C)	Temperature Difference
23 July 72	14.20	14.13	-0.07
24 July 72	18.16	16.38	-1.78
18 August 72	19.77	19.77	0
25 August 72	25.80	27.09	+1.29
28 August 72	20.13	20.59	+0.46
29 August 72	23.39	23.97	+0.58
29 August 72	20.54	21.07	+0.53
30 August 72	24.71	25.42	+0.71
5 September 72	23.50	23.94	+0.44
14 September 72	14.57	14.77	+0.20
17 October 72	7.57	6.85	-0.72
16 November 72	18.42	18.75	+0.33
17 November 72	19.33	20.51	+1.18
2 January 73	6.54	5.25	-1.29
10 January 73	-2.37	-5.35	-2.98
12 January 73*	10.02	1.96	-8.06
25 January 73	16.05	15.67	-0.38

*Reference plate failure 12 January 73.

temperatures are being compared to apparent temperatures, a major discrepancy would indicate a possible reference plate malfunction. As noted in the third column (containing temperature differences), a significant error was observed on 12 January 1973. This coincides exactly with a scanner operator's observation of a plate failure on that date. As noted for the three previous dates, there is strong evidence that some degree of malfunction, which went unobserved by scanner operators, was present even then.

The data shown in Table 18, however, do not answer all the questions about plate performance. Although the principle is sound, only one failure was observed (for analysis purposes) during the period covered in the table. Other failures were observed during the spring and summer of 1973, but the ambient plate used in the test had by then been removed to make room for a second reference lamp for the solar reflective region. Also, the dates indicated in the table do not include all flights made with the M7 scanner—the need for standardization tests (including the thermal regions) on every flight had not yet been demonstrated.

Finally, two other entries (24 July and 25 August 1972) in the table indicate a difference significantly in excess of 1°C between measurements, but they have not been associated with a plate failure. The reason behind the larger discrepancies which occurred on these two dates is unknown, but it is obvious that some quantitative measure of maximum difference must be generated before the technique will become usable.

During the winter of 1973, a new ambient plate will be constructed for use during standardization data runs. With these data runs being made every flight, some quantitative judgment of thermal reference plate operating performance (and, indirectly, of temperature calibration) should be available for each mission.

5.3 NOISE EQUIVALENT ΔT (NE ΔT)

In addition to monitoring thermal plate performance (which determines temperature accuracy), it is also very informative to monitor the NE ΔT of the thermal channel. By doing this, a check of the system's temperature resolution is possible. Before going on, however, we should be careful to distinguish the difference between the NE ΔT of the system and the NE ΔT of the infrared detector. This distinction is important because the NE ΔT observed by an investigator who is digitally processing recorded data includes noise from the optics, detector, amplifier, and tape-recorder components of the system. Hence, a particularly poor NE ΔT could be the result of a predominance of noise from any one of these components. And, in fact, tape-recorded thermal data from the M7 is usually limited by the noise of the tape recorder, as will be shown later.

The infrared detector itself, however, may have a significantly better NE ΔT than that observed from processed data. In the ideal system, the noise of the system would be detector-limited; hence, ultimate temperature sensitivity depends on the detector. Of the four

components mentioned above, the detector is the least rugged and most likely to fail. Thus, it seems reasonable to monitor the NE Δ T of the detector in conjunction with total system NE Δ T to ensure proper system performance. This study, however, will concern itself only with the system NE Δ T measurements since most investigators are interested in temperature resolution primarily from the data processing standpoint—i.e., what results can be obtained from the recorded signals.

As mentioned above, the tape-recorded thermal data from the M7 scanner is usually limited by the noise of the tape recorder. The Mincom PC-500 tape machine used in the M7 system has a dynamic range of 39.5dB (peak-to-peak), which means that 89 temperature levels are available between the minimum and maximum temperatures recorded (this assumes that the full range of the tape machine is being utilized, which is seldom the case). For a typical temperature range of 10°C, the system NE Δ T would be 0.11°C (assuming a tape-recorder-limited system). It should be obvious, here, that the NE Δ T in this system is a function of the terrain temperature range encountered—the larger the range, the larger the NE Δ T. Since the nominal NE Δ T of the HgCdTe infrared detector used in the M7 is 0.03°C (which is independent of Δ T), it is apparent that, in most cases, the noise of the tape recorder is the limiting factor in temperature resolution.

In order to quantitatively assess the noise performance of the thermal channel, data obtained from the standardization runs in 1972 and 1973 were analyzed for system NE Δ T. Table 19 is a list of the NE Δ T s calculated from that data. The theoretical tape recorder limit is plotted (assuming 39.5dB dynamic range) along with data generated from the noise levels obtained from the cold plate, hot plate, and ambient plate. These NE Δ T s were calculated according to the relationship

$$NE\Delta T = \frac{\Delta T \times 2\sigma}{\Delta V}$$

where ΔT = temperature difference between reference plates

σ = rms noise calculated from program THERML. — the factor of 2 appears because the data were averaged over 4 lines

ΔV = voltage difference between reference plates

In viewing these data, however, certain things must be kept in mind. As mentioned above, the theoretical recorder limit applies to the full dynamic range of the tape machine. In practice, this full range is not used. Hence, the recorder limit may be lower than the theoretical limit by as much as 33%. Secondly, the cold-plate noise figure is based on absolute voltages and includes a low-frequency drift inherent in the preamplifiers for the HgCdTe detector. Since the hot plate and ambient plate are measured relative to the cold plate, this drift does

TABLE 19. SUMMARY OF NEAT VALUES OVER TIME

Date	ΔT	NEAT				Comments
		Recorder Limit	Cold Plate	Hot Plate	Ambient	
14 May 72	7.9	0.09	0.35	1.09	0.20	
5 May 72	6.5	0.07	0.69	0.71	0.48	
11 May 72	9.9	0.11	0.48	0.65	0.36	
11 May 62	9.9	0.11	2.12	3.20	1.71	
12 May 72	9.8	0.11	0.89	0.49	0.76	
12 May 72	10.8	0.12	0.53	0.45	2.12	
19 May 72	6.5	0.07	2.61	1.07	0.96	
25 May 72	6.5	0.07	0.56	0.49	0.37	
25 May 72	6.5	0.07	0.41	0.54	0.39	
5 June 72	9.7	0.11	0.51	0.53	0.39	
23 July 72	10.3	0.11	1.07	0.77	0.61	
24 July 72	7.3	0.08	1.70	0.71	0.64	
18 August 72	9.1	0.10	0.72	2.12	0.59	
25 August 72	10.3	0.12	6.47	2.61	2.22	
28 August 72	10.3	0.12	0.98	0.65	0.59	
29 August 72	9.1	0.10	0.70	0.20	0.34	
29 August 72	10.3	0.12	0.48	0.41	0.23	
30 August 72	10.3	0.12	0.65	0.24	0.23	
5 September 72	9.1	0.10	0.81	0.30	0.32	
14 September 72	15.7	0.10	0.61	0.83	0.32	
17 October 72	15.7	0.18	0.95	1.87	0.34	
16 November 72	5.6	0.06	0.35	0.35	6.65	
17 November 72	5.6	0.06	3.33	0.45	13.00	
2 January 73	15.7	0.18	0.94	3.94	0.67	
10 January 73	15.7	0.18	0.87	4.81	12.91	
12 January 73	15.7	0.18	1.25	2.57	1.08	Plate failure on this date
25 January 73	15.7	0.18	0.53	1.97	7.71	
22 June 73	15.7	0.18	0.52	1.52	—	
25 June 73	15.7	0.18	0.44	1.62	—	
3 July 73	15.7	0.18	1.63	1.73	—	
5 July 73	15.7	0.18	0.63	2.58	—	
6 July 73	15.7	0.18	0.96	1.22	—	
7 July 73	15.7	0.18	0.58	1.43	—	
4 August 73	15.7	0.18	0.70	2.07	—	
5 August 73	15.7	0.18	4.04	2.43	—	
10 August 73	15.7	0.18	0.43	2.82	—	
12 August 73	15.7	0.18	0.52	1.47	—	Plate failure on 8/17/73

not affect them. Finally, the ambient plate is unpowered (i.e., it has no thermoelectric devices): so, any noise associated with thermoelectric devices would appear only in the cold and hot plate values.

In looking at the hot plate NEAT s, it is quite easy to see which missions appear to have excessively noisy temperature resolutions. An arbitrary limit is any value over three times the recorder limit. Equipment performance on most missions prior to January 1973 appears to be nominal. But note the NEAT measurements during January just prior to a reference plate failure; obviously the signals were becoming consistently noisy. Also interesting is the fact that all NEAT s calculated from the hot plate during the period June to August 1973 appear to be high (no ambient values are available because the ambient plate had been removed). On August 17, soon after the last mission listed in the table, a reference plate failure occurred and a degraded HgCdTe operating performance was noted. It would appear that one or both of these problems had been affecting the thermal channel performance for several weeks. However, since the noise on the cold plate during this period is generally acceptable, more than likely it was the reference hot plate that caused the excessively high noise.

Given more frequent standardization runs and the availability of a new ambient plate for additional data, these NEAT calculations should provide a quantitative evaluation of every mission, whether or not the thermal channel is performing within the ideal limit.

5.4 HIGH AND LOW FREQUENCY THERMAL NOISE

Until now, statistical comparisons of thermal data have been made between missions. One of the questions to be answered in this study was: What frequency variation in thermal reference signals can be expected during the course of a 12-minute run? In other words: Is the dominant noise in the thermal channel mainly attributable to high-frequency (<16 msec) or low-frequency (<12 minute) components? The frequency distribution should tell us (1) whether static reference-plate calibration of the data is adequate or whether dynamic calibration is needed; and (2) if dynamic calibration is dictated, how often must it be done.

Using the program DGNSTC., we analyzed for noise a 12-minute segment of data obtained on 7 April 1973 over Lower New York Bay. To obtain a low-frequency component, the mean and standard deviations of the hot and cold plate were calculated for all lines in the entire 12-minute segment:

Cold Plate: mean plate voltage = 185.07
standard deviation (between lines) = 92.41 (50.0%)
Hot Plate: mean plate voltage = 33.27
standard deviation (between lines) = 14.45 (43.5%)

Although the high deviation in cold-plate value can be attributed to drift (low-frequency noise) in the infrared detector preamplifiers, the high deviation in the hot plate value is inexplicable since it has been measured relative to the cold plate. In any case, because these significant deviations occur during the course of a 12-minute data collection run, it is apparent that static dark level corrections are out of the question.

To measure high-frequency thermal noise, the program DGNSTC also calculated the standard deviation of each line. This would be the noise encountered if dynamic thermal calibration were done on a line-by-line basis. The calculations obtained are as follows:

Cold Plate: mean plate voltage = 185.07
average standard deviation per line = 3.49 (1.9%)

Hot Plate: mean plate voltage = 33.27
average standard deviation per line = 2.52 (7.6%)

The average cold-plate standard deviation of each line over the entire 12-minute run is only 1.9% of the mean value as compared to a 50.0% standard deviation of all lines. Line-by-line dynamic temperature calibration is obviously needed since it provides a significantly lower error than that observed statistically from all lines.

6

CONCLUSIONS AND RECOMMENDATIONS

It has been demonstrated that valuable information about scanner performance can be gained from the calibration data ("standardization" runs) obtained during data acquisition missions. In the solar reflective region, noise information (as a function of frequency) obtained digitally from "standardization" runs can indicate possible amplifier, detector, or recorder problems. To permit up-to-date monitoring of these noise figures, it is recommended that standardization data be acquired at least once every flight. Rapid processing of this information is essential to its optimal use.

A region of darkness viewed by the rotating scan mirror in one 360-degree swing was obtained for baseline correction. We recommend that all data processors of M7 multispectral data use this region, which is located beyond the lamp reference but before the sky reference.

A new technique for obtaining values for the reference lamp pulse was examined. This technique, which uses integration instead of peak pulse value, is advantageous in that more points are available for averaging with a resulting lower noise figure. In addition, the integration is relatively insensitive to jitter in lamp pulse position. For optimal use of the reference lamp pulse information, this technique should be applied to all software associated with the extraction of radiance information.

Analyses of all past laboratory radiance calibrations on the M7 scanner have revealed large differences between "adjacent" measurements (currently scheduled approximately every two months). Such differences (as large as 50%) appear even in the absence of a physical alteration in the system—such as a new reference lamp, for example. If smaller changes between radiance calibration measurements are desired, these measurements will have to be made more frequently, most likely every 2 to 3 weeks.

Finally, we tested methods for evaluating both thermal reference plate performance and overall detector, amplifier, and tape recorder performance in the thermal region. Plate failure often begins to occur long before it is observed by the scanner operator. But it is possible, by using an ambient plate as a third reference, to determine whether thermal reference plates are failing. Thus, inclusion of an ambient reference in the standardization measurements made every flight would be desirable in order to permit reference plate evaluation as often as possible. An overall thermal region performance indicator has been demonstrated by the use of NE Δ T calculations. These permit a theoretical tape recorder limit to be compared to actual measured values. Since in most cases the system is tape-recorder-limited, any NE Δ T's larger than the theoretical limit can indicate some type of excessive noise in the system.

In summary, it has been shown that systematic recording and digital analysis of M7 scanner calibration signals can be valuable in evaluating both scanner performance and data quality.



As we acquire better knowledge through continued analysis of these calibration signals, we can more easily satisfy future data requirements to meet new user goals.

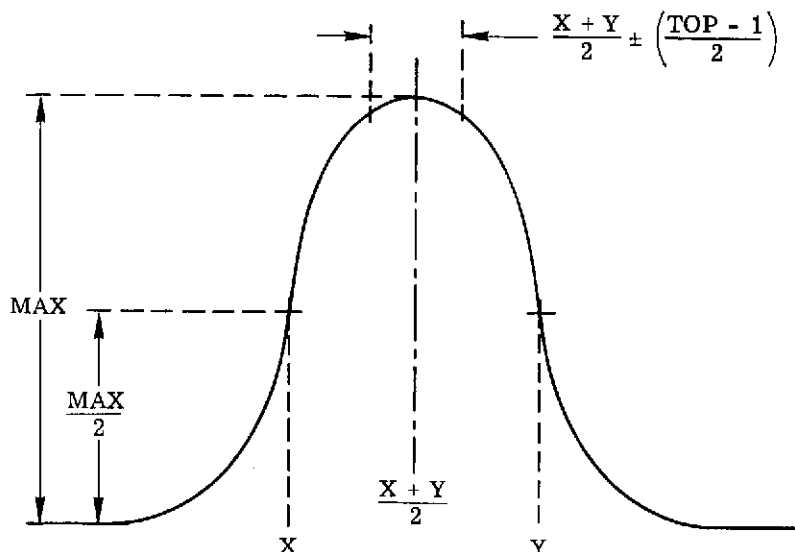
Appendix A PROGRAM CALIB.

The purpose of this program is to calculate a set of statistics concerning the reference sources of the M7 scanner. These statistics may be calculated for as many flight missions as desired (the only limitation is the physical amount of core storage in the computer). After calculating the statistics for the requested files and channels, the program can merge them with those on a special tape data base (initially produced by this program), produce plots and tables, and update a tape data base for each of 24 possible spectral channels. In addition to creating the initial tape data base, the program can be requested to simply produce plots and tables from a given tape data base previously generated.

The statistics calculated by this program are the following:

- (1) The mean of the dark level
- (2) The mean of the normalized lamp pulse level
- (3) The mean of the normalized level of the middle reselm in the lamp pulse
- (4) The mean of the reselm number of the middle reselm in the lamp pulse
- (5) The mean of the integral of the normalized solar pulse
- (6) The standard deviation from each of the previous five calculated means

All of these statistics are normalized to 100X gain except the solar statistics (normalized to 10X gain). The gain in each channel is read as input. The lamp pulse points used in the calculation of its mean are determined as follows:



- (1) Maximum height is determined [MAX]
- (2) Reselms closest to MAX/2 are found [X & Y]
- (3) The mean of X & Y is found $(X + Y)/2$
- (4) The bounds used in calculations are TOP/2 reselms on either side of $(X + Y)/2$

Normalization is achieved by subtracting the average dark level from each point of the lamp pulse and solar pulse before they are used. The mean dark level is taken from the previous line. Consequently, in order to start this chain, the lamp pulse and solar pulse are ignored in the first line of any file so that the mean dark level can be calculated. We assume that the dark level does not change significantly from line to line.

CAUTION: For the program to operate correctly, the lamp pulse and the solar pulse must be positive-going.

STEP(1)- PERFORMED 1ST TIME FUNCTION CALLED OR WHENEVER MODEL - \$START\$

The maximum number of channels to be referenced and the maximum number of files to be referenced are initialized. The beginning and ending reselms for the dark area, lamp pulse, and solar pulse are set and other pertinent variables are set.

Data cards (if any) are read that may change the default settings for the type of data base (TAPE = \$OLD\$, \$NEWS\$, OR \$PRINT\$), the maximum number of channels, the maximum number of files, the maximum number of missions to be plotted (effective only if TAPE=\$PRINT\$), the tape numbers of the tapes to be used for the tape data base, and the number of reselms at the top of the lamp pulse to be used in calculation of the lamp statistics. These variables are now checked for reasonableness. The storage for the main-in-core data base is then allocated, and the totalling arrays are zeroed. Control returns to POINT.

STEP(2)- PERFORMED BEFORE EACH FILE IS PROCESSED

The point counters for the lamp and solar pulses, for the data, and for the lines are zeroed. A flag is set so that the 1st line of the file will not be processed by the lamp or solar pulse routines.

If this is the first time through the file, data cards are read to set the data (in month, day, year form), the mission number, and any special comment. The beginning and ending reselms for the dark area, lamp pulse, solar pulse (if different from the default settings are then specified. At this point, as many cards are read

in as there are channels on the input tape. Each card specifies the multiplexor channel number, the spectral channel it represents, the aircraft channel it represents, and the gain in that channel. A title describing the spectral channel is printed along with each card. The spectral channel number and the multiplexor channel number are used to set up an array to relate the multiplexor channels to the spectral channels. [If a particular multiplexor channel is not to be used, simply assign zero as its spectral channel #.] This array is then checked for reasonableness. Likewise, the dark, lamp, & solar area boundaries are checked as well as the date and the mission number. No more than 100 reselms are allowed for either the lamp pulse or the solar pulse. In addition, there must be some dark area specified. Control returns to POINT. If this is the second pass through the file, nothing is done and control returns to POINT.

STEP(3) - PERFORMED BEFORE EACH POINT OF A SCAN LINE IS PROCESSED.

No action taken.

STEP(4) - PERFORMED AFTER EACH LINE IN FILE IS PROCESSED

If this is the first line processed (FLAG=0), the line counter is incremented, and control returns to POINT. After incrementing the line counter, the following is performed on each non-zeroed spectral channel.

1. The maximum point in the lamp pulse is found.
2. The reselm location of the two points that are 1/2 the maximum or just greater than 1/2 the maximum are found (these will correspond to the boundaries of the lamp pulse if only the top of the pulse is specified).
3. The reselm half-way between the preceding two points is found. New boundaries are set on either side of this middle according to the number of reselms requested for use at the top of the lamp pulse (LAMTOP) [Right & Left].
4. The new subset of reselms is checked to make sure they are within the original boundaries for the lamp pulse, (if not, the calculated bounds are adjusted accordingly).

The data point counter is incremented by right-left +1.

- 5a. If this is pass 1, the values of the reselm subset of the lamp pulse are accumulated, the value of the middle reselm is accumulated, and the reselm number of the middle reselm is accumulated.

5b. If this is pass 2, the squared deviations are accumulated for the reselm subset, for the middle reselm, and for the reselm number.

6. The number of points in the solar pulse is checked to make sure that it is greater than 5 and is odd.

7. A Simpson integration is then performed on the points in the solar pulse and its result accumulated if pass one. Otherwise the squared deviation is accumulated.

After all the multiplexor channels requested are processed, the point counters for the lamp pulse and the solar pulse are zeroed.

STEP5 - PERFORMED AFTER AN ENTIRE FILE HAS BEEN PROCESSED

If this is pass 1:

1. The file counter is incremented.
2. The means are calculated for each channel requested.
3. The information is stored in the main data base after being normalized to gain 100.
4. "PASS" is set to 2 and the totalling arrays are zeroed.

If this is pass 2:

1. The standard deviations are calculated for each channel requested and stored in the main data base after being normalized to gain 100.
2. "PASS" is set to 1.
3. The date, mission number, and special comments are saved.
4. The totalling arrays are zeroed.

STEP6 - PERFORMED WHENEVER MODEL = \$FINAL\$

Whenever "TAPE = \$OLD\$ or \$NEW\$:

1. A tag sort is performed on the data array.
2. The tapes specified by TBASE 1 & TBASE2 are mounted on tape drives 2 and 3.
 - a. If "TAPE" = \$NEW\$, tape unit 2 is made the output unit and its generation number is set to 1.
 - b. If "TAPE" = \$OLD\$, tape unit 2 is checked for a generation number of 1. If so, tape unit 2 is set for input and tape unit 3 is set for

output. If the generation number is not 1, the tape unit with the greater generation number is set for input, and the tape unit with the lower generation number is set for output.

3. The bin number and generation number are written on the output tape.

4. A call is made to PLOT1. to set up the grid. The minimum and maximum mission numbers to appear on the plot are determined. (The maximum mission number of the last file processed. The minimum mission number is 1 or the maximum mission # minus 61, whichever is larger.)

For each spectral channel the following are performed:

1. If "TAPE" = \$PRINT\$, the number of missions in the spectral band is read from the tape data base. If "TAPE" = \$NEWS\$, this number is always zero.

2. The storage necessary for the X and Y coordinate matrices is allocated.

3. The calculated statistics and the statistics from the tape data base are merged (ascending order based on date).

4. The merged means are then plotted against their corresponding mission numbers FOR THE LAMP ONLY.

5. The merged standard deviations are plotted against their corresponding mission numbers.

If "TAPE" = \$PRINT\$, the tapes are mounted and checked as before. The input tape is found also. In this case, it is assumed that there are no calculated statistics to merge. Therefore, only the data on the tape data base is plotted and tabulated as before. No output tape is generated and the existing tape data base remains unchanged. The maximum mission number to be plotted along the X axis is determined by the cards read in during STEP1.

PTPROC.

This routine calculates the average dark level for each line. This average is used to normalize the data points that are saved in the lamp and solar pulse arrays. In addition, the dark level is accumulated over the specified area. If "FLAG" = 0 (indicating that this is the 1st line of the file to be processed), the data points for the lamp pulse and the solar pulse are not saved.

SIMPSN.

This routine performs a Simpson integration of the data points in the solar pulse. The formula used is:

$$Q_{22} = X_1 + 4X_2 + 2X_3 + 4X_4 + \dots + 4X_{n-2} + 2X_{n-1} + X_n$$

n must be ODD

$n \geq 5$

INSERT.

This routine inserts either the calculated statistics or the statistics from the data tape into the 3-dimension coordinate array composing the main in-core data base.

STEP(1) CHANNL	13 INTEGER	The maximum multiplexor channel number being referred to by any file. It may be less than the actual number of channels available. It must not be less than 1 or greater than 13.
STEP(1) FILMAX	1 INTEGER	The maximum number of input files to be processed, plotted, and tabulated as a set (you may process fewer files but not more). This variable must not be less than 1.
STEP(1) LAMTOP	5 INTEGER	The number of data points at the top of the lamp pulse to be used in the statistical calculations. Fewer than this number may be used if the given bounds for the lamp pulse are smaller. The variable must not be less than 0 or greater than LAMPE-LAMPB+1.
STEP(1) TAPE	\$OLD\$ ALPHABETIC	\$OLD\$ indicates that a tape data base exists and the data in it should be merged with the processed data for plotting and tabulation. \$NEW\$ indicates that no tape data base exists and that a data base should be

generated from the present data. This new tape data base is written on tape TBASE1. \$PRINT\$ indicates that no data is to be processed. The existing current tape data base is plotted and tabulated. No tapes are altered. MISSION must also be assigned a value. The number assigned to MISSION will be the number of the last mission table plotted. All higher-numbered missions on the tape data base will not be plotted. All mission numbers less than MISSION-61 or 1 (whichever is higher) will not be plotted also. In either case all missions will be tabulated. Whenever TAPE = \$OLD\$ or \$NEWS\$, the mission number of the last file processed will be the last mission number to be plotted. Higher-numbered missions will be plotted and mission numbers less than MISSION-61 or 1 (whichever is higher) will not be plotted. In either case, all missions will be tabulated.

STEP(1)	MISSION	0	This is the number of the last mission to be plotted and tabulated if TAPE = \$PRINT\$.
		INTEGER	This number must not be less than 1.
STEP(1)	TBASE1	799	The bin number of a tape to be used for part of the tape data base.
		INTEGER	
STEP(1)	TBASE2	800	The bin number of the other tape of the tape data base.
		INTEGER	

NOTE: No error checking is done either
ON TBASE1 or TBASE2 before the
mount commands are issued.



STEP(2) FDATE(1)...FDATE(3)	0		Any date to be associated with the present file being processed.
	INTEGER		
			FDATE(1)--the month must not be less than 0 or greater than 12.
			FDATE(2)--the day must not be less than 0 or greater than 31.
			FDATE(3)--the year must not be less than 0 or greater than 99.
STEP(2) MISSON	0		The number of the mission to be associated with the present file being processed. If this is the last file being processed, this is also the highest mission number that will be plotted. This variable must not be less than zero.
	INTEGER		
STEP(2) COMMNT(1)... COMMNT(8)	BLANK ALPHANUMERIC		Any 48-character comment to be printed along with the tabulated results for this file.
STEP(2) LAMPB	10		This is the number of the reselm indicating the beginning of the lamp pulse. This number must not be less than the beginning reselm number of the line.
	INTEGER		
STEP(2) LAMPE	60		This is the number of the reselm indicating the ending of the lamp pulse. The variable must not be greater than the existing reselm number for the line.
	INTEGER		
STEP(2) DARKB	185		Same as LAMPB for beginning of the dark area.
	INTEGER		
STEP(2) DARKE	225		Same as LAMPE for ending of the dark area
	INTEGER		
STEP(2) SOLARB	310		Same as LAMPB for beginning of the solar area.
	INTEGER		



STEP(2) SOLARE 355 Same as LAMPE for ending of the solar area.

INTEGER

STEP(2) MPXMUX NO DEFAULT The number of the multiplexor channel. Must not be less than one or greater than 13.

INTEGER

STEP(2) SCHAN NO DEFAULT The number of the spectral channel that MPXMUX represents. This variable must not be less than 0 or greater than 24. When SCHAN = 0, the MPXMUX channel will be ignored.

INTEGER

SCHAN SPECTRAL BAND

1	F1, .71-.73
2	E1, .33-.38
3	B2, 2.0-2.6
4	B3, 1.0-1.4
5	D1, 2.0-2.6
6	D2, 1.5-1.8
7	D3, 1.0-1.4
8	C2, .67-.94
9	C4, .62-.70
10	C5, .58-.64
11	C6, .55-.60
12	C7, .52-.57
13	C8, .50-.54
14	C9, .48-.52
15	C10, .46-.49
16	C12, .41-.48

17-24 Not Assigned

STEP(2) AIRCHN NO DEFAULT This is the number of the aircraft channel MPXMUX represents.

INTEGER

No error checking is performed.

STEP(2) GAIN NO DEFAULT This is the gain to be associated with this multiplexor channel.

INTEGER

OUTPUT

PLOTS

Plots are made only for those spectral channels with data. The first plot of each pair is a plot of the mean LAMP LEVEL.

Plotting Char.

D	mean dark level
L	mean lamp level
M	mean level of middle of lamp
S	mean integral of solar

The second plot of each pair is a plot of the standard deviations. The same plotting characters are used as before. After each pair of plots follows a table of

DATE	date
MISSION	mission #
DARK MEAN	mean of dark level x 100
LAMP MEAN	mean of lamp level x 100
LAMP MIDDLE MEAN	mean level of middle of lamp x 100
SOLAR MEAN	mean integral of solar pulse x 10
DARK DEV	" " " " " x 100
LAMP DEV	" " " " " x 100
LAMP MIDDLE DEV	} standard deviations from their respective means X10
SOLAR DEV	
LAMP RESELM MEAN	mean # of point of middle of lamp pulse (ADD LAMPB-1 to get actual reselm #) x 100
LAMP RESELM DEV	standard deviation of above x 100

Lamp pulse and solar pulse are normalized by subtracting average dark level from each point before processing.

DATA CARDS SETUP

1. FILMAX = 3, TAPE = \$NEW\$, CHANNL = 5*
2. INBIN = 706, UNIT = 4, FILE = 1, NSA = 1,100,1,1,359,1 *
3. FDATE(1) = 01,11,72, MISSON = 4
4. COMMNT(1) = \$THIS IS A SPECIAL COMMENT\$*
5. MPXMUX = 1, SCHAN = 4, AIRCHN = 7, GAIN = 2*

```

6.      MPXMUX = 2, SCHAN = 5, AIRCHN = 4, GAIN = 4*
7.      "      = 3      "      = 0      "      = 8      "      = 6*
8.      "      = 4      "      = 2      "      = 1      "      = 8*

9.      FILE = 1, NSA = 1,100,1,1,359,1 *
10.     "      2      "      1,110,1,1,320,1*
11.     FDATE(1) = 01,25,72, MISSON = 7*
12.     MPXMUX = 1, SCHAN = 3, AIRCHN = 6, GAIN = 10*
13.     "      = 2      "      = 4      "      = 5      "      = 12*
14.     FILE = 2, NSA = 1,100,1,1,320,1 *
15.     "      = 3      "      = 10,60,1,1,320,1 *
16.     FDATE(1) = 02,13,72, MISSON = 18*
17.     MPXMUX = 1, SCHAN = 0, AIRCHN = 3, GAIN = 14*
18.     "      = 2      "      = 3      "      = 1      "      = 14*
19.     FILE = 3, NSA = 10,60,1,1,320,1*
20.     MODEL = $FINAL$ *
21.     MODEL = $START$*
22.     TAPE = $PRINT$, MISSON = 72*

```

1. A maximum of these files are to be processed with a maximum multiplexor channel number of five. The tape data base is assumed to be tapes 799 and 800. A data base will be started on tape 799.
2. This is the input data required by PROCESS under POINT. Tape 706 will be mounted on unit 4, and file 1 will be accessed. Every line from 1-100 will be processed and every point from 1-359 will be used. This starts the calculation of the means.
3. & 4. The date, mission, and comment given will be associated with this file.
- 5-8. Multiplexor channels 1, 2, & 4 correspond to spectral channels 4, 5, & 2. Multiplexor channel 3 is to be ignored. File one has only 4 channels and all four channels must be specified even though only three of the four channels are actually to be used. The gains associated with the channels are as listed. All gains on the printout will be normalized to gain 100.

9. This is the input data required by PROCESS under POINT. This causes the previous file to be reaccessed so that the file can be read a second time. After the first pass through the file is completed, all the means have been calculated. This second pass is required in order to calculate the standard deviations for each of the corresponding means.
10. This is more input required by PROCESS to access the second file and start the first pass through the data.
11. Again the date and mission specified will be associated with this file. Since COMMNT wasn't specified, it is assumed to be blank.
12. & 13. In this case both of the channels in file 2 are being used.
14. This caused the file to be rewound and the second pass started.
15. This encourages PROCESS to access the third file and start pass 1.
16. Same as 11.
- 17 & 18. Only multiplexor channel 2 is being referenced, but as before, both of the channels on the tape must be specified.
19. Pass 2 on the 3rd file.
20. This tells POINT to perform STEP(6) in the program. That section of the program is responsible for plotting and tabulating the results as well as updating the data base.
21. This causes POINT. to reinitialize CALIB.
22. This tells CALIB. that the tape data bases (indicated by TBASE1 & TBASE2) are to be simply plotted and tabulated with absolutely no processing to take place. After the plots & tables are finished, the program returns control to the executive system. Therefore no more data cards must ever follow this card.

ERROR COMMENTS

ERROR1. LAMPB .L. NA.

The beginning reselm location of the lamp pulse is less than the beginning reselm for the line (as specified for PROCESS).

ERROR2. LAMPE .G. NB.

The end reselm location of the lamp pulse is greater than the ending reselm for the line (as specified for PROCESS).

ERROR3. DARKB .L. NA.

Same as ERROR1. except in reference to the dark area.

ERROR4. DARKE .G. NB.

Same as ERROR2 except in reference to the dark area.

ERROR5. SOLARB .L. NA.

Same as ERROR1 except in reference to the solar pulse.

ERROR6. SOLARE .G. NB.

Same as ERROR2 except in reference to the solar pulse.

ERROR7. 13 .L. CHANNL .L. 1

The maximum # of channels to be used in computations is either greater than 13 or less than 1.

ERROR8. FILMAX .L. 1.

The maximum # of files to be processed before plotting and tabulation is less than 1.

ERROR9. 24 .L. SCHAN .L. 0

A spectral channel # greater than 24 or less than 0 was to be associated with a multiplexor channel.

ERROR10. MORE FILE THAN FILMAX.

The input required by PROCESS under POINT specified another file, but this file is one more than the number specified by FILMAX originally.

ERROR11. INVALID MONTH.

The number in FDATE (1) refers to a nonexistent month (less than zero or greater than 12).

ERROR12. INVALID DAY.

The number in FDATE(2) refers to a non-existent day (less than zero or greater than 31).

ERROR13. INVALID YEAR.

The number in FDATE(3) refers to a nonexistent year (less than zero or greater than 99).

ERROR14. INVALID MISSION NO.

The number assigned to MISSION is less than zero.

ERROR15. SOLAR REF .L. 5 RESELMS WIDE.

The value of SOLARE-SOLARB+1 is less than 4. There must be at least 4 reselms in the solar pulse in order to integrate it.

ERROR16. GAIN .L. 1.

The gain specified for the preceding multiplexor CHANNEL was less than 1.

ERROR17. INCORRECT TAPE MOUNTED.

The program was not able to read a correct header label on the tape just mounted. This can be caused by mounting the wrong tape or by specifying TAPE = \$OLD\$ (or else letting TAPE default to \$OLD\$) when the tape data base is non existent or by specifying the wrong tapes with TBASE1 & TBASE2.

ERROR18. LAMPE-LAMPB+1 .G. 100.

The value of LAMPE-LAMPB+1 is greater than 100. No more than 100 reselms can be handled in the lamp pulse.

ERROR19. SOLARE-SOLARB+1 .G. 100.

The value of SOLAR-SOLARB+1 is greater than 100. No more than 100 reselms can be handled in the solar pulse.

ERROR20. INVALID MPXMUX CHANNEL.

The value of MPXMUX is greater than 13 or less than 1. It is assumed that there will be no more than 13 and no less than 1 multiplexor channel on a tape.

ERROR21. INSUFFICIENT STORAGE.

Since this program uses dynamic storage allocation for its main incore data base, the possibility exists that some-one will try to process more data and consequently compute more statistics than can physically fit into the machine.

The main in-core data base is dimensioned FILMAX*CHANNEL*11+FILMAX*10+4.

In addition, there are two more arrays, each possibly as long as FILMAX+ENTRYS (ENTRYS is the largest number of records in any file of the tape data base.) If storage limitations are a problem:

1. Process fewer files in a set.
2. Process fewer multiplexor channels.
3. Don't attempt to merge in a large, old tape data base. Instead, create a new tape data base.

See storage requirements section of this memo.

ERROR22. LAMTOP .L. 0.

Less than 1 reselm is to be used for computations at the top of the lamp pulse.

ERROR23. LAMTOP .G. LAMP WIDTH.

More reselms are to be used in computations than exist within the defined limits of the lamp pulse.

ERROR24. NO DARK AREA PROVIDED.

The value of DARKE-DARKB+1 is less than 1. The program normalizes all the values of the points in the lamp pulse and solar pulse by subtracting the average level of the dark area from the previous line. If no dark level is specified, this normalization can't take place.

SUBROUTINES NEEDED

Following is a list of external subroutines needed for the correct operation of this program.

ASSIGN. - VERSION 2.2 This performs all the dynamic storage allocation in the a core box.

CANCEL. - Part of ASSIGN.

ERROR. - System error processing routine

GETSP0. - Part of ASSIGN.

LINK. - Routine for providing a connection to the point processing routine

PIPROC. (Part of POINT.)

MOUNT. - Routine for handling all tape mounts.

MOVER. - A routine used for flipping an array end-for-end before output by MAD.

PLOT1. }
 PLOT2. } All four routines are used in setting up and printing the point
 PLOT3. } plot of the means and standard deviations.
 PLOT4. }

POINT. The main program that repetitively calls CALIB. with different levels to progressively process the data (see POINT. writeup).

PROCESS. A routine called from POINT. that handles all I/O with data tapes (that are in ERIM format).

SETDIM. A routine for setting up the dimensioning and subscripting for the dynamically allocated arrays.

SETEOF. A routine to perform branching when an end-of-file is encountered on input.

SQRT. This routine calculates square roots.

ZERO. This routine inserts either a binary or floating point zero in any specified variables or arrays.

TAPE DATA BASE FOR CALIB.

This data base is used for storing all of the major results calculated by CALIB. For every file processed by CABIB., the following information is saved:

DATE
SPECIAL COMMENTS
MISSION NUMBER
MEAN DARK LEVEL
MEAN LAMP LEVEL
MEAN LEVEL OF MIDDLE OF LAMP
MEAN RESELM NUMBER OF MIDDLE OF LAMP
STANDARD DEVIATIONS OF PREVIOUS 5 STATISTICS

At the beginning of both tapes is stored the bin number of the tape (which is read to make sure the proper tape is mounted) and the generation # of the tape. The generation # is set to 1 when the tape data base is first generated (when TAPE = \$NEWS\$). The generation number is incremented by 1 each time the data base is updated (when TAPE = \$OLD\$; the data base is never altered when TAPE=\$PRINT\$). When the data base is being updated, the tape with the highest generation number is the input tape. The tape with the lower generation number then becomes the output tape. This output tape will be given a generation number, 1 higher than the input tape (except when the input tape has a generation number of 1; then the output tape will be given a generation number of 3; Generation number 2 is never used). The results computed from the files just processed by CABIB. are merged with the input tape data base and written on the output tape.

The organization of the tape data base is as follows:

1. There are 24 files representing up to 24 different spectral channels.
2. Each record represents the results calculated by CABIB. from 1 channel of 1 file.

3. Each file has a 1-word header record containing the number of records in the file excluding the header record.
4. If there are no results from CALIB. or from a previous data base referencing a channel, the corresponding tape data base file is simply terminated by an EOF and no header record is written.
5. The records are in ascending order of date.
6. Each tape of the data base has a 2-word label containing the bin number and a generation number.

FILE	RECORD	WORDS	DESCRIPTION	
1	1	1	BIN NO.	
		2	GENERATION NO.	
	2	3	1	NO. OF RECORDS IN 1ST FILE. IF NONE, THIS RECORD IS AN EOF
			2	DATE
			3	MISSION #
			4	MEAN OF DARK LEVEL
			5	MEAN OF NORMALIZED LAMP LEVEL
			6	MEAN OF NORMALIZED LEVEL OF THE MIDDLE RESELM IN THE LAMP PULSE
			7	RESELM IN THE LAMP PULSE (RELATIVE TO LAMPB- 1)
			8	MEAN OF THE INTEGRAL OF THE NORMALIZED SOLAR PULSE
			9	STANDARD DEVIATION OF WORD 3
			10	" " " " 4
11	" " " " 5			
12	" " " " 6			
13	MEAN OF THE RESELM NUMBER OF THE MIDDLE			
14	STANDARD DEVIATION OF WORD 11			
15-20	SPECIAL COMMENTS			

[All means & standard deviations are integers multiplied by 100. Solar pulse statistics are X10].



FILE	RECORD	DESCRIPTION
1	4	same as record 3
	:	
	:	
	:	[The form of record 3 is repeated for as many records as the number indicated in record 2].
2	1	No. of records in 2nd file. If none, this record is an EOF.
.	.	
:	:	
.	.	

[The form of file 2 is the same as file 2 starting with record 2. This is repeated for 24 possible files (each representing a different spectral channel, see description of "SCHAN" in parameter definitions)].

STORAGE REQUIREMENTS

The CALIB. program requires 7292 decimal locations before any dynamic storage allocation takes place. The formula for determining how much additional storage will be allocated for a particular data set is as follows:

$$\text{MAIN-IN-CORE DATA BASE} \\ \text{FILMAX*CHANNL*11+FILMAX*11+5}$$

In addition, more storage is allocated depending upon the size of the tape data base. The maximum amount that will be allocated in addition to the preceding quantity specified is as follows:

$$(\text{MAX}[\text{ENTRYS}] + \text{FILMAX}) * 21 + 3$$

MAX[ENTRYS] = the maximum number of missions in any one file of the tape data base.



MAD (09 AUG 1965 VERSION) PROGRAM LISTING

```

EXTERNAL FUNCTION CALIB.(STAT,DATE,MSSION,CMMNT,
1 TAG,XX,YY,YYY)
NORMAL MODE IS INTEGER
REFERENCES ON
FLCATING PCINT F1,F2,F3, MC(13), MEANC(13), MEANL(13), MEANLM(13),
1 MEANM(13), MEANS(13), SCRT., XX, YYY, STAT, GAIN(13),
2 TOTD(13), TCTL(13), TCTLM(13), TCTM(13), TCTS(13),
1 PNTL(100*13), PNTS(100*13), C22, CCEF, FCATUM(24)
DIMENSION PARAMS(8) , FDATE(3) , NSCALE(4) , BCD(4) , CMMNT(8),
1 CHNNLS(13), ERR(1009), TITLE(32), GCM(8), CUT(20),
2 PT(13)
EQLIVALENCE (MPXMX,FCATE) , (SCHAN,BCD) , (AIRCFN,CMMNT) ,
1 (DATLM,FCATUM)
VECTOR VALUES BCD(1)= $D$, $L$, $M$, $S$
VECTOR VALUES MT1 = -1
VECTOR VALUES MT2 = -2
VECTOR VALUES TITLE(1) = $F1, .71-.73$, $E1, .33-.38$,
1 $B2, 2.0-2.6$, $B3, 1.0-1.4$,
2 $D1, 2.0-2.6$, $L2, 1.5-1.8$,
3 $D3, 1.0-1.4$, $C2, .67-.94$,
4 $C4, .62-.70$, $C5, .58-.64$,
5 $C6, .55-.60$, $C7, .52-.57$,
6 $C8, .50-.54$, $C9, .48-.52$,
7 $C10, .46-.49$, $C12, .41-.48$
VECTOR VALUES ERR(001) =
1 $H'1*****ERRCR1. LAMPB .L. NA.'* $
VECTOR VALUES ERR(043) =
2 $H'1*****ERRCR2. LAMPE .G. NB.'* $
VECTOR VALUES ERR(085) =
3 $H'1*****ERRCR3. DARKB .L. NA.'* $
VECTOR VALUES ERR(127) =
4 $H'1*****ERRCR4. DARKE .G. NB.'* $
VECTOR VALUES ERR(169) =
5 $H'1*****ERRCR5. SCLARB .L. NA.'* $
VECTOR VALUES ERR(211) =
6 $H'1*****ERRCR6. SCLARE .G. NB.'* $
VECTOR VALUES ERR(253) =
7 $H'1*****ERRCR7. 13 .L. CHANNL .L. 1.'* $
VECTOR VALUES ERR(295) =
8 $H'1*****ERRCR8. FILMAX .L. 1.'* $
VECTOR VALUES ERR(337) =
9 $H'1*****ERRCR9. 24 .L. SCHAN .L. 0.'* $
VECTOR VALUES ERR(379) =
C $H'1*****ERRCR10. MORE FILES THAN FILMAX.'**
VECTOR VALUES ERR(421) =
1 $H'1*****ERRCR11. INVALID MONTH.'* $
VECTOR VALUES ERR(463) =
2 $H'1*****ERRCR12. INVALID DAY.'* $
VECTOR VALUES ERR(505) =
3 $H'1*****ERRCR13. INVALID YEAR.'* $
VECTOR VALUES ERR(547) =
4 $H'1*****ERRCR14. INVALID MISSION NUMBER.'**
VECTOR VALUES ERR(589) =
5 $H'1*****ERRCR15. SOLAR REF .L. 5 RESELM**$
VECTOR VALUES ERR(631) =
6 $H'1*****ERRCR16. GAIN .L. 1.'* $
VECTOR VALUES ERR(673) =
7 $H'1*****ERRCR17. INCORRECT TAPE MCUNTEC.'**
VECTOR VALUES ERR(715) =

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C-2



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8      $H'1*****ERROR18. LAMPE-LAMPB+1 .G. 100.'* $
VECTOR VALUES ERR(757) =
9      $H'1*****ERROR19. SOLARE-SCLARB+1 .G. 100.'* $
VECTOR VALUES ERR(799) =
0      $H'1*****ERROR20. INVALID MPXMUX CHANNEL.'* $
VECTOR VALUES ERR(841) =
1      $H'1*****ERROR21. INSUFFICIENT STORAGE.'* $
VECTOR VALUES ERR(883) =
2      $H'1*****ERROR22. LAMTOP .L. 0.'* $
VECTOR VALUES ERR(925) =
3      $H'1*****ERROR23. LAMTOP .G. LAMP WIDTH.'* $
VECTOR VALUES ERR(967) =
4      $H'1*****ERROR24. NO DARK AREA PROVIDED.'* $
STATEMENT LABEL STEP(7)
VECTOR VALUES MSG1(0) = $MEAN LEVEL$
VECTOR VALUES MSG2(0) = $DEVIATION LEVEL$
ERASABLE JUNK(225),CUNIT,OREEL,CFILE,CLINE,TWRITE,OCHAN,
1      QNWDS,PRCG,MODE1,MODE2,UNIT,CALINE,COLINE,NSA,NSB,
2      KS,NA,NB,KP,1D(1),TFLAG,IPACK,RESERV(4),QFACR(49),
3      QTITL2(19),QTITLE(19),QLIST(19),CSPARE(46),QFLAG,
4      QDANG,QBANG,GRP,QNA,QNSS,QNCHAN,QMCDE,CRECA,QRECC,
5      QFILE,QREEL,QNWRDS
ERASABLE DATA(423),ITEST,CSTART,DSTART,NV,NX,NC,L,IP,
1      ICP,NOP,NEXT,START2,READT2,READL2,READP2,LABEL2,
2      EXTRA(20),DATUM(24),ICGDE(24),ICHAN(24), IMAGE(570)
WHENEVER NEXT .G. 6, FUNCTION RETURN
TRANSFER TO STEP(NEXT)
STEP(1) LINK.(PTPROC.)
L = L + OCHAN
CHANNL = 13
FILMAX = 1
LAMTOP = 5
LAMPB = 10
LAMPE = 60
DARKB = 185
DARKE = 225
SCLARB = 310
SOLARE = 355
PARAMS(0) = 0
FILES = 0
TAPE = $OLD$
PASS = 1
MISSON = 0
TBASE1 = 799
TBASE2 = 800
READ AND PRINT DATA TAPE, CHANNL, FILMAX, MISSON, LAMTOP, TBASE1, TBASE2
WHENEVER TAPE .E. $PRINT$
    WHENEVER MISSON .L. 1, TRANSFER TO ERR14
    TRANSFER TO STEP(6)
END OF CONDITIONAL
WHENEVER FILMAX .L. 1
    TRANSFER TO ERR8
    CR WHENEVER CHANNL .G. 13 .CR. CHANNL .L. 1
    TRANSFER TO ERR7
    CR WHENEVER LAMTOP .L. 0
    TRANSFER TO ERR22
    CR WHENEVER LAMTOP .G. LAMPE - LAMPB + 1
    TRANSFER TO ERR23
END OF CONDITIONAL
SIZE = FILMAX*CHANNL*11
KK = ASSIGN.(0,0)
WHENEVER KK .L. (SIZE+FILMAX*10+4), TRANSFER TO ERR21
KK = ASSIGN.(CALIB.,PARAMS(0),SIZE...3,FILMAX,FILMAX,
```

```

1          FILMAX*8...2)
SETDIM.(CCMNT,FILMAX,8)
SETDIM.(STAT,FILMAX,CHANNL,11)
ZERC.(TCTD(1)...TCTD(CHANNL),TCTL(1)...TCTL(CHANNL),
1      TCTLM(1)...TCTLM(CHANNL),TCTS(1)...TCTS(CHANNL),
2      TCTM(1)...TCTM(CHANNL),
3      MD(1)...MD(CHANNL),STAT(1)...STAT(SIZE))
FUNCTION RETURN
STEP(2) ZERC.(PTL,PTS,PT...PT(13),LINES,FLAG)
        WHENEVER PASS .E. 1
        ZERC.(FDATE(1)...FDATE(3),MISSCN,CHNNLS(1)...CHNNLS(13))
        (KK=1,1,KK.G.8,CCMNT(KK) = $ $)
        READ AND PRINT DATA FDATE(1), MISSCN, CHNNLS(1), CCMNT(1),
1      LAMPB,LAMPE,DARKB,DARKE,SCLARB,SCLARE
        THROUGH LP18, FOR K=1,1, K .G. CACHAN
        READ AND PRINT DATA MPXMUX, SCHAN, AIRCHN, GAIN
        WHENEVER SCHAN .G. 24 .CR. SCHAN .L. 0, TRANSFER TO ERR9
        WHENEVER MPXMUX .G. 13 .CR. MPXMUX .L. 1, TRANSFER TO ERR20
        WHENEVER GAIN .L. 1, TRANSFER TO ERR16
        GAIN(K) = GAIN
        CHNNLS(MPXMUX) = SCHAN
        WHENEVER SCHAN .E. 0, TRANSFER TO LP18
        PRINT FORMAT $1H+,T60,H'SPECTRAL BAND= ',2C6*$,
1      TITLE(SCHAN*2-1),TITLE(SCHAN*2)
LP18 CONTINUE
        CHANTP = GNCHAN
        WHENEVER LAMPB .L. NA
            TRANSFER TO ERR1
        OR WHENEVER LAMPE .G. NB
            TRANSFER TO ERR2
        OR WHENEVER DARKB .L. NA
            TRANSFER TO ERR3
        OR WHENEVER DARKE .G. NB
            TRANSFER TO ERR4
        OR WHENEVER SCLARB .L. NA
            TRANSFER TO ERR5
        OR WHENEVER SCLARE .G. NB
            TRANSFER TO ERR6
        OR WHENEVER FDATE(1) .G. 12 .CR. FDATE(1) .L. 0
            TRANSFER TO ERR11
        OR WHENEVER FDATE(2) .G. 31 .CR. FDATE(2) .L. 0
            TRANSFER TO ERR12
        OR WHENEVER FDATE(3) .L. 0
            TRANSFER TO ERR13
        OR WHENEVER MISSCN .L. 0
            TRANSFER TO ERR14
        OR WHENEVER LAMPE-LAMPB+1 .G. 100
            TRANSFER TO ERR18
        OR WHENEVER SCLARE-SCLARB+1 .G. 100
            TRANSFER TO ERR19
        OR WHENEVER DARKE - DARKB + 1 .E. 0
            TRANSFER TO ERR24
        END OF CONDITIONAL
        END OF CONDITIONAL
        FLACTION RETURN
        FUNCTION RETURN
STEP(3) LINES = LINES + 1
STEP(4) WHENEVER FLAG .E. 0
        FLAG = 1
        FUNCTION RETURN
        END OF CONDITIONAL
        THROUGH LP5, FOR K=1,1,K .G. CHANTP
        WHENEVER CHNNLS(K) .E. 0, TRANSFER TO LP5
    
```

```

MAX      = C
THROUGH LP6, FOR KK=1,1, KK .G. PTL
    WHENEVER PNTL(KK,K) .G. MAX      , MAX      = PNTL(KK,K)
LP6      CONTINUE
THROUGH LP7, FOR KK=1,1, KK .G. PTL
    WHENEVER MAX      /2 .L. PNTL(KK,K), TRANSFER TO OUT1
LP7      CONTINUE
OUT1     KK = 1
        LEFT = KK
        THROUGH LP8, FOR KK=PTL,-1, KK .L. 1
            WHENEVER MAX      /2 .L. PNTL(KK,K), TRANSFER TO OUT2
LP8      CONTINUE
OUT2     KK = PTL
        RIGHT = KK
        MIDDLE = (LEFT + RIGHT)/2
        LEFT = MIDDLE - LAMTOP/2
        RIGHT = MIDDLE + LAMTOP/2
        WHENEVER LEFT .L. 1, LEFT = 1
        WHENEVER RIGHT .G. PTL, RIGHT = PTL
        PT(K) = PT(K) + RIGHT - LEFT + 1
        WHENEVER PASS .E. 1
            (KK=LEFT,1, KK.G.RIGHT, TOTL(K) = TOTL(K) + PNTL(KK,K))
            TOTLM(K) = TOTLM(K) + PNTL(MIDDLE,K)
            TOTM(K) = TOTM(K) + MIDDLE
        OTHERWISE
            (KK=LEFT,1, KK.G.RIGHT, TOTL(K) = TOTL(K) +
1              (PNTL(KK,K) - MEANL(K)).P.2)
            TOTLM(K) = TOTLM(K) + (PNTL(MIDDLE,K) -
1              MEANLM(K)).P.2
            TOTM(K) = TOTM(K) + (MIDDLE - MEANM(K)).P.2
        END OF CONDITIONAL
        WHENEVER PTS .L. 5 .AND. SOLARE - SOLARB + 1 .NE. 0, TRANSFER TO ERR15
        EXECUTE SIMPSN.
        WHENEVER PASS .E. 1
            TCTS(K) = TCTS(K) + Q22
        OTHERWISE
            TCTS(K) = TCTS(K) + (Q22 - MEANS(K)).P.2
        END OF CONDITIONAL
LP5      CONTINUE
        PTL = 0
        PTS = C
        FUNCTION RETURN
STEP(5)  WHENEVER PASS .E. 2, TRANSFER TO STCDEV
        FILES = FILES + 1
        WHENEVER FILES .G. FILMAX, TRANSFER TO ERR10
        THROUGH LP9, FOR K=1,1, K .G. CHANTP
            WHENEVER CHNNLS(K) .E. 0, TRANSFER TO LP9
            MEAND(K) = TOTD(K)/((DARKE-DARKB+1)*LINES)
            MEANL(K) = TOTL(K)/PT(K)
            MEANLM(K) = TOTLM(K)/(LINES-1)
            MEANS(K) = TOTS(K)/(LINES-1)
            MEANM(K) = TOTM(K)/(LINES-1)
            STAT(FILES,K,1) = MEAND(K)*100
            STAT(FILES,K,2) = MEANL(K)*100/GAIN(K)
            STAT(FILES,K,3) = MEANLM(K)*100/GAIN(K)
            STAT(FILES,K,4) = MEANS(K)*10/GAIN(K)
            STAT(FILES,K,9) = MEANM(K)*100
LP9      CONTINUE
        PASS = 2
OUT3     ZERO.(TCTD(1)...TCTD(CHANNL),TOTL(1)...TOTL(CHANNL),
1         TOTLM(1)...TOTLM(CHANNL),TCTS(1)...TCTS(CHANNL),FLAG,
2         TOTM(1)...TOTM(CHANNL))
        FUNCTION RETURN
    
```



```
STCDEV      THROUGH LP10, FOR K=1,1, K .G. CHANTP
            STAT(FILES,K,11) = CHNALS(K)
            WHENEVER CHNALS(K) .E. 0, TRANSFER TO LP10.
            F1 = TGT0(K)/((DARKE-DARKB+1)*LINES)
            STAT(FILES,K,5)=SQRT.(F1)*100
            F1 = TGT1(K)/PT(K)
            STAT(FILES,K,6)=SQRT.(F1)*100/GAIN(K)
            F1 = TOTLM(K)/(LINES-1)
            STAT(FILES,K,7) =SQRT.(F1)*100/GAIN(K)
            F1 = TCTS(K)/(LINES-1)
            STAT(FILES,K,8)=SQRT.(F1)*10/GAIN(K)
            F1 = TOTM(K)/(LINES-1)
            STAT(FILES,K,10) = SQRT.(F1)*100

LP10        CONTINUE
            PASS = 1
            DATE(FILES) = FDATE(3)*10000 + FDATE(1)*100 + FDATE(2)
            MISSION(FILES) = MISSON
            [KK=1,1,KK.G.8,CMMN1(FILES,KK) = CMMN1(KK)]
            TRANSFER TO CUT3

STEP(6)     PARAMS(C) = 4
            WHENEVER TAPE .E. $PRINT$, TRANSFER TO MNT
            KK = ASSIGN.(C,C)
            WHENEVER KK .L. FILES+1, TRANSFER TO ERR21
            KK = ASSIGN.(CALIB.,PARAMS(0),FILES)
            [KK=1,1,KK.G.FILES,TAG(KK) = KK]
            THROUGH LP12, FOR KK=1,1,KK .G. (FILES - 1)
            THROUGH LP13, FOR JJ=[KK+1],1,JJ .G. FILES
            WHENEVER DATE(TAG(KK)) .GE. DATE(TAG(JJ))
                TEMP = TAG(KK)
                TAG(KK) = TAG(JJ)
                TAG(JJ) = TEMP
            END OF CONDITIONAL

LP13        CONTINUE
LP12        CONTINUE
MNT         WHENEVER MT1 .NE. TBASE1
            MOUNT.(2,TBASE1,$IN$)
            MT1 = TBASE1
            END OF CONDITIONAL
            WHENEVER MT2 .NE. TBASE2
            MOUNT.(3,TBASE2,$IN$)
            MT2 = TBASE2
            END OF CONDITIONAL
            WHENEVER TAPE .E. $NEW$
                IN = 999
                OUT = 2
                BINOUT = 799
                BINCLT = TBASE1
                GENOUT = 1
                TRANSFER TO WRTLAB
            END OF CONDITIONAL
            SETEOF.(ERR17)
            READ BINARY TAPE 2, BIN2,GEN2
            WHENEVER GEN2 .E. 1
                GEN2 = GEN2 + 1
                TRANSFER TO IN2
            END OF CONDITIONAL
            SETEOF.(IN2)
            READ BINARY TAPE 3, BIN3,GEN3
            WHENEVER BIN3 .NE. TBASE2, TRANSFER TO IN2
            WHENEVER BIN2 .NE. TBASE1, TRANSFER TO ERR17
            WHENEVER GEN2 .G. GEN3
                IN = 2
                OUT = 3

IN2
```

```

        BININ = TBASE1
        BINOUT = TBASE2
        GENOUT = GEN2 + 1
    OTHERWISE
        IN = 3
        OUT = 2
        BININ = TBASE2
        BINOUT = TBASE1
        GENOUT = GEN3 + 1
    END OF CCNDITIONAL
WRTLAB  REWIND TAPE CUT
        WHENEVER TAPE .E. $PRINT$
            ZERC.(NSCALE(1)...NSCALE(4))
            NSCALE(0) = 1
            EXECUTE PLOT1.(NSCALE,5,10,6,10)
            F2 = 1.
            WHENEVER MISSCN - 61 .G. 0, F2 = MISSCN - 61
            TRANSFER TO ARND1
        END OF CCNDITIONAL
        PRINT ON LINE FORMAT $H' AT END OF JCB, PLEASE REMOVE ',
1      H'RING FROM TAPE ',I3*$, BINOUT
    WRITE BINARY TAPE OUT, BINOUT,GENOUT
    ZERC.(NSCALE(1)...NSCALE(4))
    NSCALE(0) = 1
    EXECUTE PLOT1.(NSCALE,5,10,6,10)
    F2 = 1.
    WHENEVER (MSSCN(FILES) - 61) .G. 0, F2 = MSSCN(FILES) - 61
    BLOCK = GETNXT.(8)
    LEVEL = GETNXT.(BLOCK+4)
    ADDR5 = GETNXT.(BLOCK)
ARND1   THROUGH LP14, FOR K=1,1, K .G. 24
        WHENEVER TAPE .E. $NEW$
ENTRYC  ENTRIES = 0
        WHENEVER TAPE .E. $PRINT$, TRANSFER TO LP14
        TRANSFER TO SETUP
    END OF CCNDITIONAL
    SETEOF.(ENTRYC)
    READ BINARY TAPE IN, ENTRIES
    WHENEVER TAPE .E. $PRINT$
        WHENEVER ENTRIES .E. 0, TRANSFER TO LP14
        F1 = MISSCN
        TRANSFER TO ARND2
    END OF CCNDITIONAL
SETUP   WHENEVER ENTRIES+FILES .E. 0, TRANSFER TO WRTECF
        F1 = MSSCN(FILES)
ARND2   PARAMS(0) = 5
        KK = ASSIGN.(0,0)
        WHENEVER KK .L. ((ENTRIES+FILES)*21+3), TRANSFER TO ERR21
        KK = ASSIGN.(CALIB.,PARAMS(0),ENTRIES+FILES,
1      (ENTRIES+FILES)*19...2,ENTRIES+FILES)
        SETDIM.(YY,ENTRIES+FILES,19)
        II = C
        JJ = C
        WHENEVER TAPE .E. $NEW$ .OR. ENTRIES .E. 0, TRANSFER TO CMPNEW
        SETEOF.(CMPNEW)
RDOLD   READ BINARY TAPE IN, ODATE,CYSS,CMD,CML,CMLM,CMS,OCG,CCL,ODLM,ODS,ODM,
1      CDM,OCM(1)...OCM(8)
RDNW    II = II + 1
        WHENEVER II .G. FILES, TRANSFER TO CMPOLD
        WHENEVER ODATE .L. DATE(TAG(II))
            II = II - 1
            EXECUTE INSERT.($OLD$)
            TRANSFER TO RCCLD
    
```



```

        OTHERWISE
          EXECUTE INSERT.($NEW$)
          TRANSFER TO RDNEW
        END OF CCNDITICNAL
DMPNEW  II = II + 1
        WHENEVER II .G. FILES, TRANSFER TO PLCT
        EXECUTE INSERT.($NEW$)
        TRANSFER TO DMPNEW
DMPOLD  EXECUTE INSERT.($CLD$)
        SETEOF.(PLCT)
        READ BINARY TAPE IN, CDATE,CMSS,CMC,CML,CMLM,CMS,CCC,CCL,ODLM,ODS,GMM,
1        CDM,CCM(1)...CCM(8)
        TRANSFER TO DMPOLD
PLGT    WHENEVER JJ .E. 0, TRANSFER TO WRTECF
        (KK=1,1,KK.G.(ENTRYS+FILES),YYY(KK)= -999.)
        (KK=1,1,KK.G.JJ,YYY(KK) = YY(KK,2))
        EXECUTE PLCT2.(IMAGE,F1,F2,YY(JJ,2)*2.,YY(JJ,2)/8.)
        EXECUTE PLCT3.(BCD(2),XX(1),YYY(1),JJ)
        PRINT FORMAT $1H1,T33,H'CHANNEL ',ZC6*$,TITLE(2*K-1),TITLE(2*K)
        EXECUTE PLCT4.(10,MSG1)
        PRINT FORMAT $1H0,T36,H'MISSION NUMBER**$
        EXECUTE PLCT2.(IMAGE,F1,F2,20.,0.)
        (KK=1,1,KK.G.(ENTRYS+FILES),YYY(KK)= -999.)
        THROUGH LP16, FOR II=5,1, II .G. 8
        (KK=1,1,KK.G.JJ,YYY(KK) = YY(KK,II)/10.)
        EXECUTE PLCT3.(BCD(II-4),XX(1),YYY(1),JJ)
LP16    CONTINUE
        PRINT FORMAT $1H1,T33,H'CHANNEL ',ZC6*$,TITLE(2*K-1),TITLE(2*K)
        EXECUTE PLCT4.(15,MSG2)
        PRINT FORMAT $1H0,T36,H'MISSION NUMBER**$
        WHENEVER TAPE .E. $PRINT$, TRANSFER TO ARND3
        WRITE BINARY TAPE CUT, JJ
ARND3  PRINT FORMAT $1H1,T32,H'LAMP',T60,F'LAMP',T75,H'LAMP LAMP'/1F ,
1      T19,2(H'DARK',S3,
1      H'LAMP',S1,H'MIDDLE',S3,H'SCLAR',S2),T74,2(H'RESELM',
2      S1)/
2      H' DATE MISSION ',4(H'MEAN',S3),S1,4(F'DEV',S4),
3      T75,H'MEAN DEV'/**$
        THROUGH LP17, FOR KK=1,1,KK .G. JJ
        OUT(1) = YY(KK,9)
        SUB1 = YY(KK,9)
        SUB1 = (SUB1 - SUB1/10000*10000)*100 + SUB1/10000
        OUT(2) = XX(KK)
        (M=3,1,M.G.10,CUT(M) = YY(KK,M-2))
        (M=11,1,M.G.12,CUT(M) = YY(KK,M+7))
        (M=13,1,M.G.20,CUT(M) = YY(KK,M-3))
        PRINT FORMAT $1H ,2(I6,S1),S1,10(I6,S1)/1F ,S15,8C6*$, SUB1,
1      OUT(2)...CUT(20)
        WHENEVER TAPE .E. $PRINT$, TRANSFER TO LP17
        EXECUTE MOVER.(CUT(1),CUT(20))
        WRITE BINARY TAPE CUT, OUT(1)...CUT(20)
LP17    CONTINUE
        PRINT FORMAT $H'-SOLAR MEAN AND SCLAR DEV ARE X10.'/
1      H' ALL OTHER STATISTICS ARE X100.**$
        WHENEVER TAPE .E. $PRINT$, TRANSFER TO LP14
        END OF FILE TAPE CUT
        FREESP.(BLOCK,LEVEL,ADDRES)
LP14    CONTINUE
        WHENEVER TAPE .E. $PRINT$, SYSTEM.
        END OF FILE TAPE CUT
        END OF FILE TAPE CUT
        WHENEVER IN .E. 999, FUNCTION RETURN
        REWIND TAPE IN

```



```
WRITE BINARY TAPE IN, BININ,GENCUT-1
REWIND TAPE IN
REWIND TAPE CUT
FUNCTION RETLRN
```

```
ERR1      K = 1
           TRANSFER TC BLEH
ERR2      K = 43
           TRANSFER TC BLEH
ERR3      K = 85
           TRANSFER TC BLEH
ERR4      K = 127
           TRANSFER TC BLEH
ERR5      K = 169
           TRANSFER TC BLEH
ERR6      K = 211
           TRANSFER TC BLEH
ERR7      K = 253
           TRANSFER TC BLEH
ERR8      K = 295
           TRANSFER TC BLEH
ERR9      K = 337
           TRANSFER TC BLEH
ERR10     K = 379
           TRANSFER TC BLEH
ERR11     K = 421
           TRANSFER TC BLEH
ERR12     K = 463
           TRANSFER TC BLEH
ERR13     K = 505
           TRANSFER TC BLEH
ERR14     K = 547
           TRANSFER TC BLEH
ERR15     K = 589
           TRANSFER TC BLEH
ERR16     K = 631
           TRANSFER TC BLEH
ERR17     K = 673
           TRANSFER TC BLEH
ERR18     K = 715
           TRANSFER TC BLEH
ERR19     K = 757
           TRANSFER TC BLEH
ERR20     K = 799
           TRANSFER TC BLEH
ERR21     K = 841
           TRANSFER TC BLEH
ERR22     K = 883
           TRANSFER TC BLEH
ERR23     K = 925
           TRANSFER TC BLEH
ERR24     K = 967
           TRANSFER TC BLEH
BLEH      PRINT FORMAT ERR(K)
           ERROR.
```

```

INTERNAL FUNCTION PTPROC.
WHENEVER TAPE .E. $PRINT$, FUNCTION RETURN
WHENEVER CMODE .E. 1, (I=1,1,I.G.24,K=DATUM(I),FCATUM(I)=K)
WHENEVER IP .LE. DARKE .AND. IP .GE. DARKE
    WHENEVER IP .E. DARKB, (K=1,1,K.G.CHANTP,MD(K) = 0.)
        F2 = DARKE - DARKB + 1
        (K=1,1,K.G.CHANTP, F1 = DATUM(K),MD(K) = MD(K) + F1/F2)
    WHENEVER PASS .E. 1
        (K=1,1,K.G.CHANTP,TCTD(K) = TCTD(K) + DATUM(K))
    OTHERWISE
        (K=1,1,K.G.CHANTP,TCTD(K) = TCTD(K) + (DATUM(K)
            - MEAND(K)).P.2)
1
    END OF CCNDITIONAL
    FUNCTION RETURN
    OTHERWISE
        TRANSFER TO LAMP
END OF CCNDITIONAL
LAMP
WHENEVER FLAG .E. 1 .AND. IP .LE. LAMPE .AND. IP .GE. LAMPB
    PTL = PTL + 1
    (K=1,1,K.G.CHANTP,PNTL(PTL,K) = DATUM(K) - MD(K))
    FUNCTION RETURN
    OTHERWISE
        TRANSFER TO SOLAR
END OF CCNDITIONAL
SOLAR
WHENEVER FLAG .E. 1 .AND. IP .LE. SOLARE .AND. IP .GE. SOLARB
    PTS = PTS + 1
    (K=1,1,K.G.CHANTP,PNTS(PTS,K) = DATUM(K) - MD(K))
    FUNCTION RETURN
    OTHERWISE
        FUNCTION RETURN
END OF CCNDITIONAL
END OF FUNCTION
    
```

```

INTERNAL FUNCTION SIMPSN.
WHENEVER PTS/2*2 .E. PTS, PTS = PTS - 1
Q22 = PNTS(1,K)
CCEF = 2.
THROUGH LP11, FOR KK=2,1, KK .G. PTS-1
    WHENEVER CCEF .E. 4.
        CCEF = 2.
    OTHERWISE
        CCEF = 4.
    END OF CCNDITIONAL
    Q22 = Q22 + CCEF*PNTS(KK,K)
LP11
CONTINUE
Q22 = Q22 + PNTS(PTS,K)
Q22 = Q22/3.
FUNCTION RETURN
END OF FUNCTION
    
```

```

INTERNAL FUNCTION INSERT.(TYPE)
MTAG = TAG(II)
WHENEVER TYPE .E. $NEW$
    THROUGH LP19, FOR N=1,1, N .G. CHANNL
        WHENEVER STAT(MTAG,N,11) .E. K
            JJ = JJ + 1
            XX(JJ) = MSSICK(MTAG)
    
```

```

(M=1,1,M.G.8,YY(JJ,M) = STAT(MTAG,N,M))
YY(JJ,9) = DATE(MTAG )
(KK=10,1,KK.G.17,YY(JJ,KK) = CPMNT(MTAG ,KK-9))
(M=18,1,M.G.19,YY(JJ,M) = STAT(MTAG,N,M-9))
FUNCTION RETURN
END OF CONDITIONAL
LP19 CONTINUE
OR WHENEVER TYPE .E. SOLD$
JJ = JJ + 1
XX(JJ) = CMSS
YY(JJ,1) = CMD
YY(JJ,2) = CML
YY(JJ,3) = CMLM
YY(JJ,4) = CMS
YY(JJ,5) = CDD
YY(JJ,6) = CDL
YY(JJ,7) = CDLM
YY(JJ,8) = CDS
YY(JJ,9) = CDATE
EXECUTE MOVER.(OCM(1),OCM(8))
(KK=10,1,KK.G.17,YY(JJ,KK) = OCM(KK-9))
YY(JJ,18) = CMM
YY(JJ,19) = CDM
OTHERWISE
FUNCTION RETURN
END OF CONDITIONAL
FUNCTION RETURN
END OF FUNCTION

```

Appendix B PROGRAM DGNSTC.

The purpose of this program is to calculate a few statistics from multispectral data tapes in ERIM format. These statistics can be used to observe the behavior of the data in certain specified areas of the scanline. This version has three options concerning the statistics extracted from a scene.

- (1) The mean level and the standard deviation around this mean level of the data within a specified area relative to some defined dark area.
- (2) The mean reselm number and the standard deviation around this mean of the middle of some specified pulse.
- (3) A point plot of each absolute mean and standard deviation of a specified dark area plotted line by line and/or a point plot of each mean and standard deviation of a specified area relative to the mean of the previously defined dark area plotted line by line.

For example, with the use of option (1), the user can determine if there are large-scale changes (either absolute or relative to some other area) in an area parallel to the flight line. Option (2) gives the user the capability to determine how much a particular pulse is shifting back and forth along the scanline over a given set of scanlines. The plots provided by option (3) allow the user to see exactly how the mean of a specified area (either absolute or relative to some other area) changes from one scanline to the next over a given set of scanlines (trends or discontinuities).

With all of the options, the user must specify the beginning and ending reselm numbers of two areas along the flight line to be analyzed. The first area must always be specified. The reselm numbers of the second area may be chosen such that it is zero if it is to be ignored. In addition, the maximum number of reselms within either pulse, the option type, and the maximum number of scanlines must be specified for each set of files. Also, the user must provide the multiplexer channel number to be referenced and the spectral channel it represents along with the mission number, the date, and any special comment.

Option (1) averages all the reselms within the boundaries of the first area for each line as well as over all of the selected lines. If the second pulse's width is non-zero, the average of the first area from the previous line is subtracted from each reselm of the second area. The result of this subtraction is averaged over all the selected lines. Then the program goes through the data set again and calculates the standard deviation of the reselm levels from the corresponding overall mean for the area.

Option (2) determines the reselm number of the middle of the pulse within the specified boundaries (see Fig. B.1). This is done for each line of the requested scene. After the average of all these middle reselm numbers is determined, the program goes back and calculates the standard deviation of these reselm numbers from the overall mean. The method for determining the middle of the pulse is as follows:

- (1) $FL = 0.5$
- (2) The maximum height is determined [MAX]
- (3) The reselms closest to $MAX * FL$ are found by first searching from left to right for the reselm whose level is just greater than $MAX/2$ and then performing a search from right to left. [X & Y]
- (4) If X & Y are equal to the boundaries of the pulse, $FL = FL + 0.1$. Repeat (3) above.
- (5) The mean of X & Y is found $(X + Y)/2$. This is the middle of the pulse.

NOTE: If the boundaries given for the pulse don't include reselms at or below the $MAX * FL$ level, X & Y will end up being either of the boundaries given for the pulse. Consequently, the middle reselm number given for the pulse could be quite inaccurate.

Option (3) determines the absolute average height and standard deviation from that average of the first pulse for each line. In addition, the user may request the program to determine the average height and standard deviation of a second pulse relative to the first for each line. The program then plots.

- (1) The average height of the first pulse for each line
- (2) The standard deviation of the first pulse for each line
- (3) The average height of the second pulse relative to the first pulse for each line
- (4) The standard deviation of the second pulse for each line

PROGRAM OPERATION

STEP (1) PERFORMED THE 1ST TIME DGNSTC. IS CALLED OR WHENEVER PROCESS
READS MODEL = \$START\$"

This section of the program performs the initialization necessary for POINT. and sets the default values for the input variables. Data cards are then read which set the beginning and ending reselm numbers of both pulses (only pulse 2 can have zero width; $END(2) - BEGIN(2) + 1 = 0$), the maximum number of points in either pulse, the option type the program is to execute, and the maximum number of lines to be processed. The input variables are then checked for reasonableness, and the necessary storage is allocated. Control returns to point.

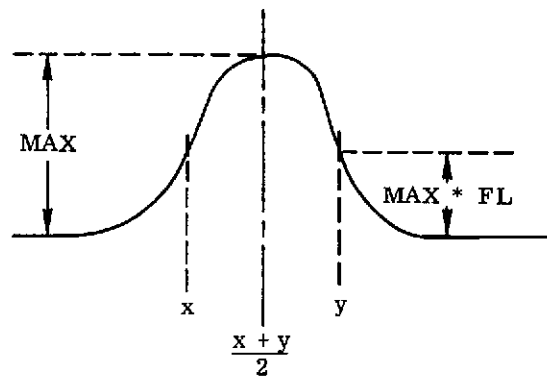


FIGURE B.1. LAMP-PULSE VOLTAGE
VERSUS RESELM POSITION,
SIMPLIFIED

STEP (2) PERFORMED BEFORE EACH FILE IS PROCESSED.

First the program zeros the point index array, the date array, the comment array, and the mission number. Then more input cards are read specifying the multiplexor channel, the spectral channel, the aircraft channel (optional), the mission number, the date, and any special comment. The input variables are also checked for reasonableness. The beginning and ending reselm numbers are also checked again for reasonableness. Control returns to point.

STEP (3) PERFORMED BEFORE EACH POINT OF A LINE IS PROCESSED

No action taken

STEP (4) PERFORMED AFTER EACH LINE IN THE FILE IS PROCESSED

The average is first calculated for pulse one. If this is the first line of the file, the program returns. This allows the program to calculate the relative height of pulse 2 in the following line. If this is not the first line of the file, the line counter is incremented; the middle reselm is determined for both pulses (if option 2); the average height of pulse 1 and the relative height of pulse 2 is calculated (if option 1). The mean and standard deviation of the height for pulse one and pulse two (if nonzero) are saved for later plotting (if option 3). Control returns to point.

STEP (5) PERFORMED AFTER AN ENTIRE FILE HAS BEEN APPROVED

If the first option is specified, the mean and standard deviation are printed out of pulse 1's height and pulse 2's relative height.

If the second option is specified, the mean middle reselm number and their standard deviations are printed for pulse 1 and pulse 2 (if requested).

If the third option is specified, the point plot image is set up and the mean and standard deviation of the pulse 1's height is plotted versus its line number. The same is performed for pulse 2's height relative to pulse 1. The pulse height (overall mean pulse height ± 25) is plotted along the Y-axis. The line numbers are plotted along the X axis. One hundred lines are plotted per page and will continue for as many pages as required to plot all the lines for which pulse height calculations were made. (this may be fewer than the maximum number of lines declared in step (1)). Control returns to point.

AVEDEV.

Given an array of points and the number of points to be referenced, this routine calculates the mean and standard deviation of those points.

FTPROC.

This routine saves the value of each reselm that is within the specified boundaries of each pulse and within the specified channel. These values are stored in an array according to the point's position relative to the beginning of the pulse and according to the pulse number (2 possible). Pulse one is used to dark-level-correct pulse two when option 1 or 3 has been requested. That is, the average level of pulse one in the previous line is subtracted from each point value of pulse two before the pulse two points are stored for later processing.

BOUNDS.

This routine determines the middle of any given pulse using the method specified in the introduction to this memo.

<u>WHEN SPECIFIED</u>	<u>INPUT VARIABLES</u>	<u>DEFAULT/MODE</u>	<u>DESCRIPTION</u>
STEP(1)	BEGIN(1)...BEGIN(2)	0 INTEGER	This is an array of beginning reselm numbers for each of 2 possible pulses. These numbers must not be less than the beginning reselm number for the line.
"	END(1)...END(2)	0 INTEGER	This is an array of ending reselm numbers for each of 2 possible pulses. These numbers must not be greater than the ending reselm number for the line.
"	PTS	50 INTEGER	This is the maximum number of reselms in either of the pulses. This number must not be less than 1.

"	TYPE	\$NORMAL\$ ALPHABETIC	This variable is used to specify which option the programmer wants to use. \$NORMAL\$ - Option 1 \$JITTER\$ - Option 2 \$LINPLT\$ - Option 3
"	LINMAX	100 INTEGER	This variable specifies the maximum number of lines that will be processed in any of the files between this card and the next MODE 1= \$START\$ or MODE 1= \$RETURN\$ card. This variable must not be less than one.
"	REJECT STEP(2) MPXMUX	\$YES\$ ALPHANUMERIC NO DEFAULT INTEGER	This variable controls the listing of Points outside ± 25 of the overall mean of the plot points. This variable is assigned the multiplexor channel number to be referenced for processing. This number must be less than or equal to 13 and greater than or equal to 1.
STEP(2)	MISSON	0 INTEGER	This is the mission number that is to be associated with this file. This number must not be less than zero.
"	FDATE(1)...FDATE(3)	0	This is the date (in month, day, year form) that is to be associated with this file. FDATE(1) must not be less than 0 or greater than 12. FDATE(2) must not be less than 0 or greater than 31. FDATE(3) must not be less than 0 or greater than 99.
"	COMMNT(1)...COMMNT(8)	BLANKS ALPHANUMERIC	This is any special comment that is to be associated with this file. No error checking is performed.

OUTPUT

When TYPE = \$NORMAL\$

MEAN,DEV,MIN, AND MAX OF DARK LEVEL CORRECTED PULSE

	DATE =	XX-XX-XX	
	MISSION =	XXXXXX	"comment"
Pulse 1	MEAN(1)=	XXXXXXXX.XX	
	DEV(1)=	XXXXXXXX.XX	
	MIN(1)=	XXXXXXX	LINE NUMBER = YYYYYY
	MAX(1)=	XXXXXXX	LINE NUMBER = YYYYYY
Pulse 2	MEAN(2)=	XXXXXXXX.XX	
	DEV(2)=	XXXXXXXX.XX	
	MIN(2)=	XXXXXXX	LINE NUMBER = YYYYYY
	MAX(2)=	XXXXXXX	LINE NUMBER = YYYYYY

The reader will notice that the minimum and maximum mean values are printed as well as the actual line number within the file where they occurred.

When TYPE = \$JITTER\$

MEAN,DEV,MIN, AND MAX OF MIDDLE RESELM VALUE

	DATE =	XX-XX-XX	
	MISSION =	XXXXXX	"special comment"
	MEAN(1) =	XXXXXXXX.XX	
	DEV(1)=	XXXXXXXX.XX	
	MIN(1)=	XXXXXXX	LINE NUMBER = YYYYYY
	MAX(1)=	XXXXXXX	LINE NUMBER = YYYYYY
	MEAN(2)	XXXXXXXX.XX	
	DEV(2)	XXXXXXXX.XX	
	MIN(2)	XXXXXXX	LINE NUMBER = YYYYYY
	MAX(2)	XXXXXXX	LINE NUMBER = YYYYYY

In this case, the means and deviations are in terms of the middle reselm number for the respective pulses. In addition to the minimum and maximum reselm numbers, the line number location within the file where the extremes were found is also printed.

When TYPE = \$LINPLT\$

First the means of pulse one are plotted versus their respective line numbers. One hundred lines are plotted per page; the plots will be continued on to as many pages as are necessary to plot the actual number of lines processed. This plot is followed by the overall mean, and deviation of all the lines as well as the minimum and maximum values with line number locations. If REJECT = \$YES\$ all those points which were not within +25 of the overall means are tabulated.

This procedure is repeated for the standard deviation of pulse 1, the mean of pulse 2, and the standard deviation of pulse 2. No minimum and maximum values are printed for the standard deviation of either pulse.

DATA CARDS SETUP

1. BEGIN(1) = 10,100, END(1) = 90,190, PTS = 91,
TYPE = \$LINPLT\$, LINMAX = 500*
2. INBIN = 700, UNIT = 4, FILE = 5, NSA = 100,489,1,1,200,1 *
3. MPXMUX = 5, SCHAN = 7, MISSON = 12,
FDATE(1) = 10,29,73, COMMNT(1) = \$ABSURD\$*
4. FILE = 5, NSA = 100,599,1,1,200,1 *
5. MPXMUX = 7, SCHAN = 8, MISSON = 12.
FDATE(1) = 10,29,73, COMMNT(1) = \$STRANGES\$*
6. MODEL = \$START\$ *
7. BEGIN(1) = 90,10, END(1) = 190,9, PTS = 91,
TYPE = \$JITTER\$, LINMAX = 400
8. FILE = 5, NSA = 100,499,1,1,200,1 *
9. MPXMUX = 7, SCHAN = 8, MISSON = 12,
FDATE(1) = 10,29,73, COMMNT(1) = \$BROKEN\$ *
10. MODEL = \$START\$ *

- 11. BEGIN(1) = 10,70, END(1) = 59,85, *
- 12. FILE = 7, NSA = 10,109,1,1,86,1 *
- 13. MPXMUX = 4, SCHAN = 8*
- 14. MODEL = \$RETURNS\$ *

1-3 These cards specify that a point plot is to be made of a maximum of 500 lines under the control of option three. Multiplexor channel 5 (representing spectral channel 7) is to be referenced. A mission number of 12 and the date 10/29/73 is to be associated with the file. Although a maximum of 500 lines are provided for, only 390 lines will actually be plotted since those are the only ones processed.

4-5 These cards are a continuation of the previous processing. Therefore a point plot is still to be made for a maximum of 500 lines with the same pulse boundaries as were used before. This time multiplexor channel 7 (representing spectral channel 8) is to be used. This time, the full 500 lines will be plotted.

6-9 These cards specify that option 2 is to be performed on pulse 1 only (pulse 2 had zero width) using multiplexor channel 7 of file 5. A maximum of 400 lines will be and are processed.

10-13 These cards specify that option 1 is to be performed on pulse 1 and 2 using multiplexor channel 4 of file 7. The maximum width of either pulse defaults to 50; the maximum number of lines to be processed defaults to 100. The mission number and date default to zero, and there is no special comment.

14. This returns control to the calling program.

ERROR COMMENTS

ERROR1. MPXMUX .G. QNCHAN

The requested multiplexor channel number is greater than the number of channels in the file.

ERROR2. PTS.L. 1

This indicates that the maximum number of points in either pulse is less than 1.

ERROR3. INVALID TYPE.

The variable TYPE was given some value other than \$NQRML\$, \$JITTER\$, or \$LINPLT\$.

ERROR4. LINMAX.L.1.

The maximum number of lines to be processed is less than 1.

ERROR5. PTS.L. PULSE WIDTH .L.D.

This indicates that the width of one of the pulses is either less than zero or greater than the maximum number of points allowed in either pulse. The number of points in a pulse is

$$\text{END}(I) - \text{BEGIN}(I) + 1. \quad I = 1 \text{ or } 2$$

ERROR6. NO DARK AREA SPECIFIED.

The width of pulse 1 is zero.

ERROR7. INSUFFICIENT STORAGE

The particular combination of input values requires more storage for processing than is available. This problem can be solved by reducing LINMAX and/or PTS.

ERROR8. 13.L.MPXMUX.L.1.

This indicates that the multiplexor channel number is either less than 1 or greater than 13.

ERROR9. 24.L.SCHAN.L.1.

This indicates that the spectral channel number is either less than 1 or greater than 24.

ERROR10. MISSON .L.0.

The variable MISSON has been assigned a value less than zero.

ERROR11. INVALID MONTH

FDATE(1) has been given a value either greater than 12 or less than zero.

ERROR12. INVALID DAY

FDATE(2) has been given a value either greater than 31 or less than zero.

ERROR13. INVALID YEAR

FDATE(3) has been given a value either greater than 99 or less than zero.

ERROR14. BEGIN(X).L.NA.

This indicates that pulse "X" has a reselm number lower than the beginning reselm number for the line.

ERROR15. END(X).6. NB.

This indicates that pulse "X" has a reselm number greater than the ending reselm number for the line.

ERROR16. LINES.G. LINMAX

The program attempted to process more lines than the declared maximum. LINMAX may have been assigned an incorrect value or the NSA field of the PROCESS input card specified more lines than were supposed to be processed.

SUBROUTINES NEEDED

The following are a list of external subroutines needed for the correct operation of the program.

ASSIGN.	This routine performs all of the dynamic storage allocation necessary in the A core box.
ERROR.	System error processing routine
LINK.	This routine provides POINT with a connection to DGNSTC.'s point-processing routine PTPROC.
PLOT2. PLOT2. PLOT3. PLOT4.	All four of these routines are used in setting up and printing the point plots of DGNSTC option 3.
POINT.	This is the program that repetitively calls DGNSTC. with different levels to progressively process the data (see POINT writeup).
PROCESS.	This routine is called by POINT. and handles all I/O with data tapes (in ERIM format).
SQRT.	This routine calculates square roots.
ZERO.	This routine inserts either a binary or floating point zero in all of the requested variables or arrays.

In addition to these external functions, a define package must also be included. This package inserts 3 new operators into the MAD compiler and defines what machine instructions they each represent. These three operators are .LI., .LIF., & .SI. and are called the indirection operators. They are used in this program in conjunction with the dynamic storage allocation routines for accessing dynamically allocated arrays without using the usual subscription routines provided by the MAD compiler. Instead, they use the two internal functions S, & S22 defined in the program for all subscription routines.

S. is used for accessing a 2-dimensional array with maximum dimensions of (X, LL/B). LL/B = PTS*LINMAX (OPTION 1) or LINMAX (OPTION 2 or 3). X=2 when TYPE=\$NORMAL\$, or TYPE = \$JITTER\$. X = 4 when type= \$LINPLT\$.

S22. is used for accessing a 2-dimensional array with maximum dimensions of (2,PTS). (See writeup on indirection operators).

STORAGE REQUIREMENTS

This program requires 2744 decimal locations before any dynamic storage allocation takes place. The following equations describe how much additional storage will be required for any given set of input cards.

$$PTS*2 + LL + 2$$

$$LL = PTS*LINMAX * 2 \text{ When type} = \$NORMAL\$$$

$$LL = LINMAX * 2 \text{ when type} = \$JITTER\$$$

$$LL = LINMAX * 4 \text{ when type} = \$LINPLT\$$$



MAD (09 AUG 1965 VERSION) PROGRAM LISTING

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EXTERNAL FUNCTION DGNSTC.
REFERENCES CN
* DEFINE PACKAGE FOR LOAD INDIRECT(.LI.,.LIF.) AND
  STORE INDIRECT(.SI.). THE VARIABLES BEING REFERENCED
  MUST BE IN THE A CORE BOX. IF THE ADDRESS BEING REFERENCED
  IS IN THE B CORE BOX, THE VARIABLE CONTAINING THE ADDRESS
  MUST HAVE A MODE OF 5.
DEFINE UNARY OPERATOR .LI., PRECEDENCE SAME AS .ABS.
MODE STRUCTURE 1 = .LI. 1
JMP      **5,AC,**+1
JMP      **6,MC,**+1
JMP      **7,LA,**+1
CLA*     B
CLT      AC
STC      T
JMP      *-3
JMP      *-5
SLW      T
JMP      *-7
END

MODE STRUCTURE 0 = .LI. 0, SAME SEQUENCE AS .LI. 1
DEFINE UNARY OPERATOR .LIF., PRECEDENCE SAME AS .ABS.
MODE STRUCTURE 0 = .LIF. 1, SAME SEQUENCE AS .LI. 1
MODE STRUCTURE 1 = .LIF. 0, SAME SEQUENCE AS .LI. 1
DEFINE BINARY OPERATOR .SI., PRECEDENCE SAME AS =
MODE STRUCTURE 1 = 1 .SI. 1
JMP      **+1,BI,**+4
JMP      **+3,AC,**+1
JMP      **+9,MC,**+1
JMP      **+10,LA,**+3
JMP      **+11,AC,**+1
JMP      **+12,LA,**+1
CLA      B
STG*     A
CLT      Z
STC*     A
JMP      *-2
STG*     A
JMP      *-4
SLW*     A
JMP      *-6
STC      T
JMP      *-10
SLW      T
JMP      *-12
END

MODE STRUCTURE 0 = 0 .SI. 0, SAME SEQUENCE AS 1 .SI. 1
MODE STRUCTURE 1 = 1 .SI. 0, SAME SEQUENCE AS 1 .SI. 1
MODE STRUCTURE 0 = 0 .SI. 1, SAME SEQUENCE AS 1 .SI. 1
NORMAL MODE IS INTEGER
FLCATING POINT FL, MEAN,DEV,TCT,SCRT.,FDATUM(24),MX1, EE(0),X(100)
DIMENSION BEGIN(2),END(2),PARAMS(2),PT(2),FCATE(3),COMMNT(8),
1          MIN(2),MAX(2),NSCALE(4),LIMIN(2),LINMAX(2),FIT(3)
EQUVALENCE (FDATUM,DATUM) , (PNTL,PARAMS(1)) ,
1          (PNTF,PARAMS(2)) , (EE(0),JUNK(0)) ,
2          (IFLAG,FDATF) , (PT,LCNT) ,
3          (INC,END) , (MS,BEGIN)
VECTOR VALUES ERR(001) = 3H'1*****ERROR2. PTS .L. 1.'*

```



```

VECTOR VALUES ERR(043) = $H'1*****ERRCR3. INVALID TYPE.'* $
VECTOR VALUES ERR(045) = $H'1*****ERRCR4. LINMAX .L. 1.'* $
VECTOR VALUES ERR(127) = $H'1*****ERRCR5. PTS.L. PULSE WIDTH .L.C.'* $
VECTOR VALUES ERR(169) = $H'1*****ERRCR6. NO DARK AREA SPECIFIED.'* $
VECTOR VALUES ERR(211) = $H'1*****ERRCR7. INSUFFICIENT STORAGE.'* $
VECTOR VALUES ERR(253) = $H'1*****ERRCR8. 13 .L. MPXMUX .L. 1.'* $
VECTOR VALUES ERR(295) = $H'1*****ERRCR9. 24 .L. SCHAN .L. 1.'* $
VECTOR VALUES ERR(337) = $H'1*****ERRCR10. MISSCN .L. 0.'* $
VECTOR VALUES ERR(379) = $H'1*****ERRCR11. INVALID MONTH.'* $
VECTOR VALUES ERR(421) = $H'1*****ERRCR12. INVALID DAY.'* $
VECTOR VALUES ERR(463) = $H'1*****ERRCR13. INVALID YEAR.'* $
VECTOR VALUES ERR(505) = $H'1*****ERRCR14. BEGIN(' ,11,H') .L. NA.'* $
VECTOR VALUES ERR(547) = $H'1*****ERRCR15. END(' ,11,H') .G. NP.'* $
VECTOR VALUES ERR(589) = $H'1*****ERRCR16. LINES .G. LINMAX.'* $
VECTOR VALUES ERR(631) = $H'1*****ERRCR1. MPXMUX .G. QNCHAN.'* $
VECTOR VALUES MSG(0) = $MEAN LEVEL$
VECTOR VALUES MSG(2) = $DEVIATION LEVEL$
VECTOR VALUES NCHAR = 10,0,15
VECTOR VALUES PCD = $$$
VECTOR VALUES IIT = $STANDARD DEV$, $MEAN $
STATEMENT LABEL STEP(7)
ERASABLE JUNK(225), CUNIT, CREEL, CFILE, CLINE, TWRITE, OCHAN,
1 CNWDS, PRCG, MODE1, MODE2, UNIT, CALINE, CDLINE, NSA, NSB,
2 KS, NA, NB, KP, ID(1), TFLAG, TPACK, RESERV(4), CFACTR(49),
3 QTITL2(19), CTITLE(19), CLIST(19), CSPARE(46), CFLAG,
4 QWAKG, GRANG, CRP, CNA, CNSS, CNGHAN, CMCDE, CRECA, QRECC,
5 CFILE, CREEL, CNWRCS
ERASABLE DATA(423), ITEST, CSTART, DSTART, NV, NX, NC, L, IP,
1 ICP, NCP, NEXT, START2, READT2, READL2, READP2, LABEL2,
2 EXTRA(20), DATUM(24), ICCDE(24), ICHAN(24), IMAGE(1040)
INTERNAL FUNCTION S22.(S1,S2) = PTS*(S1-1) + S2
INTERNAL FUNCTION S.(S3,S4) = LL/B*(S3-1) + S4
WHENEVER NEXT .G. 5, FUNCTION RETURN
TRANSFER TO STEP(NEXT)
STEP(1) LINK.(PTPRCC.)
L = L + OCHAR
LINMAX = 100
PTS = 50
TYPE = $NORMAL$
RFJECT = $YES$
(K=1,1,K.G.8, COMMENT(K) = $ $)
1 ZERO.(BEGIN...BEGIN(2), END...END(2), PARAMS...PARAMS(2),
NSCALE(1)...NSCALE(3))
READ AND PRINT DATA BEGIN(1), END(1), PTS, TYPE, LINMAX
NSCALE = 1
NSCALE(2) = -1
NSCALE(4) = -1
WHENEVER PTS .L. 1
TRANSFER TO ERR2
OR WHENEVER TYPE .NE. $NORMAL$ .AND. TYPE .NE. $JITTER$ .AND.
1 TYPE .NE. $LINPLT$
TRANSFER TO ERR3
OR WHENEVER LINMAX .L. 1
TRANSFER TO ERR4
END OF CONDITIONAL
THROUGH LPI, FOR I=1,1, I .G. 2
WHENEVER END(1)-BEGIN(1)+1 .L. 0 .CR. END(1)-BEGIN(1)+1 .G. PTS,
1 TRANSFER TO ERR5
LPI CONTINUE
B = 2
F1 = END(1) - BEGIN(1) + 1
WHENEVER F1 .L. 1 .AND.
1 (TYPE .E. $NORMAL$ .OR. TYPE .E. $LINPLT$), TRANSFER TO ERR6
    
```

```

LL= PTS*LINMAX*2
WHENEVER TYPE .E. $JITTER$, LL= LINMAX*2
WHENEVER TYPE .E. $LINPLT$
    LL = LINMAX*4
    B = 4
END OF CONDITIONAL
KK = ASSIGN.(C,C)
WHENEVER KK .L. LL+ PTS*2 + 2, TRANSFER TO ERR7
KK = ASSIGN.(C,PARAMS,PTS*2,LL)
FUNCTION RETURN
STEP(2) ZERC.(PT...PT(2),FDATE...FDATE(3),FLAG,LINES,MISCON)
SCHAN = 24
READ AND PRINT DATA MPXMUX,SCHAN,MISCON,FDATE(1),COMMNT(1),REJECT
WHENEVER MPXMUX .L. 1 .OR. MPXMUX .G. 13
    TRANSFER TO ERR8
    OR WHENEVER SCHAN .L. 1 .OR. SCHAN .G. 24
        TRANSFER TO ERR9
    OR WHENEVER MISCON .L. 0
        TRANSFER TO ERR10
    OR WHENEVER FDATE(1) .L. 0 .OR. FDATE(1) .G. 12
        TRANSFER TO ERR11
    OR WHENEVER FDATE(2) .L. 0 .OR. FDATE(2) .G. 31
        TRANSFER TO ERR12
    OR WHENEVER FDATE(3) .L. 0 .OR. FDATE(3) .G. 99
        TRANSFER TO ERR13
    OR WHENEVER MPXMUX .G. CNCHAN
        TRANSFER TO ERR1
END OF CONDITIONAL
MIN(1) = 999
MIN(2) = 999
MAX(1) = -999
MAX(2) = -999
THROUGH LP2, FOR I=1,1, I .G. 2
    WHENEVER BEGIN(I) .L. NA
        TRANSFER TO ERR14
    OR WHENEVER END(I) .G. ND
        TRANSFER TO ERR15
END OF CONDITIONAL
LP2 CONTINUE
FUNCTION RETURN
STEP(3) FUNCTION RETURN
STEP(4) IFLAG = 1
EXECUTE AVEDEV.(JUNK(77777K-PNTL+S22.(1,0)),
    1 END(1)-BEGIN(1)+1)
J = MEAN + .5
WHENEVER FLAG .E. 0
    FLAG = 1
    FUNCTION RETURN
END OF CONDITIONAL
LINES = LINES + 1
WHENEVER LINES .G. LINMAX, TRANSFER TO ERR16
THROUGH LP3, FOR I=1,1, I .G. 2
    WHENEVER END(I) - BEGIN(I) + 1 .LE. 0, TRANSFER TO LP3
    WHENEVER TYPE .E. $JITTER$
        EXECUTE BOUNDS.
        (PNTF-S.(I,LINES)) .SI. MIDDLE
        WHENEVER MIDDLE + BEGIN(I) - 1 .L. MIN(I)
            MIN(I) = MIDDLE + BEGIN(I) - 1
            LINMIN(I) = LINES + NSA - 1
        END OF CONDITIONAL
        WHENEVER MIDDLE + BEGIN(I) - 1 .G. MAX(I)
            MAX(I) = MIDDLE + BEGIN(I) - 1
            LINMAX(I) = LINES + NSA - 1
    
```

```

        END OF CONDITIONAL
        TRANSFER TO LP3
    OR WHENEVER TYPE .E. $NORMAL$
        (K=1,1,K.G.(END(I)-BEGIN(I)+1), PT(I) = P(I) + 1,
        (PNTF-S.(I,PT(I))) .SI. .LI.(PNTL-S22.(I,K)))
1
    END OF CONDITIONAL
    IFLAG = 1
    WHENEVER I .E. 2, EXECUTE AVEDEV.(JUNK(77777K-PNTL+S22.(2,C)),
    END(2)-BEGIN(2)+1)
1
    WHENEVER MEAN .L. MIN(I)
        MIN(I) = MEAN + .5
        LINMIN(I) = LINES + NSA - 1
    END OF CONDITIONAL
    WHENEVER MEAN .G. MAX(I)
        MAX(I) = MEAN + .5
        LINMAX(I) = LINES + NSA - 1
    END OF CONDITIONAL
    WHENEVER TYPE .E. $LINPLT$
        (PNTF-S.(I*2-1,LINES)) .SI. MEAN
        (PNTF-S.(I*2,LINES)) .SI. DEV
        II
LP3    CONTINUE
        FUNCTION RETURN
STEP(5) WHENEVER TYPE .E. $NORMAL$
        PRINT FORMAT $H' MEAN, DEV, MIN, AND MAX OF DARK LEVEL CORRECTED',
1        H' PULSE.'///$
    OR WHENEVER TYPE .E. $JITTER$
        PRINT FORMAT $H' MEAN, DEV, MIN, AND MAX OF MIDDLE RESELM VALUE.'//
1        //$
    END OF CONDITIONAL
    PRINT FORMAT $H'-DATE = ',I2,S1,I2,S1,I2,S10,H' MISSION = ',I6,S1C,
1        HC6*$, FDATE(1)...FDATE(3),MISSION,
2        COMMENT(1)...COMMENT(8)
    WHENEVER TYPE .E. $LINPLT$, TRANSFER TO LINPLT
    THROUGH LP5, FOR I=1,1, I .G. 2
    WHENEVER END(I)-BEGIN(I)+1 ..LE. 0, TRANSFER TO LP5
    WHENEVER TYPE .E. $NORMAL$
        EXECUTE AVEDEV.(JUNK(77777K-PNTF+S.(I,0)),PT(I))
    OTHERWISE
        EXECUTE AVEDEV.(JUNK(77777K-PNTF+S.(I,0)),LINES)
        MEAN = MEAN + BEGIN(I) - 1.
    END OF CONDITIONAL
    PRINT FORMAT $H' MEAN(' ,I1,H') = ',S10,F10.2/H' DEV(' ,I1,H') = ',
1        S10,F10.2/
1        H' MIN(' ,I1,H') = ',S10,I7,S5,H' LINE NUMBER = ',I6/
1        H' MAX(' ,I1,H') = ',S10,I7,S5,H' LINE NUMBER = ',I6*$,
2        I,MEAN,I,DEV,I,MIN(I),LINMIN(I),I,MAX(I),LINMAX(I)
LP5    CONTINUE
LINPLT WHENEVER TYPE .E. $LINPLT$
        EXECUTE PLOT1.(NSCALE,5,10,5,20)
        IFLAG = 0
        THROUGH LP10, FOR I=1,1, I .G. 4
        MS = 2
        WHENEVER I/2*2 .NE. I, MS = 0
        J = (I+1)/2
        WHENEVER END(J) - BEGIN(J) + 1 .LE. 0, TRANSFER TO LP10
        EXECUTE AVEDEV.(0,LINES)
        THROUGH LP11, FOR LCNT=101,100, LCNT .GE. (LINES+101)
        (K=(LCNT-100),1,K.G.(LCNT-1), X(K-LCNT+101) = K)
        EXECUTE PLOT2.(IMAGE,LCNT-1,LCNT-101,MEAN+25.,
1        MEAN-25.)
        NC = 100
        WHENEVER LINES .L. LCNT+1, NC = LINES - LCNT + 101
    
```

```

EXECUTE PLOT3.(HCD,X(1),EE(77777K - PNTF +
1          S.(1,LCNT-100)),NC)
PRINT FORMAT $1H1,S52,H'PULSE ',I1,S1,2C6*$,J,
1          TIT((I-I/2*2)*2),TIT((I-I/2*2)*2+1)
EXECUTE PLOT4.(ACHAR(MS),MSG(MS))
PRINT FORMAT $1H9,S55,H'LINE NUMBER'*$
LP11 CONTINUE
PRINT FORMAT $H' MEAN = ',S5,F10.2//H' DEV = ',S5,F10.2//*$,
1          MEAN,DEV
WHENEVER I/2*2 .NE. 1
PRINT FORMAT $H' MIN = ',S5,I7,S5,H'LINE NUMBER = ',I6//
1          H' MAX = ',S5,I7,S5,H'LINE NUMBER = ',I6*$,
2          MIN(J),LINMIN(J),MAX(J),LINMAX(J)
END OF CONDITIONAL
WHENEVER REJECT .E. $ND$, TRANSFER TO LP10
KK = 0
PRINT FORMAT $1H1,S50,H'POINTS OUT OF RANGE'/1H ,S45,H'LINE',
1          S6,H' MEAN',S5,H' STNDRD DEV'//*$
THROUGH LP4, FOR LCNT=1,1, LCNT .C. LINES
WHENEVER EE(77777K-PNTF+S.(I,LCNT)) .L. MEAN+25. .AND.
1          EE(77777K-PNTF+S.(I,LCNT)) .G. MEAN-25., TRANSFER TO LP4
KK = KK + 1
PRINT FORMAT $1H ,S44,I6,S2,F10.2,S2,F10.2*$, LCNT,
1          EE(77777K-PNTF+S.(J*2-1,LCNT)),
2          EE(77777K-PNTF+S.(J*2,LCNT))
LP4 CONTINUE
PRINT FORMAT $H' TOTAL NUMBER OF POINTS OUT OF RANGE = ',I6*$, KK
LP10 CONTINUE
END OF CONDITIONAL
PRINT FORMAT $1H1*$
FUNCTION RETURN
BLEH1 PRINT FORMAT ERR(K),I
ERROR
ERR1 K = 631
TRANSFER TO BLEH
ERR2 K = 1
TRANSFER TO BLEH
ERR3 K = 43
TRANSFER TO BLEH
ERR4 K = 85
TRANSFER TO BLEH
ERR5 K = 127
TRANSFER TO BLEH
ERR6 K = 169
TRANSFER TO BLEH
ERR7 K = 211
TRANSFER TO BLEH
ERR8 K = 253
TRANSFER TO BLEH
ERR9 K = 295
TRANSFER TO BLEH
ERR10 K = 337
TRANSFER TO BLEH
ERR11 K = 379
TRANSFER TO BLEH
ERR12 K = 421
TRANSFER TO BLEH
ERR13 K = 463
TRANSFER TO BLEH
ERR14 K = 505
TRANSFER TO BLEH1
ERR15 K = 547
TRANSFER TO BLEH1
    
```



```
ERR16      K = 589
           TRANSFER TO BLEH
BLEH       PRINT FCRMAT ERR(K)
```

```
INTERNAL FUNCTION AVEDEV.(PNT,PNTS)
WHENEVER IFLAG .E. 1
MEAN = (TOT=C.,K=1,1,K.G.PNTS, TOT + PNT(K)) / PNTS
TOT = (TOT=0.,K=1,1,K.G.PNTS, TOT + (PNT(K)-MEAN).P.2)
DEV = SQRT.(TOT/PNTS)
OTHERWISE
MEAN = (TOT=C.,K=1,1,K.G.PNTS,
1      TOT + .LIF.(PNTF-S.(I,K)))/PNTS
TOT = (TOT=0.,K=1,1,K.G.PNTS,
1      TOT + (.LIF.(PNTF-S.(I,K)) - MEAN).P.2)
DEV = SQRT.(TOT/PNTS)
END OF CONDITIONAL
FUNCTION RETURN
END OF FUNCTION
```

```
INTERNAL FUNCTION PTPROC.
THROUGH LP6, FOR I=1,1,I .G. 2
WHENEVER IP .LE. END(I) .AND. IP .GE. BEGIN(I)
WHENEVER CMODE .E. 1
K = FDATE(MPXMUX)
DATE(MPXMUX) = K
END OF CONDITIONAL
WHENEVER TYPE .E. $JITTER$ .OR. II .E. 1 .AND.
1 (TYPE .E. $NORMAL$ .OR. TYPE .E. $LINPLT$)
(PNTL-S22.(I,(IP-BEGIN(I)+1))) .SI. DATE(MPXMUX)
OTHERWISE
(PNTL-S22.(I,(IP-BEGIN(I)+1))) .SI.
1 DATE(MPXMUX) - J
END OF CONDITIONAL
```

END OF CONDITIONAL

```
LP6      CONTINUE
FUNCTION RETURN
END OF FUNCTION
```

INTERNAL FUNCTION BOUNDS.

```
MX1 = 0.
THROUGH LP7, FOR KK=1,1, KK .G. (END(I)-BEGIN(I)+1)
WHENEVER .LI.(PNTL-S22.(I,KK)) .G. MX1,
1 MX1 = .LI.(PNTL-S22.(I,KK))
```

LP7 CONTINUE

```
LEFT = I
THROUGH LP12, FOR F1=.5,.1, LEFT .NE. 1
THROUGH LP8, FOR KK=1,1, KK .G. (END(I)-BEGIN(I)+1)
WHENEVER MX1*F1 .LE. .LI.(PNTL-S22.(I,KK)), TRANSFER TO OUT1
```

```
LP8      CONTINUE
OUT1     LEFT = KK
```

```
LP12     CONTINUE
THROUGH LP9, FOR KK=(END(I)-BEGIN(I)+1),-1, KK .L. 1
WHENEVER MX1*F1 .LE. .LI.(PNTL-S22.(I,KK)), TRANSFER TO OUT2
```

```
LPS          CONTINUE
OUT2         RIGHT = KK
            MIDDLE = (LEFT + RIGHT + 1)/2
            FUNCTION RETURN
            END OF FUNCTION
            END OF FUNCTION
```

Appendix C RADIANCE CALIBRATION

The scanner calibration lamp signal is used basically as a transfer standard to obtain the apparent spectral radiance of terrain objects. Its main purpose is to account for responsivity changes in the scanner system. In general, these are almost impossible to monitor conveniently. The scanner components themselves are designed to respond linearly with increased radiance from the ground terrain (i.e., an increase in radiance gives a corresponding increase in detector signal). Hence, the scanner detector voltage for each channel can be represented by the following general equation:

$$V_{T+p}(\lambda) = K[L_T(\lambda) + L_p(\lambda)] \quad (C.1)$$

$$L_T = \frac{\rho_\tau E_T(\lambda)}{\pi}$$

where $V_{T+p}(\lambda)$ = scanner signal voltages recorded by aircraft recorder for each channel

K = constant dependent on system factors such as responsivity of detectors and photomultipliers, system transmission losses or gains, etc.

$L_T(\lambda)$ = radiance of target (assuming a Lambertian surface) for each channel

$L_p(\lambda)$ = radiance produced for each channel by scattering of radiation by molecular and aerosol particles in the atmosphere

ρ_τ = object directional reflectance

At present, the quantity $L_p(\lambda)$ is impractical to measure conveniently and simultaneously with airborne scanner imagery. Considerable effort is being spent on modeling the atmosphere so that the appropriate corrections can be made in the data during processing.

In terms of scanner radiance calibration, however, it is not important to consider the individual terms of Eq. C.1, but rather the total radiance received at the scanner's aperture. Hence, the apparent target radiance (which includes the contribution of path radiance) is a more appropriate quantity to measure. Simplifying Eq. C.1, then, we get

$$V_{T+p} = K L_{T+p}(\lambda) \quad (C.2)$$

where $L_{T+p}(\lambda)$ = apparent radiance of target [$L_T(\lambda) + L_p(\lambda)$] for each channel

Were it not for the fact that the constant K in Eq. C.2 actually does vary somewhat because of changes in detector and responsivity, the radiance calibration of a scanner would be easy. A quick look at a radiance source (such as a reflectance standard illuminated by calibrated irradiance standards) would suffice. Since it does vary, however, a means of removing K from Eq. C.2 is necessary.

The prime purpose of the lamp reference source, as stated earlier, is to remove the factor K . This is done by dividing the voltage obtained from the target by the lamp voltage. Hence, if the target voltage is given by Eq. C.2 and the lamp voltage is given by

$$V_L = K L_L(\lambda) \quad (C.3)$$

then, dividing C.2 by C.3 we get

$$V_{T+p} = \frac{V_L L_{T+p}(\lambda)}{L_L(\lambda)} \quad (C.4)$$

Radiance calibration is performed in a similar manner except that the target, instead of being a terrain object, is an object of known radiance. If the calibration target is 3M white paint (a well-measured and stable reflectance standard) illuminated by quartz-iodine lamps, then the voltage generated by the radiance standard is

$$V_{3M}(\lambda) = K' L_{3M}(\lambda) \quad (C.5)$$

where $L_{3M}(\lambda) = \frac{\rho_{3M} E_{QI}(\lambda)}{\pi}$

E_{QI} = spectral irradiance of quartz-iodine lamps

ρ_{3M} = directional reflectance of 3M white paint

K' = system constant which has varied from K in previous equation

Dividing C.5 by the lamp voltage

$$V_{L'}(\lambda) = K' L_L(\lambda) \quad (C.6)$$

we get

$$V_{3M} = \frac{V_{L'} \rho_{3M} E_{QI}(\lambda)}{L_L(\lambda) \pi} \quad (C.7)$$

Substituting Eq. C.7 into Eq. C.4 and rearranging, we have

$$L_{T+p}(\lambda) = \left(\frac{V_T}{V_L} \right) \left(\frac{V_{L'}}{V_{3M}} \right) \left(\frac{\rho_{3M} E_{QI}(\lambda)}{\pi} \right) \quad (C.8)$$

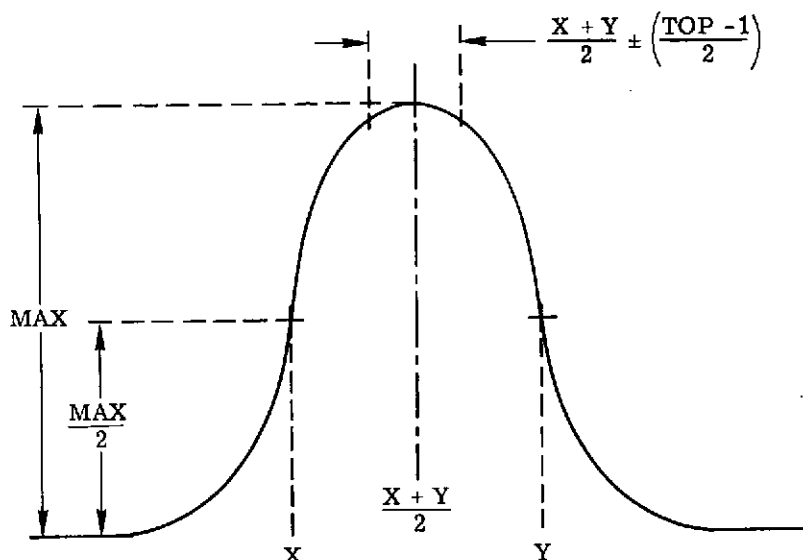
Equation C.8 gives the apparent radiance of the target in terms of known or measured quantities. It is obvious from Eq. C.8 that the accuracy of radiance calibration depends upon two factors: (1) how well ρ_{3M} and E_{QI} are known, and (2) $L_L(\lambda)$ remaining spectrally constant.

Appendix D PROGRAM LAMRAD.

The purpose of this program is to calculate a set of statistics from a set of special test runs on the M-7 scanner. These statistics are used to determine the radiance of the lamp reference source at various current levels. The test runs are made with the aircraft on the ground hooked up to laboratory power with a special test panel sealed underneath the scanner.

The user must specify the reselm numbers of the beginning and ending of the dark area, the lamp pulse and panel pulse (whose average height is to be determined), and the lamp pulse and panel pulse (whose integral is to be determined). Before the lamp pulse or panel pulse is used, the mean of the dark level from the previous line is subtracted from each reselm of the lamp and panel pulses. We assume that the dark level does not change significantly from line to line. After this, a given number of reselms are selected at the top of the panel pulse and the lamp pulse. The level of these reselms is averaged over the entire set of lines requested for the lamp pulse and the panel pulse. At the same time, the integral of the entire lamp pulse and the panel pulse can be calculated for each line and averaged over the requested lines. This is, in turn, divided by a specified pulse width resulting in a number equivalent to the mean height. After this, a level ratio (ratio of the mean lamp level to the mean panel level) and an integral ratio (ratio of the mean integral of the lamp pulse adjusted by the lamp pulse width to the mean integral of the panel pulse adjusted by the panel pulse width) are calculated. These two ratios along with the mean lamp level, mean panel level, mean lamp integral, and mean panel integral are used to calculate the standard deviation of the respective means.

The level ratio standard deviation is calculated by determining the level ratio for each line and determining the standard deviation of these level ratios from the mean level ratio for the file as a whole. A similar process is used for calculating the standard deviation of the integral ratio. The standard deviation of the lamp level and panel level is calculated by determining the square root of the average squared deviation of each of the selected reselms from the corresponding mean lamp level or mean panel level. A similar process is followed to calculate the standard deviation of the mean integral level for the lamp pulse and the panel pulse. This is done for up to 13 possible channels. The procedure for selecting the reselms at the top of the panel pulse and the lamp pulse is as follows:



1. The maximum height is determined [MAX].
2. The reselms just above MAX/2 (4*MAX/5 if this is the panel pulse) are found [X&Y] .
If the pulse boundaries are too close or the digitizing gates were too narrow, X&Y may correspond to these boundaries.
3. The level of the X&Y reselms are compared. If the difference between these levels is greater than 10 units, a 2nd degree curve is fitted to the data points. The curve is then extrapolated to determine the X&Y boundaries such that they have equal levels at these new boundaries.
4. The average of X&Y is found $(X + Y)/2$.
5. The reselms selected are those $(TOP-1)/2$ reselms on either side of $(X + Y)/2$.

The aforementioned calculations are performed for each file of the given set of files requested. After all the files have been processed, plots are made of the integral ratio vs. lamp current and then the level ratio vs. lamp current. These two plots are followed by a table of all the calculated statistics. The plots and table are made for all channels that were requested. Although the user must specify a certain area as a dark area to be used in correcting the other pulses, the user may also calculate:

- a. Mean and standard deviation levels of two pulses. The number of reselms selected for either pulse may be different.
- b. Mean and standard deviation integrals of two pulses not necessarily related to the previous pulses mentioned in (a).

NOTE: In order for this program to work correctly, all pulses must be positive-going. Also, each set of lamp radiance tests must have the files in ascending order of lamp currents and the lamp currents must be evenly spaced.

STEP(1) -- PERFORMED 1ST TIME FUNCTION CALLED OR WHENEVER "MODE1" = \$STARTS\$

This step initiates the maximum number of channels to be referenced and the maximum number of files in the set of radiance test runs. Also the minimum and maximum lamp currents are initialized in addition to the maximum number of reselms in any pulse and the maximum number of reselms to be selected at the top of the pulses. The beginning and ending reselm numbers of the pulses are zeroed.

Data cards are read in (if any) that may alter the table of constants used in calculating the radiance ratios, the maximum number of files in a set, the beginning and ending reselm numbers of the pulses, the maximum number of channels to be referenced, the minimum and maximum lamp current values, the number of reselms to be selected at the top of the pulses, and the maximum number of points in any pulse. These values are then checked for reasonableness and the storage for the data base is allocated.

At this time, as many cards are read in as there are channels to be referenced. Each card specifies the multiplexor channel number, the spectral channel it represents, the aircraft channel it represents and the lamp and panel pulse width constants to be used with this channel. Each card is checked for reasonableness and then a title is printed describing the spectral channel. After all cards are read in, the pass number is set to 1, and control returns to POINT.

STEP(2) PERFORMED BEFORE FILE IS PROCESSED

The totalling arrays and the point counters are zeroed. If this is the first pass through the file, the actual number of channels in the file is checked to make sure that it isn't less than the number of channels to be referenced. Also, the beginning and ending reselm numbers of the pulses are checked to make sure that they are within the limits of the lines in the file. Control then returns to POINT.

STEP(3) PERFORMED BEFORE EACH POINT OF A SCAN LINE IS PROCESSED.

No action taken.

STEP(4) PERFORMED AFTER EACH LINE IN THE FILE IS PROCESSED.

If this is the first line, the line counter is incremented and the average level of the dark area is determined. No other processing is done on the first line. Control returns to POINT.

For all succeeding lines during the first pass, the line counter is incremented and the following occurs.

1. Reselms are selected at the top of the 2nd and 3rd pulses as described in the introduction of this memo. The number of points actually selected is accumulated in the point counter "PNTS" for later use.

2. The value of each reselm is accumulated for the first 3 pulses.

3. A simpson integration is performed on the 4th and 5th pulses and adjusted by their respective pulse width constants. These are also accumulated separately.

4. The point counter "PT" is zeroed.

5. Control returns to point.

For all succeeding lines during the 2nd pass, the line counter is incremented and the following is done:

1. The squared deviations are accumulated for the 1st through 3rd pulses.

2. The mean is determined for the 2nd and 3rd pulses. Then the 2nd pulse mean is divided by the 3rd pulse mean. This ratio is then multiplied by the appropriate factor from the table (the level ratio)

3. The squared deviation of this ratio from the overall mean ratio is accumulated.

4. The squared deviation of the integrals are accumulated for the 5th and 6th pulses.

5. The adjusted integral of the 5th pulse is divided by the adjusted integral of the 6th pulse. This ratio is then multiplied by the appropriate factors from the table (the integral ratio).

6. The squared deviation of this ratio from the overall mean ratio is accumulated.

7. The point counter "PT" is zeroed.

8. Control returns to point.

STEP(5) PERFORMED AFTER AN ENTIRE FILE HAS BEEN PROCESSED

If this is pass 1,

1. The file counter is incremented and checked to make sure it hasn't exceeded the maximum number of files set in STEP 1.

2. The totals for pulses 1 through 3 are divided by the actual total number of reselms referenced (stored in the point counter "PNTS").

3. The totals for pulses 4 and 5 are divided by the value of the line counter minus 1.

4. The mean of pulse 2 is divided by the mean of pulse 3. This ratio is multiplied by the appropriate factor from the table. This new number is the overall mean of the level ratio.

5. The mean of pulse 4 is divided by the mean of pulse 5. This ratio is multiplied by the appropriate factor from the table. This new number is the overall mean of the integral ratio.

6. If TYPE = \$PWIDTH\$, the mean of the lamp level is saved for later calculation of the pulse width.

7. The pass number is set to 2 and control returns to POINT.

If this is pass 2,

1. The totals for pulses 1 through 3 are divided by the actual total number of points used (PNTS). The square root of this number is called the standard deviation.

2. The totals for pulses 4 and 5 are divided by the value of the line counter minus 1. The square roots of these numbers are called the standard deviation of the integrals.

3. The totals of the level ratio and integral ratio are divided by the line counter minus 1. The square roots of these numbers are called the standard deviation of the level ratio and the standard deviation of the integral ratio, respectively.

4. The pass number is set to 1 and control returns to POINT.

STEP(6) PERFORMED WHENEVER MODE1 = \$FINAL\$

This step is not performed if TYPE is not equal to PWIDTH or if any of the pulse widths are zero.

All previous working storage is freed except for the arrays containing the results calculated in step 5. New storage is allocated for use by this section of the program. The plotting image array is setup and the X coordinates are

determined. These X coordinates correspond to the lamp current and are calculated by dividing the interval between the minimum and maximum current levels (set in STEP1) into as many intervals as there are files in this set. The plotting routine is then called three times, with three different sets of Y coordinates. The 1st time is with the level ratios, the 2nd time with the level ratios multiplied by 10, the 3rd time with the level ratios multiplied by 100. The plot is then made.

The plotting routines are then setup all over again and the integral ratios for each current are used. Again the ratios are plotted 3 times. The plot is then made.

Finally, a table is produced of all the results:

1. Mean of the dark level, the lamp level, the panel level, the level ratios, and the integral ratio.
2. The standard deviations of all of the above.

Control returns to POINT.

PTPROC.

This routine saves the value of each reselm that is within the specified boundaries of each pulse. These values are stored in an array according to the position relative to the beginning of the pulse (the point counter), according to the multiplexor channel number, and according to the pulse number (5 possible). Pulse number one is considered the dark level and its uncorrected value is saved. All remaining pulses are dark-level corrected before being stored. That is, the average dark level of the previous line is subtracted from each point value before it is stored.

BOUNDS.

This routine selects the points in the 2nd and 3rd pulses that are to be used in calculations. It calculates the reselm numbers of the left and right boundaries relative to the beginning of the dpulse. (The selection procedure is described in the introduction to this memo.) In addition, this routine counts the number of points actually selected for each pulse of the first three pulses for each channel. These numbers are used later in calculating the mean and standard deviation of these pulses (see STEP5).

ADJUST.

This routine is called by BOUNDS. whenever a least-squares curve fitting is to be done. It takes the calculated coefficients from LSQAR. and solves the quadratic equation for the reselm number that will result in a symmetrical pulse. This reselm number is then used to determine the left and right boundaries of the set of reselms to be selected.

SIMPSN.

This routine performs a Simpson integration of pulses 4 or 5. The formula used is:

$$Q_{ZZ} = X_1 + 4X_2 + 2X_3 + 4X_4 + \dots + 4X_{n-2} + 2X_{n-1} + X_n$$

n must be odd
 $n \geq 5$

INPUT VARIABLES

WHERE USED	VARIABLE	DEFAULT	DESCRIPTION
STEP (1)	FACTOR (1)	(1) 2725. (13) 1244.3	table of factors that ratio of pulse 2 to pulse 3 and ratio of pulse 4 to pulse 5 is multiplied by. No checking is performed on these numbers. Once this table is changed, the default values can be reinstated only by reloading the program or by reading them in off input cards.
		(2) 133.8 (14) 1017.3	
		(3) 1016.1 (15) 840.65	
		(4) 3484.5 (16) 622.69	
		(5) 1016.1 (17) 0.	
		(6) 2166.1 (18) 0.	
		(7) 3484.5 (19) 0.	
		(8) 3078.5 (20) 0.	
		(9) 2459.7 (21) 0.	
		(10) 2111.2 (22) 0.	
		(11) 1712.7 (23) 0.	
		(12) 1469.6 (24) 0.	
FILMAX		6 <u>>1</u> INTEGER	The maximum number of files to be considered as one set of lamp radiance test runs. This number need not be exact (just so it is not fewer than the actual number of files to be processed) since the

actual number of files processed is used to determine the lamp current test points.

STEP(1)	BEGIN (1)...	0	This is an array of beginning reselm numbers for
	BEGIN(5)	INTEGER	each of 5 possible pulses. These must not be less than the beginning reselm number specified for the line.
"	END(1)...	0	This is an array of ending reselm numbers for each
	END(5)	INTEGER	of 5 possible pulses. These must not be greater than the ending reselm number specified for the line.
			NOTE: $END(K) - BEGIN(K) + 1$ must be less than or equal to
			PTS and greater than or equal to 5 (for $K = 4 \& 5$). The result may be zero if a particular pulse is to be ignored. ($K=1, \dots, 5$) This number should be the same for $K=4$ and 5 for lamp radiance tests so that the integral ratio will be correct.
"	CHANNL	13	The maximum number of channels being referenced
		INTEGER	by any file. It may be less than the actual number of channels available, but it must not be greater than the number of channels in any of the files in the set. Also, it must be between 1 & 13 inclusive.
"	MIN	3.5	This is the minimum lamp current that is used.
		FLOAT	It also corresponds to the current in the lamp of the first file to be processed in the set. It must not be less than 3.0.
"	MAX	6.0	This is the maximum lamp current that is used. It
		FLOAT	also corresponds to the current in the lamp of the last file to be processed in the set. It must not be greater than 7.0.

NOTE: If MIN, MAX, & FILMAX default, the following is assumed:

FILE	6 FILES ACTUALLY PROCESSED	5 FILES ACTUALLY PROCESSED
	LAMP CURRENT	LAMP CURRENT
1	3.5	3.5
2	4.0	4.125
3	4.5	4.75
4	5.0	5.375
5	5.5	6.0
6	6.0	

STEP(1)	TOP(1)... TOP(2)	5 INTEGER	The number of data points at the top of pulses 2 and 3 to be used in the calculations. Fewer than this number may be used if the pulses are strangely unsymmetric. This number must be less than or equal to the pulse width.
"	PTS	50 INTEGER	This is the maximum number of resels in any of the 5 pulses. This number must not be less than 1.
"	MPXMUX	NO DEFAULT (N/D) INTEGER	This is the number of the multiplexor channel. This number must not be less than 1 or greater than 13.
"	SCHAN	N/D INTEGER	This is the number of the spectral channel that MPXMUX represents. This number must not be less than 0 or greater than 24. When SCHAN=0, the corresponding MPXMUX channel will be ignored.
"	AIRCHN	N/D INTEGER	This is the number of the aircraft channel that MPXMUX represents. No checking is done on this number.
"	TYPE	N/D INTEGER	This is a switch to inform the program that pulse width calculations are to be made (TYPE=\$PWIDTH\$)
"	PFILE	5 INTEGER	This variable specifies which file of the following set is to be used for pulse width calculations.

"	PCONST	3 FLOATING	This is the pulse width constant that is to be used to convert the lamp integral into a lamp level for this associated multiplexor channel.
"	PANCON	7.9 FLOATING	This is the pulse width constant that is to be used to convert the panel integral into a panel level for the associated multiplexor channel.

OUTPUT

PLOTS

Plots are made only for those spectral channels whose SCHAN was not equal to 0. The first plot of each pair is a plot of the level ratios:

- \$ - the level ratio multiplied by 100 for each current level
- * the level ratio multiplied by 10 for each current level
- \$8 the level ratio for each current level

The second plot of each pair is a plot of the integral ratios for each current level. The same plotting characters as before are used. After each pair of plots follows a table of all the statistics calculated.

CRRNT	lamp current being referenced
DARK MEAN	mean of dark level
LAMP MEAN	mean of selected reselms at top of lamp pulse
PANEL MEAN	mean of selected reselms at top of panel pulse
LAMP INTEGRL MEAN	mean adjusted integral of lamp pulse
PANEL INTEGRL MEAN	mean adjusted integral of panel pulse
LEVEL RATIO	mean of the level ratio
INTEGRL RATIO	mean of the integral ratio
DARK DEV	
LAMP DEV	
PANEL DEV	Standard deviation of the previous means
LAMP INTEGRL DEV	
PANEL INTEGRL DEV	
LEVEL RATIO DEV	
INTEGRL RATIO DEV	

The lamp pulse and the panel pulse are both dark-level normalized by subtracting the mean dark level of the previous line from all the reselms to be used in calculations

If TYPE=\$PWIDTH\$, the lamp integral and the panel integral have been divided by the pulse width constant. This turns the LAMP INTEGRL & the PANEL INTEGRL columns into mean levels of the lamp and panel pulses.

DATA CARDS SETUP

```

1 BEGIN(1) = 10,60,80,60,80, END(1)=50, 70, 90, 70, 90, CHANNL=4, PTS = 41*
2 MPXMUX = 1, SCHAN = 2, AIRCHN = 3*
3 MPXMUX = 2, SCHAN = 3, AIRCHN = 4*
4 MPXMUX = 3, SCHAN = 4, AIRCHN = 5 *
5 MPXMUX = 4, SCHAN = 5, AIRCHN = 6*
6 INBIN = 701, FILE = 1, UNIT = 4, NSA = 10,100,1,1,100,1 *
7 FILE = 1, NSA = 10, 100, 1, 1, 200, 1 *
8 FILE = 2, NSA 10, 100, 1, 1, 200, 1 *
9 FILE=2, NSA = 10, 100, 1, 1, 200, 1 *
10 FILE = 3, NSA = 10, 100, 1, 1, 200, 1 *
11 FILE=3, NSA = 10, 100, 1, 1, 200, 1 *
12 FILE = 4, NSA = 10, 100, 1, 1, 200, 1 *
13 FILE = 4, NSA = 10, 100, 1, 1, 200, 1*
14 FILE = 5, NSA - 10, 100, 1, 1, 200, 1, *
15 FILE = 5, NSA = 10, 100, 1, 1, 200, 1 *
16 FILE = 6, NSA = 10, 100, 1, 1, 200, 1 *
17 FILE = 6, NSA = 10, 100, 1, 1, 200, 1 *
18 MODEL = $FINAL$*
19 MODEL = $START$ *
20 FILMAX = 4, BEGIN(1) = 10, 60, 80, 60, 80, END(1) = 50, 70, 90, 70, 90,
    CHANNL = 3, MIN = 4.0, MAX = 5.5, PTS = 41*
21 MPXMUX=1, SCHAN=3, AIRCHN=5 *
22 MPXMUX=3, SCHAN=0, AIRCHN=7 *
23 MPXMUX=2, SCHAN=4, AIRCHN=6 *
24 FILE=9, NSA=1, 100, 1, 1, 100, 1, *
25 FILE=9, NSA=1,100,1,1,100,1 *
26 FILE = 8, NSA=1,100,1,1,100,1 *
  
```

```

27 FILE = 8, NSA = 1, 100, 1, 1, 100, 1 *
28 FILE = 7, NSA = 1, 100, 1, 1, 100, 1 *
29 FILE = 7, NSA = 1, 100, 1, 1, 100, 1*
30 MODEL=$ FINAL$ *
31 MODEL= $START$*

32 FILMAX=1, BEGIN(1)=10,80,120,12,12, END(1)=70,119,159,11,11, CHANNL=3,
3   PTS=61 , TYPE = $PWIDTH$, PFILE=4*
33 MPXMUX = 1, SCHAN = 2*
34 MPXMUX = 2, SCHAN = 3*
35 MPXMUX = 5, SCHAN = 4*
36 FILE = 7, NSA = 20,40,1,1,160,1*
37 MODEL= $START$ *
38 FILMAX =4, BEGIN(1)=10,12,12,80,120, END(1)=70,11,11,119,159, CHANNL=3, PTS=61*
39 MPXMUX=1, SCHAN=2, PCONST=8.9*
40 MPXMUX=2, SCHAN=3, PCONST=17.6*
41 MPXMUX=5, SCHAN=4 , PCONST=14.0, PANCON=4.9*
42 FILE=4, NSA=20,120,1,1,160,1 *
43 FILE=4, NSA=20, 120, 1, 1, 160, 1 *
44 FILE =5, NSA=20, 120, 1, 1, 160, 1 *
45 FILE = 5, NSA = 20, 120, 1, 1, 160, 1 *
46 FILE = 6, NSA = 20, 120, 1, 1, 160, 1 *
47 FILE = 6, NSA = 20, 120, 1, 1, 160, 1 *
48 FILE = 7, NSA = 20, 120, 1, 1, 160, 1 *
49 FILE = 7, NSA = 20, 120, 1, 1, 160, 1 *
50 MODEL = $FINAL$ *
51 MODEL = $RETURN$ *
    
```

1 This card specifies that the dark area begins at reselm 10 and ends at reselm #50. The lamp pulse begins at reselm #60 and ends at reselm # 70. The panel " " " " # 80 " " " " # 90. The lamp " (to be integrated) begins at reselm #60 & ends at #70. The panel " " " " # 80 " " " #90. Only four channels are to be referenced. A maximum of 41 reselms are in any one pulse. The default FACTOR array will be used. A maximum of 6 files will be

- referenced (default). The minimum current level is 3.5 and the maximum current level is 6.0 (default). A maximum of 5 points will be selected at the top of pulse 2 and 3 (default).
- 2-5 These cards specify that multiplexor channels 1, 2, 3, & 4 will correspond to spectral channels 2, 3, 4, & 5, and to aircraft channels 3, 4, 5, & 6.
- 6 This is the input data required by PROCESS under POINT. Tape 701 will be mounted on unit 4 and file 1 will be accessed. Every line from 1 through 100 will be processed and every point from 1 to 200 will be used. This starts the calculation of the means.
- 7 This is more input data required by PROCESS under point. INBIN & UNIT do not have to be specified since the tape is already mounted. This starts the calculation of the standard deviations.
- 8-17 These cards correspond to cards 6&7 (see above). It is implied by the ordering of the cards that file 1 references the lowest lamp current of 3.5 amperes and that each successive file references a higher lamp current than the previous. It is implied by the number of files referenced that the lamp current levels are 3.5, 4.0, 4.5, 5.0, 5.5, & 6.0 amperes.
- 18 This tells POINT to perform STEP(6). This section of the program is responsible for plotting & tabulating the data that has been calculated previously.
- 19 This tells POINT to start all over again with STEP(1).
- 20 These cards specify that:
- a maximum of 4 files are to be processed
 - The dark area begins at reselm #10 & ends at reselm #50;
 - the lamp pulse " 60 " 70;
 - the panel " 80 " 90.
 - The lamp pulse (to be integrated) begins at 60 & ends at 70;
 - the panel " 80 " 90.
 - Only 3 channels are to be referenced.
 - The minimum current level is 4.0 amperes.
 - The maximum " " " 5.5 "
 - A maximum of 41 reselms are in any 1 pulse.
 - The default FACTOR array will be used (default).

- A maximum of 5 points will be selected at the top of pulse 2 & 3 (default).
- 21-23 These cards specify that multiplexor channels 1 & 2 will correspond to spectral channels 3 & 4, and to aircraft channels 5 & 6. Multiplexor channel 3 will be ignored.
- 24-29 These cards perform the same functions as cards 6-17. It is implied by the number of files referenced and the order they are referenced that file 9 represents a lamp current of 4.0 amperes, file 8 represents a lamp current of 4.75 amperes, and file 7 represents a lamp current of 5.5 amperes. You will notice that despite the original declaration of FILMAX=4, the lamp current levels are based on the actual number of files referenced.
- 30 Same as card 18
- 31 Same as card 19
- 32-37 This requests the program to perform pulse width calculations on the 4th file of the next data set. The mean level of the lamp pulse and panel pulse are calculated and saved.
- 38-50 This performs the integral ratio calculations of files 4 through 7. The ratio of the lamp integral to the panel integral is printed; the lamp and panel integral are printed divided by the pulse width constant for the appropriate channel. File 7 (the 4th file of the set) is used for pulse width calculations.
- 51 Returns control to the program that called POINT.

ERROR COMMENTS

ERROR1. 1 .G. MPXMUX. G. 13.

This indicates that MPXMUX is either less than 1 or greater than 13.

ERROR2. 0. .G. SCHAN .G. 24.

This indicates that SCHAN is either less than 0 or greater than 24.

ERROR3. FILMAX .L. 1.

This indicates that the maximum number of files to be processed is less than 1.

ERROR4. 1 .G. CHANNL .G. 13.

This indicates that the maximum number of channels to be referenced is either less than 1 or greater than 13.

ERROR5. CURRENT MIN INVALID

This indicates that the minimum current level is less than 3.0 amperes or greater than 7.0 amperes.

ERROR6. CURRENT MAX INVALID.

This indicates that the maximum current level is greater than 7.0 amperes or less than 3.0 amperes.

ERROR7. INSUFFICIENT STORAGE

Since this program uses dynamic storage allocation for its incore data bases, the possibility exists that someone will try to process more data than can physically fit into the machine. The main incore data base requires $FILMAX + CHANNL * 14 + PTS * (2 + CHANNL * 5) + 5$ locations. (See the section on storage requirements for more detail.)

ERROR8. TOP(X) .L.O.

This indicates that the number of points to be selected at the top of pulse X is less than zero. "X" is 1 when referencing the lamp pulse; "X" is 2 when referencing the panel pulse.

ERROR9. TOP(X) .G. P WIDTH

This indicates that the number of points to be selected at the top of pulse X is larger than the number of reselms in the pulse. "X" is 1 when referencing the lamp pulse; "X" is 2 when referencing the panel pulse.

ERROR10. CHANNL .G. QNCHAN.

This indicates that the specified maximum number of channels to be referenced is greater than the number of channels in the file.

ERROR11. BEGIN(X) .L. NA.

This indicates that the beginning reselm number of pulse "X" is less than the beginning reselm number for the lines of the file.

ERROR12. END(X) .G. NB.

This indicates that the ending reselm number of pulse "X" is greater than the ending reselm number for the lines of the file.

ERROR13. PULSE WIDTH .G. PTS.

This indicates that the width of one of the pulses is larger than the declared maximum number of reselms in any one pulse.

ERROR14. PULSE WIDTH .L. 5.

This indicates that the width of one of the pulses is less than 5 reselms.

ERROR15. MORE FILES THAN FILMAX.

This indicates that the program attempted to process more files than originally declared with FILMAX.

ERROR16. NO DARK AREA PROVIDED.

This indicates that $END(1) - BEGIN(1) + 1$ was less than or equal to zero.

ERROR17. DISCRIMINANT .L. 0.

After the 2nd degree least-squares curve was calculated, the equation must be solved for the two zeros. Unfortunately, the discriminant was less than 0, indicating that the roots of the equation are imaginary. This might indicate a misshapen pulse where the left and right boundaries are not lower than the peak. Consequently, the boundaries cannot be determined at the top of the pulse.

ERROR18. PTS. .L. 1.

This indicates that the declared maximum number of resels in any one pulse is less than 1.

ERROR19. AVE HEIGHT NOT FOUND

This indicates that a pulse had a width of zero and $TYPE = \$PWIDTH\$$ was not specified.

ERROR20. PFILE. .L. 1.

This indicates that the relative number of the file relative to the first file of the next data set was less than zero.

SUBROUTINES NEEDED

The following are a list of external subroutines needed for the correct operation of this program:

ASSIGN.	this performs all the dynamic storage allocation necessary in the B core box.
CANCEL.	Part of ASSIGN
ERROR	System error processing routine
FREESP.	This routine frees as much of the dynamically allocated space as necessary. (Part of ASSIGN)
GETNXT.	Part of ASSIGN

LINK. This routine provides POINT with a correction to the LAMRAD's point-processing routine PTPROC. (Part of POINT).

LSQAR. This routine performs a least squares curve fit to a given set of data.

PLOT1.
PLOT2.
PLOT3.
PLOT4.) All four of these routines are used in setting up and printing the point plots of the lamp radiance curves.

POINT. This is the program that repetitively calls LAMRAD. with different levels to progressively process the data. (See POINT. writeup).

PROCESS. This is a routine called by POINT. that handles all I/O with data tapes (in ERIM format).

SETDIM. This routine sets up the dimensioning and subscriptions information necessary for the dynamically allocated arrays.

SQRT. This routine calculates square roots.

ZERO. This routine inserts either a binary or floating point zero in all of the requested variables or arrays.

PULSE WIDTH CALCULATIONS

The purpose for performing pulse width calculations in lieu of just calculating mean levels and the level ratio is four-fold:

1. We found that integration process usually results in a lower standard deviation than can be achieved with mean levels.
2. Calculating integrals goes a lot faster since boundaries don't have to be determined and no curve fitting is ever done.
3. Changes in the calculated pulse width provide a way to determine if changes in the shape of the pulse have occurred and how drastic these changes might be.
4. Through the use of pulse width constants, the results can be messaged by the user to account for errors in the digitization process or for errors in the data.

The general method for pulse width calculation is as follows:

1. The program calculates the mean level of the lamp and panel from a



file chosen by the user for pulse width calculations. These means (for each channel) are saved for later use.

2. The user then instructs the program to calculate the mean integral of the lamp and panel and provides pulse width constants to divide into these integrals. Consequently, the integral is no longer an area measurement, but a measure of the average height of the pulse.

3. These adjusted integrals are then used for the integral ratio. Standard deviations are ^{also} calculated for these adjusted integrals.

4. This process (#2 & #3) is repeated for each file of the lamp radiance calibration set.

5. After all the files are processed, the following is printed:

- a. mean lamp height from step #1.
- b. mean panel height from step #1
- c. integral of the lamp. This is the adjusted integral of the lamp multiplied by the pulse width constant.
- d. integral of the panel (similar calculations as in c).
- e. calculated pulse width for lamp. Integral of lamp (c.) divided by the mean lamp height from step #1.
- f. calculated pulse width for panel (similar calculations as in e).
- g. pulse width constant used for the lamp
- h. pulse width constant used for the panel

STORAGE REQUIREMENTS

The LAMRAD program requires 4545 decimal locations before any dynamic storage allocation takes place. The formula for determining how much additional storage will be allocated for a particular data set is as follows:

AFTER MODEL = \$START\$ &

BEFORE MODEL = \$FINAL\$

FILMAX*CHANNL*14+PTS*(CHANNL*5+2) +5



AFTER MODEL = \$FINAL\$ &

BEFORE MODEL = \$START\$

FILMAX*(CHANNL*14+2) +4



MAC (09 AUG 1965 VERSION) PROGRAM LISTING

```

EXTERNAL FUNCTION LAMRAC.(MEAN,DEV,XX,YY,FNT,X,Y)
REFERENCES CN
NORMAL MODE IS INTEGER
FLCATING POINT TCF(2), FACTOR(24), MIN, MAX, TCI(13*6), TCT1(2),
1 TCT2(13), TCT3(13), SCRT., MEAN, DEV, X, Y, F(2),
2 Q22, F1, F2, F3, FDATA(24), MAX, CCEF, MX1, A(3),
3 XX,YY,SAVLAM(13),FWICL,PCCNST(13*2),SAVPA(13),PANCCA,
4 FWICP
DIMENSION CHNNLS(13), BEGIN(5), ENC(5), PARAMS(7), NSCALE(4),
1 TITLE(32), FT(5), BCC(3), ERR(85C), PNTS(13*2),
2 ITRY(85C), IIT(3)
EQUVALENC (CHNNLS,AIRCHA), (BEGIN,MFXMUX), (ENC,SCFAN),
1 (FCATLM,CATLM), (ITRY(1),ERR(1))
VECTOR VALLES BCC(1) = $$$, $$, $B$
VECTOR VALLES TITLE(1) = $F1, .71-.73$, $E1, .33-.38$,
1 $B2, 2.0-2.6$, $B3, 1.0-1.4$,
2 $C1, 2.0-2.6$, $C2, 1.5-1.8$,
3 $C3, 1.0-1.4$, $C4, .67-.94$,
4 $C4, .62-.70$, $C5, .58-.64$,
5 $C6, .55-.60$, $C7, .52-.57$,
6 $C8, .50-.54$, $C9, .48-.52$,
7 $C10, .46-.49$, $C12, .41-.48$
VECTOR VALLES MSG = $PADIANCE$
VECTOR VALLES FACTOR(1) = 2725.,133.8,1016.1,3484.5,1016.1,2166.1,
1 3484.5,3078.5,2459.7,2111.2,1712.7,1469.6,
2 1244.3,1017.3,840.65,622.69,C.,C.,O.,C.,C.,
3 C.,C.,C.
VECTOR VALLES F(1) = .5, .8
VECTOR VALLES PCCNST(1) = 3.,3.,3.,3.,3.,2.,3.,3.,3.,3.,3.,3.,2.
VECTOR VALLES SAVLAM(1) = 0.,C.,C.,C.,0.,C.,C.,C.,C.,C.,C.,C.,C.
VECTOR VALLES PFLAG = 2
VECTOR VALLES IIT = $LEVEL RATIC$, $INTGRL RATIC$
VECTOR VALLES
C ERR(1) = $H'1*****ERRCR1. 1 .G. MFXMUX .G. 13.'* $
VECTOR VALLES
1 ERR(43) = $H'1*****ERRCR2. 0 .G. SCFAN .G. 24.'* $
VECTOR VALLES
2 ERR(85) = $H'1*****ERRCR3. FILMAX .L. 1.'* $
VECTOR VALLES
3 ERR(127) = $H'1*****ERRCR4. 1 .G. CHANNL .G. 13.'* $
VECTOR VALLES
4 ERR(169) = $H'1*****ERRCR5. CURRENT MIN INVALID.'* $
VECTOR VALLES
5 ERR(211) = $H'1*****ERRCR6. CURRENT MAX INVALID.'* $
VECTOR VALLES
6 ERR(253) = $H'1*****ERRCR7. INSUFFICIENT STORAGE.'* $
VECTOR VALLES
7 ERR(295) = $H'1*****ERRCR8. TCF(' ,I1,+') .L. C.'* $
VECTOR VALLES
8 ERR(337) = $H'1*****ERRCR9. TCF(' ,I1,+') .G. F WIDTH.'* $
VECTOR VALLES
9 ERR(379) = $H'1*****ERRCR10. CHANNL .G. CNCFAN.'* $
VECTOR VALLES
C ERR(421) = $H'1*****ERRCR11. BEGIN(' ,I1,+') .L. NA.'* $
VECTOR VALLES
1 ERR(463) = $H'1*****ERRCR12. ENC(' ,I1,+') .G. NB.'* $
VECTOR VALLES
2 ERR(505) = $H'1*****ERRCR13. PULSE WIDTH .G. FTS.'* $
VECTOR VALLES
3 ERR(547) = $H'1*****ERRCR14. PULSE WIDTH .L. 5.'* $

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VECTOR VALUES
4 ERR(569) = $F'1*****ERRCR15. MORE FILES THAN FILMAX.'**$
VECTOR VALUES
5 ERR(631) = $F'1*****ERRCR16. NO DARK AREA PROVIDED.'** $
VECTOR VALUES
6 ERR(673) = $F'1*****ERRCR17. DISCRIMINANT .L. C.'** $
VECTOR VALUES
7 ERR(715) = $F'1*****ERRCR18. PTS .L. 1.'** $
VECTOR VALUES
8 ERR(757) = $F'1*****ERRCR19. AVE HEIGHT NOT FOUND.'**$
VECTOR VALUES
9 ERR(799) = $F'1*****ERRCR20. PFILE .L. 1.'** $
STATEMENT LABEL STEP(17)
ERASABLE JUNK(225),LUNIT,CREEL,CFILE,CLINE,TWRITE,CCHAN,
1 CNWDS,PRCG,MODE1,MODE2,UNIT,CALINE,CCLINE,NSA,NSB,
2 KS,NA,NE,KF,IC(1),TFLAG,IPACK,RESERV(4),CFACR(45),
3 GTITLE2(19),CTITLE(19),GLIST(19),CSHARE(46),CFLAG,
4 QCRANG,CRANG,GRF,CNA,GNSS,CNCHAN,CMODE,CRECA,CRECC,
5 SFILE,CREEL,CNWDS
ERASABLE DATA(422),ITEST,CSTART,CSTART,AV,AX,AC,L,IP,
1 ICF,NCF,NEXT,START2,READT2,REACL2,REALF2,LABEL2,
2 EXTRA(20),CALUM(24),ICCLE(24),ICFAN(24),IMAGE(940)
WHENEVER NEXT .G. 6, FUNCTION RETURN
TRANSFER TO STEP(NEXT)
STEP(1) LINK.(IPTRCG.)
L = L + CCHAN
CHANNL = 13
FILMAX = 6
MIN = 3.5
MAX = 6.0
PTS = 50
(P=1,1,P.G.2,TCF(P)=5.)
ZERO.(BEGIN...BEGIN(5),END...END(5),PARAMS,NSCALE,FILES,
1 CHANLS...CHANLS(13))
READ AND PRINT DATA FACTOR(L),FILMAX,BEGIN(1),END(1),CHANNL,MIN,MAX,TCF(1),
1 PTS,TYPE,PFILE
WHENEVER TYPE .E. $FWIDTH$ .AND. PFLAG .E. 2, PFLAG = 0
PASS = 1
WHENEVER FILMAX .L. 1
TRANSFER TO ERR3
OR WHENEVER CHANNL .L. 1 .OR. CHANNL .E. 13
TRANSFER TO ERR4
OR WHENEVER MIN .L. 3. .OR. MIN .G. 7.
TRANSFER TO ERR5
OR WHENEVER MAX .G. 7. .OR. MAX .L. 3.
TRANSFER TO ERR6
OR WHENEVER PTS .L. 1
TRANSFER TO ERR12
OR WHENEVER PFILE .L. 1
TRANSFER TO ERR20
END OF CONDITIONAL
TCP = END(1) - BEGIN(1) + 1
WHENEVER TCP .LE. 0, TRANSFER TO ERR16
THROUGH LP, FOR K=1,1, K .G. 5
WHENEVER END(K) - BEGIN(K) + 1 .G. PTS, TRANSFER TO ERR12
WHENEVER END(K) - BEGIN(K) + 1 .L. 5 .AND. K .GE. 4 .AND.
1 END(K) - BEGIN(K) + 1 .NE. 0, TRANSFER TO ERR14
LP CONTINUE
THROUGH LP12, FOR K=1,1, K .G. 2
WHENEVER TCP(K) .L. 0.
TRANSFER TO ERR8
OR WHENEVER TCP(K) .G. END(K+1)-BEGIN(K+1)+1
1 .AND. END(K+1)-BEGIN(K+1)+1 .NE. 0

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        TRANSFER TO ERR9
    END OF CCNDITIONAL
LP12    CONTINUE
        SIZE = FILMAX*CHANNL*7
        I = PTS*CHANNL*5
        KK = ASSIGN.(C,C)
        WHENEVER KK .L. SIZE*2 + PTS*2 + I + 5, TRANSFER TO ERR7
        KK = ASSIGN.(LAMRAC.,PARAMS,SIZE...3,SIZE...3)
        BLOCK = GETNXT.(8)
        LEVEL = GETNXT.(BLOCK+4)
        ADDR5 = GETNXT.(BLOCK)
        KK = ASSIGN.(LAMRAC.,PARAMS,PTS,PTS,I...3)
        SETDIM.(MEAN,FILMAX,CHANNL,7)
        SETDIM.(DEV,FILMAX,CHANNL,7)
        SETDIM.(PNT,PTS,CHANNL,5)
        CANCEL.(LAMRAC.)
        THROUGH LP1, FOR K=1,1, K .G. CHANNL
            PANCCN = C.
            READ AND PRINT DATA MPXMLX,SCHAN,AIRCHN,PCCNST,PANCCN
            WHENEVER MPXMLX .G. 13 .CR. MPXMLX .L. 1, TRANSFER TO ERR1
            WHENEVER SCHAN .G. 24 .CR. SCHAN .L. C, TRANSFER TO ERR2
            WHENEVER PANCCN .E. C.
                PCCNST(MPXMLX,2) = 7.9
            OTHERWISE
                PCCNST(MPXMLX,2) = PANCCN
            END OF CONDITIONAL
            CHANLS(MPXMLX) = SCHAN
            PCCNST(MPXMLX,1) = PCCNST
            WHENEVER SCHAN .E. C, TRANSFER TO LP1
            PRINT FORMAT $1H+,T99,H'SPECTRAL BAND = ',2C6$,
                TITLE(SCHAN*2-1),TITLE(SCHAN*2)
LP1    1 CONTINUE
        PASS = 1
        FUNCTION RETURN
STEP(2) ZEPG.(TCT...TCT(78),TCT1...TCT1(2),TCT2...TCT2(13),FLAG,
1      TCT3...TCT3(13),PT...PT(5),LINES,PNTS...PNTS(39))
        WHENEVER PASS .E. 1
            WHENEVER CHANNL .G. CNCHAN, TRANSFER TO ERR10
            THROUGH LP13, FOR K=1,1, K .G. 5
                WHENEVER END(K)-BEGIN(K)+1 .E. C
                    WHENEVER K .LE. 3, (KK=1,1,KK.G.13,PNTS(KK,K) = 1)
                        TRANSFER TO LP13
                    CR WHENEVER BEGIN(K) .L. NA
                        TRANSFER TO ERR11
                    CR WHENEVER END(K) .G. NB
                        TRANSFER TO ERR12
            END OF CCNDITIONAL
LP13    CONTINUE
        END OF CCNDITIONAL
        FUNCTION RETURN
STEP(3) FLACTION RETURN
STEP(4) LINES = LINES + 1
        J = C
        THROUGH LP3, FOR K=1,1, K .G. CHANNL
            THROUGH LP22, FOR J=J+1,1, CHANLS(J) .NE. C .CR. J .G. 13
                TCT(K,1) = C.
                (KK=1,1,KK.G.PT(1),TCT(K,1) = TCT(K,1) +
                    PNT(KK,K,1)/TCP)
1      WHENEVER FLAG .E. C, TRANSFER TO LP3
            THROUGH LP4, FOR F=2,1, P .G. 4
                WHENEVER END(F-1)-BEGIN(F-1)+1 .E. C, TRANSFER TO LP4
            EXECUTE BOUNDS.
            WHENEVER PASS .E. 1
    
```

```

        (KK=LEFT,1,KK.G.RIGHT,TCT(K,P) = TCT(K,P) +
1                                     FNT(KK,K,P-1))
    OTHERWISE
        TCT1(P-2) = C.
        WHENEVER P .NE. 2
1         (KK=LEFT,1,KK.G.RIGHT,TCT1(P-2) = TCT1(P-2) +
1                                     FNT(KK,K,P-1)/TCP(P-2))
        END OF CONDITIONAL
1         (KK=LEFT,1,KK.G.RIGHT,TCT(K,P) = TCT(K,P) +
1         (FNT(KK,K,P-1)-MEAN(FILES,K,P-1)).P.2)
    END OF CONDITIONAL
LP4    CONTINUE
        WHENEVER PASS .E. 2 .AND. END(2)-BEGIN(2)+1 .NE. C .AND.
1         END(3)-BEGIN(3)+1 .NE. C
        TCT1 = TCT1(1)/TCT1(2)*FACTOR(CHNALS(J))
        TCT2(K) = TCT2(K) + (TCT1 - MEAN(FILES,K,6)).P.2
    END OF CONDITIONAL
        THROUGH LP5, FOR P=5,1, P .G. 6
        WHENEVER END(P-1)-BEGIN(P-1)+1 .E. C, TRANSFER TO LP5
        EXECUTE STAMPS.
        WHENEVER PASS .E. 1
            TCT(K,P) = TCT(K,P) + G22
        OTHERWISE
            TCT1(P-4) = G22
            TCT(K,P) = TCT(K,P) + (G22 - MEAN(FILES,K,P-1)).P.2
        END OF CONDITIONAL
LP5    CONTINUE
        WHENEVER PASS .E. 2 .AND. END(4)-BEGIN(4)+1 .NE. C .AND.
1         END(5)-BEGIN(5)+1 .NE. C
        TCT1 = TCT1(1)/TCT1(2)*FACTOR(CHNALS(J))
        TCT3(K) = TCT3(K) + (TCT1 - MEAN(FILES,K,7)).P.2
    END OF CONDITIONAL
LP3    CONTINUE
        (P=1,1,P.G.5,PT(P) = C)
        FLAG = 1
        FUNCTION RETURN
STEP(5) WHENEVER PASS .E. 2, TRANSFER TO STDEEV
        FILES = FILES + 1
        WHENEVER FILES .G. FILMAX, TRANSFER TO ERR15
        J = C
        THROUGH LP6, FOR K=1,1, K .G. CHANAL
LP21   THROUGH LP21, FOR J=J+1,1, CHNALS(J) .NE. C .OR. J .G. 13
        THROUGH LP2, FOR P=1,1, P .G. 5
            WHENEVER TYPE .E. $PWIDTH$ .AND. FFLAG .E. C
1             .AND. P .G. 3, TRANSFER TO LP2
            WHENEVER P .G. 2, TRANSFER TO INTGRL
            WHENEVER PNTS(K,P) .E. C
                MEAN(FILES,K,P) = C.
                TRANSFER TO LP2
            END OF CONDITIONAL
            MEAN(FILES,K,P) = TCT(K,P+1)/PNTS(K,P)
            TRANSFER TO LP2
INTGRL WHENEVER LINES .LE. 1
            MEAN(FILES,K,P) = C.
            TRANSFER TO LP2
        END OF CONDITIONAL
        MEAN(FILES,K,P) = TCT(K,P+1)/(LINES - 1)
LP2    CONTINUE
        WHENEVER TYPE .E. $PWIDTH$ .AND. FFLAG .E. C
            SAVLAM(K) = MEAN(1,K,2)
            SAVPAN(K) = MEAN(1,K,3)
            TRANSFER TO LP6
        OR WHENEVER MEAN(FILES,K,3) .E. C.
            MEAN(FILES,K,6) = C.
    
```

```

        TRANSFER TO CK1
    END OF CONDITIONAL
    MEAN(FILES,K,6) = MEAN(FILES,K,2)/MEAN(FILES,K,3)*
        FACTOR(CHNNLS(J))
CK1    1    WHENEVER MEAN(FILES,K,5) .E. C.
        MEAN(FILES,K,7) = C.
        TRANSFER TO LP6
    END OF CONDITIONAL
    MEAN(FILES,K,7) = MEAN(FILES,K,4)/MEAN(FILES,K,5)*
        FACTOR(CHNNLS(J))
LP6    1    CONTINUE
        PFLAG = 1
        PASS = 2
        FUNCTION RETURN
STEPDEV THROUGH LP7, FOR K=1,1, K .G. CHANNL
        (P=1,1,P.G.3,F1=TCT(K,P+1)/PNTS(K,P),
    1    DEV(FILES,K,P) = SCRT.(F1))
        (P=4,1,P.G.5,F1=TCT(K,P+1)/(LINES-1),
    1    DEV(FILES,K,P) = SCRT.(F1))
        F1 = TCT2(K)/(LINES-1)
        DEV(FILES,K,6) = SCRT.(F1)
        F1 = TCT3(K)/(LINES-1)
        DEV(FILES,K,7) = SCRT.(F1)
LP7    CONTINUE
        PASS = 1
        FUNCTION RETURN
STEP(6) EXECUTE PLOT1.(NSCALE,09,6,4,14)
        WHENEVER TYPE .NE. 4FWIDTH$ .AND. (END(1)-BEGIN(1)+1 .E. C
    1    .OR. END(2)-BEGIN(2)+1 .E. C .OR. END(3)-BEGIN(3)+1 .E. C
    2    .OR. END(4)-BEGIN(4)+1 .E. C
    3    .OR. END(5)-BEGIN(5)+1 .E. C), TRANSFER TO ERR19
        KK = FREESP.(BLOCK,LEVEL,ACCRES)
        KK = ASSIGN.(C,C)
        WHENEVER KK .L. FILMAX*2 + 2, TRANSFER TO ERR7
        KK = ASSIGN.(LAMRAD.,PARAMS,FILMAX,FILMAX)
        (I=1,1,I.G.FILES,X(I) = MIN + (MAX - MIN)/(FILES-1)*(I-1))
        J = C
        THROUGH LP6, FOR K=1,1, K .G. CHANNL
LP20   THROUGH LP20, FOR J=J+1,1, CHNNLS(J) .NE. C .OR. J .G. 13
        THROUGH LPS, FOR P=1,1, P .G. 2
        WHENEVER P .E. 1 .AND. (END(2)-BEGIN(2)+1 .E. C
    1    .OR. END(3)-BEGIN(3)+1 .E. C)
            TRANSFER TO LPS
        OR WHENEVER P .E. 2 .AND. (END(4)-BEGIN(4)+1 .E. C
    1    .OR. END(5)-BEGIN(5)+1 .E. C)
            TRANSFER TO LP9
        END OF CONDITIONAL
        EXECUTE PLOT2.(IMAGE,7.,3.C,10000.,1000.)
        PRINT FORMAT $1F1,T31,H'SPECTRAL BAND ',2C6,F'/',2C6*$',
    1    TITLE(CHNNLS(J)*2-1),TITLE(CHNNLS(J)*2),
    2    TIT((P-1)*2),TIT((P-1)*2+1)
        THROUGH LP1C, FOR KK=1,1, KK .G. 3
        (I=1,1,I.G.FILES,Y(I) = MEAN(I,K,P+5)*10.P.(2-KK))
        EXECUTE PLOT3.(BCD(KK),X(1),Y(1),FILES)
LP1C   CONTINUE
        EXECUTE PLOT4.(8,MSG)
        PRINT FORMAT $1F5/1F5,T4C,F'CURRENT'*$
LPS    CONTINUE
        PRINT FORMAT $1F1,T33,F'LAMP PANEL',T53,
    1    F'LAMP PANEL LEVEL INTEGRL'/1F .T49,
    2    F'LEVEL INTEGRL',T1C8,2(F'RATIC ',)T9,
    3    2(H'DARK LAMP PANEL INTEGRL INTEGRL',T69),T13C/
    4    F' CRNT ',5(H'MEAN',S4),2(F'RATIC',S5),T7C,
    5    7(H'DEV',S5)///$
    
```



```

PWIDL = MEAN(PFILE,K,4)*PCCNST(J,1)/SAVLAM(K)
PWIDP = MEAN(PFILE,K,5)*PCCNST(J,2)/SAVPAN(K)
THRELOC LP11, FOR KK=1,1, KK .G. FILES
  PRINT FORMAT $1F ,F5.3,5(F7.2,S1),T47,2(F9.2,S1),T67,7(F7.2,S1)*4,
1      X(KK),MEAN(KK,K,1)...MEAN(KK,K,7),
2      DEV(KK,K,1)...DEV(KK,K,7)
LP11  CONTINUE
      PRINT FORMAT $F'-N E DELTA L'//*4
      THRELOC LP23, FOR KK=1,1, KK .G. FILES
        PRINT FORMAT $2F ,F10.4*4, FACTOR(CHANNELS(J))*DEV(KK,K,4)*2
1      /MEAN(KK,K,4)
LP23  CONTINUE
      PRINT FORMAT $F'-FACTOR(' ,I2,F') = ',F10.5,S3,F' LW/CM*CM-STER-UM'//
1      F' - XIC'//
1      F' * - XIC'/H'      S - X1'*4, CHANNELS(J),
1      FACTOR(CHANNELS(J))
      PRINT FORMAT $F'-RESULTS FROM PULSE WIDTH CALCULATIONS.'//
1      F'C INTEGRAL OF LAMP',S10,F10.4/
1      F' INTEGRAL OF PANEL',S9,F10.4/
2      F' MEAN LAMP HEIGHT',S10,F10.4/
2      F' MEAN PANEL HEIGHT',S9,F10.4*4,
2      PWIDL*SAVLAM(K),PWIDP*SAVPAN(K),SAVLAM(K),SAVPAN(K)
      PRINT FORMAT $F' CALCULATED PULSE WIDTH',S4,F10.4,F' - LAMP'//
2      IF ,I30,F10.4,F' - PANEL'//
4      F' PULSE WIDTH CONSTANT LSEC',S1,F10.4,F' - LAMP'//
5      IF ,I30,F10.4,F' - PANEL'*4,
6      PWIDL,PWIDP,PCCNST(J,1),PCCNST(J,2)
LPE  CONTINUE
      TYPE = 4 $
      PFLAG = 2
      (K=1,1,K.G.13,SAVLAM(K) = C.)
      FUNCTION RETURN
BLEF  PRINT FORMAT ERR(I)
      FPROR.
ERR1  I = 1
      TRANSFER TO BLEF
ERR2  I = 43
      TRANSFER TO BLEF
ERR3  I = 85
      TRANSFER TO BLEF
ERR4  I = 127
      TRANSFER TO BLEF
ERR5  I = 169
      TRANSFER TO BLEF
ERR6  I = 211
      TRANSFER TO BLEF
ERR7  I = 253
      TRANSFER TO BLEF
ERR8  I = 295
      TRANSFER TO BLEF+1
ERR9  I = 337
      TRANSFER TO BLEF+1
ERR10 I = 379
      TRANSFER TO BLEF
ERR11 I = 421
      TRANSFER TO BLEF+1
ERR12 I = 463
      TRANSFER TO BLEF+1
ERR13 I = 505
      TRANSFER TO BLEF
ERR14 I = 547
      TRANSFER TO BLEF
ERR15 I = 589
      TRANSFER TO BLEF
    
```

```

ERR16      I = 631
            TRANSFER TO BLEH
ERR17      I = 673
            TRANSFER TO BLEH
ERR18      I = 715
            TRANSFER TO BLEH
ERR19      I = 757
            TRANSFER TO BLEH
ERR20      I = 799
            TRANSFER TO BLEH
BLEH1      PRINT FORMAT ERR(I),K
            ERRCR.
    
```

```

INTERNAL FUNCTION PTPROC.
THROUGH LP18, FOR P=1,1, P .G. 5
  WHENEVER IF .LE. END(P) .AND. IF .GE. BEGIN(P)
  WHENEVER CMODE .E. 1, (I=1,1,1.G.13,K=FCATUM(I),CATUM(I)=K)
    PT(P) = PT(P) + 1
    I = C
    THROUGH LP19, FOR K=1,1, K .G. 13
      WHENEVER CHANNELS(K) .E. 0, TRANSFER TO LP19
      I = I + 1
      WHENEVER P .E. 1
        FNT(PT(P),I,P) = CATUM(K)
      OTHERWISE
        FNT(PT(P),I,P) = CATUM(K) - TCT(I,1)
      END OF CONDITIONAL
    CONTINUE
  END OF CONDITIONAL
CONTINUE
FUNCTION RETURN
END OF FUNCTION
    
```

LP15

LP18

```

INTERNAL FUNCTION BOUNDS.
    
```

```

  WHENEVER P .E. 2
    LEFT = 1
    RIGHT = PT(1)
    TRANSFER TO RTN
  END OF CONDITIONAL
  MX1 = C.
  THROUGH LP14, FOR KK=1,1, KK .G. PT(P-1)
    WHENEVER FNT(KK,K,P-1) .G. MX1, MX1 = FNT(KK,K,P-1)
  CONTINUE
  THROUGH LP15, FOR KK=1,1, KK .G. PT(P-1)
    WHENEVER MX1 * F(P-1) .L. FNT(KK,K,P-1), TRANSFER TO CLT1
  CONTINUE
  KK = 1
  LEFT = KK
  THROUGH LP16, FOR KK=PT(P-1),-1, KK .L. 1
    WHENEVER MX1 * F(P-1) .L. FNT(KK,K,P-1), TRANSFER TO CLT2
  CONTINUE
  KK = PT(P-1)
  RIGHT = KK
  WHENEVER FNT(LEFT,K,P-1) .L. FNT(RIGHT,K,P-1)-10 .AND. P .E. 4
    KK = LEFT
    (I=1,1,1.G.PT(P-1),YY(I)= FNT(I,K,P-1),XX(I)= I)
    EXECUTE LSCAR.{>X,YY(1),ITRY,1,PT(P-1),A(1),A(2),A(3)}
    
```

LP14

LP15

CLT1

LP16

CLT2

```

        EXECUTE ADJUST.
    CR WHENEVER FNT(RIGHT,K,P-1) .L. FNT(LEFT,K,P-1)-10 .AND. P .E. 4
        KK = RIGHT
        (I=1,1,F.C.PT(P-1),YY(I)= FNT(I,K,P-1),XX(I)= I)
        EXECUTE LSCAR.(XX,YY(1),ITRY,1,F(P-1),A(1),A(2),A(3))
        EXECUTE ADJUST.
    END OF CONDITIONAL
    MIDDLE = (LEFT + RIGHT)/2
    LEFT = MIDDLE - TCF(P-2)/2. + .5
    RIGHT = MIDDLE + TCF(P-2)/2. - .5
    WHENEVER LEFT .L. 1, LEFT = 1
    WHENEVER RIGHT .G. PT(P-1), RIGHT = PT(P-1)
    PNTS(K,P-1) = PNTS(K,P-1) + RIGHT - LEFT + 1
    FUNCTION RETURN
    END OF FUNCTION
    
```

RTN

```

    INTERNAL FUNCTION SIMPSN.
    WHENEVER PT(P-1)/2*2 .E. PT(P-1), PT(P-1) = PT(P-1) - 1
    Q22 = PNT(1,K,P-1)
    CCEF = 2.
    THROUGH LP17, FOR KK=2,1, KK .G. PT(P-1) - 1
        WHENEVER CCEF .E. 4.
            CCEF = 2.
            OTHERWISE
                CCEF = 4.
        END OF CONDITIONAL
    Q22 = Q22 + CCEF*FNT(KK,K,P-1)
    CONTINUE
    Q22 = Q22 + FNT(PT(P-1),K,P-1)
    WHENEVER TYPE .E. $FWIDTH:
        Q22 = Q22/FCCNST(J,P-4)
    END OF CONDITIONAL
    Q22 = Q22/3.
    FUNCTION RETURN
    END OF FUNCTION
    
```

LP17

```

    INTERNAL FUNCTION ADJUST.
    A(1) = A(1) - FNT(KK,K,P-1)
    F1 = A(2).P.2 - 4.*A(3)*A(1)
    WHENEVER F1 .L. C.,TRANSFER TO ERP17
    F2 = (-A(2) + SQRT.(F1))/(2.*A(3))
    F3 = (-A(2) - SQRT.(F1))/(2.*A(3))
    WHENEVER F2 .L. F3 .AND. KK .E. RIGHT
        LEFT = F2
    CR WHENEVER F2 .GE. F3 .AND. KK .E. RIGHT
        LEFT = F3
    CR WHENEVER F2 .L. F3
        RIGHT = F2
    OTHERWISE
        RIGHT = F3
    END OF CONDITIONAL
    FUNCTION RETURN
    END OF FUNCTION
    END OF FUNCTION
    
```

Appendix E PROGRAM THERML.

The purpose of this program is to calculate a set of statistics from a given set of files. This program is very similar to CALIB. with the exceptions that a tape data base is not used and all data is assumed to be of one spectral channel (infrared). The plots and table produced are identical in format to CALIB.

The user must specify the beginning and ending reselm numbers of the cold plate, the hot plate, and the ambient area. Both the hot plate and the ambient area reselms are corrected by subtracting the mean of the cold plate from the previous line. We are assuming that the cold plate mean does not change significantly from line to line.

After this, all the reselms in the cold plate, the hot plate, and the ambient area are averaged to get a mean cold plate level, a mean hot plate level, and a mean ambient level. Then the standard deviation of each reselm from its respective mean is calculated.

The aforementioned calculations are repeated for each of the files requested. After all the files have been processed, they are sorted into ascending numerical order of date. Plots are then made of the mean cold plate level, mean hot plate level, and the mean ambient level versus mission number. This is followed by a plot of the respective standard deviation versus mission number and a tabulation of all the calculated statistics, dates, mission numbers and comments.

STEP(1) - PERFORMED THE 1ST TIME THERML..IS CALLED OR WHENEVER PROCESS. READS

MODEL = \$START\$

This section of the program performs the initialization necessary for POINT and sets up the default values for the input variables. Data cards are then read that may set the maximum number of files to be read, the maximum number of points in any one pulse, and the beginning and ending reselm numbers of the cold plate, the hot plate, and the ambient area. The input variables are then checked for reasonableness. After this, the dynamic storage for the program is allocated, and the program returns control to POINT.

STEP(2) - PERFORMED BEFORE EACH FILE IS PROCESSED.

First the totalling array, the point counter array, the date array, the line counter, and the mission number are zeroed.

If this is the first pass through the data, the mission number, the date, and any special comment are read off data cards. These variables are checked for reasonableness as well as the continued reasonableness of the beginning and ending reselm numbers for the pulses. The program returns control to POINT. If this is pass two, the program does nothing except return to POINT.

STEP(3) - PERFORMED BEFORE EACH POINT OF A SCAN LINE IS PROCESSED.

No action taken.

STEP(4) - PERFORMED AFTER EACH LINE IN THE FILE IS READ.

First the line counter is incremented, and the mean of the cold plate is determined (This value will be used in the cold plate correction of the next line). If this is the first line of the file to be processed, nothing else is done and the program returns control to POINT.

If this is pass one, the level of each reselm within each of the three possible pulses is accumulated in the totalling array. If this is the second pass through the data, the standard deviation of the reselm levels from the mean level within each of the 3 possible pulses is accumulated in the totalling arrays. After both pass 1 or pass 2, the point counter array is zeroed, and control returns to POINT.

STEP(5) PERFORMED AFTER AN ENTIRE FILE HAS BEEN PROCESSED

If this is the first pass through the file, the file counter is incremented and then checked to see if it has exceeded the declared maximum number of files to be processed. Then, the means are calculated for the cold plate, the hot plate, and the ambient area; the mission number and data are saved; the special comment is stored; the pass number is set to 2; and control returns to POINT. If this is the 2nd pass through the data, the standard deviation is determined for the cold plate, the hot plate, and the ambient area; the pass number is set to 1; and control returns to POINT.

STEP(6) PERFORMED WHENEVER PROCESS READS MODEL = \$FINAL\$

After the statistics are put into ascending order of date, the plotting-image array is set up. The first plot is then made up of the means of the cold plate, the hot plate, and the ambient area versus the mission numbers. The 2nd plot is made of the standard deviations of the cold plate, the hot plate, and the ambient area versus the mission number. In both plots, the mission # of the last file processed is largest mission number plotted. The smallest mission number plotted is 1 or the mission number of the last file processed minus 61, whichever is larger. After this, all of the statistics, dates, mission numbers, and special comments are tabulated, and control returns to POINT.

PTPROC.

This routine saves the value of each reselm that is within the specified boundaries of each pulse. These values are stored in an array according to the position relative to the beginning of the pulse (the point counter for each pulse) and according to the pulse number (3 possible). Pulse number 1 is considered the cold plate, and its uncorrected value is saved. All the remaining pulses are cold-plate corrected before being stored. That is, the average cold plate level of the previous line is subtracted from each point value before it is stored.

INPUT VARIABLES			
WHEN READ	VARIABLE	DEFAULT/MODE	DESCRIPTION
STEP(1)	FILMAX	1 INTEGER	The maximum number of files that are to be processed. Fewer files may be processed, but not more. This number can not be less than 1.
STEP(1)	BEGIN(1)... BEGIN(3)	0 INTEGER	This is an array of beginning reselm numbers for each of 3 possible pulses. (Begin (1) - cold plate, Begin (2) - hot plate, Begin (3) - ambient area.) These numbers must not be less than the beginning reselm numbers for the line.
STEP(1)	END(1)... END(3)	0 INTEGER	This is an array of ending reselm numbers for each 3 possible pulses. These numbers must not be greater than the ending reselm number for the line.
STEP(1)	PTS	50 INTEGER	This is the maximum number of reselms in any of the three possible pulses. This number must not be less than 1.
STEP(2)	MISSION	0 INTEGER	This is the mission number that is to be associated with this file. This number must not be less than 1.
STEP(2)	FDATE(1)...FDATE(3)	0 INTEGER	This is the date (in month, day, year, form) that is to be associated with this file. FDATE(1) must not be less than 0 or greater than 12. FDATE(2) must not be less than 0 or greater than 31. FDATE(3) must not be less than 0 or greater than 99.
STEP(2)	COMMNT(1)... COMMNT(8)	BLANKS ALPHANUMERIC	This is any special comment that is to be associated with this file. No error checking is performed on this array.



OUTPUT

PLOTS

Only two plots are made by this program. The first plot is of the means of the cold plate, the hot plate, and the ambient area versus the mission number:

§ = mean of the cold plate

* = mean of the hot plate

8 = mean of the ambient area

The second plot is the standard deviations of the cold plate, the hot plate, and the ambient area versus the mission number. The same plotting characters as before are used.

After the plots follows a table of all the statistics calculated along with the dates, the mission numbers, and the special comments:

DATE	the date associated with this data
MISSION	the mission # associated with this data
COLD PLATE MEAN	the mean level of the cold plate
HOT PLATE MEAN	the mean level of the hot plate
AMBIENT MEAN	the mean level of the ambient area
COLD PLATE DEV	the standard deviation of the cold plate
HOT PLATE DEV	the standard deviation of the hot plate
AMBIENT DEV	the standard deviation of the ambient area

DATA CARDS SETUP

- FILMAX = 4, BEGIN(1) = 10,60,80, END(1) = 50, 70, 90,
PTS = 41*
- INBIN = 777, UNIT = 4, FILE = 8, NSA = 1, 100, 1, 1, 200, 1 *
- MISSION = 60, FDATE(1) = 10,29,50,
COMMNT = \$MY BIRTHDAY\$*
- FILE = 8, NSA = 1, 100, 1, 1, 200, 1 *
- FILE = 9, NSA = 1, 100, 1, 1, 200, 1 *
- MISSION = 62, FDATE(1) = 11, 01, 72,
COMMNT = \$WHEN I WAS HIRED \$*
- FILE = 9, NSA = 1, 100, 1, 1, 200, 1*
- FILE = 7, NSA = 1, 100, 1, 1, 200, 1*

9. MISSION = 61, FDATE(1) = 02, 31, 70,
COMMNT = \$ABSURDITY**2 \$ *
10. FILE = 7, NSA = 1, 100, 1, 1, 200, 1 *
11. MODEL = \$FINAL\$ *
12. MODEL = \$RETURN\$ *

1. This card specifies that the maximum number of files to be processed is four, the beginning reselm # of the cold plate is 10, and the ending reselm # is 50. The beginning reselm # of the hot plate is 60 and the ending reselm # is 70. The beginning reselm # of the ambient area is 80 and the ending reselm # is 90. A maximum of 41 reselms are in any one of the pulses.
2. This is the input data required by PROCESS under POINT. Tape 777 will be mounted on unit 4 and file 8 will be accessed. Every line from 1 to 100 will be processed and every reselm from 1 to 200 will be used. This starts the calculation of the means by pass 1.
3. These cards specify that mission number 61, the date 10, 29, 50, and the comment \$MY BIRTHDAY\$ will be associated with this file.
4. This is more input data required by PROCESS under POINT. INBIN & UNIT do not have to be specified since the tape is already mounted. This starts the calculation of the standard deviations for pass 2.
5. See card 2
6. See card 3
7. See card 4
8. See card 2
9. See card 3
10. See card 4
11. This tells POINT to perform STEP(6). This section of the program is responsible for plotting and tabulating the previously calculated statistics. The last mission number that will be plotted is mission number 61 since this is

the mission number of the last file processed. Mission number 1 will be the first plotted. Mission number 62 will not get plotted but will be included in the tabulated statistics. As can be seen, fewer files may be processed than originally declared, and the files may be in any order (being careful of course to have the largest desired mission number to be plotted as the last file to be processed).

12. This tells POINT to return control to the original program that called POINT.

ERROR COMMENTS

ERROR 1. FILMAX.L.1.

This indicates that the maximum number of files to be processed is less than 1.

ERROR 2. PTS.L.1.

This indicates that the declared maximum number of reselms of any one pulse is less than 1.

ERROR 3. PTS.L. PULSE WIDTH.L.1.

This indicates that the width of one of the pulses is either less than 1 or greater than the declared maximum number of reselms (PTS).

ERROR 4. INSUFFICIENT STORAGE.

Since the program uses dynamic storage allocation for its incore data bases, the possibility exists that someone will try to process more data than can physically fit into the machine. The main in-core data base requires:

$FILMAX*18 + PTS*3 + 9 + FILMAX$ locations when $FILMAX$ is greater than or equal to 6. It requires $FILMAX*18+PTS*3+15$ locations when $FILMAX$ is less than 6. (See the section on storage requirements.)

ERROR5. MISSION .L.0.

This indicates that the mission number to be associated with the file is less than 0.

ERROR6. INVALID MONTH.

This indicates that $FDATE(1)$ is either less than 0 or greater than 12.

ERROR7. INVALID DAY.

This indicates that $FDATE(2)$ is either less than 0 or greater than 31.

ERROR8. INVALID YEAR.

This indicates that $FDATE(3)$ is either less than 0 or greater than 99.

ERROR9. BEGIN(X).L. NA.

This indicates that the beginning reselm number of pulse "X" is less than the beginning reselm number for the lines of the file.

ERROR10.END(X).G.NB.

This indicates that the ending reselm number of pulse "X" is greater than the ending reselm number for the lines of the file.

ERROR11. MORE FILES THAN FILMAX.

This indicates that the program attempted to process more files than originally declared with FILMAX.

SUBROUTINES NEEDED

The following is a list of external subroutines needed for the correct operation of this program:

ASSIGN .	this routine performs all the dynamic allocations necessary in the A core box.
ERROR.	System error processing routine
LINK.	this routine provides POINT with a connection to THERML.'s point-processing routine PTPROC. (Part of POINT.)
PLOT1. } PLOT2. } PLOT3. } PLOT4. }	All four of these routines are used in setting up and printing the point plots of the thermal statistics calculated.
POINT.	this is the program that repetitively calls THERML. with different levels to progressively process the data (see POINT. writeup).
PROCESS.	This routine, called by POINT., handles all I/O with data tapes (in ERIM format).
SQRT.	This routine calculates square roots.
ZERO.	this routine inserts either a binary or floating point zero in all of the requested variables or arrays.

In addition to these external functions, a define package must also be included. This package inserts 3 new operators into the MAD compiler and defines what machine instructions they each represent. These three operators are .LI., .SI.,

and .LIF. and are called the indirection operators. They are used in this program in conjunction with the dynamic storage allocation routines for accessing dynamically allocated arrays without using the usual subscription routines provided by the MAD compiler. Instead, they use the two internal functions S32. and S82. defined in the program for all subscripting.

S32. is used for accessing a 2-dimensional array with maximum dimensions of (FILMAX,3).

S82. is used for accessing a 2-dimensional array with maximum dimensions of (FILMAX,8).

STORAGE REQUIREMENTS

This program requires 1959 decimal locations of core before any dynamic storage allocation takes place. The equation for determining how much storage will be allocated with any given set of input cards is as follows:

$$\text{FILMAX} * 19 + \text{PTS} * 3 + 9 \text{ when } \text{FILMAX} \geq 6$$

$$\text{FILMAX} * 18 + \text{PTS} * 3 + 15 \text{ when } \text{FILMAX} < 6$$



MAC (09 AUG 1965 VERSION) PROGRAM LISTING

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EXTERNAL FUNCTION THERPL.(X,Y)
REFERENCES CA
* DEFINE PACKAGE FOR LOAD INDIRECT(.LI.,.LIF.) AND
  STORE INDIRECT(.SI.). THE VARIABLES BEING REFERENCED
  MUST BE IN THE A CORE BCX. IF THE ADDRESS BEING REFERENCED
  IS IN THE B CORE BCX, THE VARIABLE CONTAINING THE ADDRESS
  MUST HAVE A MODE OF 5.
DEFINE UNARY OPERATOR .LI., PRECEDENCE SAME AS .ABS.
MODE STRUCTURE I = .LI. 1
  JMP      **5,AC,**+1
  JMP      **6,MQ,**+1
  JMP      **7,LA,**+1
  CLA*     B
  CUI     AC
  STC     T
  JMP     *-3
  STC     T
  JMP     *-5
  SLW     T
  JMP     *-7
  END

MODE STRUCTURE O = .LI. 0, SAME SEQUENCE AS .LI. 1
DEFINE UNARY OPERATOR .LIF., PRECEDENCE SAME AS .ABS.
MODE STRUCTURE I = .LIF. 0, SAME SEQUENCE AS .LI. 1
MODE STRUCTURE C = .LIF. 1, SAME SEQUENCE AS .LI. 1
DEFINE UNARY OPERATOR .SI., PRECEDENCE SAME AS =
MODE STRUCTURE I = 1 .SI. 1
  JMP      **1,BT,**+4
  JMP      **8,AC,**+1
  JMP      **9,MQ,**+1
  JMP      **10,LA,**+3
  JMP      **11,AC,**+1
  JMP      **12,LA,**+1
  CLA     B
  STC*    A
  LUT     Z
  STG*    A
  JMP     *-2
  STC*    A
  JMP     *-4
  SLW*    A
  JMP     *-6
  STC     T
  JMP     *-10
  SLW     T
  JMP     *-12
  END

MODE STRUCTURE O = 0 .SI. 0, SAME SEQUENCE AS 1 .SI. 1
MODE STRUCTURE I = 1 .SI. 0, SAME SEQUENCE AS 1 .SI. 1
MODE STRUCTURE C = 0 .SI. 1, SAME SEQUENCE AS 1 .SI. 1
NORMAL MODE IS INTEGER
FLOATING POINT TCT(4),SQRT.,          X,Y,F1,F2,FDATUM
DIMENSION BEGIN(3),END(3),PARAMS(8),NSCALE(4),PT(3),BCD(3),
1   ERR(463),FDATE(3),CMPMT(8)
1   EQUIVALENCE (FDATUM,DATUM(1)) , (MEAN,PARAMS(3)) ,
1   (DEV,PARAMS(4)) , (PNT,PARAMS(5)) ,
2   (DATE,PARAMS(6)) , (CMPMT,PARAMS(7)),
3   (TAG,PARAMS(8))
VECTOR VALUES BCD(1) = $$$ , $$$ , $$$

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VECTOR VALUES MSG1 = $MEAN LEVEL$
VECTOR VALUES MSG2 = $DEVIATION LEVEL$
VECTOR VALUES ERR(001) = $H'1*****ERRRCR1. FILMAX .L. 1.'* $
VECTOR VALUES ERR(043) = $H'1*****ERRRCR2. PTS .L. 1.'* $
VECTOR VALUES ERR(085) = $H'1*****ERRRCR3. PTS .L. PULSE WDT .L. 1.'*$
VECTOR VALUES ERR(127) = $H'1*****ERRRCR4. INSUFFICIENT STORAGE.'* $
VECTOR VALUES ERR(169) = $H'1*****ERRRCR5. MISSION .L. 0.'* $
VECTOR VALUES ERR(211) = $H'1*****ERRRCR6. INVALID MONTH.'* $
VECTOR VALUES ERR(253) = $H'1*****ERRRCR7. INVALID DAY.'* $
VECTOR VALUES ERR(295) = $H'1*****ERRRCR8. INVALID YEAR.'* $
VECTOR VALUES ERR(337) = $H'1*****ERRRCR9. BEGIN(' ,11,H' ) .L. NA.'* $
VECTOR VALUES ERR(379) = $H'1*****ERRRCR10. END(' ,11,H' ) .G. NO.'* $
VECTOR VALUES ERR(421) = $H'1*****ERRRCR11. MORE FILES THAN FILMAX.'*$
STATEMENT LABEL STEP(1)
ERASABLE JCRK(225),CUNIT,CREEL,CFILE,CLINE,TWRITE,CHAN,
1 GRWDS,PRCG,MODE1,MODE2,UNIT,CALINE,CBLINE,NSA,NSB,
2 KS,NA,NB,KP,ID(1),IFLAG,IFACK,RESERV(4),GFACTR(49),
3 RTITL2(19),RTITLE(19),CLIST(19),GSPARE(46),QFLAG,
4 QDARG,GPARC,GRP,GNA,GNSS,CNCHAN,GMCDE,GRECA,GRECC,
5 QFILE,CPEEL,CNWRDS
ERASABLE DATA(423),ITEST,CSTART,CSTART,NV,NX,NC,L,IP,
1 ICP,NCP,NEXT,START2,READ12,READL2,READP2,LABEL2,
2 EXTRA(20),DATUM(24),ICCODE(24),ICHAN(24), IMAGE(570)
INTERNAL FUNCTION S32.(S1,S2) = 3*(S1-1) + S2
INTERNAL FUNCTION S82.(S3,S4) = 8*(S3-1) + S4
WHENEVER NEXT .G. 6, FUNCTION RETURN
TRANSFER TO STEP(NEXT)
STEP(1) LINK.(PTPRCC.)
L = L + OCHAN
FILMAX = 1
PTS = 50
ZERU.(BEGIN...BEGIN(3),END...END(3),PARAMS...PARAMS(8),FILES,
1 NSCALE...NSCALE(4))
READ AND PRINT DATA FILMAX, BEGIN(1), END(1), PTS
WHENEVER FILMAX .L. 1
TRANSFER TO ERR1
OR WHENEVER PTS .L. 1
TRANSFER TO ERR2
END OF CONDITIONAL
THROUGH LPI, FOR I=1,1, I .G. 3
WHENEVER END(I)-BEGIN(I)+1 .L. 1 .OR. END(I)-BEGIN(I)+1 .G. PTS,
1 TRANSFER TO ERR3
LPI CONTINUE
J = FILMAX
WHENEVER FILMAX .L. 6, J = 6
I = FILMAX*3
K = PTS*3
KK = ASSIGN.(0,0)
WHENEVER KK .L. I*2 + FILMAX*12 + K + 9 + J, TRANSFER TO ERR4
PASS = 1
KK = ASSIGN.(THERML.,PARAMS,FILMAX,J)
KK = ASSIGN.(C,PARAMS,I,I,K,FILMAX,FILMAX*B,FILMAX)
F1 = END(1) - BEGIN(1) + 1
FUNCTION RETURN
STEP(2) ZERU.(TOT...TOT(4),PI...PI(3),EDATE...EDATE(3),FLAG,LINES,
1 MISSCN)
WHENEVER PASS .E. 1
(K=1,1,K.G.8,COMNT(K) = $ $)
READ AND PRINT DATA MISSCN, EDATE(1), COMNT(1)
WHENEVER MISSCN .L. 0
TRANSFER TO ERR5
OR WHENEVER EDATE(1) .L. 0 .CR. EDATE(1) .G. 12
TRANSFER TO ERR6

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OR WHENEVER FDATE(2) .L. 0 .CR. FDATE(2) .G. 31
TRANSFER TO ERR7
OR WHENEVER FDATE(3) .L. 0 .CR. FDATE(3) .G. 99
TRANSFER TO ERR8
END OF CONDITIONAL
THROUGH LP2, FOR K=1,1, K .G. 3
    WHENEVER BEGIN(K) .L. NA
        TRANSFER TO ERR9
    OR WHENEVER END(K) .G. NB
        TRANSFER TO ERR10
    END OF CONDITIONAL
LP2 CONTINUE
END OF CONDITIONAL
FUNCTION RETURN
STEP(3) FUNCTION RETURN
STEP(4) LINES = LINES + 1
        J = (TOT=0.,K=1,1,K.G.PT(1), TOT + .LI.(PNT-S32.(K,1))/F1)+.5
        WHENEVER FLAG .E. 0
            FLAG = 1
            TRANSFER TO CUT
        END OF CONDITIONAL
        WHENEVER PASS .E. 1
            (K=1,1,K.G.3, TCT(K+1) = TCT(K+1) +
                (TCT=0.,I=1,1,I.G.PT(K),
                TCT + .LI.(PNT-S32.(I,K))))
            1
            1 OTHERWISE
            (K=1,1,K.G.3, TCT(K+1) = TCT(K+1) +
                (TCT=0.,I=1,1,I.G.PT(K),
                TCT + (.LI.(PNT-S32.(I,K)) -
                .LIF.(MEAN-S32.(FILES,K)).P.2))
            1
            1
            2
        END OF CONDITIONAL
CUT (K=1,1,K.G.3, PT(K) = 0)
FUNCTION RETURN
STEP(5) WHENEVER PASS .E. 2, TRANSFER TO STUDEV
        FILES = FILES + 1
        WHENEVER FILES .G. FILMAX, TRANSFER TO ERR11
        (K=1,1,K.G.3, (MEAN-S32.(FILES,K)) .SI.
            1 TCT(K+1)/((END(K) - BEGIN(K) + 1)*(LINES-1)))
        X(FILES) = MISSON
        (DATE-FILES) .SI. FDATE(2) + 100*FDATE(1) + 10000*FDATE(3)
        (K=1,1,K.G.8, (CMMNT-S82.(FILES,K)) .SI. CMMNT(K))
        PASS = 2
        FUNCTION RETURN
STUDEV (K=1,1,K.G.3, TCT = TCT(K+1)/((LINES-1)*(END(K)-BEGIN(K)+1)),
        1 (DEV-S32.(FILES,K)) .SI. SQRT.(TOT))
        PASS = 1
        FUNCTION RETURN
STEP(6) (K=1,1,K.G.FILES, (TAG-K) .SI. K)
        THROUGH LP3, FOR K=1,1, K .G. (FILES-1)
        THROUGH LP4, FOR I=(K+1),1, I .G. FILES
            WHENEVER .LI.(DATE-.LI.(TAG-K)) .GE. .LI.(DATE-.LI.(TAG-1))
                J = .LI.(TAG-K)
                (TAG-K) .SI. .LI.(TAG-1)
                (TAG-1) .SI. J
            END OF CONDITIONAL
LP4 CONTINUE
LP3 CONTINUE
NSCALE = 1
EXECUTE PLCT1.(NSCALE,5,10,6,10)
F2 = 1.
WHENEVER X(FILES)-61. .GE. 1., F2 = X(FILES) - 61.
F1 = X(FILES)
EXECUTE PLCT2.(IMAGE,F1,F2,510.,0.)
THROUGH LP5, FOR I=1,1, I .G. 3
    
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      (K=1,1,K.G.FILES,Y(K) = .LIF.(MEAN-S32.(K,I)))
      EXECUTE PLCT3.(DCD(I),X(I),Y(I),FILES)
LP5  CONTINUE
      PRINT FORMAT %IH1*$
      EXECUTE PLCT4.(10,MSG1)
      PRINT FORMAT %IHC,T36,H'MISSIEN NUMBER'*$
      EXECUTE PLCT2.(IMAGE,F1,F2,84.,0.)
      THROUGH LP6, FOR I=1,1, I .G. 3
      (K=1,1,K.G.FILES,Y(K) = .LIF.(DEV-S32.(K,I)))
      EXECUTE PLCT3.(BCD(I),X(I),Y(I),FILES)
LP6  CONTINUE
      PRINT FORMAT %IH1*$
      EXECUTE PLCT4.(15,MSG2)
      PRINT FORMAT %IHC,T36,H'MISSIEN NUMBER'*$
      PRINT FORMAT %IH1,T17,2(H'COLO FCT',T41),F100/IH ,T16,
1     2(H'PLATE PLATE AMBIENT',T40),T100/
2     H' DATE MISSIEN ',3(H'PEAN ',3(H'DEV',S5))//*$
      THROUGH LP7, FOR I=1,1, I .G. FILES
      (K=1,1,K.G.3,Y(K) = .LIF.(MEAN-S32.(.LI.(TAG-I),K)),
1     Y(K+3) = .LIF.(DEV-S32.(.LI.(TAG-I),K)))
      (K=1,1,K.G.8, CCMNT(K) = .LI.(CCMNT-S82.(.LI.(TAG-I),K)))
      K = .LI.(DATE-.LI.(TAG-I))
      K = (K - K/10000*10000)*100 + K/10000
      PRINT FORMAT %IH ,16,S1,F6,S1,6(F7.2,S1)/IH ,T15,BC6*%,
1     K,X(.LI.(TAG-I)),Y(1)...Y(6),CCMNT(1)...CCMNT(8)
LP7  CONTINUE
      PRINT FORMAT %H'-$$ - COLO PLATE'/F' * - FCT PLATE'/H' 8 - AMBIENT'/
1     %IH1*$
      FUNCTION RETURN
BLEH1 PRINT FORMAT ERR(I),K
      ERROR.
ERR1  I = 1
      TRANSFER TO BLEH
ERR2  I = 43
      TRANSFER TO BLEH
ERR3  I = 85
      TRANSFER TO BLEH
ERR4  I = 127
      TRANSFER TO BLEH
ERR5  I = 169
      TRANSFER TO BLEH
ERR6  I = 211
      TRANSFER TO BLEH
ERR7  I = 253
      TRANSFER TO BLEH
ERR8  I = 295
      TRANSFER TO BLEH
ERR9  I = 337
      TRANSFER TO BLEH1
ERR10 I = 375
      TRANSFER TO BLEH1
ERR11 I = 421
      TRANSFER TO BLEH
BLEH  PRINT FORMAT ERR(I)
      ERROR.

INTERNAL FUNCTION PIPROC.
      THROUGH LP8, FOR K=1,1, K .G. 3
      WHENEVER IP .LE. END(K) .AND. IP .GE. BEGIN(K)
      WHENEVER QMCDE .E. 1

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      K = FDATEM
      DATEM(1) = K
      END OF CONDITIONAL
      PT(K) = PT(K) + 1
      WHENEVER K .E. 1
        (PKT-S32.(PT(1),1)) .SI. DATEM(1)
      OTHERWISE
        (PAT-S32.(PT(K),K)) .SI. DATEM(1) - J
      END OF CONDITIONAL
    END OF CONDITIONAL
  LP8 CONTINUE
  FUNCTION RETURN
  END OF FUNCTION
  END OF FUNCTION
```

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