https://ntrs.nasa.gov/search.jsp?R=19830023072 2020-03-21T03:14:44+00:00Z

General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)

AUG 1983
RECEIVED
NASA STI FACILITY
ACCESS DEPT.

NASA

Technical Memorandum 84985

NIMBUS-7 ERB MATGEN Science Document

(NASA-TM-84985) NIMBUS-7 ERB MATGEN SCIENCE N83-31343
DOCUMENT (NASA) 135 p HC A07/MF A01
CSCL 09B
Unclas
G3/61 28366

April 1983

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

NIMBUS-7 ERB-MATGEN SCIENCE DOCUMENT

Prepared For

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND 20771

Prepared By

RESEARCH AND DATA SYSTEMS, INC.
10300 GREENBELT ROAD
LANHAM, MARYLAND 20706

Under

CONTRACT NO. NAS 5-26123
TASK ASSIGNMENT 21

TECHNICAL MONITOR

DR. LEE KYLE

APRIL 1983

The requirement for the use of the International System of Units (SI) has been waived for this document under the authority of NPD 2220.4, paragraph 5.d.

PREFACE

This ERB MATGEN Science Document was prepared for NASA under contract NAS 5-26123 by Harold V. Soule of Research and Data Systems, Inc.

This document was developed to describe in detail the algorithms and data flow used to completely convert sensor data into equivalent radiometric data. The Nimbus satellite location, orientation and sensor orientation algorithms (at the data gathering time) and relevant software for use in data footprint location are also detailed. The computer housekeeping and data flow algorithms required to facilitate these computations are outlined. Calibrated and located earth radiances and irradiances, calibrated solar irradiances, pertinent housekeeping data and orbital summary data are recorded on the ERB Master Archive Tape (MAT).

The MATGEN has been continually improved resulting in at present over 14 versions. The early versions (up to 10) contain data for only one day's observations on a magnetic tape. Versions 11 and greater contain 3 day's observations on a magnetic tape in a densor format. In addition, other changes were made in the data flow and a Trailing Documentation File (TDF) was added to version 11 and greater. The detailed information regarding the tape content in each version will be contained in the User's Guides and where applicable will be noted in this document.

The scientific algorithms used in the MATGEN program were established by the ERB NIMBUS Experiment Team (NET) whose members and affiliations are given below.

ERB NET Members

* Kyle, L.	NASA/GSFC
**Arking, A.	NASA/GSFC
**Campbell, G.G.	CIRA, Colorado State U.
***Coulson, K.L.	University of California, Davis
Hickey, J.R.	Eppley Lab., Inc.
House, F.B.	Drexel University
Ingersoll, A.P.	California Inst. of Technology
Jacobowitz, H.	NOAA/NESS

**Maschhoff, R.H.	Gulton Inductries Inc.
Smith, G.L.	NASA/LaRC
Stowe, L.L.	NOAA/NESS
Vonder Haar, T.H.	Colorado State University

*Elected NET Leader
**Elected Members
***Left the NET because of other committments.

The computer algorithms were written by Systems and Applied Sciences Corporation under a separate contract. John Kogut and Richard Heasty did the original programming in 1977, 1978 and 1979 but many other analysis have helped maintain the program in subsequent years.

The Editor would particular like to thank the following individuals who gave important assistance in assembling the material for this document.

Mr. J. Hickey	Eppley Lab
Dr. H. Jacobowitz	NOAA
Dr. L. Kyle	NASA

TABLE OF CONTENTS

FIGURES

1.0 INTRODUCTION

1.1 SCIENCE DOCUMENT PURPOSE

Details regarding the ERB scientific algorithms and the manner in which they are implemented on a computer are necessary in any analysis or ERB MATGEN diagonistic work. This document describes in detail the manner in which raw ERB data counts in conjunction with satellite housekeeping and location data is processed producing calibrated earth and solar radiation. These calibrated data are recorded on magnetic tape on an orbit by orbit basis with each day covering one data day. There are about 14 Nimbus-7 orbits per data day. At the beginning of each tape there is a header file and following the up to three days calibrated data, a Calibration Adjustment Table (CAT), and Trailing Documentation File (TDF) (version 11 and greater).

During the development of this document it was noted that important algorithms such as those used in the Digital Solar Aspect Sensor (DSAS) which were used in but not programmed in MATGEN were not available elsewhere. Therefore the DSAS data reduction was put into Appendix A.

The overall input/output characteristics of MATGEN are shown in Figure 1.1. This Figure also gives the basic MATGEN tasks. The basic MATGEN task is computing the sensed radiances and irradiances using satellite transmitted data. The geographic location of the data, orbital and daily data averages are also determined by this set of algorithms.

The MATGEN subprograms are divided into a number of basic tasks in Figure 1.2. It will be noted that each task makes use of both the outputs of other tasks and of other data which are generated separately (i.e. ILT and UFO data). The characteristics of the basic MATGEN tasks shown in Figure 1.2 are as follows:

TASK I - Solar Location

This program determines the exact "butchered" Julian time* so that the exact double precision earth sun distances can be determined. It also computes the minimum solar elevation determining the pre-set time at which space reference data and then the solar data is used.

TASK II - ERB Status, Housekeeping Update and Temperature Determination

This aspect of ERBMAT reads all logical status indicators from odd digital "A" words. It also determines ILT status and updates

---

* Julian time divided into hours, minutes and seconds see section 3.1

ORIGINAL PAGE IS
OF POOR QUALITY

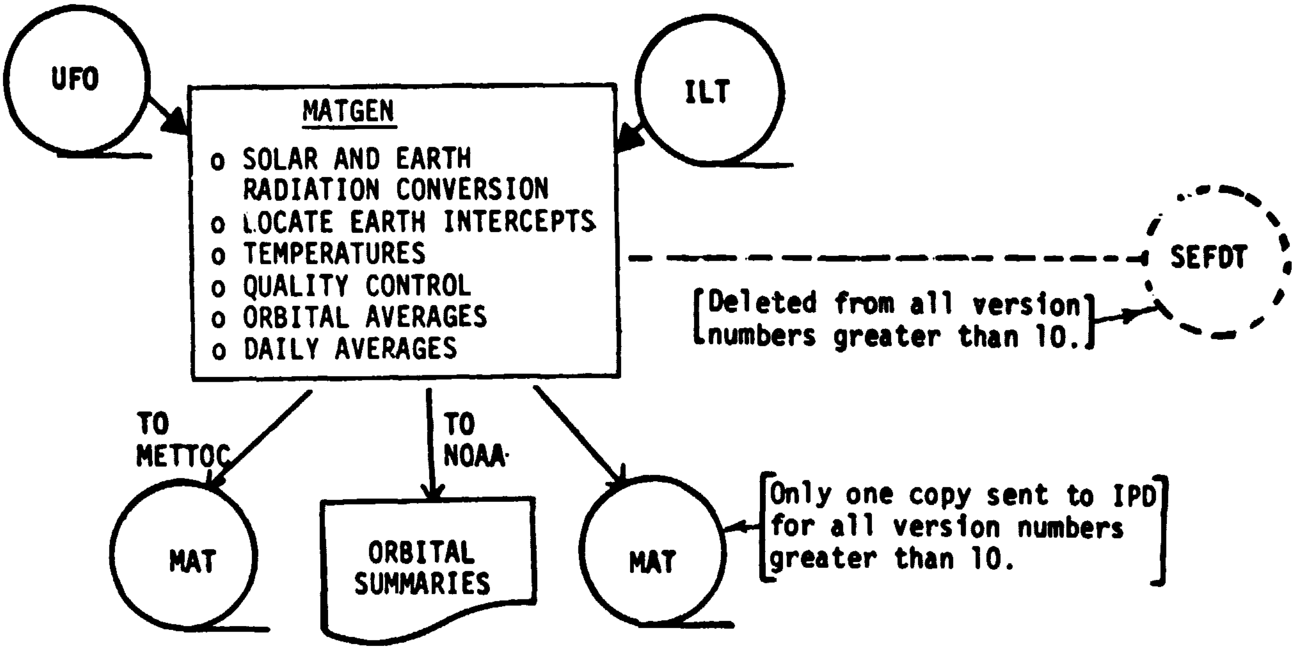
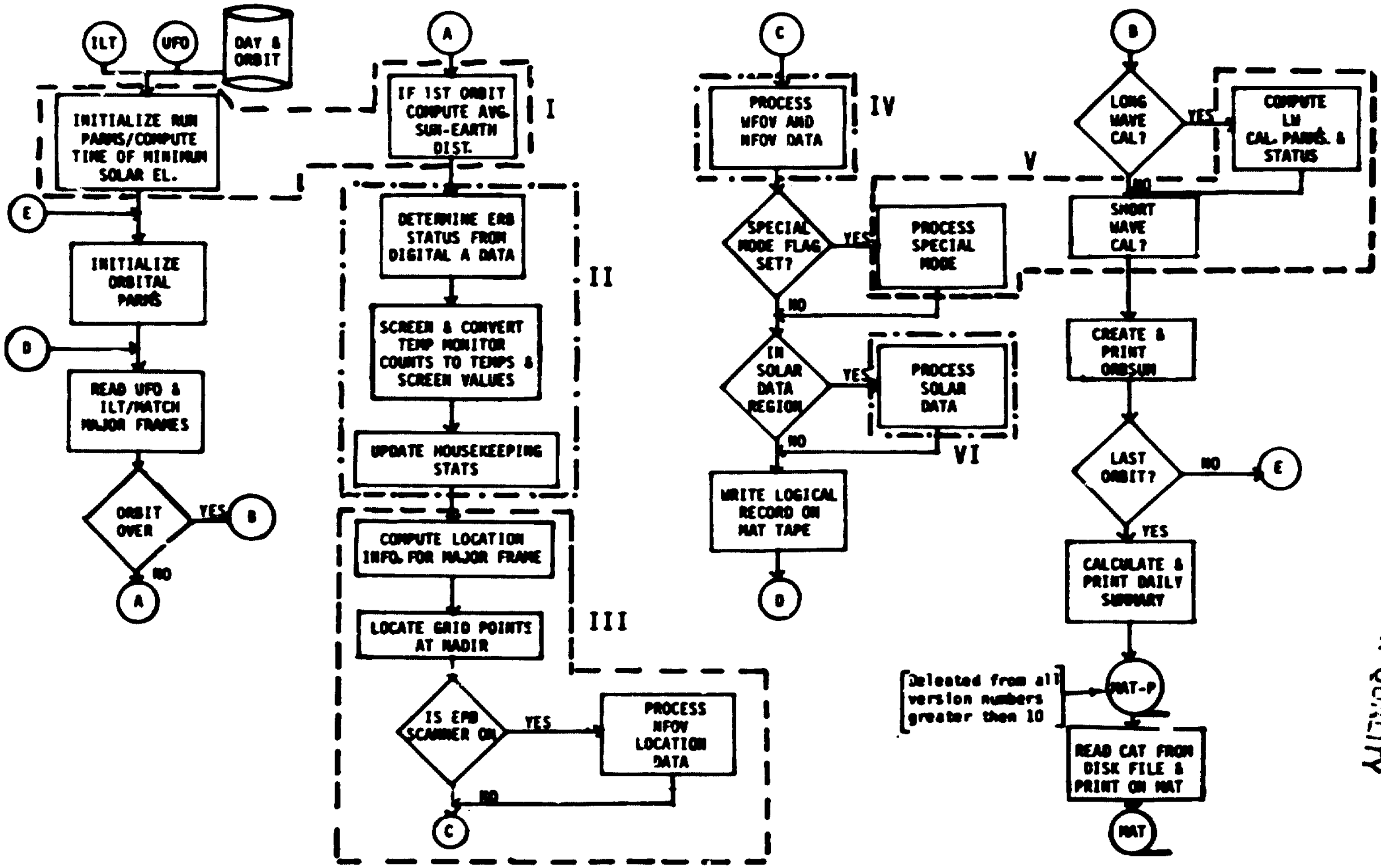


FIGURE 1.1 Overall MATGEN Data Processing Flow



ORIGINAL PAGE IS OF POOR QUALITY

FIGURE 1.2 General MATGEN Data Flow showing the locations of the various tasks delineated in this document.

the housekeeping data for use in next digital A frame analysis. All pertinent temperature counts are converted to temperatures for use in the data reduction.

TASK III - Geographical Location

Using ILT data the geographical nadir grid points and attitude of ERB at the time of data acquisition is determined. The narrow field-of-view (NFOV) channel pointing locations are also computed.

TASK IV - Radiation Data Conversion

All of the earth channel count data are coverted into equivalent radiances or irradiances using these routines.

TASK V - Special Mode Processing

Several instrument calibration measurements made at frequent intervals are processed by this program. They include the staircase electronics calibration, NFOV scanner space and interval calibration target viewing and the wide field-of-view intercomparison of channels 11 and 12. The channel gains and gain change corrections are also done by these programs. Both long and shortwave solar and earth flux values are corrected. Regression analysis is used to correct for gain and linearity changes.

TASK VI - Solar Data Processing

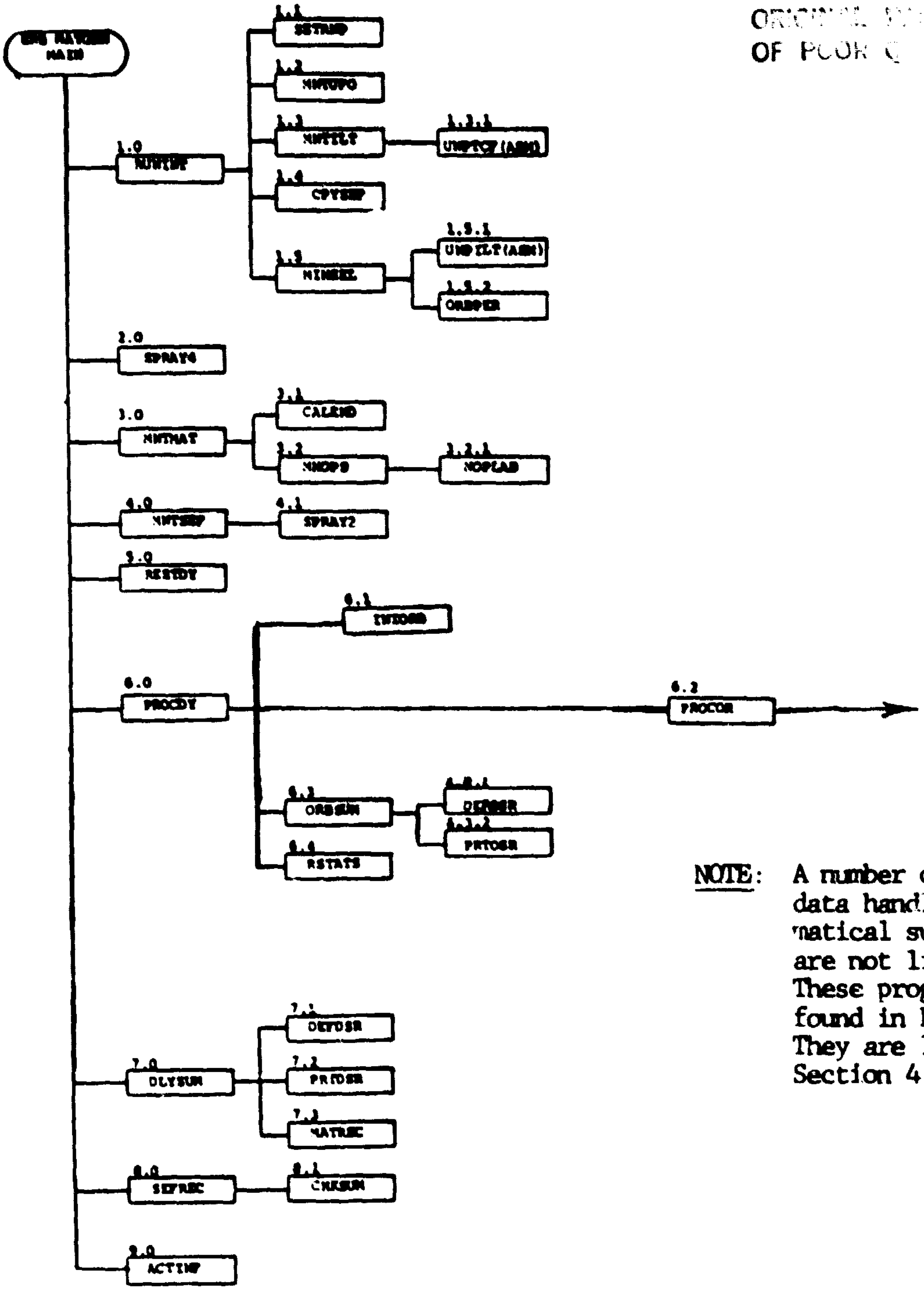
Using appropriate temperature and housekeeping data all of the solar data are converted from counts into solar irradiances.

Figure 1.3 shows all of the MATGEN subroutines and their inter-relationships. Many of these subroutines are primarily of a data manipulation nature and therefore have only been listed and briefly described in Appendix B. The MATGEN code number following each subroutine name has been included in the figure identification of all flow diagrams. This should aid in cross-referencing the subroutines and the data flow. All of the data flow diagrams are from the SASC document listed in the references.

A summary of the terms and abbreviations used in this document will be found in Appendix C. Some pertinent terms are included with their use in this document.

HIERARCHY CHART

ORIGINAL PAGE IS
OF POOR QUALITY



NOTE: A number of bookkeeping, data handling and mathematical support programs are not listed here. These programs will be found in Reference 1. They are listed in Section 4.4.

Figure 1.3 MATGEN Computer Hierarchy Chart Showing the Subroutine Relationships. In this report these subroutines are reoriented into the various tasks given in Figure 1.2

ORIGINAL PAGE IS
OF POOR QUALITY

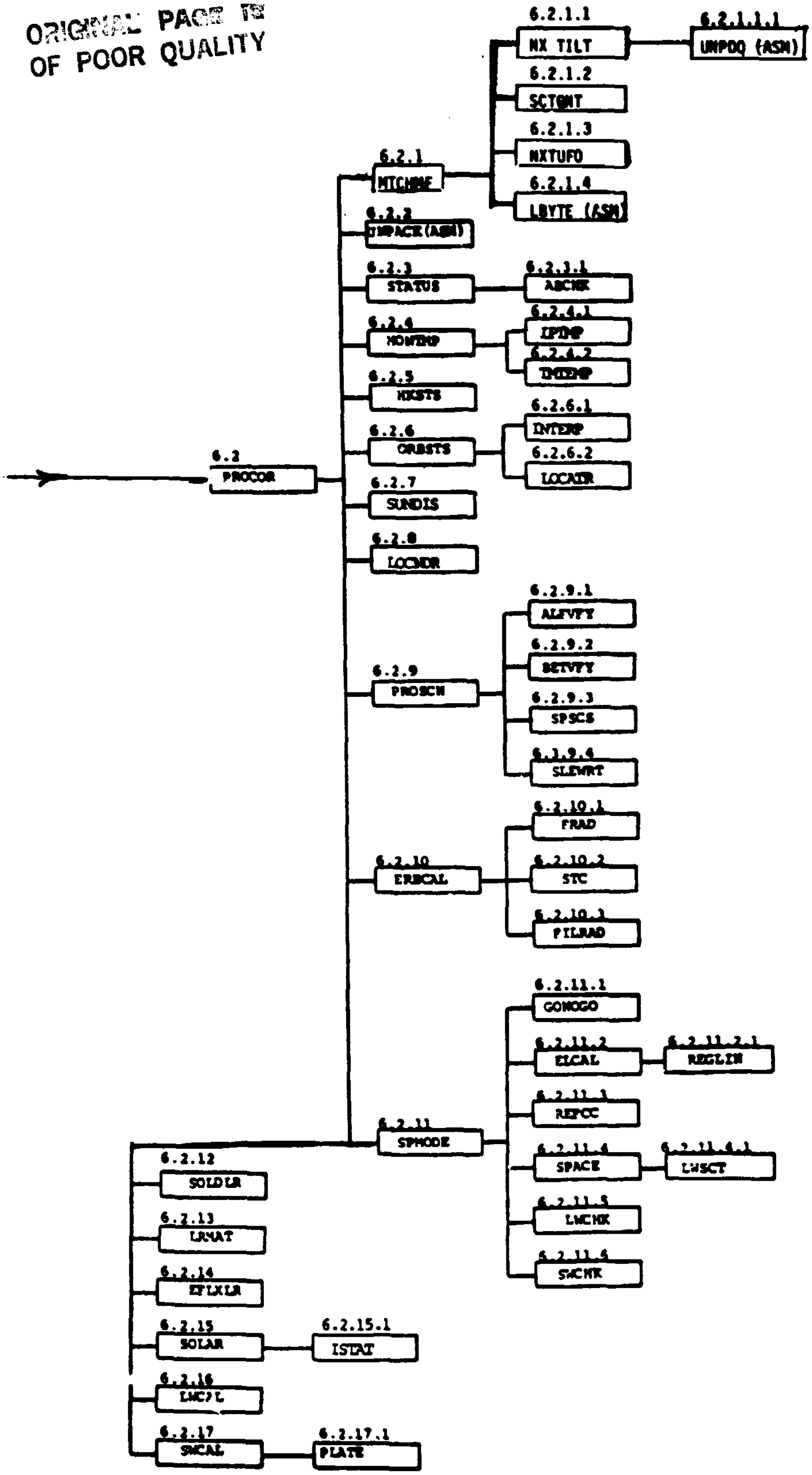


FIGURE 1.3 (CONTINUED)

1.2 GENERAL MATGEN OBJECTIVE

The MATGEN program accomplishes the following specific operations:

- o Reads satellite data from the UFO and the ephemeris data from the ILT.
    - o Matches UFO and ILT records
    - o Unpacks UFO Digital A data and telemetry data
- o Unpacks Digital A data to determine Instrument Status during M.F.
- o Converts temperature monitor counts to temperature and maintain statistics.
- o Interpolates orbital parameters for each observation
- o Convert instrument counts to irradiances or radiances and screen for validity.
- o Processes special modes
    - o Channel 10C tests
    - o Electronic Calibrations
    - o GO/NO GO tests
    - o Space View checks
    - o Reference Channel Calibrations
    - o Long wave channel checks
    - o Short wave channel checks
- o Processes NFOV instrument data
    - o Screens instrument angles for validity
    - o Locates instrument field of views on earth
    - o Computes statistics on performance of scanning channels
- o Computes solar irradiances for orbit
- o Maintains information for Orbital and Daily Summary records
- o Writes Master Archival tape with records containing located and converted major frame data, orbital and daily summary information.
- o This program which is no longer used wrote the Solar Earth Flux Data tape (SEFDT) which was a monthly tape and was a subset of the MAT's for the month. In all cases to avoid confusion SEFDT subroutines will be identified in this document.

2.0 INPUT PARAMETER DEFINITIONS

2.1 DATA FROM USER FORMATTED OUTPUT (UFO) TAPE

2.1.1 Introduction

The ERB UFO tape is generated by a CDC 3200 computer and each file contains one data orbit's worth of data. A data orbit is defined as beginning at one descending node and ending at the following descending node. Data will be written only when the ERB Sensor system is "ON" or when ERB is turned from ON to OFF and a physical record is incomplete where it will be completed with ERB OFF data. No duplicate data will be written and no data records will be written through data GAPS.

The ERB data will be extracted from a DATA Tape (DT) which has time in ascending order. Time from each VIP major frame is noise smoothed.

2.1.2 Parameters

The following parameters are extracted from the ERB UFO tape by the MATGEN program in subroutine NXTUFO.

2.1.2.1 Data Orbit Number

The Nimbus-7 data orbit number is not the same as the standard NASA data orbit number. It starts with the time this polar orbit satellite crosses the equator going South (the descending node). Thus South of the equator the number is (N+1) while North of the equator it is (N). The numbering system was started immediately after launch in October 24, 1978 and continues sequentially thereafter including leap year's extra day. There are 13.8 orbits per day. First ERB-7 scientific data was taken November 16, 1978.

2.1.2.2 S/C Day Number

The S/C Day Number starts with the Greenwich time at which the S/C crosses the equator on the descending node at a local time nearest midnight. It has a 24 hour duration.

The ILT data tape supplies MATGEN with S/C time correction information which MATGEN processes and uses in data processing.

2.1.2.3 Sync Word/Bit Slip Summary (2LSB of 8)

Bit Slip Flag - This flag is set to 1 if any one or more of the 80 minor frame sync bit slip flags indicate a 1; otherwise set it to zero. (1 bit)

Bad Sync Word Flag - This flag is set to 1, if any one or more at the 80 minor frame bad sync word flags indicate a 1, otherwise set it to 0. (1 bit)

Minor frames flagged with both bit slip and bad sync word indicate loss of sync. These minor frames will contain "old" data, i.e., data from previous minor/major frames.

2.1.2.4 Spacecraft Major Frame Time (24 bits)

This is spacecraft time in integer seconds. This is the time of the beginning of the VIP major frame.

2.1.2.5 Minor Frame Sync Bit Slip and Bad Sync Word Flags (160 bits)

There are 80 bits allocated to the sync bit slip flags and 80 bits to the bad sync word flags. These will be placed in the record starting in pairs from minor frame 1 to 80. The pairs will be bad sync word flag first followed by sync bit slip flag.

2.1.2.6 ERB Digital A Data

A description of this data is contained in Table 2.1 through 2.5. Table 2.1 contains a complete description of the data content of the Digital A data format. Table 2.2 is the major frame format in abbreviated form. Table 2.3 gives the even digital word meanings while 2.4 describes the odd digital word meanings. The TM word assignments are given in Table 2.5. All of these tables are from the Gulton (revised 1975) report.

OF POOR

TABLE 2.1

DIGITAL A DATA FORMAT
DATA CHANNEL DESCRIPTIONS

BTE Channel Number	Power Source	Sampling Rate	Description
1S through 10S	CP	1/1	Solar Channels
11E through 14E	CP	1/4	Earth Flux Channels
15 through 22	CP	2/1	Scan Channels
23 through 70	CP	1/16	Platinum Wire Thermometers
71 through 150	CP	1/16	Temperature & Voltage Monitors
151	CP	2/1	Alpha Angle Encoder
152	CP	1/1	Beta Angle Encoder
153 through 168	CP	1/16	Digital Data

ABBREVIATIONS

S = Solar Channels
E = Earth Flux Channels
+PTM, −PTM = Platinum Thermometer Data (plus or minus)
PTM EX = Platinum Thermometer Bridge Excitation Data (plus or minus)
CH = Channel
BB = Blackbody
DIG WD = Digital Word
TM = Temperature or Voltage Monitor
MSB = Most Significant Bit
LSB = Least Significant Bit
α = Scan Head Angle
β = Gimbal Angle
γ = Solar Assembly Angle
n = Angle Symbol
Sign = Polarity Sign Bits
10 LSB and 10 Sign = Ten least significant bits and ten sign bits of ten preceding PTM and channel words in chronological order from MSB to LSB.
γ=6 Bit Gray Code for Solar Channel Assembly Encoder

NOTE: The digital Data Word makeup is shown in the following Tables. Even numbered "digital words" are actually 10 bits of voltage monitor data. All channel, PTM, TM, Angle Words have MSB first and LSB last. +PTM CH20 is positive readout of platinum wire thermometer measuring scanning channel #20 chopping reference temperature. (−PTM) BB19 is negative readout of platinum wire thermometer in blackbody area viewed by channel 19.

The entire digital A format is described in the following Tables.

TABLE 2.2

DIGITAL A MAJOR FRAME FORMAT

VIP COLUMN NO.

Minor Frame Number	9	13	18	24	29	33	49	56	65
0	10 BITS β <	+PTM CH 19	+PTM CH 20	10 MSB CH 15	10 MSB CH 16	10 MSB CH 17	10 MSB CH 18	10 MSB CH 19	10 MSB CH 20
1	10 MSB CH 21	10 MSB CH 22	9 BITS α < & 1 BIT β MOTION	DIG WD #1	10 LSB	10 SIGN	TM 1	TM 2	TM 3
2	10 MSB 1S	10 MSB 2S	10 MSB 3S	10 MSB 4S	10 MSB 5S	10 MSB 6S	10 MSB 7S	10 MSB 8S	10 MSB 9S
3	10 MSB 10S	10 LSB	10 SIGN	10 MSB CH 15	**10 MSB CH 16**	10 MSB 17	10 MSB 18	10 MSB 19	10 MSB 20
4	10 MSB 21	10 MSB 22	CHAN 11E	+PTM CH 11E	10 LSB	10 SIGN	9 BITS α < & 1 BIT β MOTION	TM 4	TM 5
5	10 BITS β <	+PTM CH 21	+PTM CH 22	10 MSB CH 15	10 MSB CH 16	10 MSB CH 17	10 MSB CH 18	10 MSB CH 19	10 MSB CH 20
6	10 MSB CH 21	10 MSB CH 22	9 BITS α < & 1 BIT β MOTION	+PTM EX BB (DIG WD #2)	10 LSB	10 SIGN	TM 6	TM 7	TM 8
7	10 MSB 1S	10 MSB 2S	10 MSB 3S	10 MSB 4S	10 MSB 5S	10 MSB 6S	10 MSB 7S	10 MSB 8S	10 MSB 9S
8	10 MSB 10S	10 LSB	10 SIGN	10 MSB CH 15	10 MSB 16	10 MSB 17	10 MSB 18	10 MSB 19	10 MSB 20
9	10 MSB 21	10 MSB 22	CHAN 12E	−PTM CH 11E	10 LSB	10 SIGN	9 BITS α < & 1 BIT β MOTION	TM 9	TM 10
10	10 BITS β <	−PTM CH 19	−PTM CH 20	10 MSB CH 15	10 MSB CH 16	10 MSB CH 17	10 MSB CH 18	10 MSB CH 19	10 MSB CH 20
11	10 MSB CH 21	10 MSB CH 22	9 BITS α < & 1 BIT β MOTION	DIG WD #3	10 LSB	10 SIGN	TM 11	TM 12	TM 13
12	10 MSB 1S	10 MSB 2S	10 MSB 3S	10 MSB 4S	10 MSB 5S	10 MSB 65	10 MSB 7S	10 MSB 8S	10 MSB 9S
13	10 MSB 10S	10 LSB	10 SIGN	10 MSB CH 15	10 MSB 16	10 MSB 17	10 MSB 18	10 MSB CH 19	10 MSB 20
14	10 MSB 21	10 MSB 22	CHAN 13E	+PTM BB 19	10 LSB	10 SIGN	9 BITS α < & 1 BIT β MOTION	TM 14	TM 15
15	11 BITS β <	−PTM CH 21	−PTM CH 22	10 MSB CH 15	10 MSB CH 16	10 MSB CH 17	10 MSB CH 18	10 MSB CH 19	10 MSB CH 20
16	10 MSB CH 21	10 MSB CH 22	9 BITS α < & 1 BIT β MOTION	(DIG WD #4) −PTM EX BB	10 LSB	10 SIGN	TM 16	TM 17	TM 18
17	10 MSB 1S	10 MSB 2S	10 MSB 3S	10 MSB 4S	10 MSB 5S	10 MSB 6S	10 MSB 7S	10 MSB 8S	10 MSB 9S
18	10 MSB 10S	10 LSB	10 SIGN	10 MSB CH 15	10 MSB 16	10 MSB 17	10 MSB 18	10 MSB CH 19	10 MSB 20
19	10 MSB 21	10 MSB 22	CHAN 14E	+PTM BB 20	10 LSB	10 SIGN	9 BITS α < & 1 BIT β MOTION	TM 19	TM 20

OF POOR QUALITY

TABLE 2.2 (CONT'D)

Minor Frame Number	MAJOR FRAME FORMAT — VIP COLUMN NO. 9	13	18	24	29	33	49	56	65
20	10 BITS $\beta <$	+PTM CH 19	+PTM CH 20	10 MSB CH 15	10 MSB CH 16	10 MSB CH 17	10 MSB CH 18	10 MSB CH 19	10 MSB CH 20
21	10 MSB CH 21	10 MSB CH 22	9 BITS $\alpha <$ & 1 BIT β MOTION	DIG WD #5	10 LSB	10 SIGN	TM 21	TM 22	TM 23
22	10 MSB 1S	10 MSB 2S	10 MSB 3S	10 MSB 4S	10 MSB 5S	10 MSB 6S	10 MSB 7S	10 MSB 8S	10 MSB 9S
23	10 MSB 10S	10 LSB	10 SIGN	10 MSB CH 15	10 MSB 16	10 MSB 17	10 MSB 18	10 MSB 19	10 MSB 20
24	10 MSB 21	10 MSB 22	CHAN 11E	+PTM CH 12E	10 LSB	10 SIGN	9 BITS $\alpha <$ & 1 BIT β MOTION	TM 24	TM 25
25	10 BITS $\beta <$	+PTM CH 21	+PTM CH 22	10 MSB CH 15	10 MSB CH 16	10 MSB CH 17	10 MSB CH 18	10 MSB CH 19	10 MSB CH 20
26	10 MSB CH 21	10 MSB CH 22	9 BITS $\alpha <$ & 1 BIT β MOTION	(DIG WD #6) +PTM EX SCAN CH	10 LSB	10 SIGN	TM 26	TM 27	TM 28
27	10 MSB 1S	10 MSB 2S	10 MSB 3S	10 MSB 4S	10 MSB 5S	10 MSB 6S	10 MSB 7S	10 MSB 8S	10 MSB 9S
28	10 MSB 10S	10 LSB	10 SIGN	10 MSB CH 15	10 MSB 16	10 MSB 17	11 MSB 18	10 MSB 19	10 MSB 20
29	10 MSB 21	10 MSB 22	CHAN 12E	−PTM CH 12E	10 LSB	10 SIGN	9 BITS $\alpha <$ & 1 BIT β MOTION	TM 29	TM 30
30	10 BITS $\beta <$	−PTM CH 19	−PTM CH 20	10 MSB CH 15	10 MSB CH 16	10 MSB CH 17	10 MSB CH 18	10 MSB CH 19	10 MSB CH 20
31	10 MSB CH 21	10 MSB CH 22	9 BITS $\alpha <$ & 1 BIT β MOTION	DIG WD #7	10 LSB	10 SIGN	TM 31	TM 32	TM 33
32	10 MSB 1S	10 MSB 2S	10 MSB 3S	10 MSB 4S	10 MSB 5S	10 MSB 6S	10 MSB 7S	10 MSB 8S	10 MSB 9S
33	10 MSB 10S	10 LSB	10 SIGN	10 MSB CH 15	10 MSB 16	10 MSB 17	10 MSB 18	10 MSB CH 19	10 MSB 20
34	10 MSB 21	10 MSB 22	CHAN 13E	+PTM BB 20	10 LSB	10 SIGN	9 BITS $\alpha <$ & 1 BIT β MOTION	TM 34	TM 35
35	10 BITS $\beta <$	−PTM CH 21	−PTM CH 22	10 MSB CH 15	10 MSB CH 16	10 MSB CH 17	10 MSB CH 18	10 MSB CH 19	10 MSB CH 20
36	10 MSB CH 21	10 MSB CH 22	9 BITS $\alpha <$ & 1 BIT β MOTION	(DIG WD #8) −PTM EX SCAN CH	10 LSB	10 SIGN	TM 36	TM 37	TM 38
37	10 MSB 1S	10 MSB 2S	10 MSB 3S	10 MSB 4S	10 MSB 5S	10 MSB 6S	10 MSB 7S	10 MSB 8S	10 MSB 9S
38	10 MSB 10S	10 LSB	10 SIGN	10 MSB CH 15	10 MSB 16	10 MSB 17	10 MSB 18	10 MSB CH 19	10 MSB 20
39	10 MSB 21	10 MSB 22	CHAN 14E	+PTM BB 22	10 LSB	10 SIGN	9 BITS $\alpha <$ & 1 BIT β MOTION	TM 39	TM 40

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 2.2 (CONT'D)

MAJOR FRAME FORMAT

Minor Frame Number	VIP COLUMN NO. 9	13	18	24	29	33	49	56	65
60	10 BITS β <	+PTM CH 19	+PTM CH 20	10 MSB CH 15	10 MSB CH 16	10 MSB CH 17	10 MSB CH 18	10 MSB CH 19	10 MSB CH 20
61	10 MSB CH 21	10 MSB CH 22	9 BITS α < & 1 BIT β MOTION	DIG WD #13	10 LSB	10 SIGN	TM 61	TM 62	TM 63
62	10 MSB 1S	10 MSB 2S	10 MSB 3S	10 MSB 4S	10 MSB 5S	10 MSB 6S	10 MSB 7S	10 MSB 8S	10 MSB 9S
63	10 MSB 10S	10 LSB	10 SIGN	10 MSB CH 15	10 MSB 16	10 MSB 17	10 MSB 18	10 MSB 19	10 MSB 20
64	10 MSB 21	10 MSB 22	CHAN 11E	+PTM CH 12E	10 LSB	10 SIGN	9 BITS α < & 1 BIT β MOTION	TM 64	TM 65
65	10 BITS β <	+PTM CH 21	+PTM CH 22	10 MSB CH 15	10 MSB CH 16	10 MSB CH 17	10 MSB CH 18	10 MSB CH 19	10 MSB CH 20
66	10 MSB CH 21	10 MSB CH 22	9 BITS α < & 1 BIT β MOTION	(DIG WD #14) +15V MON	10 LSB	10 SIGN	TM 66	TM 67	TM 68
67	10 MSB 1S	10 MSB 2S	10 MSB 3S	10 MSB 4S	10 MSB 5S	10 MSB 6S	10 MSB 7S	10 MSB 8S	10 MSB 9S
68	10 MSB 10S	10 LSB	10 SIGN	10 MSB CH 15	10 MSB 16	10 MSB 17	10 MSB 18	10 MSB 19	10 MSB 20
69	10 MSB 21	10 MSB 22	CHAN 12E	−PTM CH 12E	10 LSB	10 SIGN	9 BITS α < & 1 BIT β MOTION	TM 69	TM 70
70	10 BITS β <	−PTM CH 19	−PTM CH 20	10 MSB CH 15	10 MSB CH 16	10 MSB CH 17	10 MSB CH 18	10 MSB CH 19	10 MSB CH 20
71	10 MSB CH 21	10 MSB CH 22	9 BITS α < & 1 BIT β MOTION	DIG WD #15	10 LSB	10 SIGN	TM 71	TM 72	TM 73
72	10 MSB 1S	10 MSB 2S	10 MSB 3S	10 MSB 4S	10 MSB 5S	10 MSB 6S	10 MSB 7S	10 MSB 8S	10 MSB 9S
73	10 MSB 10S	10 LSB	10 SIGN	10 MSB CH 15	10 MSB 16	10 MSB 17	10 MSB 18	10 MSB CH 19	10 MSB 20
74	10 MSB 21	10 MSB 22	CHAN 13E	+PTM BB 21	10 LSB	10 SIGN	9 BITS α < & 1 BIT β MOTION	TM 74	TM 75
75	10 BITS β <	−PTM CH 21	−PTM CH 22	10 MSB CH 15	10 MSB CH 16	10 MSB CH 17	10 MSB CH 18	10 MSB CH 19	10 MSB CH 20
76	10 MSB CH 21	10 MSB CH 22	9 BITS α < & 1 BIT β MOTION	(DIG WD #16) −15V MON	10 LSB	10 SIGN	TM 76	TM 77	TM 78
77	10 MSB 1S	10 MSB 2S	10 MSB 3S	10 MSB 4S	10 MSB 5S	10 MSB 6S	10 MSB 7S	10 MSB 8S	10 MSB 9S
78	10 MSB 10S	10 LSB	10 SIGN	10 MSB CH 15	10 MSB 16	10 MSB 17	10 MSB 18	10 MSB CH 19	10 MSB 20
79	10 MSB 21	10 MSB 22	CHAN 14E	−PTM BB 22	10 LSB	10 SIGN	9 BITS α < & 1 BIT β MOTION	TM 79	TM 80

OF POOR QUALITY

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 2.2 (CONT'D)

Minor Frame Number	MAJOR FRAME FORMAT — VIP COLUMN NO. 9	13	18	24	29	33	49	56	65
40	10 BITS $\beta <$	+PTM CH 19	+PTM CH 20	10 MSB CH 15	10 MSB CH 16	10 MSB CH 17	10 MSB CH 18	10 MSB CH 19	10 MSB CH 20
41	10 MSB CH 21	10 MSB CH 22	9 BITS $\alpha <$ & 1 BIT β MOTION	DIG WD #9	10 LSB	10 SIGN	TM 41	TM 42	TM 43
42	10 MSB 1S	10 MSB 2S	10 MSB 3S	10 MSB 4S	10 MSB 5S	10 MSB 6S	10 MSB 7S	10 MSB 8S	10 MSB 9S
43	10 MSB 10S	10 LSB	10 SIGN	10 MSB CH 15	10 MSB 16	10 MSB 17	10 MSB 18	10 MSB 19	10 MSB 20
44	10 MSB B 21	10 MSB 22	CHAN 11E	+PTM CH 11E	10 LSB	10 SIGN	9 BITS $\alpha <$ & 1 BIT β MOTION	TM 44	TM 45
45	10 BITS $\beta <$	+PTM CH 21	+PTM CH 22	10 MSB CH 15	10 MSB CH 16	10 MSB CH 17	10 MSB CH 18	10 MSB CH 19	10 MSB CH 20
46	10 MSB CH 21	10 MSB CH 22	9 BITS $\alpha <$ & 1 BIT β MOTION	(DIG WD #10) +PTM EX EARTH CH	10 LSB	10 SIGN	TM 46	TM 47	TM 48
47	10 MSB 1S	10 MSB 2S	10 MSB 3S	10 MSB 4S	10 MSB 5S	10 MSB 6S	10 MSB 7S	10 MSB 8S	10 MSB 9S
48	10 MSB 10S	10 LSB	10 SIGN	10 MSB CH 15	10 MSB 16	10 MSB 17	10 MSB 18	10 MSB 19	10 MSB 20
49	10 MSB 21	10 MSB 22	CHAN 12E	−PTM CH 11E	10 LSB	10 SIGN	9 BITS $\alpha <$ & 1 BIT β MOTION	TM 49	TM 50
50	10 BITS $\beta <$	−PTM CH 19	−PTM CH 20	10 MSB CH 15	10 MSB CH 16	10 MSB CH 17	10 MSB CH 18	10 MSB CH 19	10 MSB CH 20
51	10 MSB CH 21	10 MSB CH 22	9 BITS $\alpha <$ & 1 BIT β MOTION	DIG WD #11	10 LSB	10 SIGN	TM 51	TM 52	TM 53
52	10 MSB 1S	10 MSB 2S	10 MSB 3S	10 MSB 4S	10 MSB 5S	10 MSB 6S	10 MSB 7S	10 MSB 8S	10 MSB 9S
53	10 MSB 10S	10 LSB	10 SIGN	10 MSB CH 15	10 MSB 16	10 MSB 17	10 MSB 18	10 MSB 19	10 MSB 20
54	10 MSB 21	10 MSB 22	CHAN 13E	−PTM BB 19	10 LSB	10 SIGN	9 BITS $\alpha <$ & 1 BIT β MOTION	TM 54	TM 55
55	10 BITS $\beta <$	−PTM CH 21	−PTM CH 22	10 MSB CH 15	10 MSB CH 16	10 MSB CH 17	10 MSB CH 18	10 MSB CH 19	10 MSB CH 20
56	10 MSB CH 21	10 MSB CH 22	9 BITS $\alpha <$ & 1 BIT β MOTION	(DIG WD #12) −PTM EX EARTH CH	10 LSB	10 SIGN	TM 56	TM 57	TM 58
57	10 MSB 1S	10 MSB 2S	10 MSB 3S	10 MSB 4S	10 MSB 5S	10 MSB 6S	10 MSB 7S	10 MSB 8S	10 MSB 9S
58	10 MSB 10S	10 LSB	10 SIGN	10 MSB CH 15	10 MSB 16	10 MSB 17	10 MSB 18	10 MSB 19	10 MSB 20
59	10 MSB 21	10 MSB 22	CHAN 14E	−PTM BB 20	10 LSB	10 SIGN	9 BITS $\alpha <$ & 1 BIT β MOTION	TM 59	TM 60

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 2.3

Even Digital Words	Col	Row
2 +PTM Excitation Voltage BB	24	06
4 −PTM Excitation Voltage BB	24	16
6 +PTM Excitation Voltage Scan Ch	24	26
8 −PTM Excitation Voltage Scan Ch	24	36
10 +PTM Excitation Voltage Earth Ch	24	46
12 −PTM Excitation Voltage Earth Ch	24	56
14 +15 Volt Monitor	24	66
16 −15 Volt Monitor	24	76

TABLE 2.4

DESCRIPTION OF ODD DIGITAL WORD BITS

Digital Word	Bits	Description
7	4	"Stepper Drives ON" command verification (*)
	5	"Calibration Check" command verification (*)
	6	∝ not in Space Position (From Encoder)("Digital 0" only when in Space Position)
	7	∝ not in Shortwave Position (From Encoder)
	8	β not in Shortwave Position (From Encoder)
	9	∝ not in Longwave Position (From Encoder)
	10	β not in Longwave Position (From Encoder)
9	1-3	Same as Digital 3 bits 1-3
	4-6	Instrument ID. Bit 6=Engr. Unit 4.5=Proto/Flight Unit 4=Flight Unit
	7	"Reference Chan Shutters OPEN/CLOS" (*)
	8	"Chan 12 Shutter OPEN/CLOS" (*)
	9	"Heat Radiator B Code Bit 2" CLOS/OPEN (*)
	10	"Heat Radiator B Code Bit 1" CLOS/OPEN (*)
11	1	β not 273° (From Encoder)
	2	∝ not 0° (From Encoder)
	3	Sync Error (should be zero)
	4	Scan Logic enabled for scanning. Should become a Digital "1" after "Scan ON" command.
	5	If routine 5 is selected, this bit is a Digital "1" when in the Routine 4 section.

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 2.4 (CONT'D)

DESCRIPTION OF ODD DIGITAL WORD BITS

Digital Word	Bits	Description
	6	Same as Digital 3 bit 8.
	7	Same as Digital 3 it 7.
	8	"Scan ON" command verification (*)
	9	"Solar Door OPEN/CLOSE" command verification (*)
	10	"PRP No. 1/2" command verification (*)
13	1	External BB connected to ERB. Allows processing of target data through S/S.
	2	β not 357° (From Encoder)
	3	β not 3° (From Encoder)
	4	β not 87° (From Encoder)
	5	β not 177° (From Encoder)
	6	β not 205° (From Encoder)
	7	β not 183° (From Encoder)
	8	β not 19.5° (From Encoder)
	9	β not 154° (From Encoder)
	10	β not 340° (From Encoder)
15	1	Not Used
	2-6	Repeats
	2	Same as Digital 5 bit 2
	3	Same as Digital 5 bit 3
	4	Same as Digital 7 bit 5
	5	Same as Digital 5 bit 5
	6	Same as Digital 5 bit 6
	7	Same as Digital 7 bit 6
	8	Same as Digital 3 bit 8
	9	Same as Digital 3 bit 7
	10	Same as Digital 3 bit 2

OF POOR QUALITY

TABLE 2.5

DIGITAL A TM WORD ASSIGNMENTS

Function No.	Monitor Point	TM Number(s)
14901	Channel 11E Shutter	1, 21, 41, 61
14902	Channel 12E Shutter	2, 22, 42, 62
14903	Scan Channel 19 Baffle Port	3, 23, 43, 63
14904	Scan Channel 20 Baffle Port	4, 24, 44, 64
14905	Scan Channel 21 Baffle Port	5, 25, 45, 65
14906	Scan Channel 22 Baffle Port	6, 26, 46, 66
14907	9S Module	7, 47
14908	10S Module	8, 48
14909	13E Module	9, 49
14910	14E Module	10, 50
14911	Channel 1S Thermopile Base	11
14912	Channel 2S Thermopile Base	12
14913	Channel 3S Thermopile Base	13
14914	Channel 4S Thermopile Base	14
14915	Channel 5S Thermopile Base	15
14916	Channel 6S Thermopile Base	16
14917	Channel 7S Thermopile Base	17
14918	Channel 8S Thermopile Base	18
14919	Channel 9S Thermopile Base	19
14920	Channel 10S Thermopile Base	20
14921	Channel 11E Thermopile Base	76
14922	Channel 12E Thermopile Base	77
14923	Channel 13E Thermopile Base	78
14924	Channel 14E Thermopile Base	79
14925	Channel 1S Module	31
14926	Channel 2S Module	32
14927	Channel 3S Module	33
14928	Channel 6S Module	34
14929	Main Frame Radiator Plate Top-Front	35
14930	Main Frame Radiator Plate Bottom-Front	36
14931	Solar Channel Heat Sink Front	37
14932	Solar Channel Heat Sink Back	38
14933	Earth Flux Channel Heat Sink Bottom	39
14934	Earth Flux Channel Heat Sink Top	40
14935	Main Frame Radiator Plate Bottom-Rear	51
14936	Main Frame Connector Plate	52
14937	Electronics Plate Frame Outboard Rear Corner	53
14938	Gimbal Bearing Housing	54
14939	Gimbal Motor (β)	55
14940	Solar Channel Assembly Drive Motor (γ)	56

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 2.5 (CONT'D)

DIGITAL A TM WORD ASSIGNMENTS

Function No.	Monitor Point	TM Number(s)
14941	Shortwave Channels Detectors	57
14942	Scan Motor (α)	58
14943	Beam Blocker-Chopper Motor	59
14944	Post Amplifier-Sync-Demod. Area	60
14945	Power Supply Area	71
14946	A/D Area	72
14947	Main Frame Radiator Plate Top Rear	73
14948	Scan Mechanism Remote Bearing	74
14949	Channel 12E FOV Stop	75
14950	+15V Logic Level	80
14951	Scan Channel 19 Baffle	27, 67
14952	Scan Channel 20 Baffle	28, 68
14953	Scan Channel 21 Baffle	29 69
14954	Scan Channel 22 Baffle	30, 70

2.1.2.7 ERB Digital B Data

A list of the data elements is contained in Table 2.6.

2.1.2.8 ERB Analog Data

A list of this data is contained in Table 2.7.

2.2 DATA FROM IMAGE LOCATION TAPE (ILT)

2.2.1 Introduction

The ERB-ILT is generated by a CDC-3300 computer program. The first data file will contain time correction information for the entire tape. Each subsequent file will contain one orbit's worth of data. A file will contain at most, data beginning at approximately one descending node and ending at approximately the following descending node. Data will only be written when ERB Sensor system power is "ON" and no duplicate data will be written.

2.2.2 Parameters

The following parameters are extracted from the ERB-ILT tape by the MATGEN program in subroutine NXTILT.

2.2.2.1 Time Correction Data

The time correction file contains information which allows the user to create linear functions which relate spacecraft time to GMT.

2.2.2.2 Data Orbit No.

The data orbit number for data ontained in this file. Data within the file will be from descending node (DN) to descending node.

2.2.2.3 GMT Year

The year number corresponding to the data contained in items 2.2.2.8 thru 2.2.2.20 below.

2.2.2.4 GMT 1/12 Day

The day number corresponding to the data contained in items 2.2.2.8 thru 2.2.2.20 below, with Day No. 1 being January 1st.

2.2.2.5 GMT Milliseconds of 1/12 Day

The integer number of seconds of the day corresponding to the data contained in items 2.2.2.8 thru 2.2.2.20 below.

2.2.2.6 S/C 1/12 Days

Spacecraft time given in 1/12 days to be added to S/C time to get the corresponding spacecraft time for the associated data in items 2.2.2.7 thru 2.2.2.20 below.

ORIGINAL P
OF POOR Q

TABLE 2.6 DIGITAL B DATA

Item No.	Function Number	Function Digital 1/0	Acronym	Gate I.D.	Data Form	Data Rate	Data Location		
							Row	Col.	Bits
P-1	14001	Electronics On/Off	ELECT	7B32	DB	3/16	1	6	7
P-2	14002	Scan On/Off	SCAN	8B33	DB	3/16	2	6	8
P-3	14003	Scan Off Reset On/Off	SCAN OFF	9B34	DB	3/16	3	6	9
P-4	14004	Space Look On/Off	SPA LOOK	0B50	DB	3/16	19	6	0
P-5	14005	Short-Wave Check On/Off	SH WAVE	1B51	DB	3/16	20	6	1
P-6	14006	Long-Wave Check On/Off	LG WAVE	2B52	DB	3/16	21	6	2
P-7	14007	Solar Ch. 1° Right On/Off	SLR C 1R	8B56	DB	3/16	25	6	8
P-8	14008	Solar Ch. 1° Left On/Off	SLR C 1L	8B32	DB	3/16	1	6	8
P-9	14009	Go/No Go Test Off/On	GO/NO GO	9B33	DB	3/16	2	6	9
P-10	14010	Temp Controller On/Off	TMP CONT	0B51	DB	3/16	20	6	0
P-11	14011	Stepper Drives Off/On	STEP DRV	1B52	DB	3/16	21	6	1
P-12	14012	Ref Ch Shutters Close/Open	REF CSH	7B56	DB	3/16	25	6	7
P-13	14013	Ch 12E Shutter Close/Open	C 12E SH	9B32	DB	3/16	1	6	9
P-14	14014	Ch 12E FOV NAR/Wide	C 12E FV	0B52	DB	3/16	21	6	0
P-15	14015	Cal Initiate On/Off	CAL INIT	6B54	DB	3/16	23	6	6
P-16	14016	Chopper Operating Yes/No	CH OPER	7B54	DB	3/16	23	6	7
P-17	14017	Heat Rad a Front Close/Open	RDA FRNT	8B54	DB	3/16	23	6	8

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 2.6 DIGITAL B DATA

Item No.	Function Number	Function Digital State, m 1/10/00	Acronym	Gate I.D.	Data Form	Data Rate	Data Location		
							Row	Col.	Bits
P-18	14018	Heat Rad A Rear Closed/Open	RDA REAR	9B54	DB	3/16	23	6	9
P-19	14019	Heat Rad B Front Closed/Open	RDB FRNT	5B56	DB	3/16	25	6	5
P-20	14020	Heat Rad B Rear Closed/Open	RDB REAR	6B56	DB	3/16	25	6	6
P-21	14021	Scan 1 Bit 1 On/Off	1SC BT 1	0B56	DB	3/16	25	6	0
P-22	14022	Scan 2 Bit 2 On/Off	2SC BT 2	1B56	DB	3/16	25	6	1
P-23	14023	Scan 3 Bit 4 On/Off	3SC BT 4	2B56	DB	3/16	25	6	2
P-24	14024	MF 1 in Scan Bit 1 On/Off	1 FR SC 1	0B55	DB	3/16	24	6	0
P-25	14025	MF 2 in Scan Bit 2 On/Off	2 FR SC 2	1B55	DB	3/16	24	6	1
P-26	14026	MF 3 in Scan Bit 4 On/Off	3 FR SC 4	2B55	DB	3/16	24	6	2
P-27	14027	Short Grid Processing Yes/No	SHORT GD	9B56	DB	3/16	25	6	9
P-28	14028	Yoke Heater On/Off (ISM)	YOKE HTR	2B57	DB	3/16	26	6	2
P-29	14030	Solar Chan Door Open/Closed	SLR DOOR	3B48	DB	3/16	17	6	8
P-30	14031	PRP No. 1/No. 2	PRP 1/2	9B49	DB	3/16	18	6	9

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 2.7 ANALOG DATA

Item No.	Function Number	Function	Acronym	Gate I.D.	Data Form	Data Rate	Data Location		
							Row	Col.	Bits
P-31	14101	-24.5 Volt TM Monitor	-24V TLM	A258	A	1/16	27	61	
P-32	14102	Front Mount Tab Temp	F MTG T	A322	A	1/16	36	75	
P-33	14103	Back Mount Tab Temp	R MTG T	A386	A	1/16	46	10	
P-34	14104	Gimbal Motor Temp	G MTG T	A450	A	1/16	55	15	
P-35	14105	Scan Motor Temp	SC MTR T	A514	A	1/16	64	36	
P-36	14106	Chopper Motor Temp	CH MTR T	A581	A	1/16	73	75	
P-37	14107	Heat Radiator Plate Temp	RAD PL T	A578	A	1/16	73	40	
P-38	14108	Temp Controller Voltage	T. CONT V	A365	A	1/16	43	10	
P-39	14109	-15 Volt Monitor	-15 VOLT	A380	A	1/16	45	15	

2.2.2.7 S/C Time Milliseconds

Spacecraft clock time in milliseconds to be added to S/C 1/12 days above to get the corresponding time for the associated data in items 2.2.2.8 thru 2.2.2.20 below.

2.2.2.8 X (S/C Location)

The X co-ordinate of spacecraft location (in earth-centered inertial co-ordinates true of date) at time specified in items 2.2.2.3, 4, 5 expressed in meters.

2.2.2.9 Y (S/C Location)

As in item 2.2.2.8 above for Y co-ordinate.

2.2.2.10 Z (S/C Location)

As in item 2.2.2.8 above for Z co-ordinate.

2.2.2.11 Greenwich Hour Angle from Aries

The angle between the inertial x-axis and the earth fixed x-axis, expressed in 10^{-6} radians.

2.2.2.12 X' (Spacecraft Velocity)

The X-component of the spacecraft velocity in km/second scaled by 2^{18} corresponding to the position given.

2.2.2.13 Y' (Spacecraft Velocity)

The same in item 2.2.2.12 above, for Y component.

2.2.2.14 Z' (Spacecraft Velocity)

The same in item 2.2.2.12 above, for Z component.

2.2.2.15 Sun Right Ascension (Azimuth)

The angle measured in the plane of the equator from a fixed inertial axis in space (vernal equinox), to a plane normal to the equator (meridian) which contains the sun (true of date) and positive counterclockwise as seen as +Z $(-\pi \leq \phi \leq \pi)$. Figure 2.1 shows the geometric orientations of these angles.

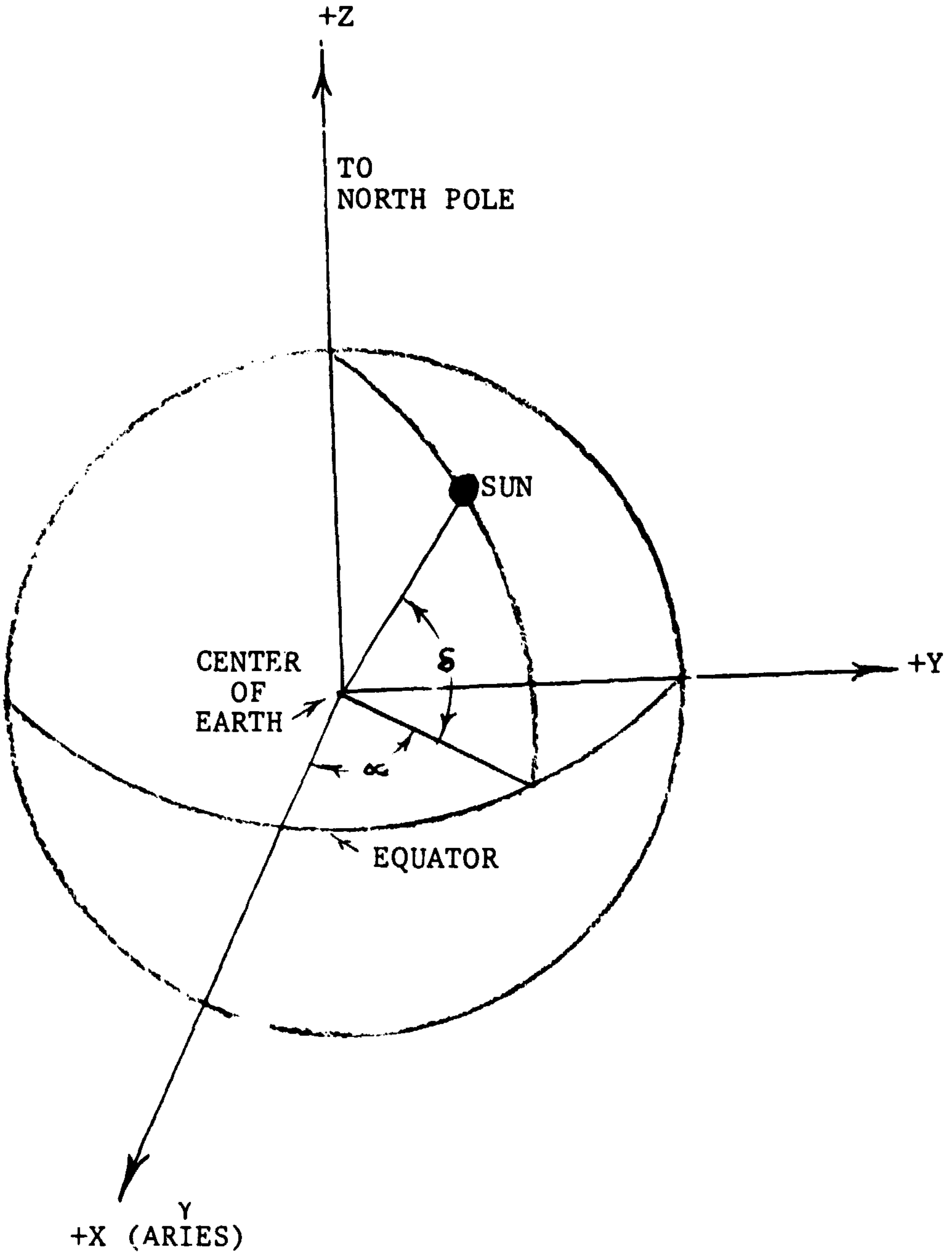


FIGURE 2.1 Celestial Sphere Geometric Angle Orientations

2.2.2.16 Sun Declination (Elevation)

The angle between the sun and inertial equator measured in a plane normal to the inertial equator, which contains the sun and the earth center (true-of-date) positive above equator. $(-\frac{\pi}{2} \leq \delta - \frac{\pi}{2})$.

2.2.2.17 Sub. Sat. Longitude

East longitude of normal from spacecraft to ellipsoid, expressed in 10^{-6} radians. Equatorial radius = 6378.144 Km, Polar radius = 6356.759 Km.

2.2.2.18 Sub. Sat. Latitude

Same as in item 2.2.2.17 above, for Geodetic Latitude.

2.2.2.19 Altitude

The distance from the spacecraft to ellipsoid measured along the normal, expressed in meters.

2.2.2.20 S/C DAY/TWI/NT Status

Code describing spacecraft orbital position:

0 = DAY (S/C & Subtract Pt. both illuminated)
1 = TWILIGHT (Earth-Night)(S/C illuminated, Subtract Pt. in shade)
2 = NIGHT (S/C & Subtract Pt. both in shade)

2.2.2.21 Repeat For 2nd GMT Minute

Items 2.2.2.8 (X S/C Position) through 2.2.2.20 (Spacecraft D/T/N Status) are repeated for the second GMT minute contained in this 2 min 8 sec data period. That is, the time of these values will be for 60 GMT seconds after the GMT given in items 2.2.2.3 through 2.2.2.5

2.2.2.22 Repeat For 3rd GMT Minute

As above for third GMT minute contained in this 2 min 8 sec data period, but only if 3 minutes of ephemeris data coincide with the 2 minute 8 second time period contained in this record.

2.2.2.23 GMT (MS) of Start of First VIP Major Frame

This is given as increment in milliseconds from the time given in items 2.2.2.3 through 2.2.2.5 above.

2.2.2.24 S/C Time (1/12 Days) of Start of First VIP Major Frame

S/C time in 1/12 days to be added to the next 24-bit word (item 2.2.2.25).

2.2.2.25 S/C Time (MS) (1/12 Days) of Start of First VIP Major Frame (24 Bits)

This provides the start time of data which follows in items 2.2.2.26 through 2.2.2.34. It is given as S/C milliseconds to be added to the previous 24 bit word (item 2.2.2.24) and will be the time at the beginning of the first major VIP frame.

2.2.2.26 VIP Major Frame Q/C (160 Bits)

There are 80 bits allocated to the sync quality flags and 80 bits to the sync loss flags.

2.2.2.27 Sensor - S/C Status

The spacecraft status and events shown below

ERB ELECT	ON/OFF
ERB SCAN	ON/OFF
ERB STEPPER DRIVER	OFF/NO
ERB CHOPPER OPERATING	YES/NO

2.2.2.28 S/C Pitch

The spacecraft pitch angle at the time given in items 2.2.2.23 through 2.2.2.25.

2.2.2.29 S/C Yaw

The same as in 2.2.2.28 for yaw.

2.2.2.30 S/C Roll

The same as in 2.2.2.28 for roll.

2.2.2.31 S/C Pitch Rate

This describes rate of change of S/C Pitch.

2.2.2.32 S/C Roll Rate

The same as in 2.2.2.31 for roll rate.

2.2.2.33 DSAS Right Ascension to Sun (Azimuth Angle)

The azimuth angle is the tenths-of-degrees relative to the S/C axes from the Digital Solar Aspect Sensor (DSAS) data and ranges fro -1800 to 1800 with negative values for Sun directions to the left of S/C track (-Y hemisphere). The azimuth angle is zero when sun direction is aligned with S/C XZ-plane.

2.2.2.34 DSAS Declination to Sun (Elevation Angle)

The elevation angle in tenths-of-degrees relative to the S/C axes is obtained from the DSAS subsystem. Values range from -1800 to 1800 with positive values corresponding to sun directions below the S/C XY-plane (+Z hemisphere).

2.2.2.35 Additional Attitude Data

Fifteen additional sets of items 2.2.2.28 through 2.2.2.34 for a total of 16 sets. Each set is for 1 spacecraft second after previous set.

2.2.2.36 Additional Data

Seven additional sets of items 2.2.2.24 through 2.2.2.34 for a total of 8 sets (8 VIP frames) for 2 Min. 8 Sec of coverage. (NOTE: GMT of each VIP frame is implicitly 16 sec. (S/C time) later than the previous one).

2.2.2.37 Start Data Quality Loss Time (24 Bits)

The start time of an interval contained in this 2 Min 8 Sec period, where Data Quality Loss has occurred, expressed as a GMT (milliseconds) increment from time given in item 2.2.2.23. The values should be multiples of 40 milliseconds (1/25 seconds).

2.2.2.38 End Data Quality Loss Time

The end time (milliseconds increment from time in item 2.2.2.23) of the Data Quality Loss interval described above.

2.2.2.39 Additional Data Quality Loss Time

Sixty-one additional pairs of Data Quality loss intervals as described in items 2.2.2.37 and 2.2.2.38.

2.2.2.40 Data Quality Loss Interval Count

Integer value indicating number of valid bit slip intervals described in this record.

2.3 DATA FROM DISK DATA SET

Data from the disk data set is updated manually and provides information for MATGEN to set up the necessary run parameters.

The following parameters are extracted from the Disk Data by the MATGEN program in subroutine SETRNP.

2.3.1 ERBON Time - Time that ERB was last turned on calculated in days from January 1, 1978.

2.3.2 UFO tape numbers, sequence numbers, start orbit, stop orbit and first file.

2.3.3 ILT tape numbers, sequence numbers, start orbit, stop orbit, first file and day/fraction of day (modified Julian day) of the start of the data.

2.3.4 Master Archival Tape (MAT) tape number and sequence number.

3.0 SOLAR LOCATION ALGORITHMS (Reference Task 1, Figure 1.2)

3.1 MINIMUM SOLAR ELEVATION TIME

3.1.1 Introduction

The solar channels are oriented along the velocity vector and because of geometric deviations only view the sun during one short period per orbit. It is necessary at some time just prior to solar viewing to view space for reference purposes. Thus it is necessary to estimate the time of the next minimum solar elevation to properly process the solar data.

This processing is done in the following manner:

> The maximum and minimum solar elevation for an orbit occurs when the Z component of the spacecraft velocity is zero. Given the cartesian orbital elements at a particular time, the corresponding Keplerian elements are computed, and the orbits eccentric anomaly when ZDOT = 0 is computed. Using Kepler's equation for the two body orbit for this eccentric anomaly, the resulting mean anomaly, and thus time is computed. Whether the computed time is for the maximum or minimum solar elevation is determined from the position of the satellite.

The Digital Solar Aspect Sensor (DSAS) angle definitions and comments are not computed by the MATGEN program. However, because of their importance in MATGEN work, they are included in Appendix A.

Another important parameter used in the correction of the solar data is the sun-earth distance. This distance computed to a double precision accuracy has also been used to determine the accuracy of other parameter computations such as the butchered Julian day (which because of an oversight neglected the leap year extra day).

3.1.2 Reference

Kepler's Equation as described in "Foundation of Astrodynamics" by A.E. Rey.

3.1.3 ORBPER

Purpose: To calculate the approximate orbital period of a satellite given its state vector in cartesian coordinates.

Method: Kepler's Laws for two-body motion are used to find the semi-major axis of the orbit and then its approximate period. MKS units are used in the subroutine.

References: 'Foundations of Astrodynamics' by A. Roy

Figure 3.1 shows the ORBPER data flow

3.2 SUN/EARTH DISTANCE

A cosine polynomial function fitted to the sun/earth distance in the U.S. Nautical Almanac were used to determine this factor. Double precision computations using butchered Julian days is required to obtain a sufficiently accurate correction factor.

Reference: Kepler's equation is described in "Foundation of Astrodynamics" by A.E. Rey.

3.2.1 CALEND

Purpose: To convert butchered Julian dates to calendar dates and times. January 1, 1978 @ 0000Z = Day 0.0.

Method: Use as a reference day, calendar date January 1, 1904 = Julian day 2416481 and compute number days since then. The fraction leftover can be converted to time.

Reference: None

Figure 3.2 shows the CALEND data flow.

ORIGINAL PAGE IS OF POOR QUALITY

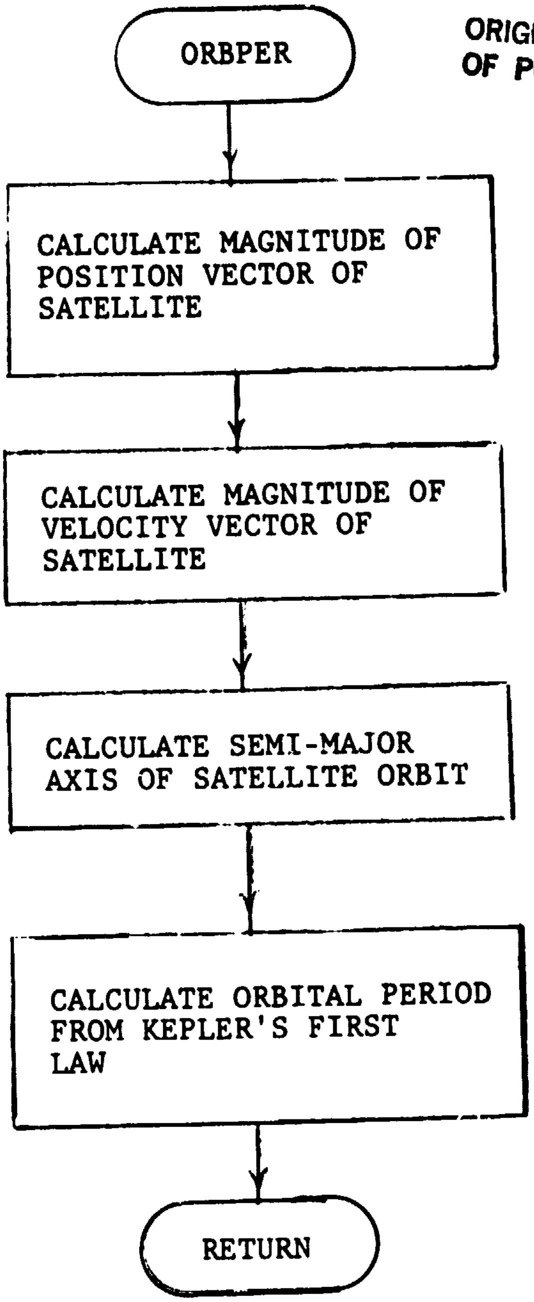


FIGURE 3.1 ORBPER Data Flow Chart (MATGEN 1.5.2)

ORIGINAL PAGE IS
OF POOR QUALITY

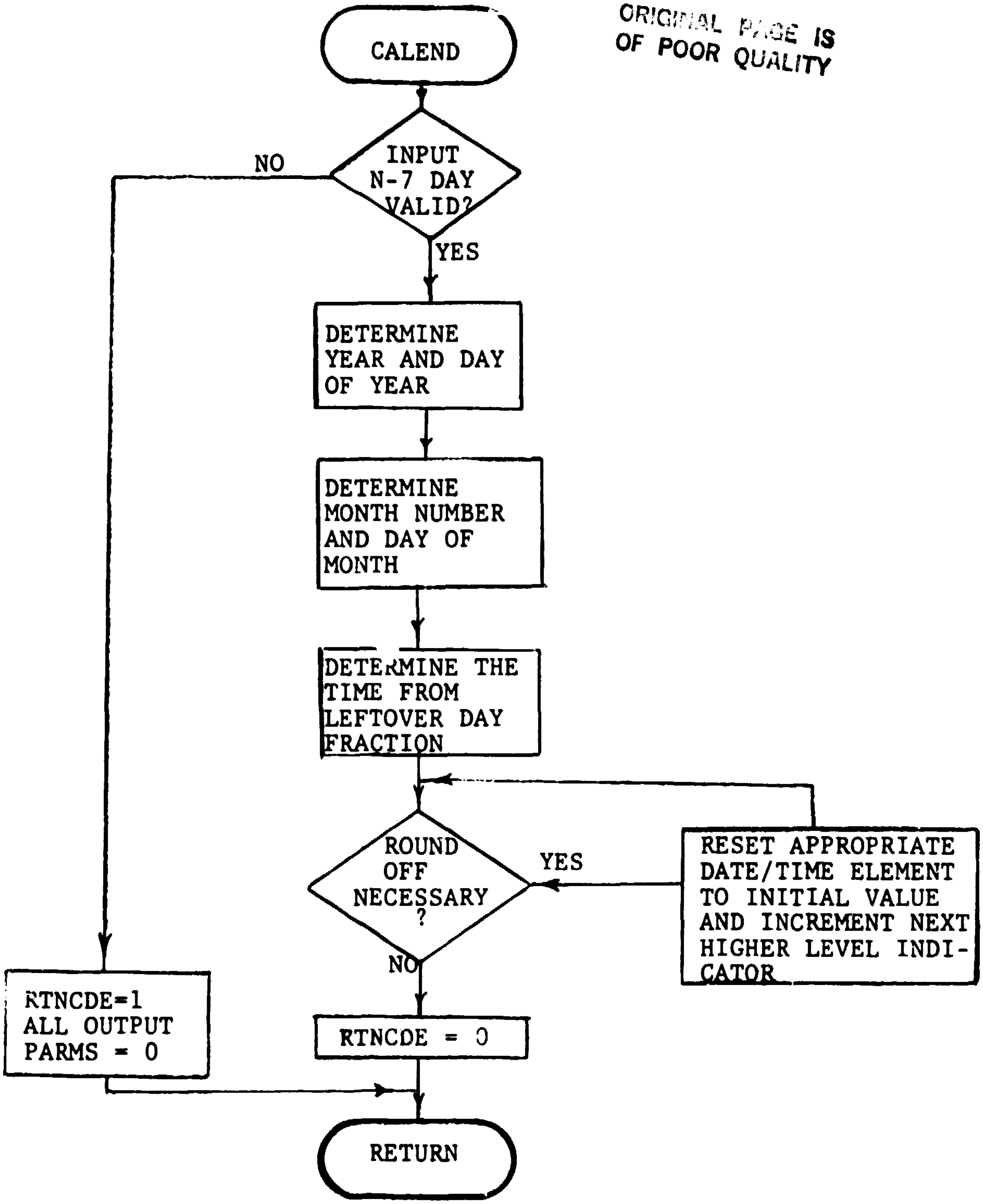


FIGURE 3.2 CALEND Data Flow Chart (MATGEN 3.1)

3.2.2 REAL*8 SUNDIS

Purpose: To compute the sun-earth distance given the time in Nimbus-7 modified Julian days (MJD).

Method:
(1) Compute mean anomaly (MA) and eccentricity (E).
(2) Compute eccentric anomaly (EA) from MA, and E.
(3) Compute true anomaly (TA) from EA and E.
(4) Compute SUNDIS from TA and E.

The exact earth sun distance variation as a function of time was required to determine a reference distance to which all of the ERB solar measured fluxes could be referenced.

References: Tom Von Flandern, U.S. Naval Observatory

Restrictions: The numbers published in the nautrical almanac may change over time. The numbers present are valid in the 1979 Almanac. It would be advisable to check the accuracy every couple of years. The claimed precision of the parent routine (SUNLOC) is RMS error = 0.000303, maximum error = 0.0000658.

Figure 3.3 shows the SUNDIS data flow.

3.2.3 MINSEL

Purpose: Estimate the time of the next minimum solar elevation for the first orbit of a MATGEN run. MINSEL also calls the subroutine which computes the orbital period.

Method: Maximum and minimum solar elevation for an orbit occurs when the Z component of the spacecraft velocity is zero. Given the cartesian orbital elements at a particular time the corresponding Keplerian elements are computed, and the orbits eccentric anomaly when Z DOT = 0 is computed. Using Kepler's equation for the two body orbit for this eccentric anomaly, the resulting mean anomaly, and thus the time is computed.

Whether the computed time is for the maximum or minimum solar elevation is determined from the position of the satellite.

Figure 3.4 shows the MINSEL data flow.

ORIGINAL PAGE IS
OF POOR QUALITY

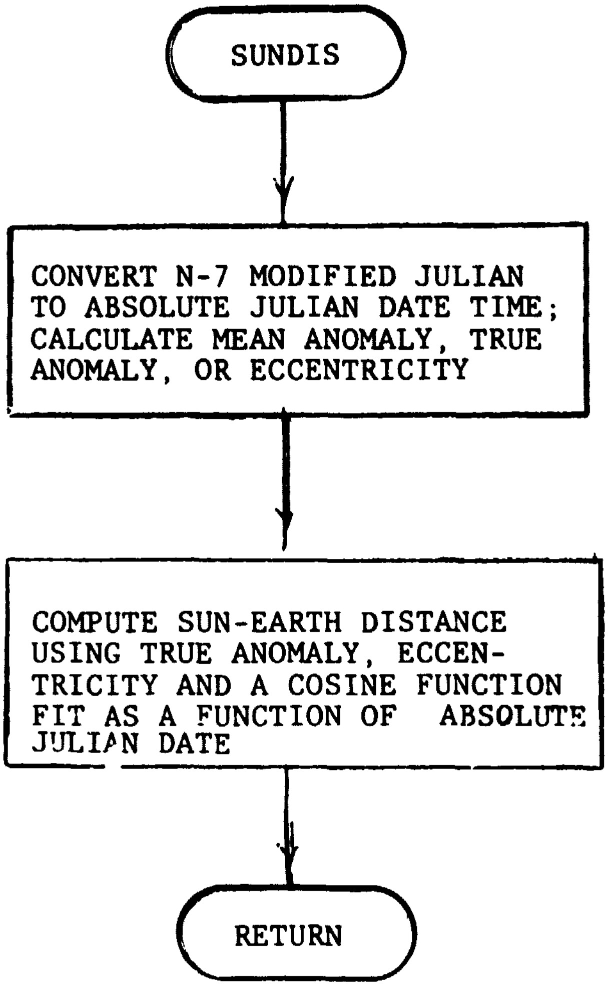


FIGURE 3.3 SUNDIS Data Flow (MATGEN 6.2.7)

ORIGINAL PAGE IS
OF POOR QUALITY

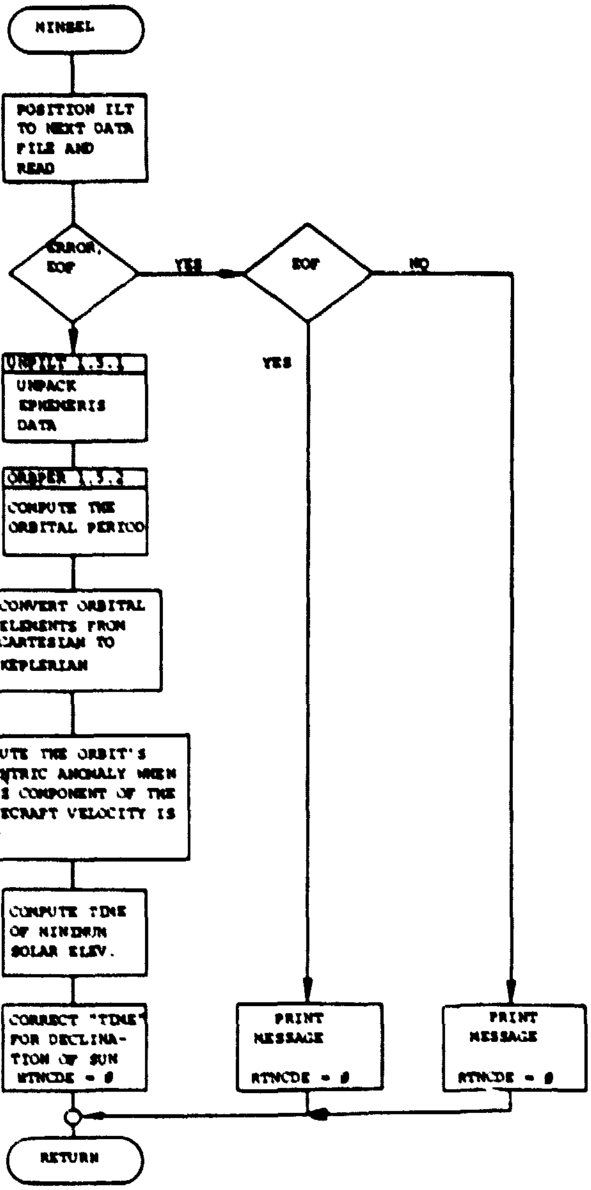


FIGURE 3.4 MINSEL Data Flow (MATGEN 1.5)

4.0 SENSOR STATUS, TEMPERATURES AND HOUSEKEEPING

Both sensor and data status information and data processing algorithms have been extensively used in ERB. Status information is therefore spread throughout the data handling system.

Temperature information in many cases was measured and transmitted from Nimbus every few seconds. The vast quantity of temperature data have made it essential that much of it be averaged in data reduction. Regression curve fitting using experimental data was used to convert the counts to temperatures.

One often thinks of data manipulation as a form of housekeeping. As will be noted in Appendix B there are more of these type subroutines than data reduction routines. A brief description of each is contained in this Appendix.

4.1 ERB STATUS DETERMINATION

4.1.1 Introduction

A considerable number of sensor status measurements have been built into the ERB. The resultant information is periodically monitored and transmitted to the ground station. In addition, the data flow is monitored and one bit flags are generated when the data do not meet quantity control requirements.

The location of this status information in the data, its characteristics and meaning are indicated in this section.

4.1.2 Reference

All of the data status information is contained in the Gulton (revised 1975) report. The equations are given in Soule (1983).

4.1.3 Status Details

The instrument functional requirements document gives the ERB instrument status. These instrument status words are principally in the Digital A Table.

There are eight odd digital words located in Column 24 of the Digital A format. These eight words are status words and each bit of each word indicates unique instrument status. The status for each of these bits is defined in Table 2.1 through 2.7.

4.1.4 STATUS

Purpose: To determine the ERB status for one major frame.

Method: From "Digital Words" input, key command verification words are determined which indicate the status of the ERB instrument. Important status is described in the coded decimal integer returned via the calling sequence.

References:

Science and Applications Computing Center User's Guide. Preliminary Edition. December 1975. NASA-GSFC. Greenbelt, Maryland.

Figure 4.1 shows STATUS data flow.

4.2 TEMPERATURE DATA CONVERSION

4.2.1 Introduction

The importance of temperature measurement is indicated by the fact that almost half of the Digital A data record consists of temperature counts. Very high accuracy temperature measurements were made on internal calibration target areas and certain sensors. These measurements were made with balanced circuits using platinum resistance temperature sensors. Polynominals were used to accurately curve fit the data counts to laboratory measured temperatures.

4.2.2 References

Ardanuy, P., (1981), Estimate of the Effect of PTM coefficient errors on the Nimbus-7 Radiance and Irradiance measurements. Contract NAS 5-26123, Task 1.

4.2.3 Temperature Count Conversion

Both platinum resistance temperature sensors and thermistors were used to measure a large number of component temperatures on ERB-6 and 7. Individual calibration of the platinum resistance sensors provided accuracies requiring a power series and coefficients for each unit, to duplicate. A single set of coefficients was used in a power series for both the ERB-6 and 7 thermistors.

4.2.3.1 Platinum Resistance Equations and Coefficients

To convert Digital PTM Output to Temperature (Celsius) (PTM = Platinum Temperature Monitor) the following equation from reference 4 was used:

ORIGINAL PAGE IS
OF POOR QUALITY

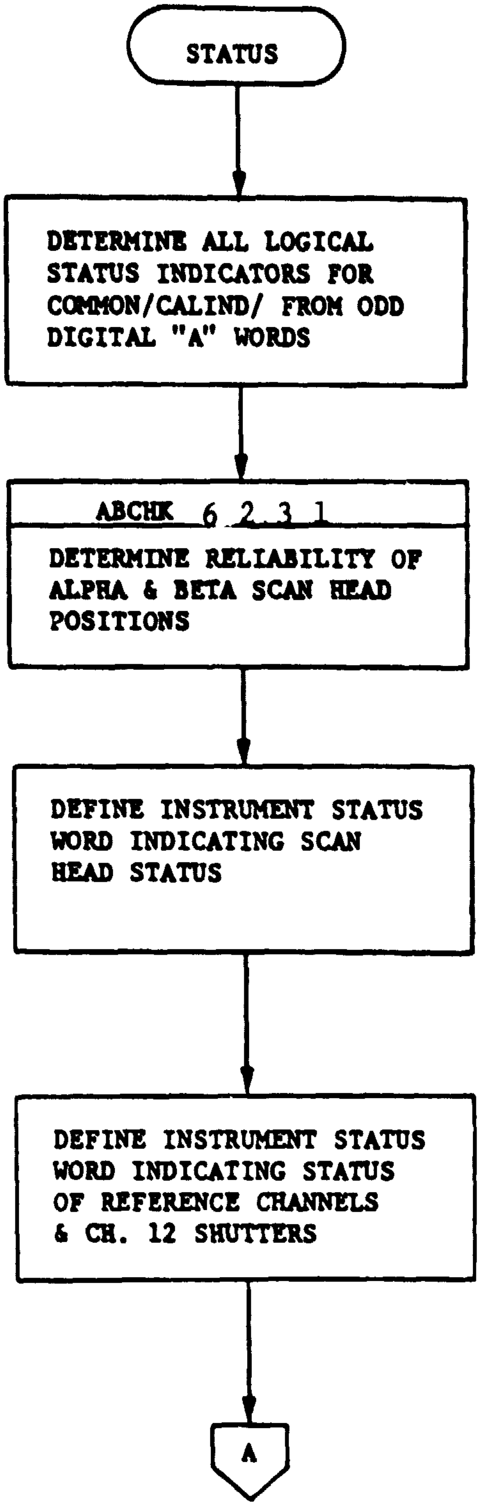


FIGURE 4.1 STATUS Data Flow (MATGEN 6.2.3)

ORIGINAL PAGE IS
OF POOR Q

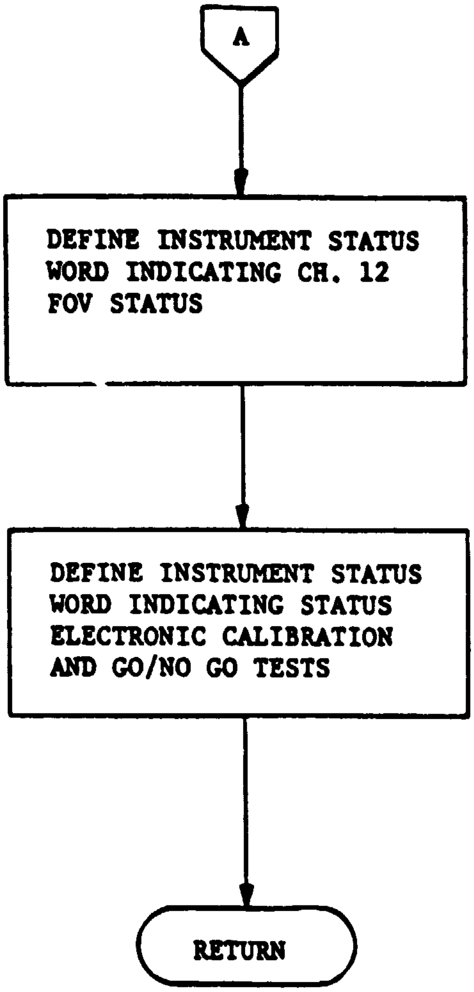


FIGURE 4.1 (CONTINUED)

ORIGINAL PAGE IS
OF POOR QUALITY

$$T = \sum_{i=0}^{5} C_i^{(n)} R^i \qquad (4.1)$$

$C_i^{(n)}$ = calibration coefficients (i = 0, 1...,5) for PTM no. N

$$R_T = \frac{V_p - V_N}{|V_{EP} + V_{EN}| + 2048} \qquad (4.2)$$

V_P = PTM output voltage (counts) in positive mode
V_N = PTM output voltage (counts) in negative mode
V_{EP} = PTM excitation voltage (counts) in positive mode
V_{EN} = PTM excitation voltage (counts) in negative mode

These voltages are transformed to counts using this equation. The PTM volts which are in the numerator of the equation must be transformed with an 11 bit conversion of 204.7 counts per volt, while the excitation voltages in the denominator of the equation are transformed with a 10 bit resolution of 102.3 counts per volt.

Where

V_{PP} = positive PTM voltage
V_{PN} = negative PTM voltage
V_{EP} = positive excitation voltage
V_{EN} = negative excitation voltage

Note that the numerator is the algebraic difference of the actual voltages and not of their absolute values, whereas the excitation voltages are added according to their absolute values. Since this equation is the equivalent of the previous one used in the ERB data reduction, it follows that the algebraic difference of the counts is used in the numerator while the absolute value of the excitation counts is used in the denomonator. The numerator count sign values are found in a separate box in the digital A major frame format.

(a) The following constants were used to convert the ERB-7 platinum resistance counts to temperatures (°C).

ORIGINAL PAGE IS
OF POOR QUALITY

For ERB-6:

The coefficients for ERB-7 ERBMAT are:

```
PTMCO/-0.11159, 43.704, 3.97491, 0.12585, 0.3106, 0., Channel 11 Module
      -0.11159, 43.704, 3.97491, 0.12585, 0.3106, 0.,    "    12    "
      -0.11159, 43.704, 3.97491, 0.12585, 0.3106, 0.,    "    19    "
      -0.11159, 43,704, 3.97491, 0.12585, 0.3106, 0.,    "    20    "
      -0.11159, 43.704, 3.97491, 0.12585, 0.3106, 0.,    "    21    "
      -0.11159, 43.704, 3.97491, 0.12585, 0.3106, 0.,    "    22    "
      -0.11159, 43.704, 3.97491, 0.12585, 0.3106, 0.,    "    19 Internal BB
      -0.11159, 43.704, 3.97491, 0.12585, 0.3106, 0.,    "    20    "
      -0.11159, 43.704, 3.97491, 0.12585, 0.3106, 0.,    "    21    "
      -0.11159, 43.704, 3.97491, 0.12585, 0.3106, 0.,    "    22    "
```

$$R = \begin{matrix} 1.15 \times 10^4 \text{ if ICKT} = 1 \\ 1.30 \times 10^4 \text{ if ICKT} = 2 \end{matrix}$$

NOTES:
(a) ICKT = 1 for all TM's except: 55,58,59,60,71,72
(b) If IE_0 1 or 1023, TC = 999.9
(c) If x - 0, TC = 999.9

NPTM-I*4 - Platinum temperature monitor indicator.
NPTM= 1 for ch. 11 module
NPTM= 2 for ch. 12 module
NPTM= 3 for ch. 19 module
NPTM= 4 for ch. 20 module
NPTM= 5 for ch. 21 module
NPTM= 6 for ch. 22 module
NPTM= 7 for ch. 19 internal black body
NPTM= 8 for ch. 20 internal black body
NPTM= 9 for ch. 21 internal black body
NPTM= 10 for ch. 22 internal black body

4.3 SOFTWARE DATA FLOW

To implement these temperature equations MONTEMP was required to screen the raw data and determine whether it was within limits. IPTMT computed the PTM temperatures and TMTEMP computed the thermistor temperatures. The statistics of the temperatures was computed by subroutine HKSTS.

4.3.1 MONTMP

Purpose: To convert platinum temperature monitor (PTM) and thermistor monitor (TM) counts to temperatures for one major frame.

Method: PTM excitation counts are screened and function IPTMT is called to obtain scaled temperatures (Degrees C x 10) from them. These temperatures are then also screened. TM counts output and appropriate circuit parameters are passed to subroutine TMTEMP to obtain scaled temperatures (Degrees C x 10). Thermistor counts are compared with preset limits and if out-of-range, an out-of-limits counter is incremented and the temperature for these erroneous count is replaced by an average temperature for that thermistor.

References: None

As shown in Figure 4.3.1, M0NTMP uses IPTMT to convert the PTM values and the TMTEMP program to compute the thermistor temperatures.

4.3.2 IPTMT

Purpose: To compute platinum temperature monitor temperatures from output voltage counts and excitation voltage counts. Temperatures are in degrees Celsius x 10.

Method: Excitation voltage counts are checked for being within a very generous range. If not within this range, temperatures are assigned a default value of 9999 and execution returns to calling routine. If the output voltage counts are equal, the temperature is assigned an average, or rather an approximate value. Otherwise, the temperature calculation algorithm is executed.

References: P. Ardanuy, (1981), An estimate of the effect of platinum temperature monitor coefficient errors on the Nimbus-7 radiance and irradiance measurements.

Figure 4.3.2 shows the IPTMT flow.

4.3.3 Thermistor Equations and Coefficients

The equation and coefficients for both ERB-6 and 7 count conversion to temperatures are:

$$T(^{o}C) = (C_1 + C_2x + C_3x^3)^{-1} - 273.16 \qquad 4.3$$

ORIGINAL PAGE IS
OF POOR QUALITY

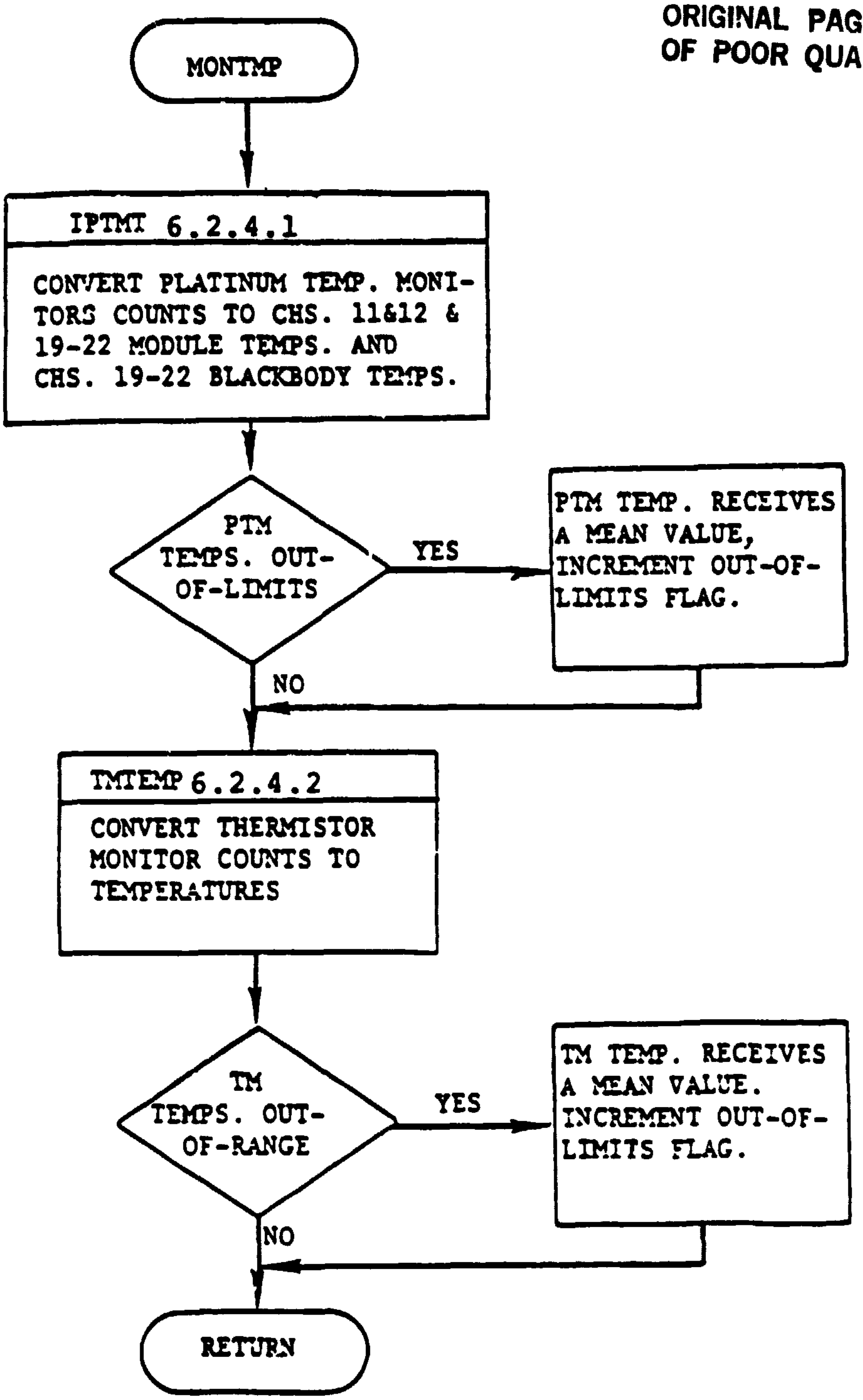


FIGURE 4.3.1 MONTMP Data Flow Chart (MATGEN 6.2.4)

ORIGINAL PAGE IS
OF POOR QUALITY

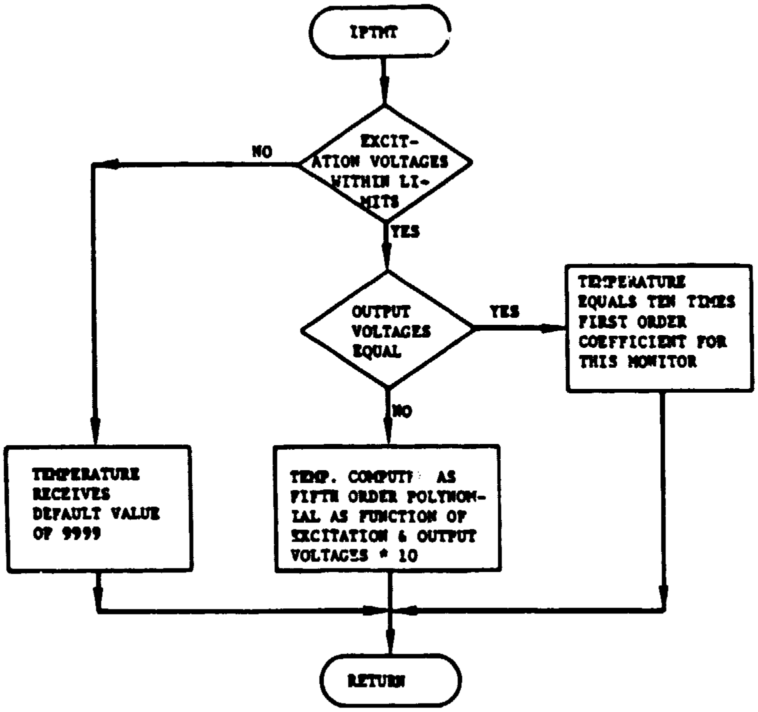


FIGURE 4.3.2 IPMT Flow Diagram (MATGEN 6.2.4.1)

ORIGINAL PAGE IS
OF POOR QUALITY

$$x = \ln\left(\frac{E_i R_2 - R}{E_o}\right)$$

4.4

$C_1 = 1.02433 \times 10^{-3}$

$C_2 = 2.40027 \times 10^{-4}$

$C_3 = 1.54612 \times 10^{-7}$

$E_i = 15.0$ volts (input voltage)

$E_o + IE_o \times \frac{100}{1023.}$ (thermistor output voltage)

$R = 10000$

4.3.4 TMTEMP

Purpose: To compute thermistor monitor temperatures from output voltage counts and the circuit resistance. Temperatures returned are in degrees Celsius.

Method: Thermistor monitor counts are checked for being within a specified range. If not within this range, temperatures are assigned a default value of 999.9 and execution returns to calling routine. If within specified range, the circuit resistance is determined from the circuit type and the temperature calculation algorithm is executed. During the course of algorithm execution, if the natural logarithm of a non-positive number is attempted, a default value of 999.9 is again assigned to the thermistor monitor temperature.

References: None

COMMENTS:

All of these thermistors used a single averaged set of coefficients to determine the thermal temperatures. They were not calibrated in the manner the platinum resistance units were supposed to have been calibrated.

Figure 4.3.3 shows the TMTEMP data flow.

ORIGINAL PAGE IS
OF POOR QUALITY

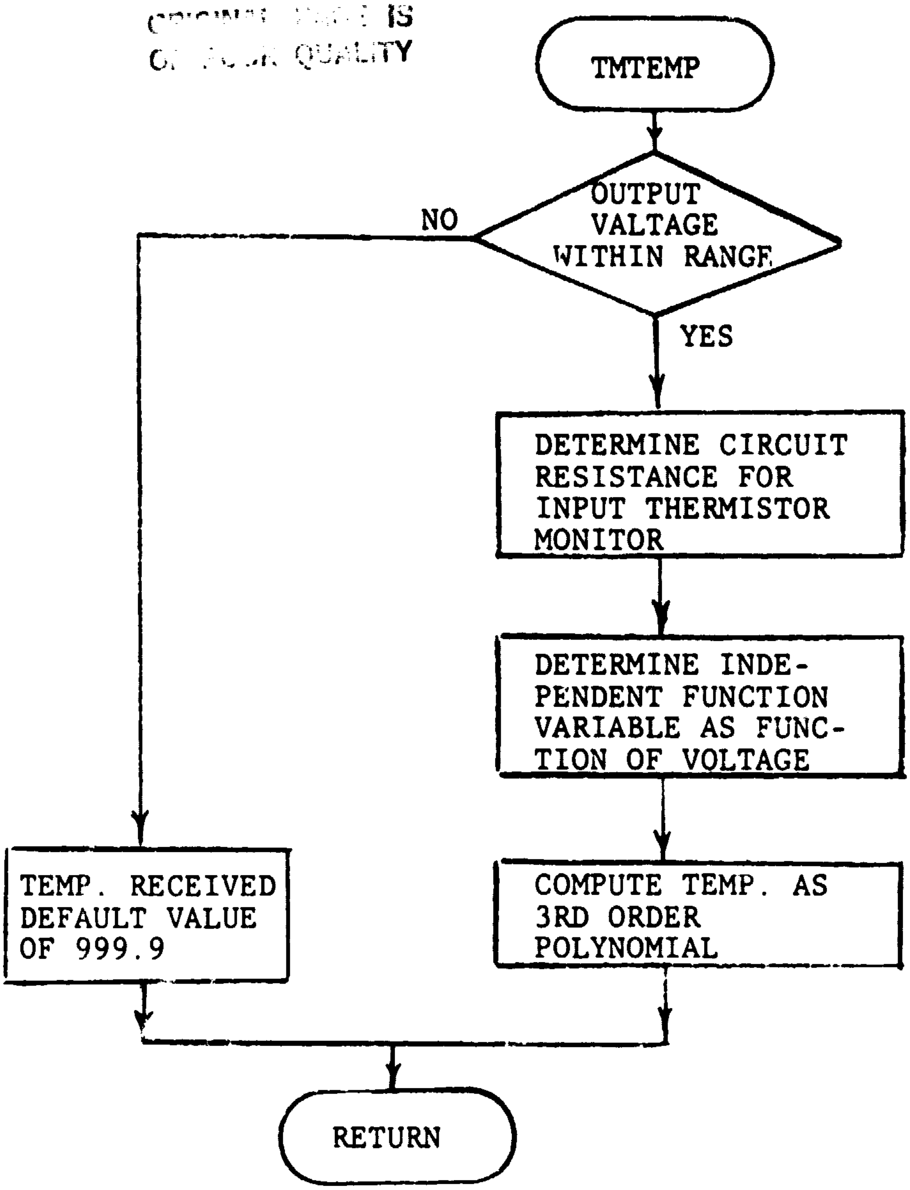


FIGURE 4.3.3 TMTEMP Data Flow Chart (MATGEN 6.2.4.2)

4.3.5 HKSTS

Purpose: To compute statistics for the ERB instrument temperatures.

Method: Subroutine RSTATS is used to update the statistics for groups of thermistors and platinum temperature monitors.

Reference: Subroutine HKSTS from Nimbus-6 software

Figure 4.3.4 shows the HKSTS data flow.

4.4 HOUSEKEEPING

ERB INGEST MAIN PROGRAM

Purpose: To process NIMBUS-7 ERB data

Method: ERB instrument measurements are read from the UFO tape and spacecraft ephemereris and time correction information is read from the ILT. For each 16 seconds of ERB data (one VIP major frame) the data from the two tapes are matched and quality screened. The locations on the earth where the instruments are pointing are found, and the instrument counts are converted to irradiances. Statistics for special operating modes are kept. The output data are written onto the MAT.

Figure 4.3.5 shows the MAIN data flow.

ORIGINAL PAGE IS
OF POOR QUALITY

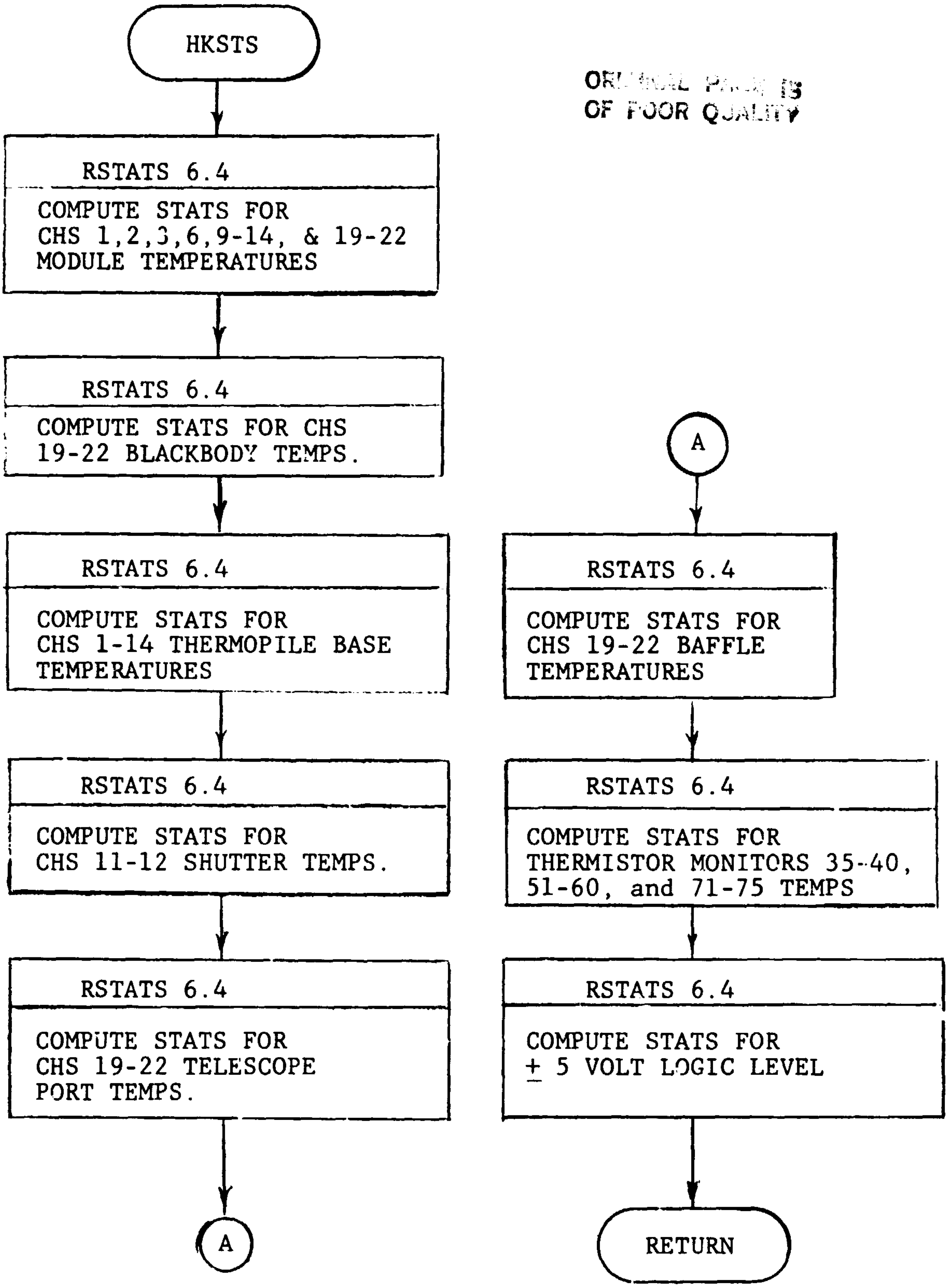
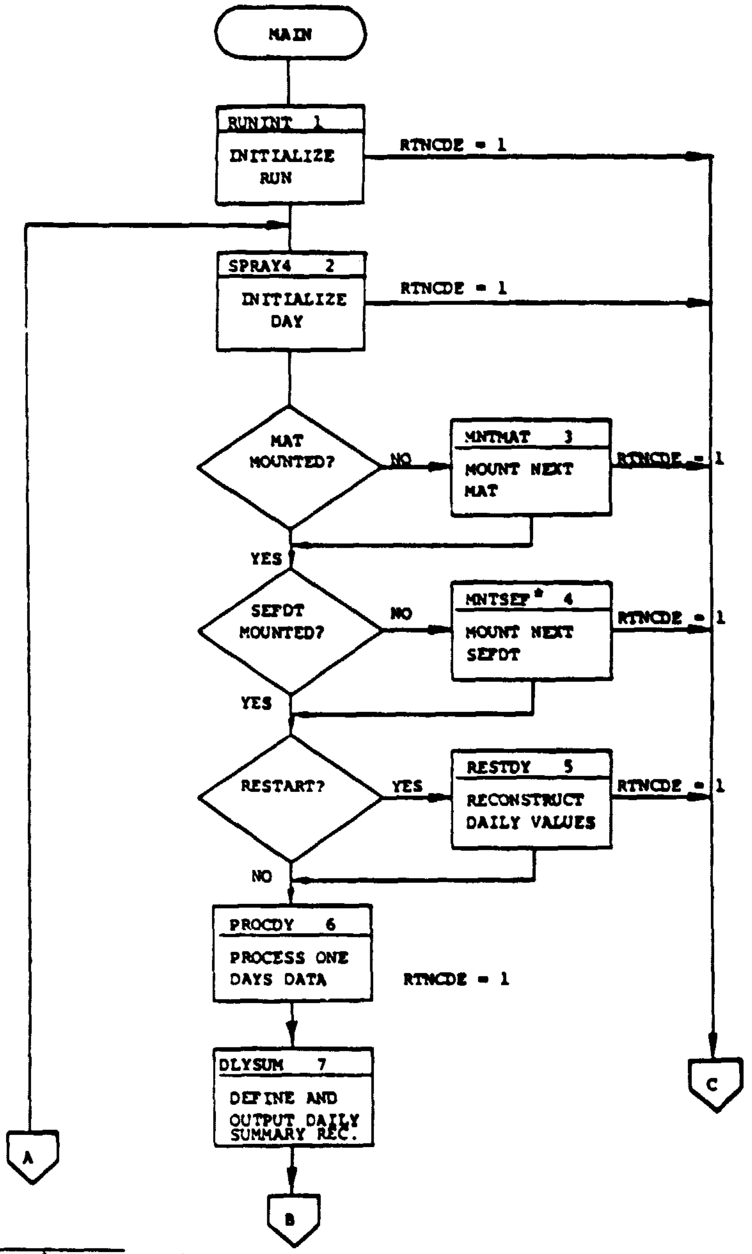


FIGURE 4.3.4 HKSTS Flow Diagram (MATGEN 6.2.5)

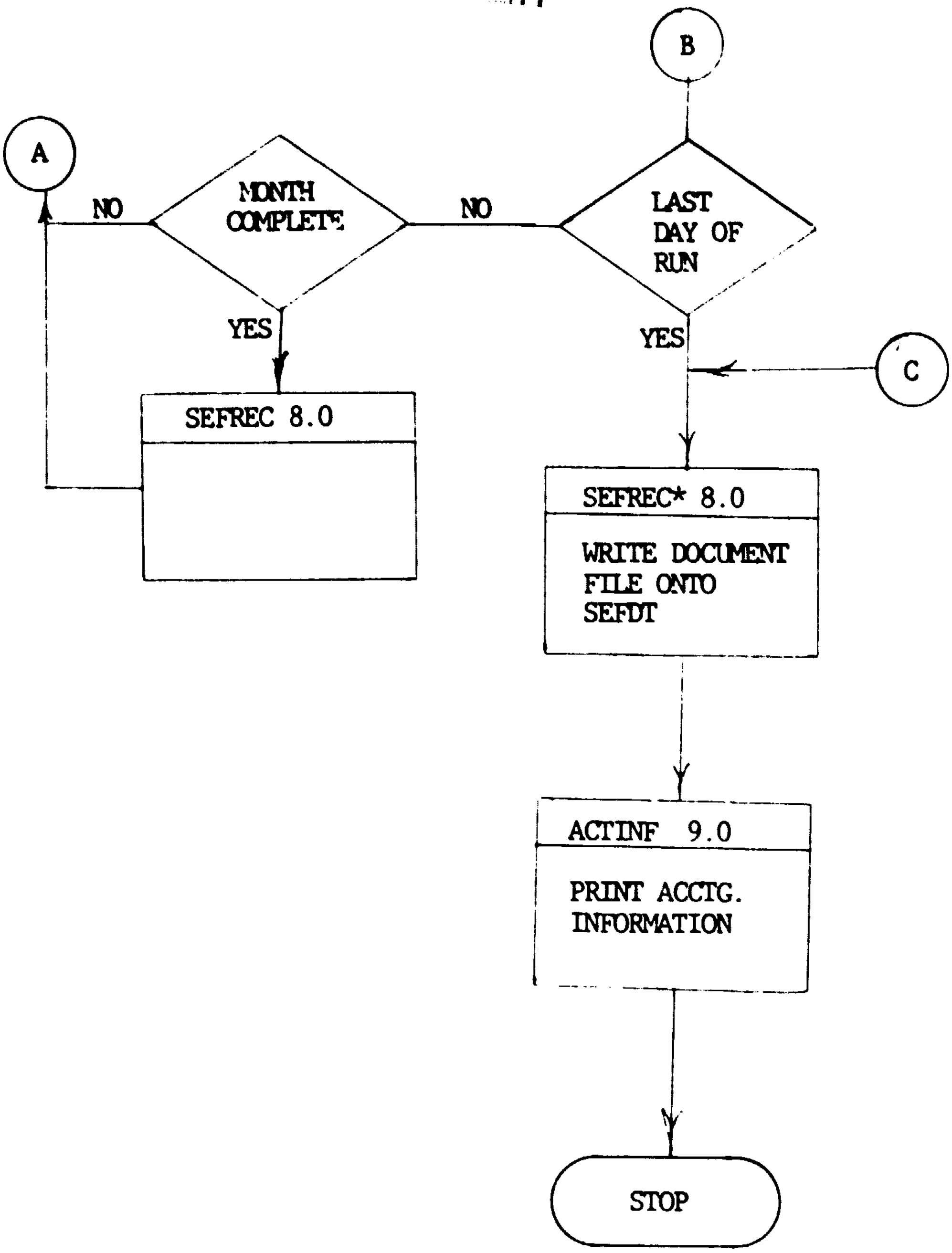
ORIGINAL PAGE IS
OF POOR QUALITY



*SEFDT no longer mounted.

FIGURE 4.3.5 MAIN Flow Diagram (ERB MATGEN)

ORIGINAL PAGE IS
OF POOR QUALITY



---

*No Data Written to SEFDT

FIGURE 4.3.5 (Continued)

5.0 LOCATION ALGORITHMS

5.1 INTRODUCTION

The following MATGEN subroutines determine the earth-location of the Nimbus-6/7 spacecraft (S/C) Sub-Satellite Point (SSP), the WFOV image centroid and the nine sub-target area centers from each of the four NFOV telescopes. Inputs to MATGEN include the Image Location Tape (ILT) and User Formatted Output (UFO's) tapes.

An individual ILT contains up to 7 days of data within a set of files, each containing up to a maximum of one orbit of data (104 minutes). Each physical data record contained within these files contains a maximum of 2 minutes 8 seconds of data (8 VIP frames) and contains all information necessary to locate data plus data quality loss interval information. (Data quality lost intervals are produced before or during Nimbus data telemetry and are indicated by start and stop times during which there are sync and/or bit losses rendering the data unusable).

The S/C ephemeris data is given at every integer GMT minute. Interpolation/extrapolation algorithms are used to alleviate the need for any ILT overlaps. For each minute of ILT data there exists the components of the S/C geocentric inertial position and velocity vectors.

The following information is also produced (Ref. 1):

- o GMT and S/C clock times
- o Solar right ascension and declination
- o SSP geocentric latitude and longitude
- o S/C altitude normal to the earth elliposid
- o Three components of the S/C attitude
- o Data quality loss start and stop times

When data are found to exist simultaneously within the ILT and UFO, MATGEN processes an appropriate set of major frames of data and writes them onto the Master Archival Tape (MAT). Within MATGEN, processing (location, calibration and computations) occurs on an orbit-by-orbit basis within subroutine PROCOR. Within this subroutine, processing occurs on a major frame-by-frame basis. For every major frame, three relevant subroutines are used. These are ORBSTS (which locates the SSP and the WFOV image centroid), LOCNDR (which locates the nine sub-target area centers from each of the four NFOV telescopes

ORIGINAL PAGE IS
OF POOR QUALITY

when the scanner is in "NADIR" mode) and PROSCN (which locates the nine subtargets area centers from each of the four NFOV telescopes when the scanner is in "SCAN" mode). Each of these three subroutines calls another subroutine LOCATR which incorporates the effects of S/C attitude onto the true Line of Sight (LOS) of the WFOV channels and NFOV telescopes. Another capability of this subroutine is the correction for the lateral spread of the four NFOV telescopes and their individual elevation deviations.

Having obtained, from the appropriate subroutine, the geocentric inertial position vector of the SSP or the WFOV and NFOV image points on the earth ellipsoid, the latitudes and longitudes in a geodetic fixed reference frame are obtained.

The algorithm employed by MATGEN is of the form:

$$\lambda = \tan^{-1}\left(\frac{y}{x} - h\right)$$

$$\varphi = \tan^{-1}\left(\frac{a^2}{b^2} \times \frac{z}{(x^2 + y^2)^{\frac{1}{2}}}\right)$$

Where:

λ	is the longitude
φ	is the latitude (geodetic)
a	is the equatorial earth radius
b	is the polar earth radius
h	is the Greenwich hour angle
x	is the first inertial geocentric position vector component
y	is the second inertial geocentric position vector component
z	is the third inertial geocentric position vector component

5.1.1 References

1. Nimbus-7 Nimbus Operation Processing System, Requirements Document #NG-14, Tape Spec. No. T123044 ERB-ILT, ERB Image Location Tape, 1977.

2. Nimbus-7 Nimbus Observation Processing Systems, Requirements Doc. #NG-1, Tape Spec. No. T113011 ERB-UFO, ERB User Formatted Output, 1977.

3. MATGEN Source Code, Version 9, Subroutines ORBSTS, LOCNDR and PROSCN.
4. Memorandum from 415/9/NOPS Manager for Distribution regarding "Nimbus-7 Image Location Tapes (ILT's) for the First Year in Orbit), November 24, 1980.
5. Data Validation of ERB-7 MAT Data, November, December 1978, January, February 1979 Results, prepared for Goddard Space Flight Center, NASA by Research and Data Systems, Inc.

5.2 ERB TIME, POSITION AND ANGLE COMPUTATIONS

The nature of the solar data made it important that the exact time in "butchered" Julian days be determined. Unfortunately Julian day accuracies have been a problem for a variety of reasons. For some data this time was needed to double precision accuracy.

In Appendix A is given the manner in which the DSAS hardware operates and the solar angles determined. Although these algorithms are not in MATGEN, they are used in the solar data work and are not readily available elsewhere.

5.2.1 Earth Location Algorithms

The earth location of the field of view of the Nimbus-7 ERB sensors in the MATGEN program is determined by calculating the intersection point between the vector representing the ERB field-of-view and the earth's surface. Geometric identification of the vectors and coordinate system used in this section are given in Figures 5.1 and 5.2. John Kogut provided the equations in this section.

To compute the earth location of the field-of-view at any specified time, the following parameters are required:

Spacecraft position vector ($\vec{X}$) in Earth Centered Inertial (ECI) coordinates.

Spacecraft velocity vector ($\vec{V}$) in ECI (Figure 5.1).

Spacecraft attitude angles Roll (R), Pitch (P), and Yaw (Y) in the spacecraft coordinate system (Figure 5.2).

The direction cosines for the field-of-view vector (scan angles) in the spacecraft coordinate system α, β, and μ

The Greenwich Hour angle at the specified time (Θ_g).

The values for the equatorial (ERAD), and polar (PRAD) radii of the earth.

ORIGINAL PAGE IS
OF POOR QUALITY

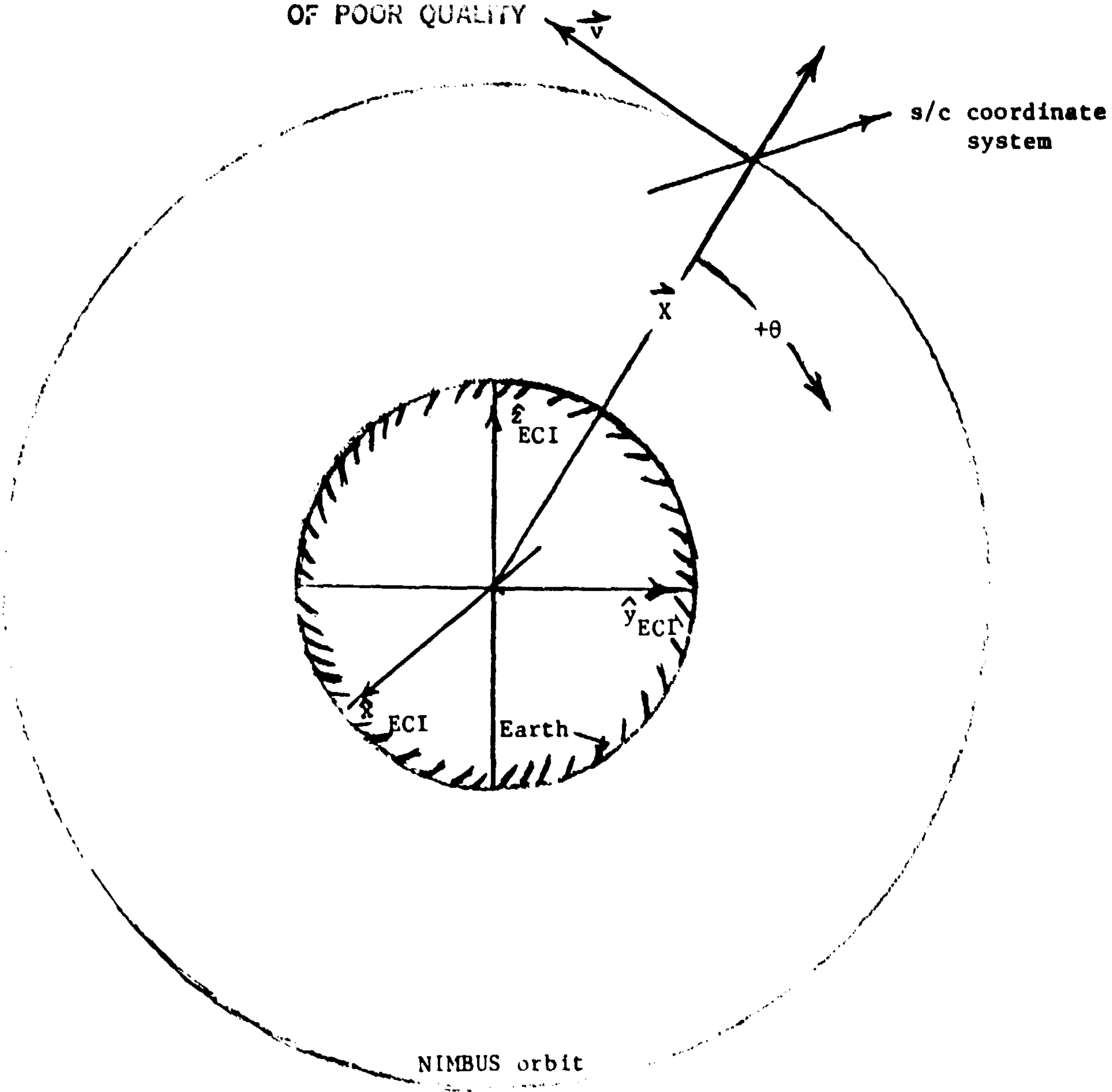
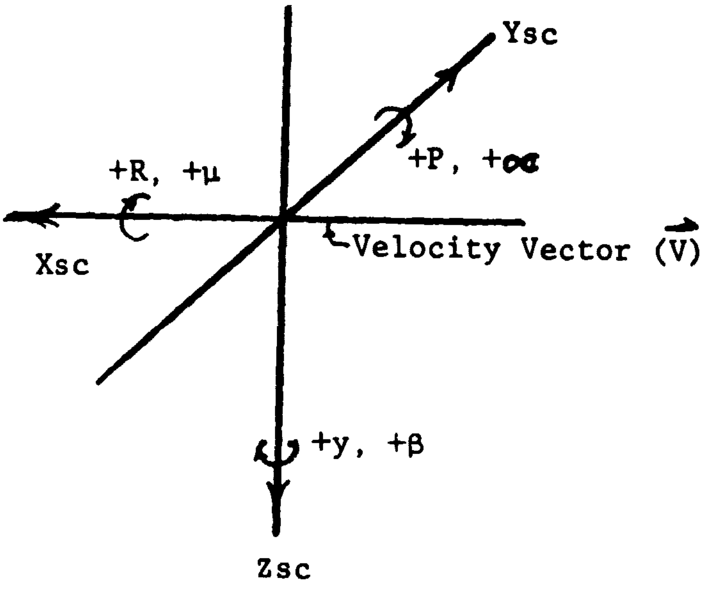


FIGURE 5.1 Spacecraft (S/C) Position and Velocity Vectors

ORIGINAL PAGE IS
OF POOR QUALITY



Attitude Angles R, P, Y

Field of view angles α, β, μ

FIGURE 5.2 Spacecraft Coordinate System

The earth location of the sensor field of view is specified by giving the Earth Centered Fixed geodetic latitudes and the longitude of the intersection point between the field-of-view vector and the surface of the earth.

In the spacecraft coordinate system the field-of-view unit vector $\hat{s}$ is initially along the Zsc axis, and thus produces the components (0,0,1). Rotating $\hat{s}$ about the appropriate axes by the field of view angles (α, β, μ) gives, $\hat{s}$ in the form:

$$s_x = \sin\alpha \cos\beta \cos\mu + \sin\beta \sin\mu \qquad 5.1$$

$$s_y = \sin\alpha \sin\beta \cos\mu - \cos\beta \sin\mu \qquad 5.2$$

$$s_z = \cos\alpha \cos\mu \qquad 5.3$$

To take into account the effect of the spacecraft attitude offsets form the rotation matrix $[A]$ from the roll, pitch and yaw angles. If

SR = sin R
CR = cos R
SP = sin P 5.4
CP = cos P
SY = sin Y
CY = cos Y

then the components of $[A]$ are:

A_{11} = CP·CY + SP·SR·SY
A_{12} = -CP·SY + SP·SR·CY
A_{13} = SP·CR
A_{21} = CR·SY
A_{22} = CR·CY 5.5
A_{23} = - SR
A_{31} = -SP·CY + CP·SR·SY
A_{32} = SP·SY + CP·SR·CY
A_{33} = CP·CR

Assuming the attitude correction angles are small, the small angle approximation can be used without compromising the desired accuracy of the final location. The field of view unit vector corrected for attitude S' then becomes:

$$S'_x = (CP\cdot CY + P\cdot R\cdot Y)\,S_x + (-CP.Y+P.R.CY)S_y+(P.R)S_z \qquad 5.6$$
$$S'_y = (CR\cdot Y)S_x + (CR\cdot CY)S_y + (-R)S_z \qquad 5.7$$
$$S'_z = (P\cdot CY + CP\cdot R\cdot Y))S_x + (P\cdot Y + CP\cdot R\cdot CY)S_x + (CP\cdot CR)\,S_z \qquad 5.8$$

ORIGINAL PAGE IS
OF POOR QUALITY

The field of view unit vector is transformed from the spacecraft coordinate system to the Earth Centered Inertial coordinate system. In this procedure the direction cosines between the spacecraft and ECI coordinate system are determined assuming that the z axis in the spacecraft coordinate system is normal to the earth ellipsoid so its components (Z_1, Z_2, Z_3) in ECI coordinates are:

$$Z_1 = -X_1 \qquad 5.9$$
$$Z_2 = -X_2$$

Z_3 is computed in the following manner:

$$e^2 = 1 - \left(\frac{PRAD}{ERAD}\right)^2$$

$$c = ERAD / |\vec{X}|$$

$$D = \tan^{-1} (X_3/(X_1^2 + X_2^2)^{\frac{1}{2}}$$

$$F = \frac{c}{2} \sin (2D) \qquad 5.10$$

$$G = (\tfrac{1}{2} - 2c) \sin^2 D + C$$

$$P = D + F e^2(1 + G e^2)$$

$$Z_3 = -\tan (P) (Z_1^2 + Z_2^2)^{\frac{1}{2}}$$

So the direction cosines for the Z axis are:

$$\vec{Z} = (Z_1^2 + Z_2^2 + Z_3^2)^{\frac{1}{2}}$$

$$D_{31} = Z_1 / |\vec{Z}| \qquad 5.11$$

$$D_{32} = Z_2 / |\vec{Z}|$$

$$D_{33} = Z_3 / |\vec{Z}|$$

The spacecraft y axis in ECI coordinates is calculated by crossing spacecraft Z axis with the velocity vector $\vec{V}$

$$y_1 = (Z_2 V_3 - Z_3 V_2)$$

$$y_2 = (Z_3 V_1 - Z_1 V_3) \qquad 5.12$$

$$y_3 = (Z_1 V_2 - Z_2 V_1)$$

$$|\vec{Y}| = (y_1{}^2 + y_2{}^2 + y_3{}^2)^{\frac{1}{2}} \qquad 5.13$$

ORIGINAL PAGE IS
OF POOR QUALITY

$$D_{21} = y_1 / |\vec{Y}|$$

$$D_{22} = y_2 / |\vec{Y}| \qquad 5.14$$

$$D_{23} = y_3 / |\vec{Y}|$$

The spacecraft x axis completes the right handed system so it is the y axis crossed with the Z axis

$$D_{11} = D_{22}\, D_{33} - D_{23}\, D_{32}$$

$$D_{12} = D_{23}\, D_{31} - D_{21}\, D_{33} \qquad 5.15$$

$$D_{13} = D_{21}\, D_{32} - D_{22}\, D_{31}$$

5.2.1.1 Field-of-View

Thus the field of view unit vector in ECI coordinates (SI) is:

$$SI_1 = D_{11}\, S_x' + D_{21}\, S_y' + D_{31}\, S_z'$$

$$SI_2 = D_{12}\, S_x' + D_{22}\, S_y' + D_{32}\, S_z' \qquad 5.16$$

$$SI_3 = D_{13}\, S_x' + D_{23}\, S_y' + D_{33}\, S_z'$$

To find the intersection point between this vector and the surface of the earth, represent the ellipsoid surface of the earth in parametric form as:

$$E(\mu_1, u_2) = \begin{pmatrix} ERAD \cos\mu_1 \cos u_2 \\ ERAD \sin\mu_1 \cos u_2 \\ PRAD \sin\mu_2 \end{pmatrix} \qquad 5.17$$

The parametric form of the line representing the field of view unit vector is:

$$L(\mu) = \vec{X} + \mu \widehat{SI} \qquad 5.18$$

solving for μ gives

$$\mu = \frac{-B - (B^2 - AC)^{\frac{1}{2}}}{A} \qquad 5.19$$

where

$$A = PRAD^2\,(SI_1{}^2 + SI_2{}^2) + ERAD^2\,(SI_3{}^2)$$

$$B = PRAD^2\,(x_1\, SI_1 + x_2\, SI_2) + ERAD^2\,(x_3\, SI_3) \qquad 5.20$$

$$C = PRAD^2\,(x_1{}^2 + x_2{}^2) + ERAD^2\,(s_3{}^2 - PRAD^2)$$

The field of view vector intersects the surface of the earth only when μ is a real number greater than 0.

The ECI vector which represents this intersection point is then:

$$\vec{I} = \vec{X} + \mu \widehat{S\ell} \qquad 5.21$$

5.2.1.2 Latitude and Longitude

The geodetic latitude ϕ, and longitude λ associated with this intersection point are then given by

$$\phi = \tan^{-1} \left(\frac{\mathrm{ERAD}^2}{\mathrm{PRAD}^2} \cdot \frac{I_3}{\left(I_1^2 + I_2^2 + I_3^2\right)^{1/2}} \right) \qquad 5.22$$

$$\lambda = \tan^{-1} (I_2/I_1) - \theta_g \qquad 5.23$$

5.3 BASIC LOCATION SUBROUTINES

To accomplish the tasks indicated in the introduction, Subroutines PROCOR, ORBSTS, LOCNDR, PROSCN and LOCATR are required. PROCOR primarily processes the earth observation channels and therefore was put in Section 6.0. The others operate in the following manner:

5.3.1 ORBSTS

Purpose: Update orbital parameters for a major frame. Spacecraft position, velocity, and attitude are updated for each half second during the major frame. The WFOV latitude and longitude, the subsatellite latitude and longitude, spacecraft altitude and solar right ascension are updated to 2, 6, 10 and 14 seconds from the beginning of the major frame. Solar declination, zenith angle, azimuth angle from the subsatellite track, and a flag telling if the subsatellite point is illuminated or not are updated to the middle of the major frame.

Method: Linear interpolation of scalars and vectors

Reference: None

Figure 5.3 indicates the ORBSTS data flow.

[illegible]
OF POOR QUALITY

ORIGINAL PAGE IS
OF POOR QUALITY

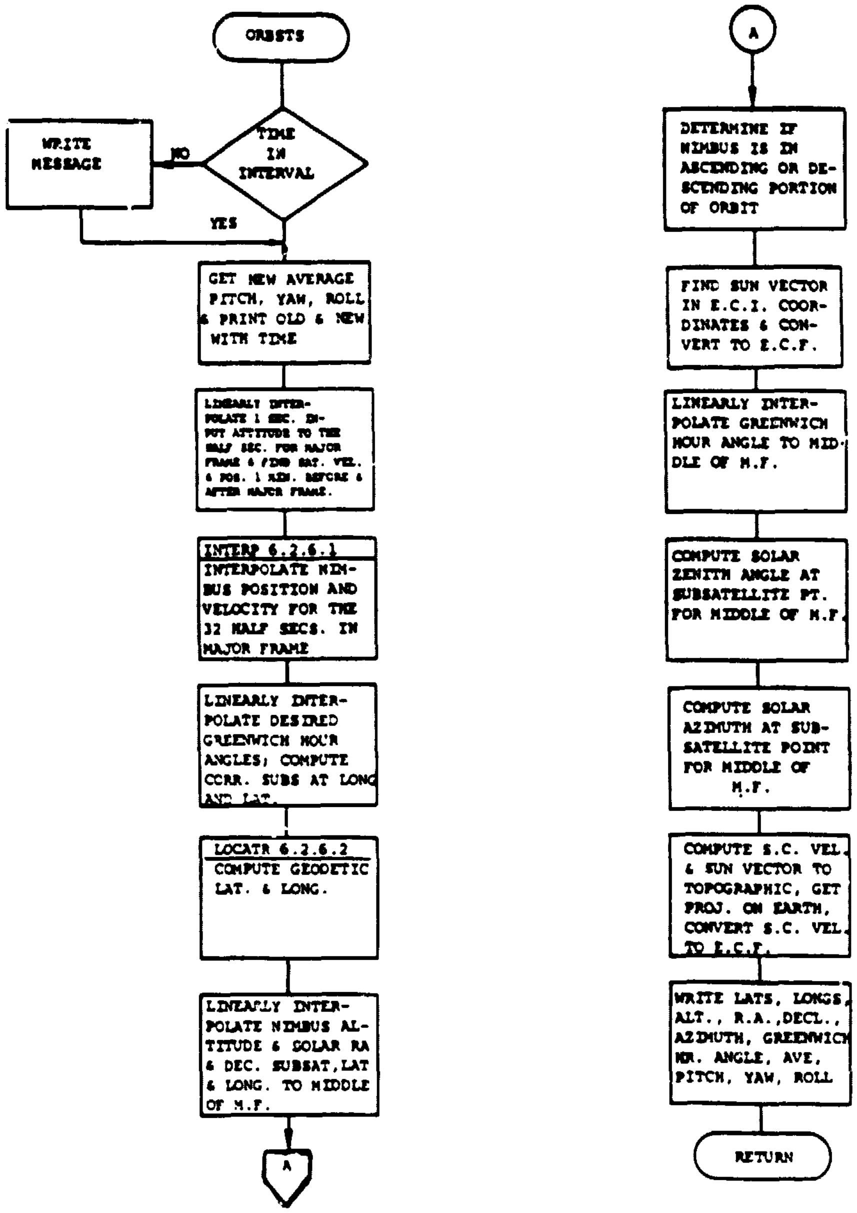


FIGURE 5.3 ORBSTS Data Flow Diagram (MATGEN 6.2.6)

5.3.2 LOCNDR

Purpose: To locate the field of view for the scanning channels when the instrument is in Nadir position.

Method: The four corners of the field of view for each scope are located each half second. Then the 9 sub-field of views are found by interpolation. The method is the same used in subroutine PROSCN.

Reference: None

Figure 5.4 gives LOCNDR data flow.

5.3.3 PROSCN

Purpose: To process scan information and scan error checks, to locate field-of-view subpoint latitudes and longitudes, and to update scan statistics for one major frame.

Method: If the instrument is determined to be scanning, subroutine ALFVFY and BETVFY are called to determine the number of scan errors for this major frame. The scan information word is constructed and then the statistics are updated for the scan modes. Latitudes and longitudes are determined for each of the four slopes of the nine field-of-view subpoints which occur every half second or 32 times in a major frame, giving 1152 locations. Statistics are then updated for the space scan counts and the gimbal slew rates.

Reference: None

Figure 5.5 shows the PROSCN data flow.

5.3.4 LOCATR

Purpose: Calculates the geodetic latitude and longitude which the ERB scanner views for given satellite position, velocity, pitch, roll, yaw, and scanner angles.

Method: This routine determines the scan vector in earth centered frame and finds the intersection of the scan vector with the surface of the earth. If they do not intersect, the latitude and longitude are filled.

Figure 5.6 shows the LOCATR data flow.

ORIGINAL PAGE IS
OF POOR QUALITY

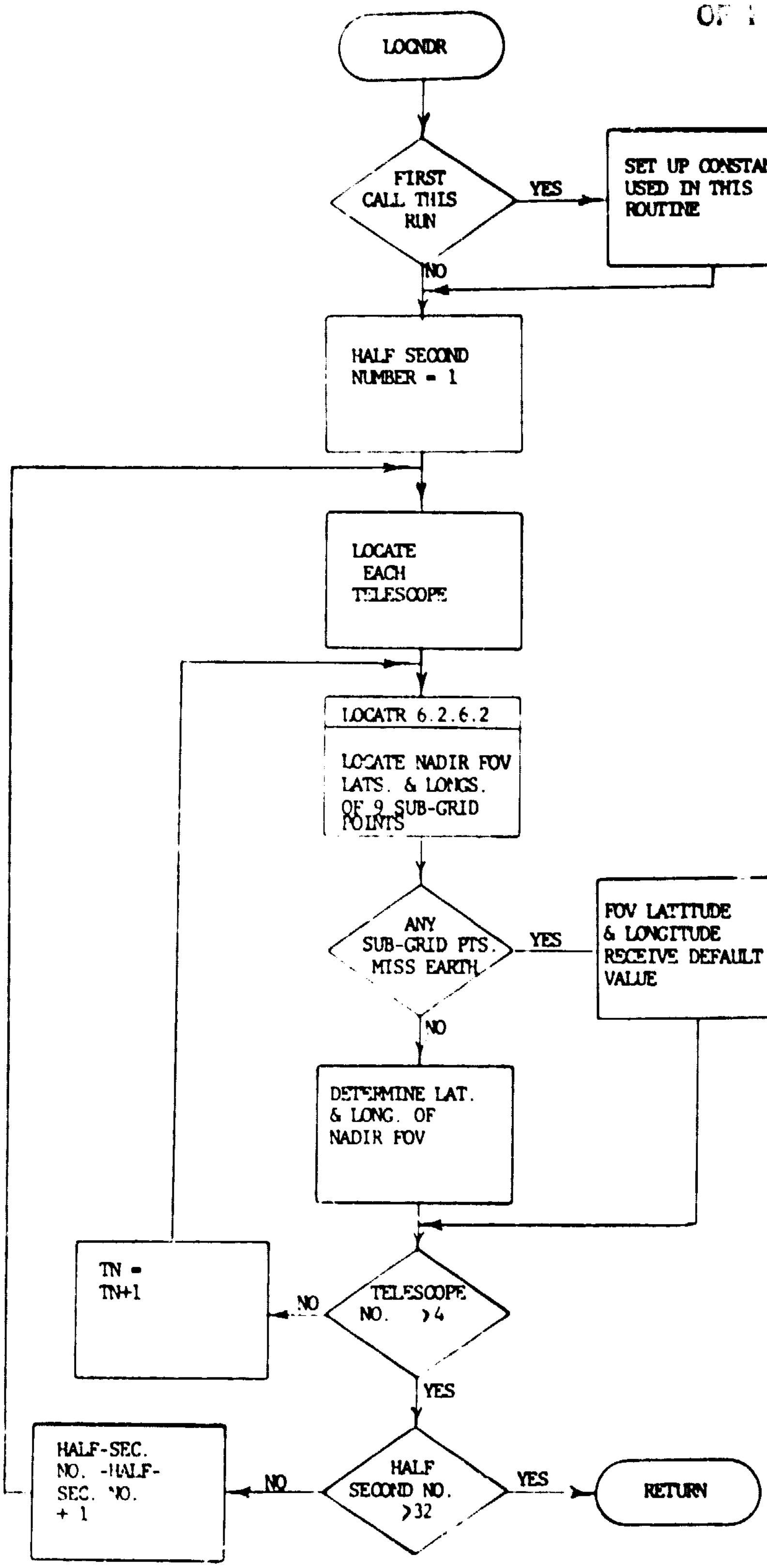


FIGURE 5.4 LOCNDR Flow Chart (MATGEN 6.2.8)

ORIGINAL PAGE IS
OF POOR [illegible]

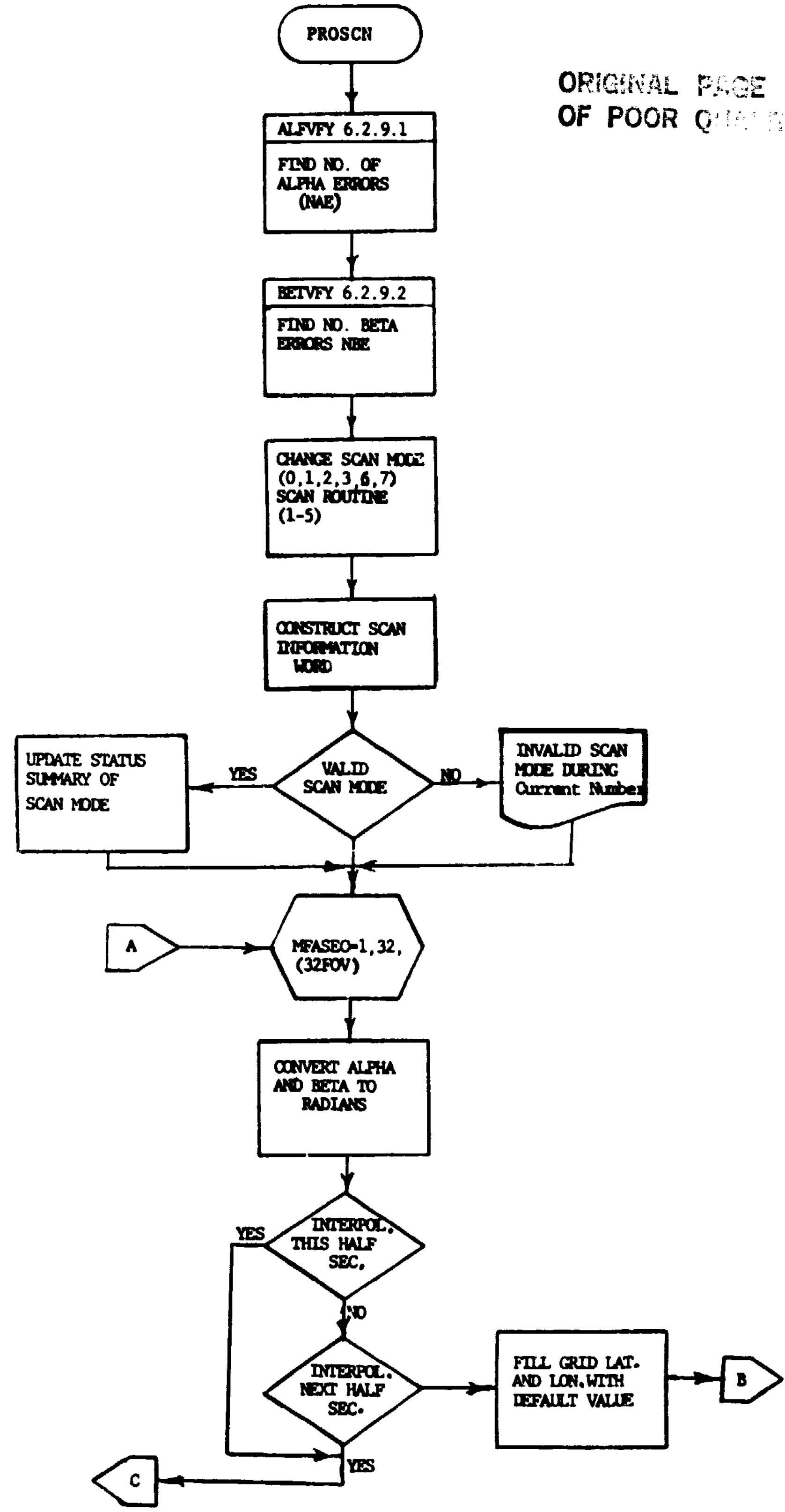


FIGURE 5.5 PROSCN Data Flow (MATGEN 6.2.9)

ORIGINAL PAGE IS
OF POOR QUALITY

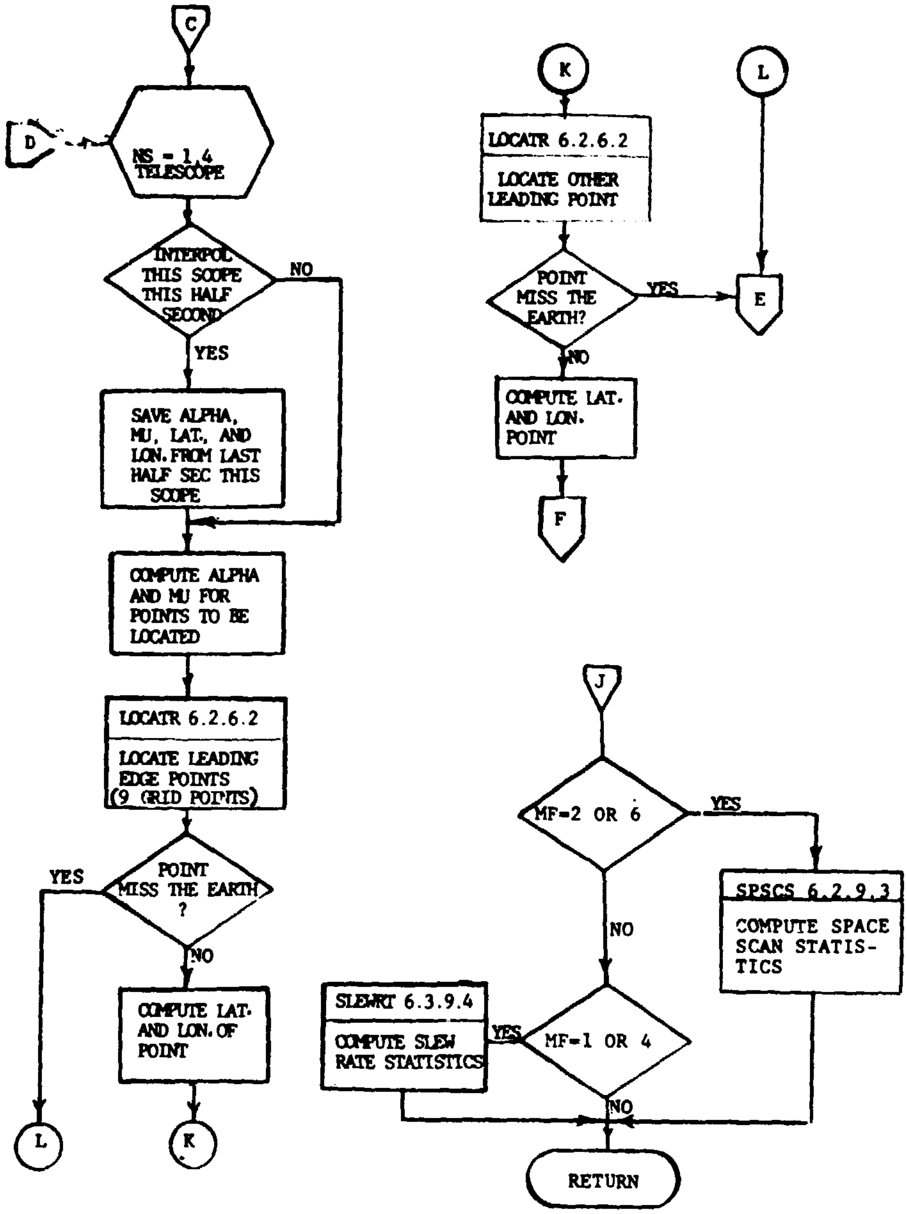


FIGURE 5.5 (CONTINUED)

ORIGINAL PAGE IS
OF POOR QUALITY

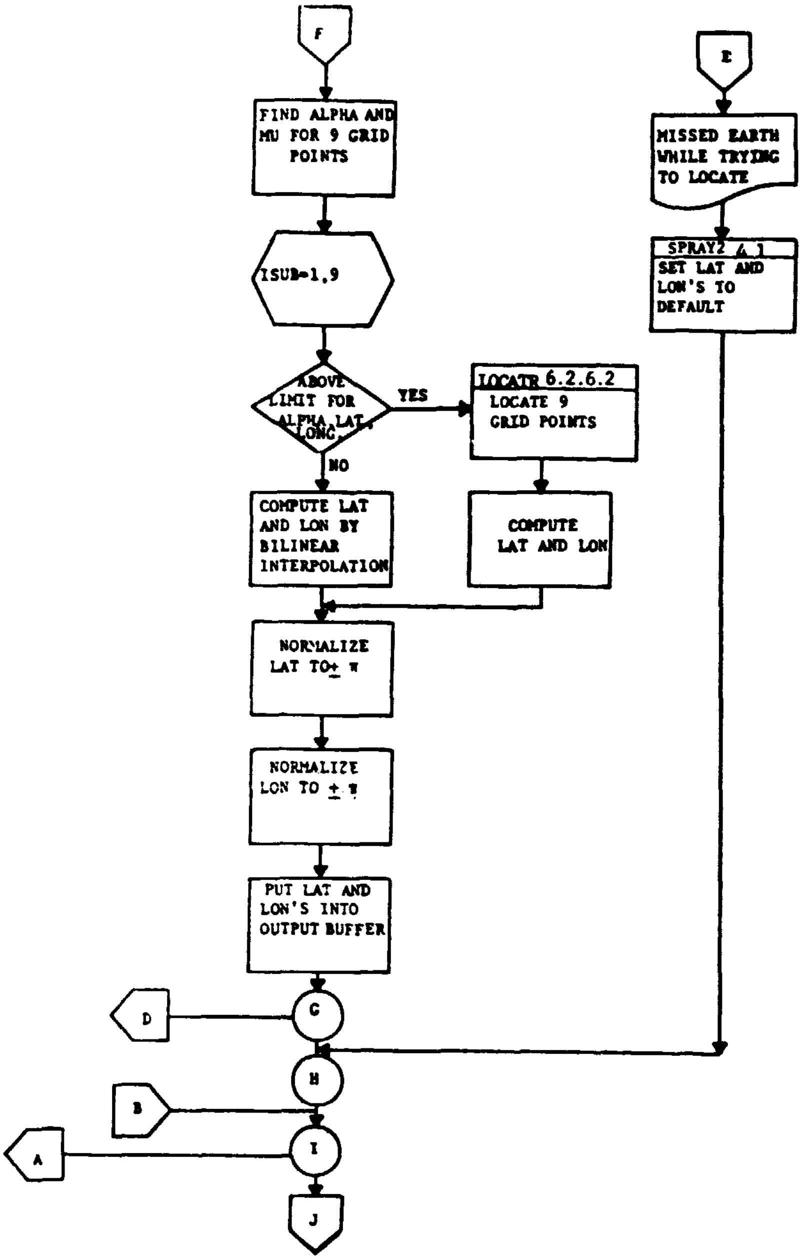


FIGURE 5.5 (CONTINUED)

ORIGINAL PAGE IS
OF POOR QUALITY

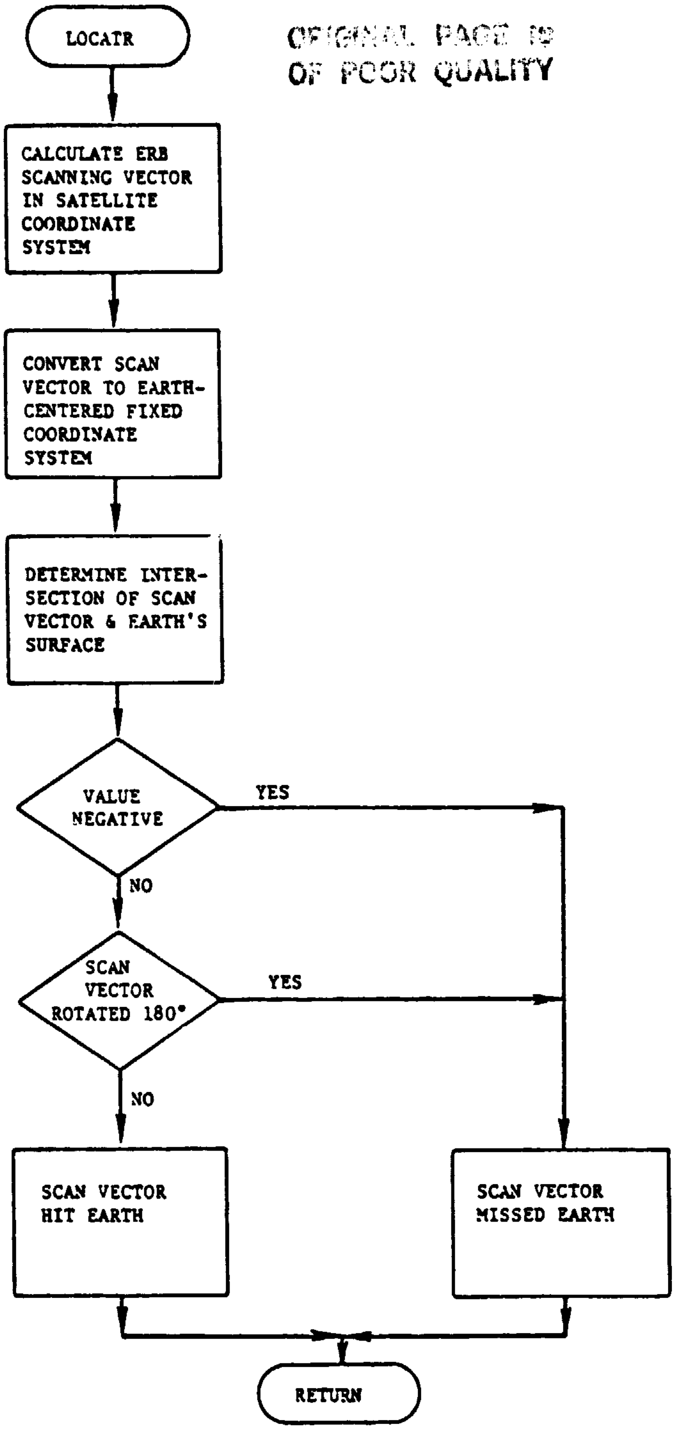


FIGURE 5.6 LOCATR Data Flow (MATGEN 6.2.6.2)

5.4 SUPPLEMENTAL SUBROUTINES

A number of routines are required to provide inputs to the section 5.2 basic location software. INTERP interpolates for the velocity vectors between computed vectors. The NFOV encoder angles (α) and (β) are verified by ALFVFY and BETVFY while the slew rate statistics are determined by SLEWRT.

5.4.1 INTERP

Purpose: Given the position and velocity vectors for the spacecraft at time T1 and T2, this subroutine linearly interpolates to find the spacecraft position and velocity at some intermediate time T.

Method: Using velocity vectors for two given positions and related times, incremental velocity vectors at incremented times were determined. This program is called R*8.

Figure 5.7 shows the INTERP data flow.

5.4.2 ALFVFY

Purpose: To verify that the alpha encoder positions are appropriate for the particular major frame.

Method: Using the major frame count, nominal alpha encoder positions are chosen. An initial value is taken from array "IVAL" and an increment is added on to produce more values. This increment is found in array "INC" and it is added on the number of times indicated in array "NINC". The number of different initial values in the major frame is known through array "NTVLS". These nominal values are tested against the actual alpha encoder positons. If there is more than a one encoder position difference, an alpha positon error counter is incremented, and the encoder value put in common /ASCAN/, which is used in the scanning. If a major frame is missing, a major frame error counter is incremented.

Figure 5.8 shows the ALFVFY data flow.

ORIGINAL PAGE IS
OF POOR QUALITY

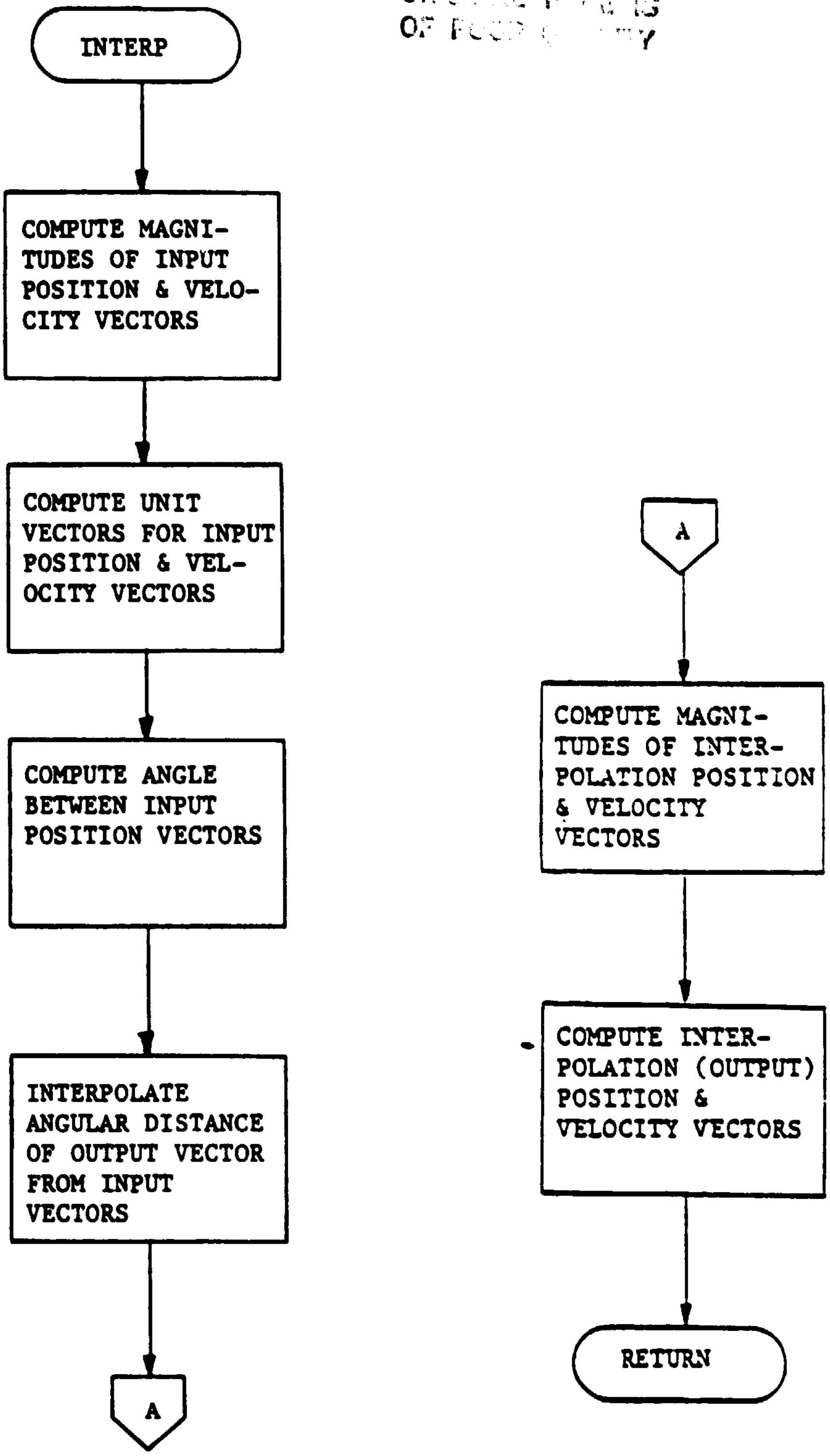


FIGURE 5.7 INTERP Flow Diagram (MATGEN 6.2.6.1)

ORIGINAL PAGE IS
OF POOR QUALITY

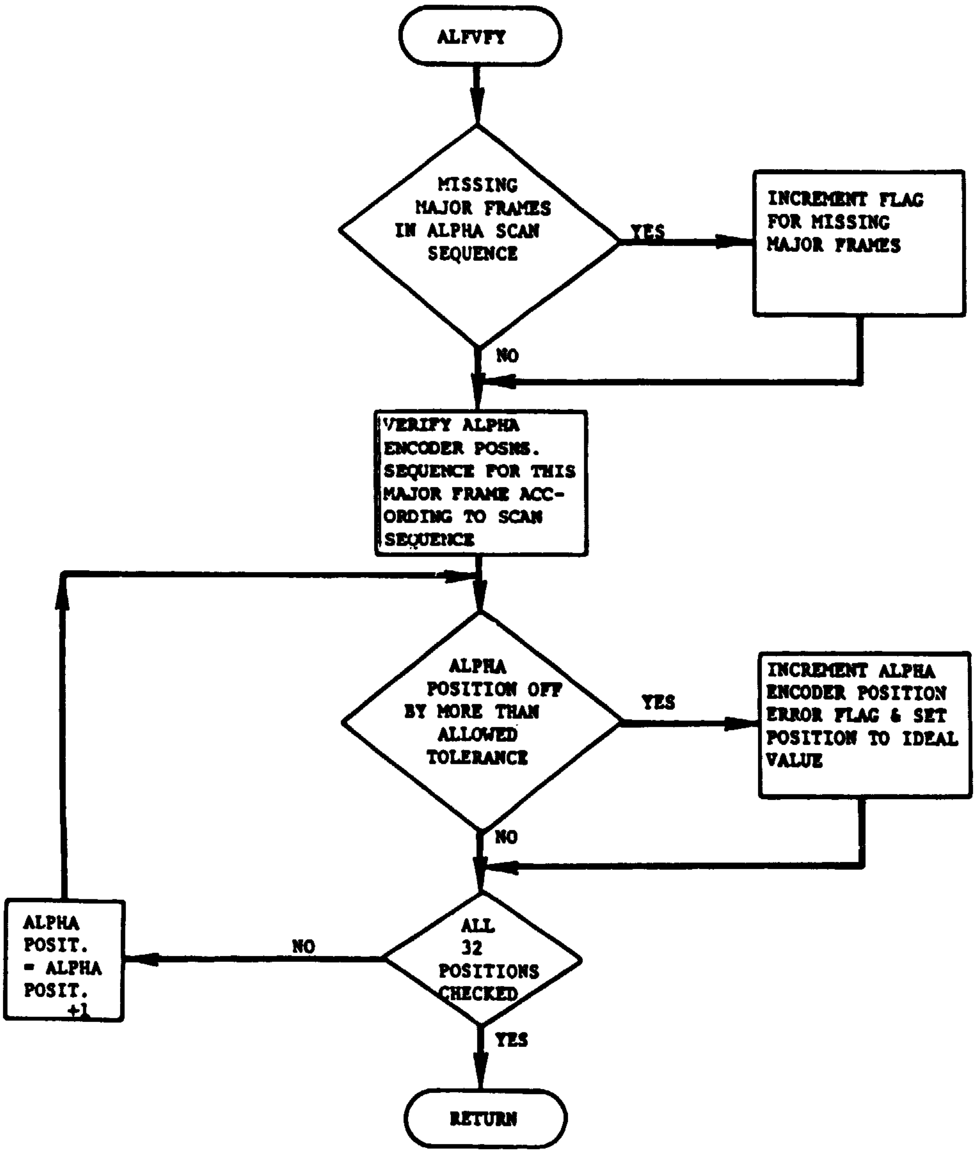


FIGURE 5.8 ALFVFY Flow Diagram (MATGEN 6.2.9.1)

5.4.3 BETVFY

Purpose: To verify that the beta encoder positions are appropriate for the particular major frame.

Method: Using the major frame count, scan mode indicator, and scan mode #5 routine indicator, the nominal beta encoder positons are chosen from array "IBETA". Each value is repeated during a major frame the number of times indicated in array "NSAME". The number of different beta values is known for array "NVALS". These are tested against the actual beta encoder positions. If there is more than a one encoder position difference, a beta position error counter is incremented and the ideal encoder value is put in common /B SCAN/ instead of actual /B SCAN/. It is used in the scanning sequency only if the scan is in transition and a transitional counter error is incremented.

Reference: None

Figure 5.9 shows the BETVFY data flow.

5.4.4 SLEWRT

Purpose: To update statistics for beta gimbal slew rates

Method: The subroutine is called if this is the third, fifth, or seventh major frame in the scan sequence. Beta slews take place between the tenth and eleventh seconds of major frame three. They also occur between the first and second seconds of major frame five, and between the thirteenth and sixteenth seconds of major frame seven. Subroutine RSTATS is called to update the statistics for the amount of beta encoder position movement during consecutive seconds.

Reference: None

Figure 5.10 shows the SLEWRT data flow.

ORIGINAL PAGE IS
OF POOR QUALITY

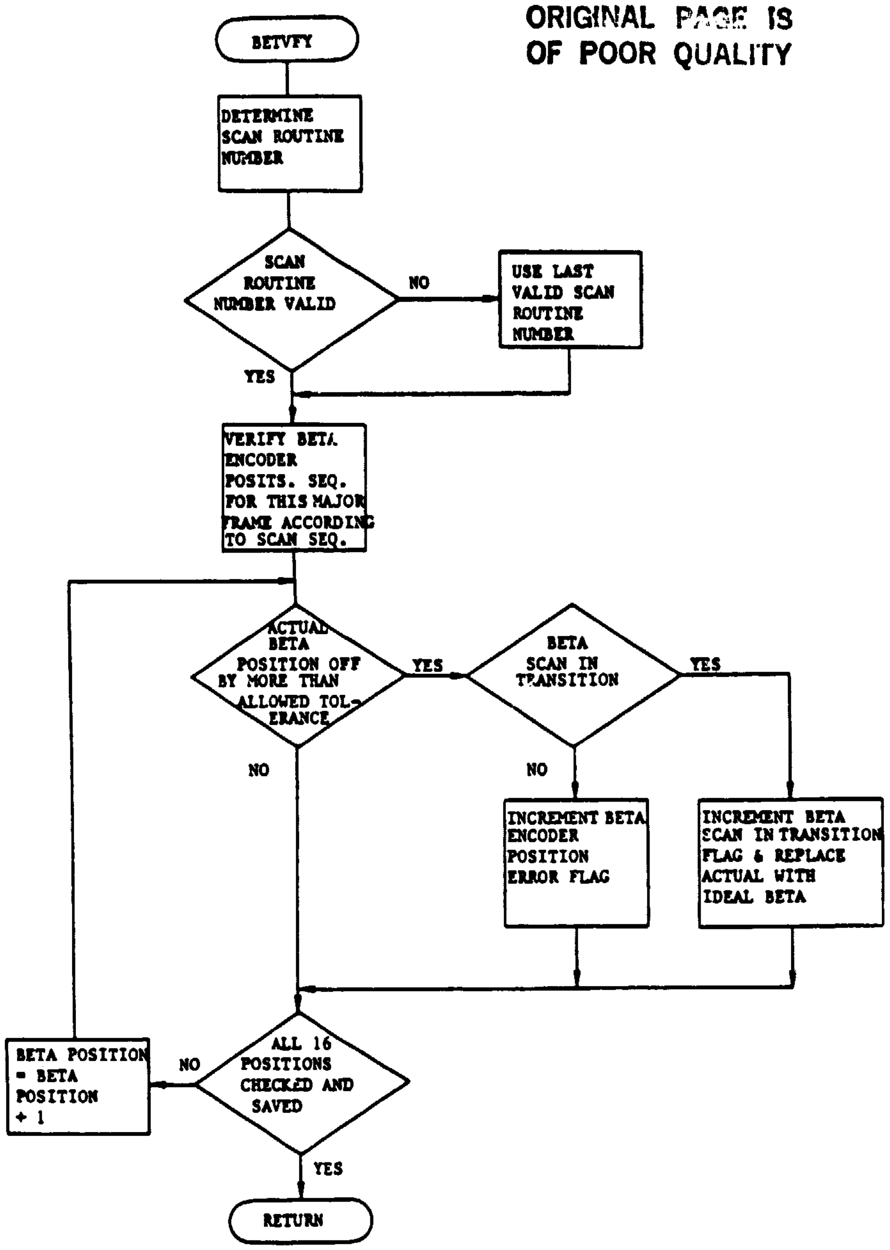


FIGURE 5.9 BETVFY Flow Chart (MATGEN 6.2.9.2)

OF POOR QUALITY

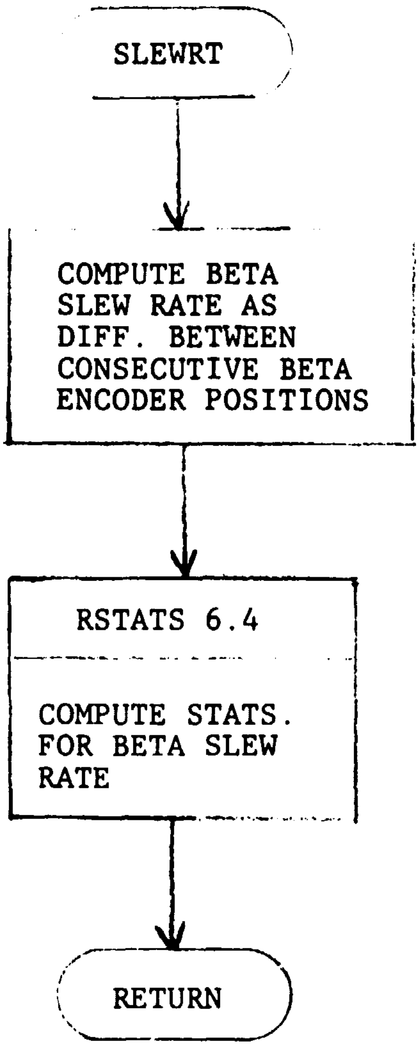


FIGURE 5.10 SLEWRT Data Flow (MATGEN 9 3.9.4)

6.0 EARTH OBSERVATION CHANNELS

6.1 INTRODUCTION

The earth viewing channels consist of four sensors having field-of-views (FOV) which encompass the entire earth's disc and a narrow ring of space outside the disc. Two of these Wide Field-of-View (WFOV) channels accept only visible and near infrared radiation and the other two accept in addition radiation out to 50 um.

The earth scanning Narrow Field-of-View (NFOV) channels follow a number of different scanning modes. Four of them receive visible and near infrared radiation while the other four view only infrared radiation from 4.5 to 50.0 um. A general program called ERBCAL (Section 6.1.2) converts all of the earth viewing channel counts into radiances or irradiances. The other subroutines modify this conversion applying various correction factors.

Since the earth channel computer data reduction subprograms do not treat the various channels separately it will be necessary to give the equations used to convert from counts into radiances or irradiances first and then give the subroutines used to accomplish these tasks next (in Section 6.4).

In the case of the infrared scanning channels the conversion from calibrated blackbody into an earth radiation distribution theoretical calibration is unique and will be treated separately (Section 6.5).

6.2 WIDE FIELD-OF-VIEW (WFOV) CHANNELS

There were four wide field-of-view sensors, two longwave (channels 11 and 12) and two shortwave (channels 13 and 14). The optical centerlines of these channels were continuously pointed parallel to the local vertical of Nimbus-7. Channel 11 was used principally for calibration and was kept shuttered most of the time. The algorithms listed in Section 6.2 were developed for these channels.

6.2.1 Algorithms Channels (11-12)

For channels 11 and 12 wide field-of-view sensors the basic equation used to convert ERB-7 counts to blackbody equivalent irradiances. This equation for the fixed earth flux channels 11 and 12 was:

ORIGINAL PAGE IS
OF POOR QUALITY

$$H_T \cdot F_T = \left[\Delta W - \varepsilon_s F_s \sigma T_s^4 + \varepsilon_D F_D \sigma (T_D + k \cdot V)^4\right] \qquad 6.1$$

where

$H_T \cdot F_T$ = Combined Target irradiance (watts/m^2) and target configuration factor[3].

ΔW = Effective thermopile irradiance (watts/m^2)

ε_s = Emissivity of the FOV stop

F_s = Configuration factor of FOV stop

σ = The Stefan-Boltzman constant = 5.6697 x 10^{-8} watts/m^{2}K^4

T_s = Temperature of the FOV stop (K) (Thermister value)

ε_D = Emissivity of the thermopile

F_D = Configuration factor of the thermopile

T_D = Temperature of the thermopile (K) (plot res. value)

k = Correction factor for the temperature of the thermopile surface ($^\circ$K/count)

V = Thermopile output (counts)

The equation developed for ΔW for ERB-7 is:

$$\Delta W = \frac{\left[V - V_o + b(T - 25^\circ C)\right]}{s + a\,(T - 25^\circ C)\ 2.9} \qquad 6.2$$

where

V_o = Zero offset in counts at 25°C

b = Zero offset temperature coefficient (counts/°C)

T = Module temperature (°C)

s = Channel sensitivity at 25°C (counts/watts m^{-2})

a = Sensitivity temperature coefficient (counts/watts m^{-2}/°C)

6.2.2 Channels 13-14

For the ERB-7 fixed earth flux channels 13 and 14 the following equations were used to convert from counts to radiance:

$$H_T = (V - V_o)/s' \qquad 6.3$$

ORIGINAL PAGE IS
OF POOR QUALITY

$$H_T \cdot F_T = \left[\Delta W - \epsilon_s F_s \sigma T_s^4 + \epsilon_D F_D \sigma (T_D + k \cdot V)^4\right] \tag{6.1}$$

where

$H_T \cdot F_T$ = Combined Target irradiance (watts/m^2) and target configuration factor[3].

ΔW = Effective thermopile irradiance (watts/m^2)

ϵ_s = Emissivity of the F0V stop

F_s = Configuration factor of F0V stop

σ = The Stefan-Boltzman constant = 5.6697×10^{-8} watts/m^{2}K^4

T_s = Temperature of the F0V stop (K) (Thermister value)

ϵ_D = Emissivity of the thermopile

F_D = Configuration factor of the thermopile

T_D = Temperature of the thermopile (K) (plot res. value)

k = Correction factor for the temperature of the thermopile surface ($^\circ$K/count)

V = Thermopile output (counts)

The equation developed for ΔW for ERB-7 is:

$$\Delta W = \frac{V - \left[V_0 + b(T - 25^\circ C)\right]}{s + a(T - 25^\circ C)\ 2.9} \tag{6.2}$$

where

V_0 = Zero offset in counts at 25°C

b = Zero offset temperature coefficient (counts/$^\circ$C)

T = Module temperature ($^\circ$C)

s = Channel sensitivity at 25°C (counts/watts m^{-2})

a = Sensitivity temperature coefficient (counts/watts m^{-2}/$^\circ$C)

6.2.2 Channels 13-14

For the ERB-7 fixed earth flux channels 13 and 14 the following equations were used to convert from counts to radiance:

$$H_T = (V - V_c)/s' \tag{6.3}$$

ORIGINAL PAGE IS
OF POOR QUALITY

$$s' = s\left[1.0 + (0.01)(A)(T_B - 25^{\circ}C)\right] \tag{6.4}$$

where

H_T = Target irradiance (watts/m^2)

V = Channel output (counts)

V_o = Channel offset (counts)

s' = Corrected channel sensitivity (counts/watts m^{-2})

s = Channel sensitivity in vacuum at 25°C

A = Channel sensitivity correction factor (% per °C deviation from from 25°C)

T_B = Channel thermopile base temperature (°C)

6.3 NFOV PROCESSING ALGORITHMS

The scanning narrow field-of-view channels are divided into shortwave (0.2 to 4.8 um) and longwave (4.5 to 50.0 um) data processing routines. As will be noted in the following algorithms and data processing, there is a considerable difference in the way the two spectral regions are processed.

6.3.1 Narrow Field-of-View Short Wavelength Channels

The scanning shortwave length channels used the same equations as were used for channels 13 and 14. They are given in Section 4.1.

6.3.2 Algorithms Channels (15-18)

For the ERB-7 channels 15 and 18 the following equations are used to convert from counts to radiance:

$$H_T = (V - V_o)/s' \tag{6.5}$$

$$s' = s\left[1.0 + (0.01)(A)(T_B - 25^{\circ}C)\right] \tag{6.6}$$

where

H_T = Target irradiance (watts/m^2)

V = Channel output (counts)

V_o = Channel offset (counts)

s' = Corrected channel sensitivity (counts/watts m^{-2} sr^{-1})

s = Channel sensitivity in vacuum at 25°C

A = Channel sensitivity correction factor (% per °C deviation from 25°C)

T_B = Channel thermopile base temperature (°C)

6.4 SOFTWARE AND DATA FLOW

As indicated in the Introduction, the basic subroutine converting counts into radiances or irradiances is accomplished by ERBCAL. In order to obtain the input data required to process the earth channels updating of the data is required. This is accomplished by the routine PROCOR.

6.4.1 ERBCAL

Purpose: To convert digital counts from channels 11-22 to irradiances (W*M**-2,CHNLS 11-14) and radiances (W*M**-2/STER,CHNLS 15-22)

Method: The counts are converted using several different formula.

The input to FRAD was developed by NOAA personnel using laboratory vacuum cold chamber measurements. These measurements were made with the entire sensor system in the satellite viewing a uniform temperature controlled target which emitted essentially blackbody radiation. Several different target temperatures were maintained in the calibration. In addition, the sensor temperature was also carefully regulated at several different values.

The resulting data was quite linear for a range of target temperature when the sensor temperature was kept constant. Thus a linear relationship having a constant slope and offset target radiance value was determined.

Figure 6.1 shows the ERBCAL data flow.

6.4.2 PROCOR

Purpose: To process all of the data in one orbit, update the statistics and counters for the orbit and find the time of the minimum solar elevation, and do the long wave scanning and short wave calibrations.

Method: The orbit is processed one major frame at a time. For each UFO major frame, the corresponding attitude and ephemeris data is found. The Digital A data is then unpacked and the status of the instrument is found using the odd digital words. The irradiances, temperatures, locations and special mode processing are done by the appropriate subroutines. The solar data is collected according to the predicted time of the minimum solar elevation, then searched to find the actual time at the end of the orbit. The counters and values for the histogram are updated for each major frame.

Figure 6.2 shows the PROCOR data flow.

OF POOR

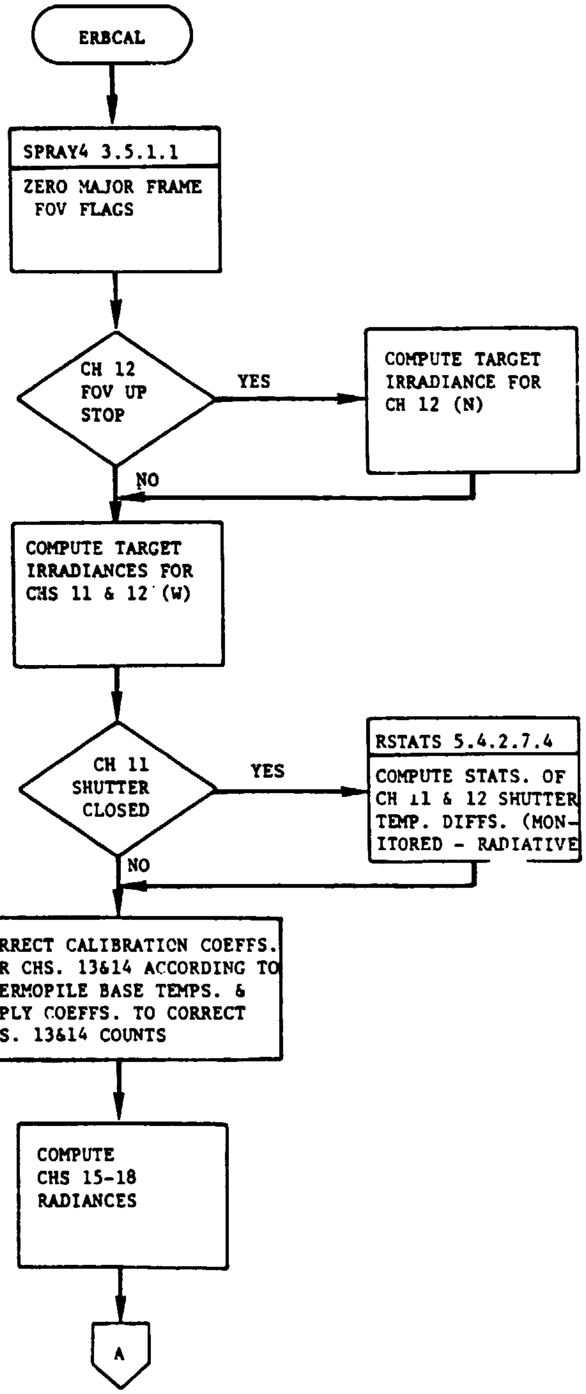


FIGURE 6.1 ERBCAL Data Flow Chart (MATGEN 6.2.1.0)

ORIGINAL PAGE IS
OF POOR QUALITY

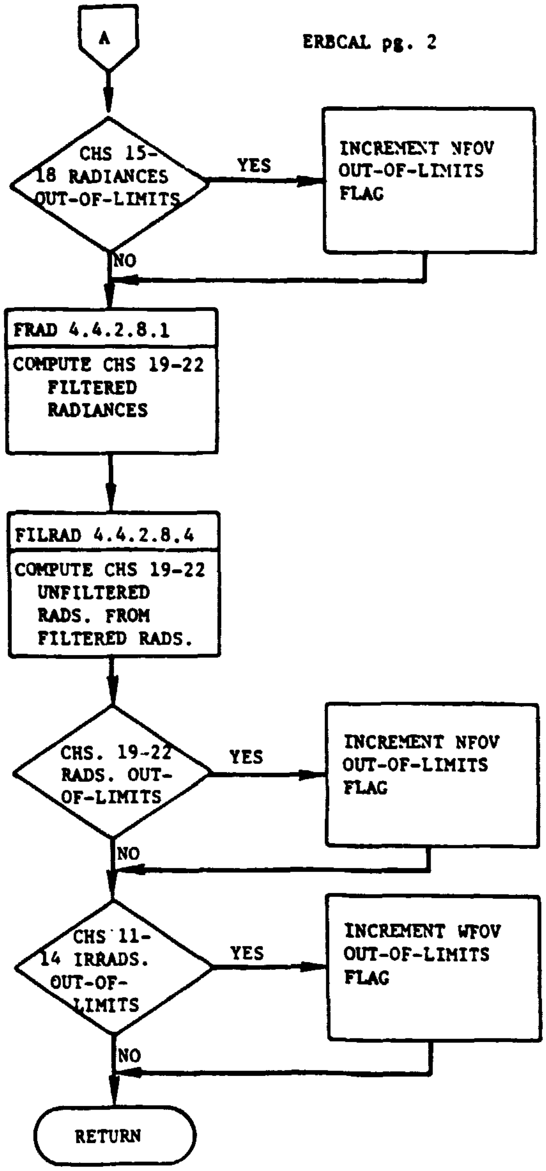


FIGURE 6.1 (Continued)

ORIGINAL PAGE IS
OF POOR QUALITY

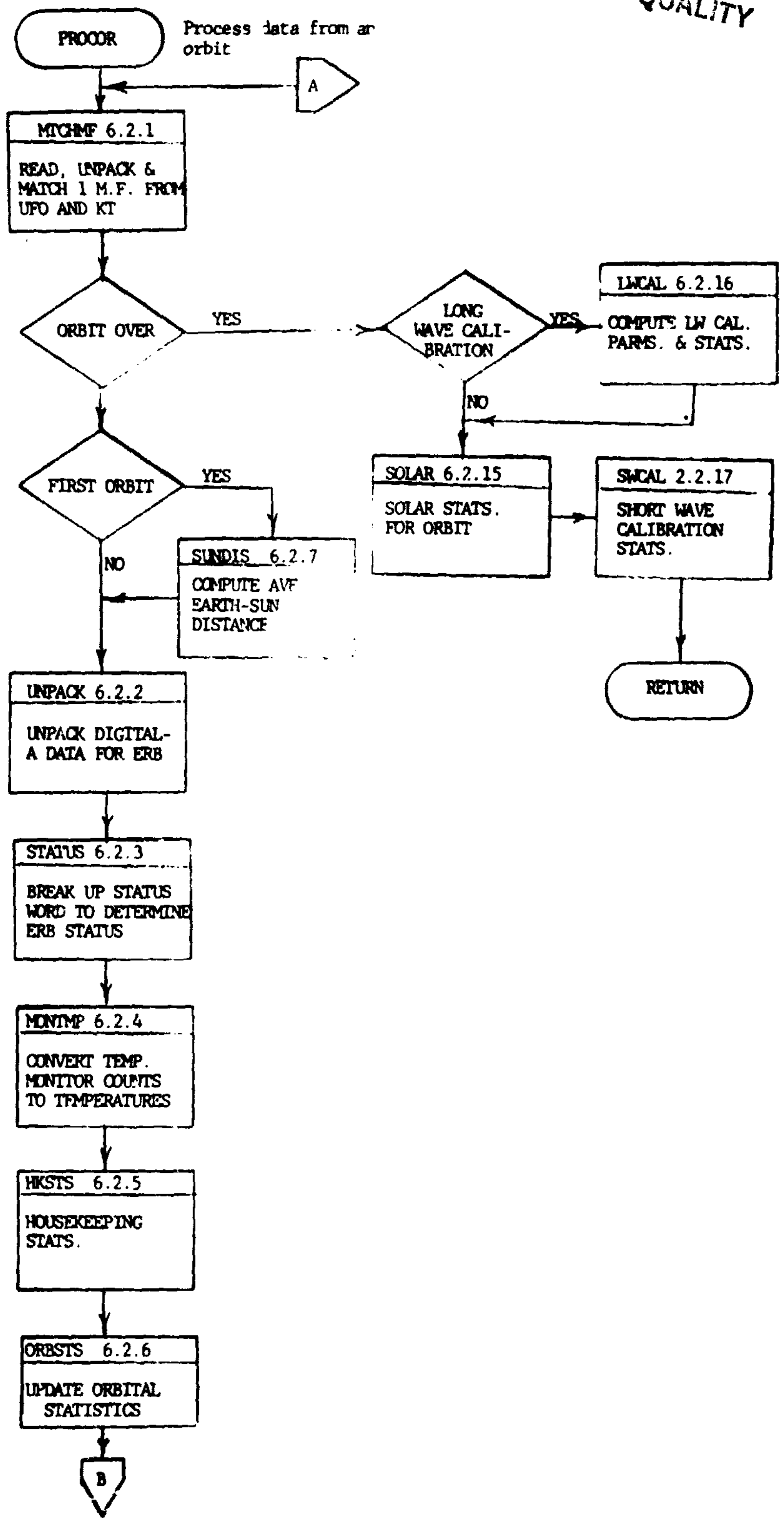


FIGURE 6.2 PROCOR Data Flow (MATGEN 6.2)

ORIGINAL PAGE IS
OF POOR QUALITY

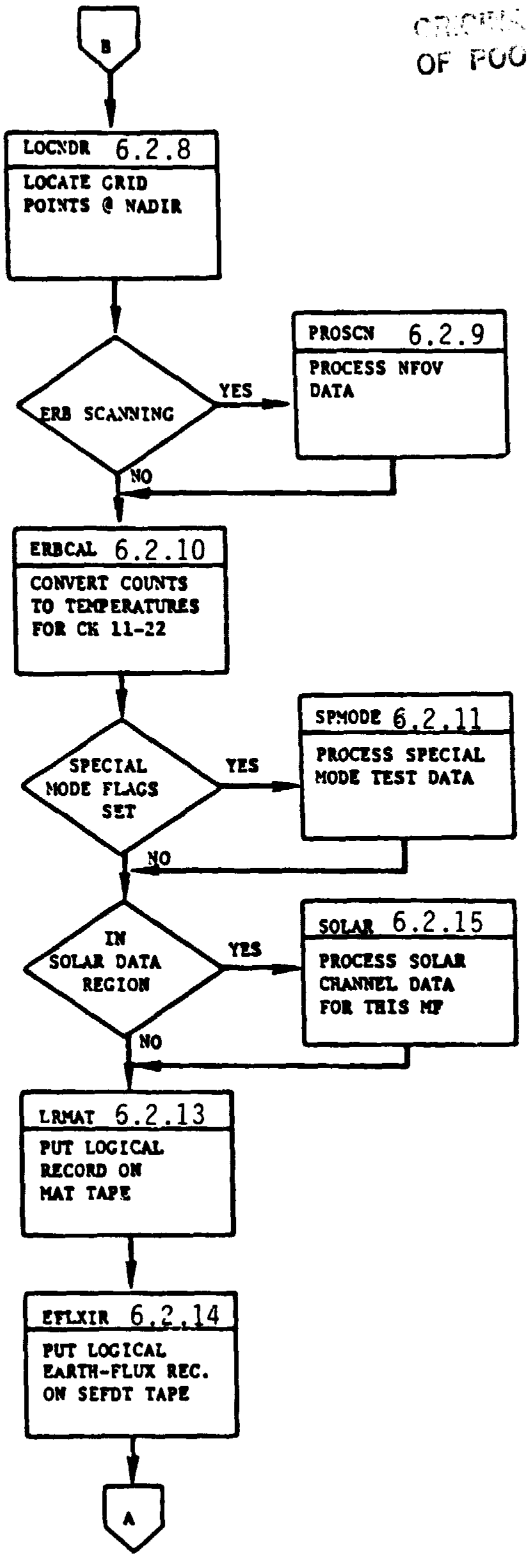


FIGURE 6.2 (CONTINUED)

6.4.3 Scanning Channel Temperature Corrections and Statistics

Long wavelength scanning channel temperature correction because to an error in the ERB-7 PTM coefficients is accomplished by FRAD. This subprogram is contained in Section 6.4.4.1.

6.4.3.1 STC

Purpose:	To correct channel calibrations for temperature variation.
Method:	A linear correction is applied to the sensitivity at 25 degrees centigrade.

The sensor calibration depended upon the sensor tempeature. Thus a simple equation relating the offset to a reference sensor temperature of 25°C was developed for most of the ERB sensors.

In the case of channels 11 and 12, a different procedure was used to correct for this offset. Both the shutter blackbody energy emission and the sensor emission were used in the algorithm.

Reference: Function STC from Nimbus-6 software

Figure 6.3 shows the STC data flow.

6.4.3.2 FRAD

Purpose:	To compute a filtered radiance in milliwatts per meter squared per steradian from a given temperature in degrees Celsius.
Method:	Depending on the temperature interval of the given temperature, a set of coefficients is determined for the radiance algorithm polynominal AX**4 + BX**3 + CX**2 + DX + E, where X is the natural logarithm of the input temperature in degrees Kelvin. If the temperature is outside the acceptable range, a default of 999.9 is returned.

References: H.V. Soule, Memo on B.B. calibrated sensor corrections.

Program Calling Sequence: FRAD(TC)

COMMENTS:

The validity of this assumption is presently under investigation.

Figure 6.4 shows the data flow of FRAD.

ORIGINAL PAGE IS
OF POOR QUALITY

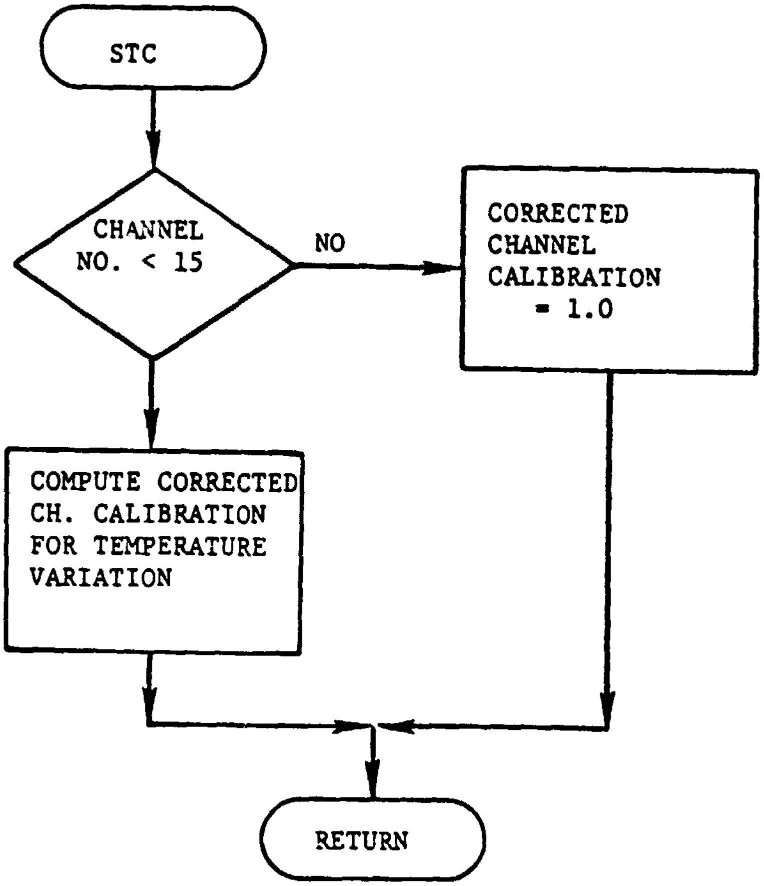


FIGURE 6.3 STC Data Flow Chart (MATGEN 6.2.10.2)

ORIGINAL PAGE IS
OF POOR QUALITY

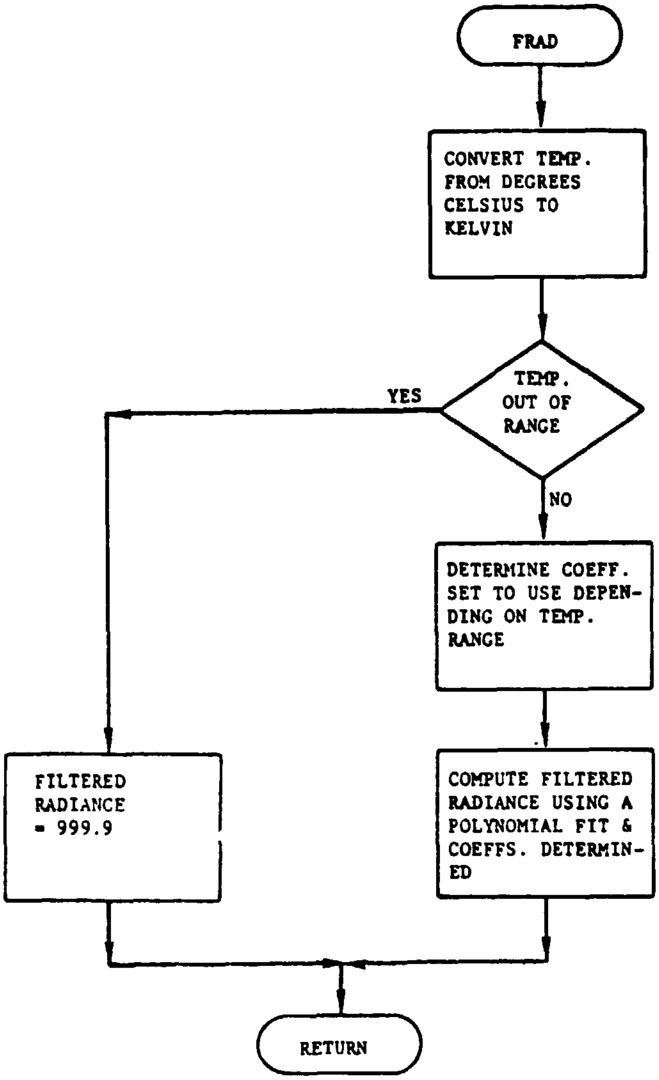


FIGURE 6.4 FRAD Data Flow Chart (MATGEN 6.2.10.1)

6.5 LONGWAVE SCANNING CHANNELS

These scanning channels were used to check the calibration of many of the other earth viewing channels. This was because these longwave channels made use of accurate warm and cold calibration targets.

However, all calibration was done using the energy spectral distribution of a blackbody. It was therefore necessary to correct the blackbody irradiances to typical earth spectral distributed irradiances. Thus, the convolution blackbody irradiance was determined using equation 6 and appropriate coefficients. Equations 6.8 through 6.10 determined the unfiltered earth irradiances.

The present state-of-the-art makes it impossible to calibrate the sensors using an earth radiance spectral distribution. There is a considerable difference in sensor response to sources having different spectral distributions. However, if the response of the complete sensor system to narrow bandwidth radiation throughout the spectral region of interest is measured, then it is relatively easy to compute its response to any known source spectral intensity distribution. This type response measurement is commonly made using a monochrometer. Lacking this measurement, if the spectral transmission of the filter and the response of the detector as a function of wavelength is known, the complete sensor system response can be determined. The error produced by different source spectral distributions is largest in the infrared when filter and detector response as a function of wavelength vary considerably as a function of wavelength. For this situation the following assumptions must be made:

* The measured (count) response of an infrared detector is only dependent on the total received radiation energy. Thus, the relationship between two different spectral sources, such as a blackbody and earth/atmosphere, can be determined by equating their detected filtered values.
* Determination of the filtered values requires the measurement or an estimate of the complete sensor system response as a function of wavelength.

* For the same total filtered (or detector sensed) thermal radiation, the detector emitted radiation back toward the source will be the same and can be neglected because ratios of unfiltered blackbody radiance to earth/atmosphere radiance are usually determined.

ORIGINAL PAGE IS
OF POOR QUALITY

6.5.1 COMPUTATIONS:

In these computations, the basic criteria was the determination of the amount of unfiltered earth/atmosphere radiation producing the same filtered detected radiance as the calibration blackbody unfiltered radiance. These two detected filtered radiances produce the same recorded counts. Thus it is necessary to know the theoretical relationship or ratio of unfiltered earth/atmosphere radiance to unfiltered blackbody radiance for the filter transmission and detector spectral detection characteristics. In the laboratory it is almost impossible to duplicate the spectral distribution produced by the earth/atmosphere in an accurate manner.

Using the above technique FRAD (Section 6.3.4.1) computed the filtered blackbody radiance. FILRAD (Section 6.4.1.1) converted the longwave filtered radiances to unfiltered radiances.

6.5.2 Channels 19-22 Algorithms

For ERB-7 the equation used to convert from counts to filtered radiance was:

$$N_T = N_m + a_o + a_1 \cdot V \qquad 6.7$$

where N_m = module radiance ($wm^{-2}ster^{-1}$)

a_o = channel intercept ($w \cdot m^{-2}ster^{-1}$)

a_1 = channel slope ($w \cdot m^{-2}ster^{-1}/count$)

V = channel output (counts)

Coefficients a_o and a_1 were determined from early inflight calibrations as well as from preflight thermal-vacuum calibrations.

The module radiance is computed by the solution of:

$$N_m = \exp \{ A_o + A_1 \left[\ln(T)\right] + A_2 \left[\ln(T)^2\right] + A_3 \left[\ln(T)^3\right] + A_4 \left[\ln(T)^4\right] \} \quad 6.8$$

Here the coefficients Ai, i = 0,1,....,4, are determined prior to launch for the temperature ranges 50K-200K, 200K-298K and 298K-400K and are given in the ERB-7 MATGEN (ref. 3).

If the filtered radiance reading from the channel is less than or equal to 30.0 W/m^2 sr the unfiltered radiance (R) is computed using the Stefan-Boltzmann law as follows:

$$R = \frac{\sigma \; T^4}{\pi} \qquad 6.9$$

$$\ln R = \ln \left(\frac{\sigma}{\pi}\right) + 4 \ln T = \ln \left(\frac{\sigma}{\pi}\right) + 4 \sum_{n=o}^{4} A_n (\ln R_f)^n \qquad 6.10$$

ORIGINAL PAGE IS
OF POOR QUALITY

where

R_f = filtered radiance (Watts/m^2 sr)
R = unfiltered radiance (Watts/m^2 sr)
T = equivalent blackbody temperature (K) (plat.res.value)
σ = Stefan-Boltzmann constant
A_n = regression coefficients

Thus, knowing the filtered radiance and the regression coefficients, the unfiltered radiance can be computed.

Different sets of regression coefficients are used depending on the filtered radiance value. The regression coefficients for equation 2.15 for the two ranges of filtered radiance values is given by:

for a range of 0.005 R_f 17.5 W/m^2 sr	for a range of 17.5 R_f 30.0 W/m^{2}sr
$A_0 = 4.68705$	$A_0 = 4.68888$
$A_1 = 2.03572 \times 10^{-1}$	$A_1 = 2.00549 \times 10^{-1}$
$A_2 = 4.14465 \times 10^{-3}$	$A_2 = 5.78289 \times 10^{-3}$
$A_3 = -3.24279 \times 10^{-4}$	$A_3 = -1.18646 \times 10^{-3}$
$A_4 = -5.80911 \times 10^{-5}$	$A_4 = 1.63483 \times 10^{-4}$

Several special cases apply to filtered radiances less than 30.00 W/m^2 sr).

If $R_f < 0$, $|R_f|$ is used in the conversion formula and the resulting unfiltered radiance is multiplied by -1.0.

If $R_f < -3.0$ W/m^2 sr the unfiltered radiance is set "out of range".

If $0.0 \leq |R_f| \leq 0.005$ the unfiltered radiance is set equal to the filtered radiance.

For telescope readings of the filtered earth irradiance (R_f) greater than 30.0 W/m^2 sr the unfiltered radiance is computed using the formula:

$$R = a_0 + a_1 R_f \qquad 6.11$$

The values for a_0 and a_1 for equation 5.5 have the values:

$a_0 = 8.8584$ W/m^2 sr
$a_1 = 1.2291$
In MATGEN $R_f = N_T$

If the filtered radiance is greater than 300.0 W/m^2 sr the unfiltered radiance value is set "out of range".

Implementation of this conversion from blackbody calibration values to earth wavelength dependent radiation is accomplished by FILRAD.

6.5.3 FILRAD

Purpose: Convert long wave filtered radiances to unfiltered radiances.

Method: Compute the equivalent blackbody temperature for the observation by fitting it to a polynomial in the filter radiance. Then using this equivalent blackbody temperature and the Stefan-Boltzman law, compute the unfiltered radiance. This approach is somewhat in error.

References: "Applying Nimbus-3 methods to ERB-G" L-Stowe-NOAA-NESS 8-29-78.

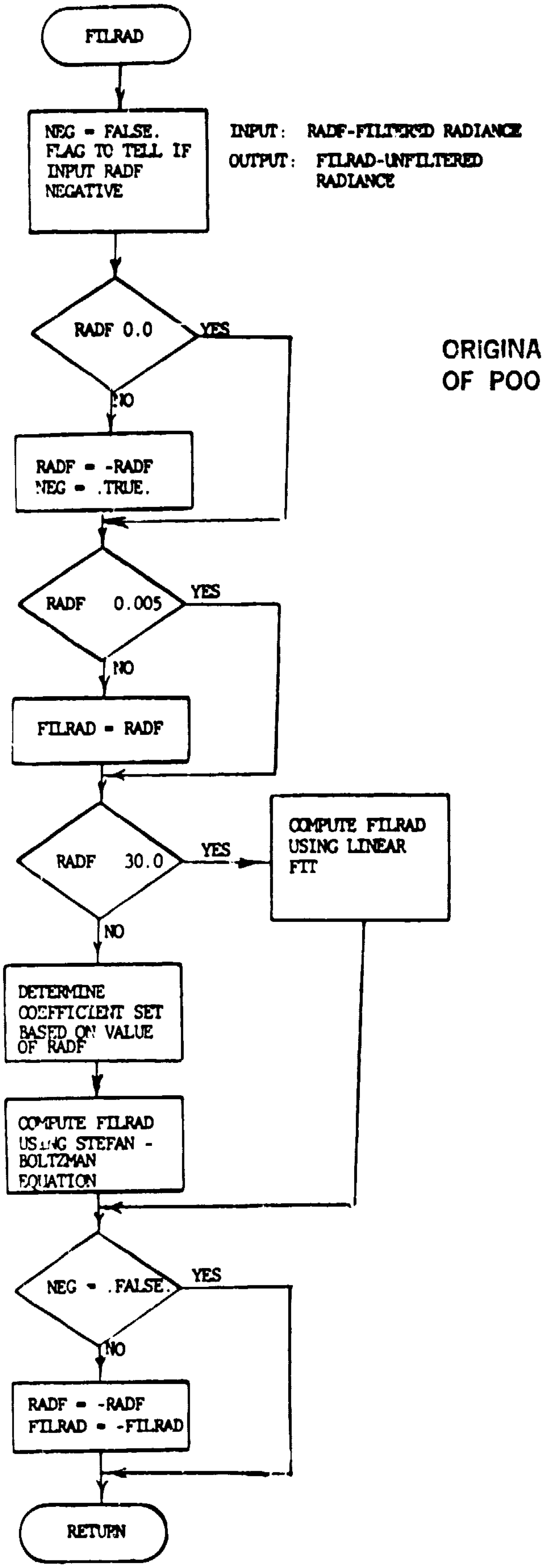
Modified By: R.D. Heasty to use in MATGEN
J.A. Kogut 5-79 to compute unfiltered radiances from filtered radiance using a linear fit when the filtered radiance is 30 watts/M**2 Sr. This change is based on the memo by L. Stowe of NOAA dated 3-29-79 "Conversion of filtered radiances to unfiltered for the ERB long wave scanning channels (LWSC)".

Figure 6.5 shows the FILRAD data flow.

6.5.4 COMMENTS:

With few exceptions all sensors were calibrated in the laboratory and in operation using a radiation source having a black or gray body energy distribution. The common practice was to assume that all observed radiation also had this type distribution and thus could be related to the calibrations via the sensor system.

It has been noted that there is considerable difference in the response of a sensor to blackbody and earth/atmosphere emitted radiation. This difference wouldn't matter if the sensor system were perfect, i.e. the filter had a perfectly rectangular transmission and the detector sensitivity were constant at all measured wavelengths. Unfortunately this type response does not occur in any sensor.



ORIGINAL PAGE IS
OF POOR QUALITY

FIGURE 6.5 FIRAD Data Flow (MATGEN) 6.2.10.3)

7.0 SPECIAL MODE PROCESSING

7.1 INTRODUCTION

There are a number of special data processing requirements required in ERB. These include processing the electronic calibration, the space viewed data and other ERB calibration data. In addition, data updating and interchannel comparisons are needed. The special modes requiring processing are determined by SPMODE.

7.1.1 SPMODE

Purpose:	To process special modes of ERB data
Method:	The routine determines which special modes are to be processed, then calls the appropriate routine to do so.

Comments

As will be noted in Figure 7.1 showing the SPMODE data flow, the electronic (stair case) voltages used to determine the gain stability are checked. Also channels 11 and 12 are compared to determine any channel 12 degradation.

7.2 DATA UPDATING, QUALITY CONTROL AND REGRESSION/CORRECTION

In the ERBMAT program it has been necessary to perform a number of routine updating and quality control tasks as well as determine data statistics and correlate some of the data. The following MATGEN programs accomplish these tasks.

7.2.1 SWCAL

Purpose:	To compute ratios of the shortwave scanning channels views of the terrestrial target reduced to the (0.0) source direction (normal to target) to the reflectance values obtained from Nimbus-6 orbit 276 during short wave check.
Method:	The short wave data from disc unit 24 is searched until the solar peak is found. Net counts averages for channels 15-18 are obtained, as well as the solar elevation, solar azimuth, and various spacecraft temperatures. The offsets for these channels are determined and function PLATE is called to determine reflectance ratios for net counts minus offsets for each channel. These reflectance ratios are divided by the offsets and these values are called "observed counts". Finally, subroutine RSTATS is called to update statistics for the ratio of these observed counts to predicted ones.

C-2

ORIGINAL PAGE IS
OF POOR QUALITY

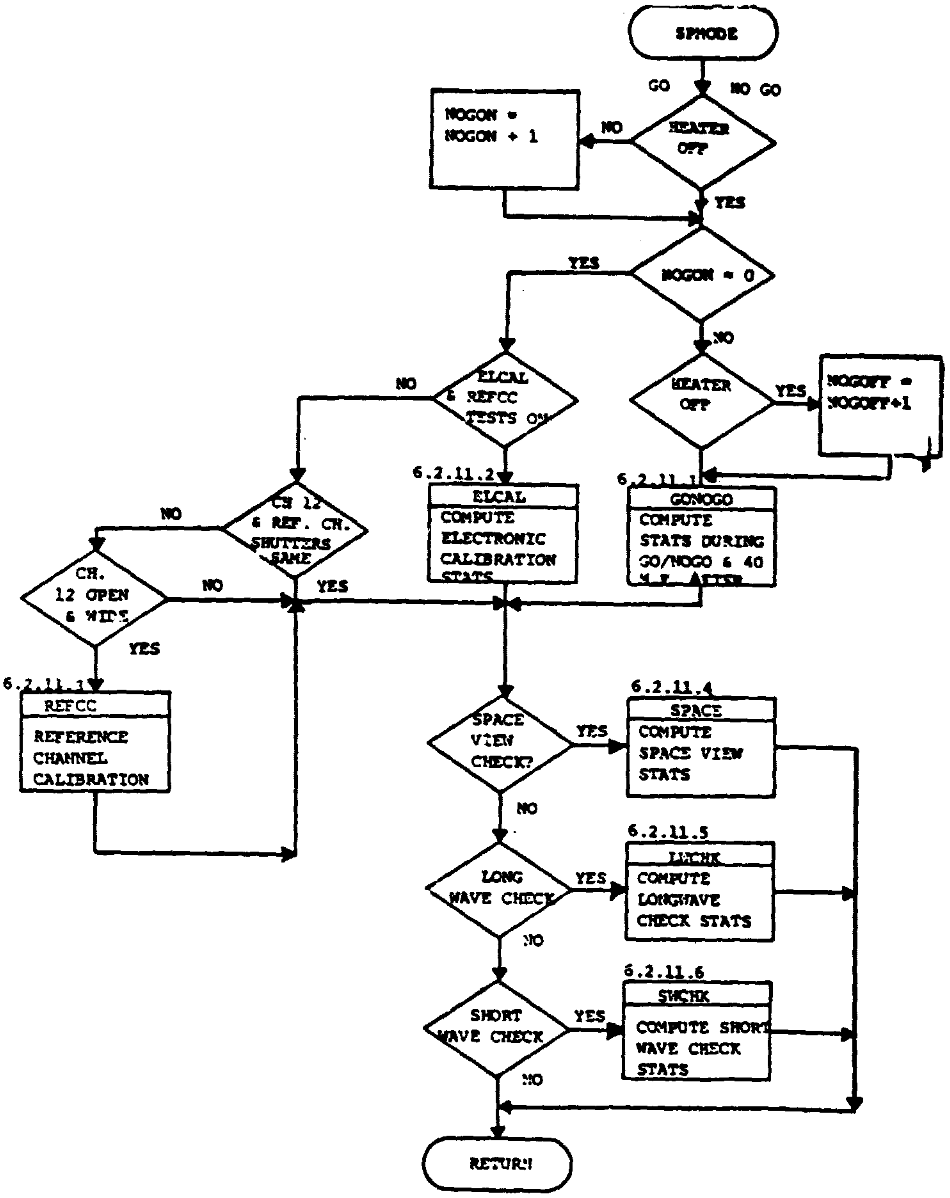


FIGURE 7.1 SPMODE Data Flow (MATGEN 6.2.11)

ORIGINAL PAGE IS
OF POOR QUALITY

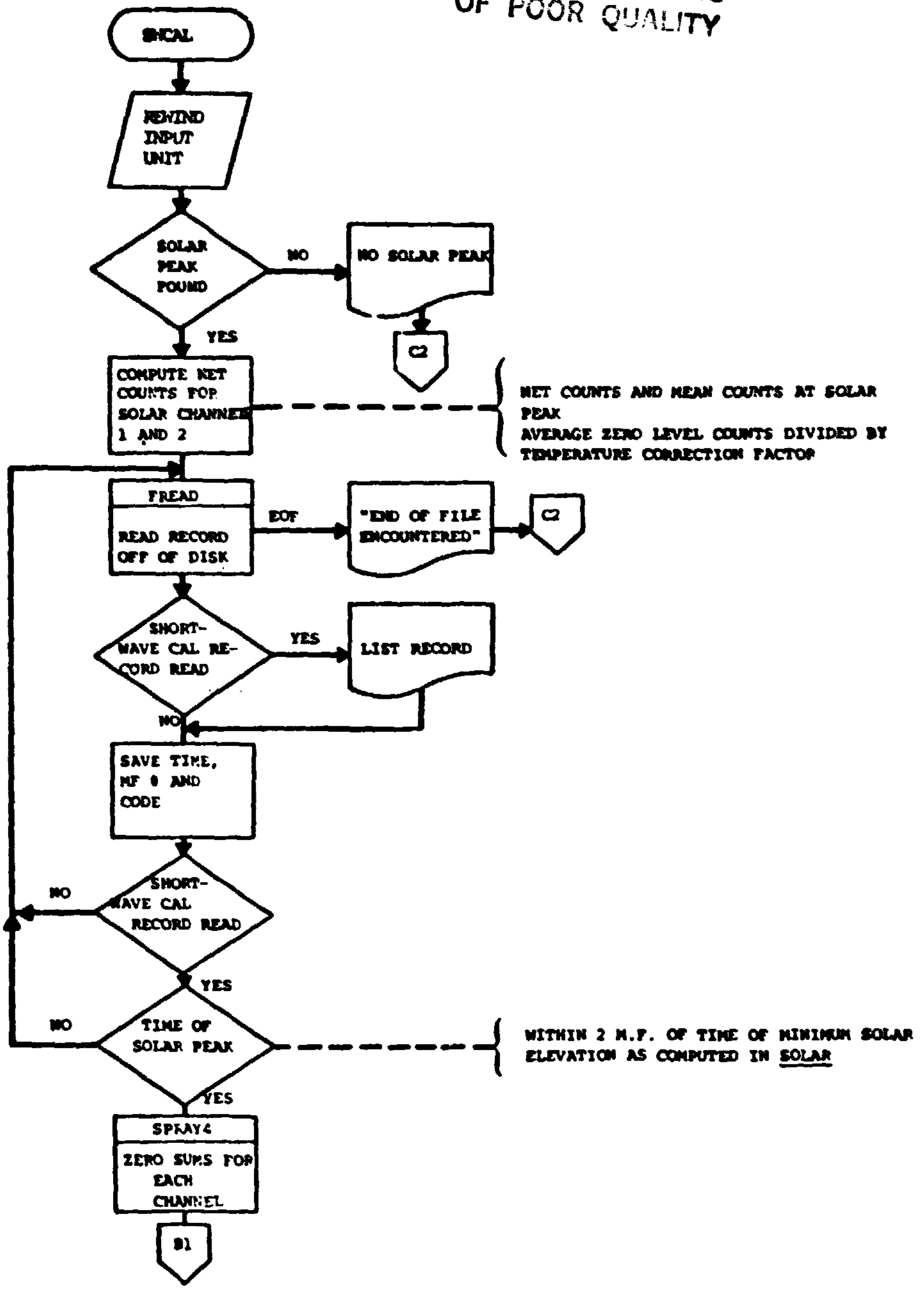


FIGURE 7.2 SWCAL Data Flow Chart (MATGEN 6.2.17)

ORIGINAL PAGE IS
OF POOR QUALITY

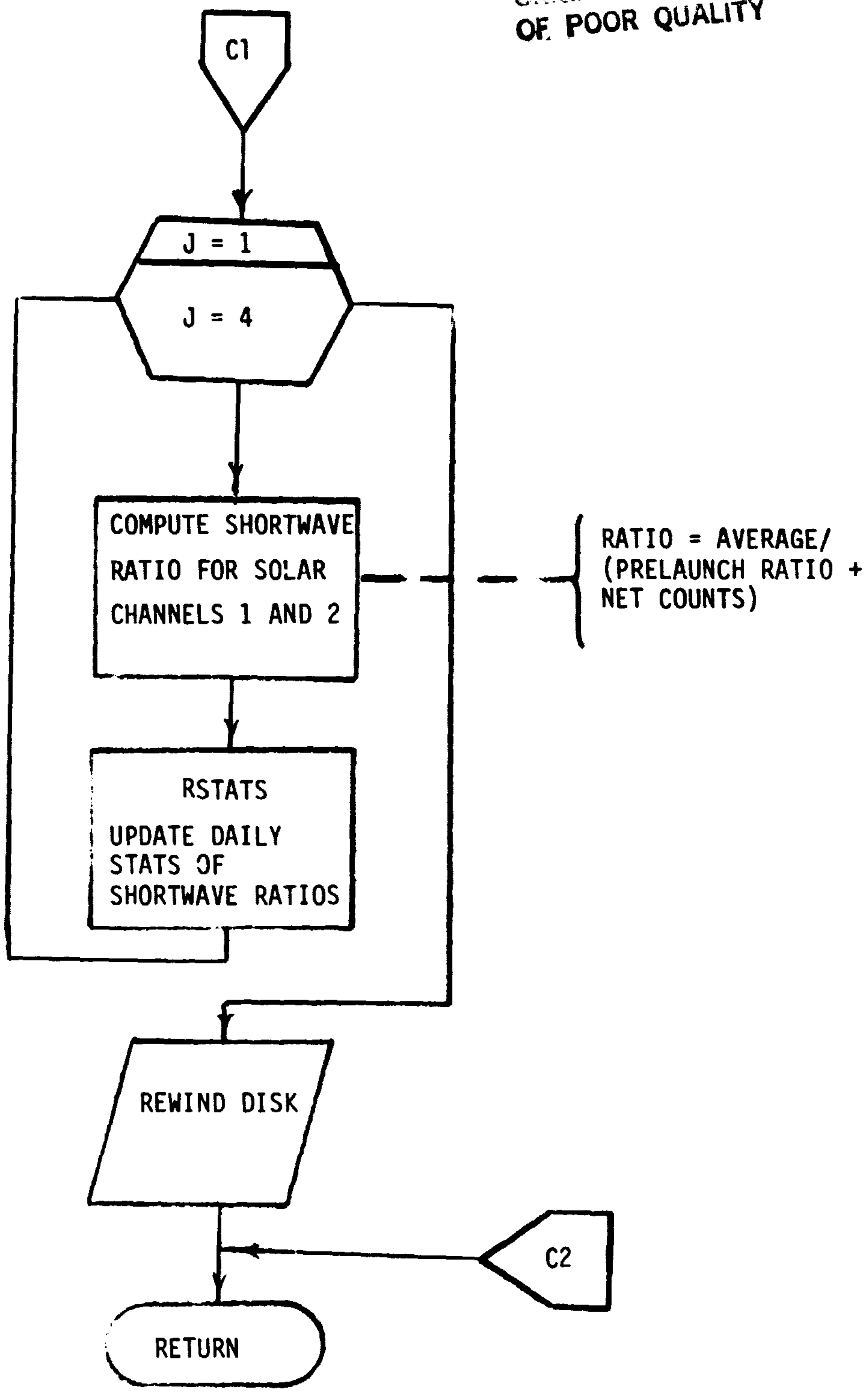
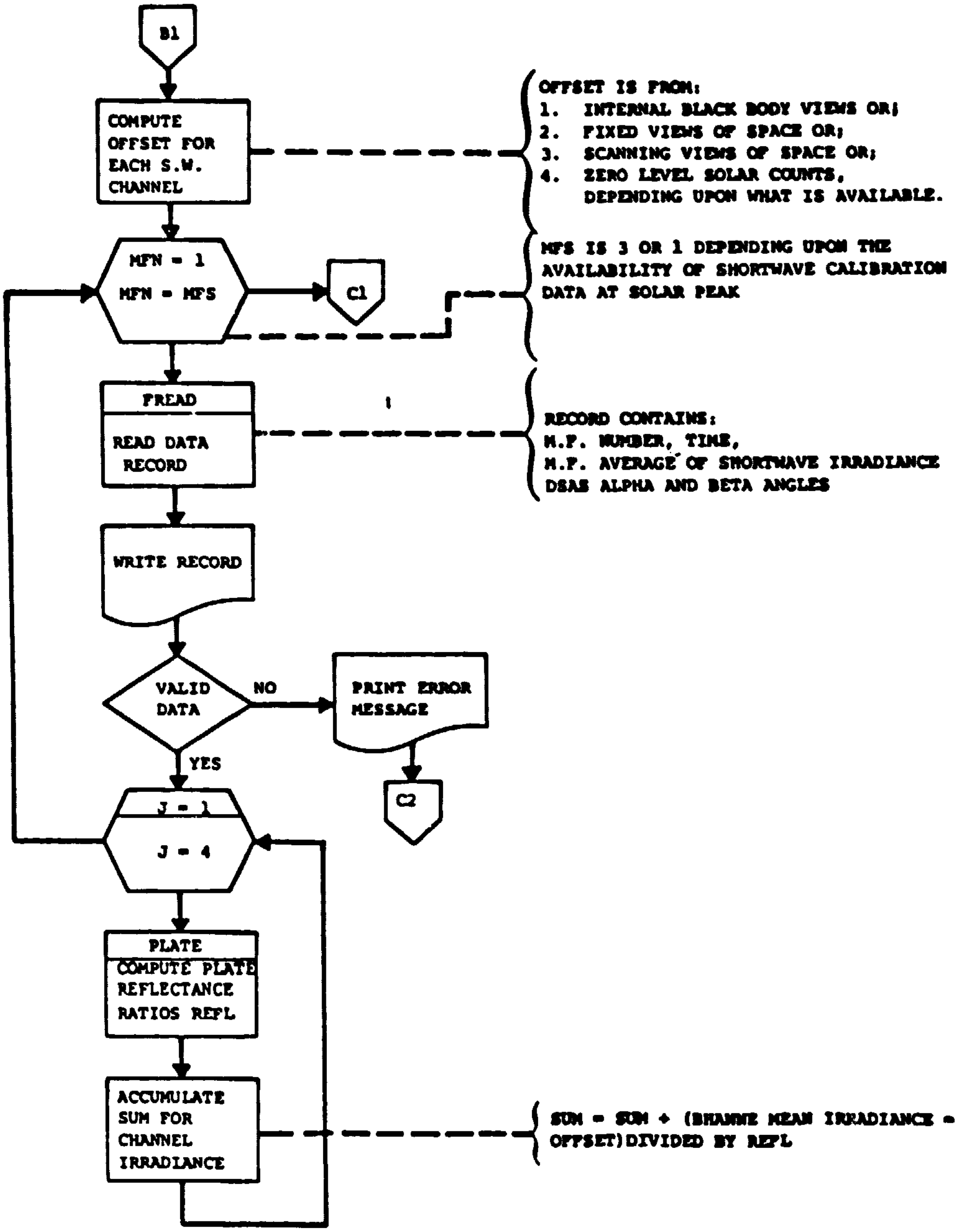


FIGURE 7.2 (CONTINUED)

ORIGINAL PAGE IS
OF POOR QUALITY



OFFSET IS FROM:
1. INTERNAL BLACK BODY VIEWS OR;
2. FIXED VIEWS OF SPACE OR;
3. SCANNING VIEWS OF SPACE OR;
4. ZERO LEVEL SOLAR COUNTS,
DEPENDING UPON WHAT IS AVAILABLE.

MFS IS 3 OR 1 DEPENDING UPON THE AVAILABILITY OF SHORTWAVE CALIBRATION DATA AT SOLAR PEAK

RECORD CONTAINS:
M.F. NUMBER, TIME,
M.F. AVERAGE OF SHORTWAVE IRRADIANCE
DSAS ALPHA AND BETA ANGLES

SUM = SUM + (CHANNEL MEAN IRRADIANCE - OFFSET) DIVIDED BY REFL

FIGURE 7.2 (CONTINUED)

Reference: None

Figure 7.2 shows SWCAL data flow.

7.2.2 SWCHK

Purpose: To update counts statistics for scanning channels 15-18 during short wave check (commented out at present) and to write onto disc the current major frame averages of channels counts and detector, target, port, and baffle temperatures.

Method: Subroutine RSTATS is called to update scanning channel counts during short wave check (commented out at present). Subroutine LWSCT computes major frame averages of the module, target, port, and baffle temperatures. Detector temperature ITM(57) replaces the module temperatures.

Reference: None

Figure 7.3 shows the SWCHK data flow.

7.2.3 REFCC

Purpose: To update irradiances statistics for earth flux channels eleven and twelve either with shutters both open or both closed.

Method: As long as earth flux channels eleven and twelve shutters have remained either both open or both closed for more than ten consecutive major frames, statistics for channel eleven irradiances, channel twelve irradiances, and channel twelve minus channel eleven irradiances are updated via call to suroutine RSTATTS. Statistics are updated for each case separately; cases being shutters both open or both closed.

Figure 7.4 gives the REFCC data flow.

ORIGINAL PAGE IS
OF POOR QUALITY

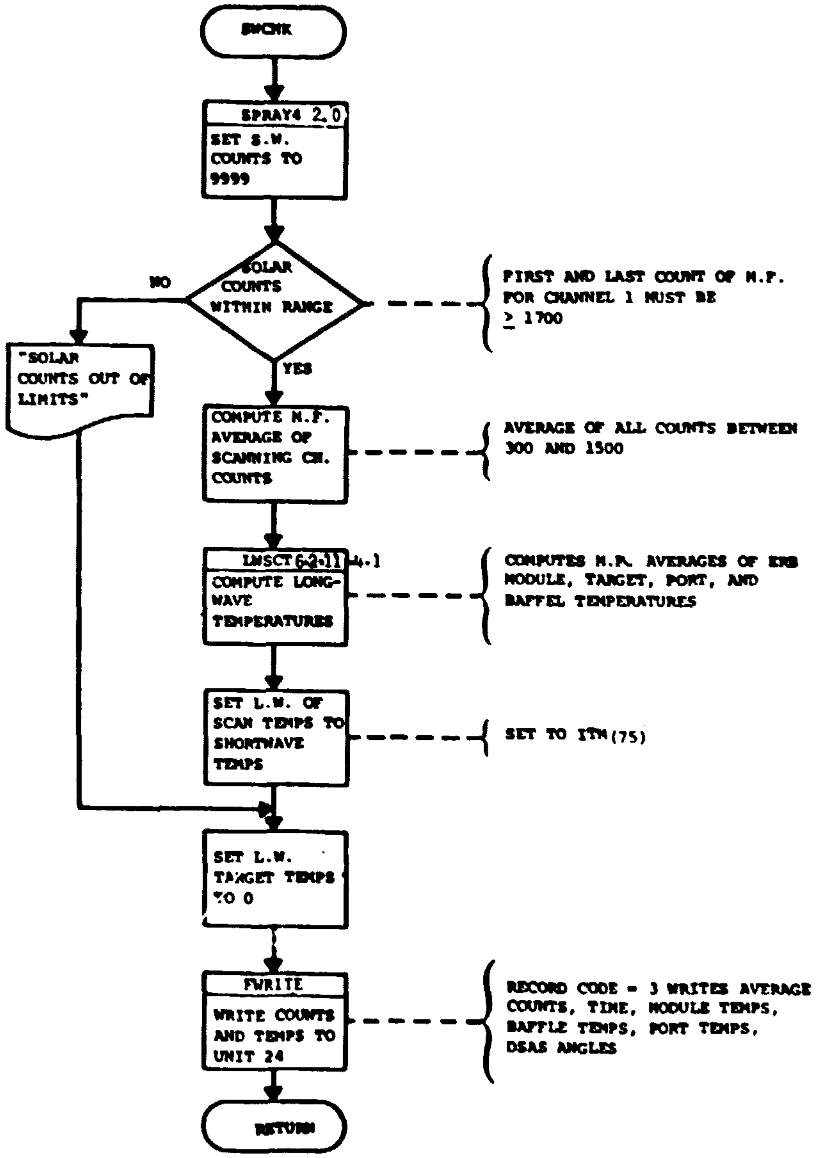


FIGURE 7.3 SWCHK Data Flow Chart (MATGEN 6.2.11.6)

ORIGINAL PAGE IS
OF POOR QUALITY

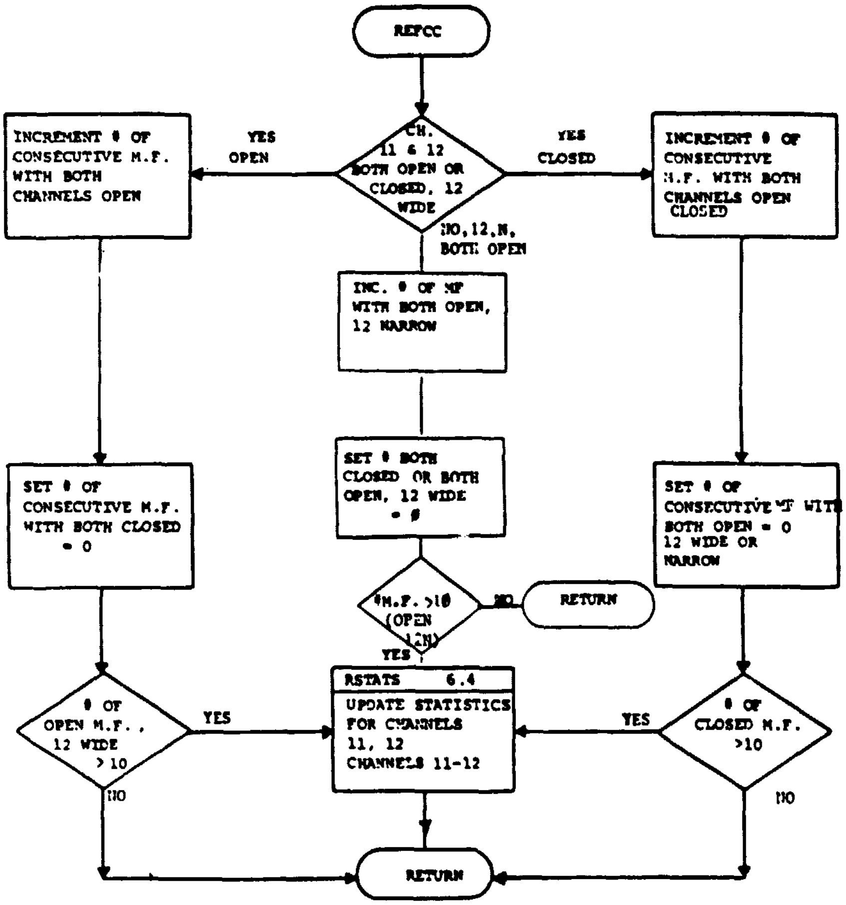


FIGURE 7.4 REFCC Flow Diagram (MATGEN 6.2.11.3)

7.3 CALIBRATION ALGORITHMS

Electronic calibration of ERB is used to monitor the channel gains and enable correction for any change in gain. Other calibration requirements include computing the shortwave scanning channel reflectances from a solar illuminated plate (subroutine PLATE), determining the statistics of the internal blackbody and space data (subroutine LWCAL) and updating the detector count statistics (SPSCS, LWCHK and GONOGO).

7.3.1 ELCAL

Purpose: To analyze the results when electronic calibration signals are applied to the solar and earth flux detectors.

Method: The calibration signals are applied as a staircase-shaped pulse at 0, 30, 60 and 90 percent of some nominal value. In the first major frame of the calibration sequence, 5 samples of the 0% pulse and 8 of the 30% pulse are stored in the program for each of the 10 solar channels, 2 samples of 0% and 2 samples of 30% are stored for each earth flux channels. In the second major frame, corresponding samples of the 60% and 90% calibration pulses are stored. The program then calculates the gain and linearity of each channel by means of a regression analysis.

Reference: Subroutine ELCAL in Nimbus-6 software

Figure 7.5 gives the ELCAL data flow.

7.3.2 PLATE

Purpose: To compute PLATE reflectances ratios for short-wave scanning channels fifteen through eighteen.

Method: Given the channel number and the source direction (elevation and azimuth angles), values of the reflectance ratios are chosen corresponding to intervals of the elevation and azimuth angles. These values are then interpolated linearly to obtain the PLATE reflectance.

Reference: None

RESTRICTIONS:

A PLATE reflectance ratio of 1.0 is returned for elevations outside the range of -5 to 15 degrees or azimuths outside the range -20 to 20 degrees.

ORIGINAL PAGE IS
OF POOR QUALITY

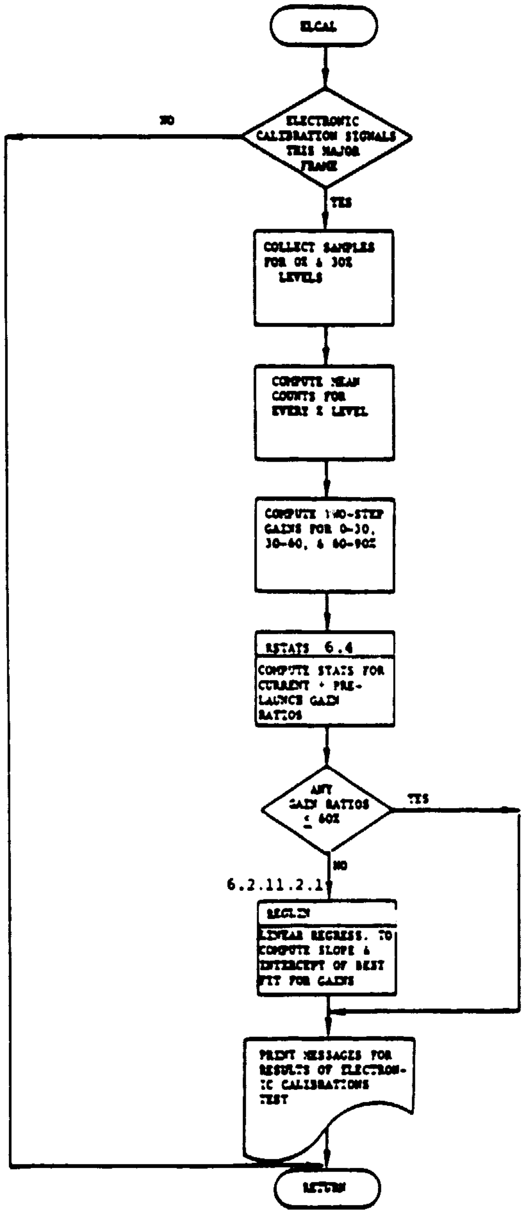


FIGURE 7.5 ECAL Data Flow (MATGEN 6.2.11.2)

ORIGINAL PAGE IS
OF POOR QUALITY

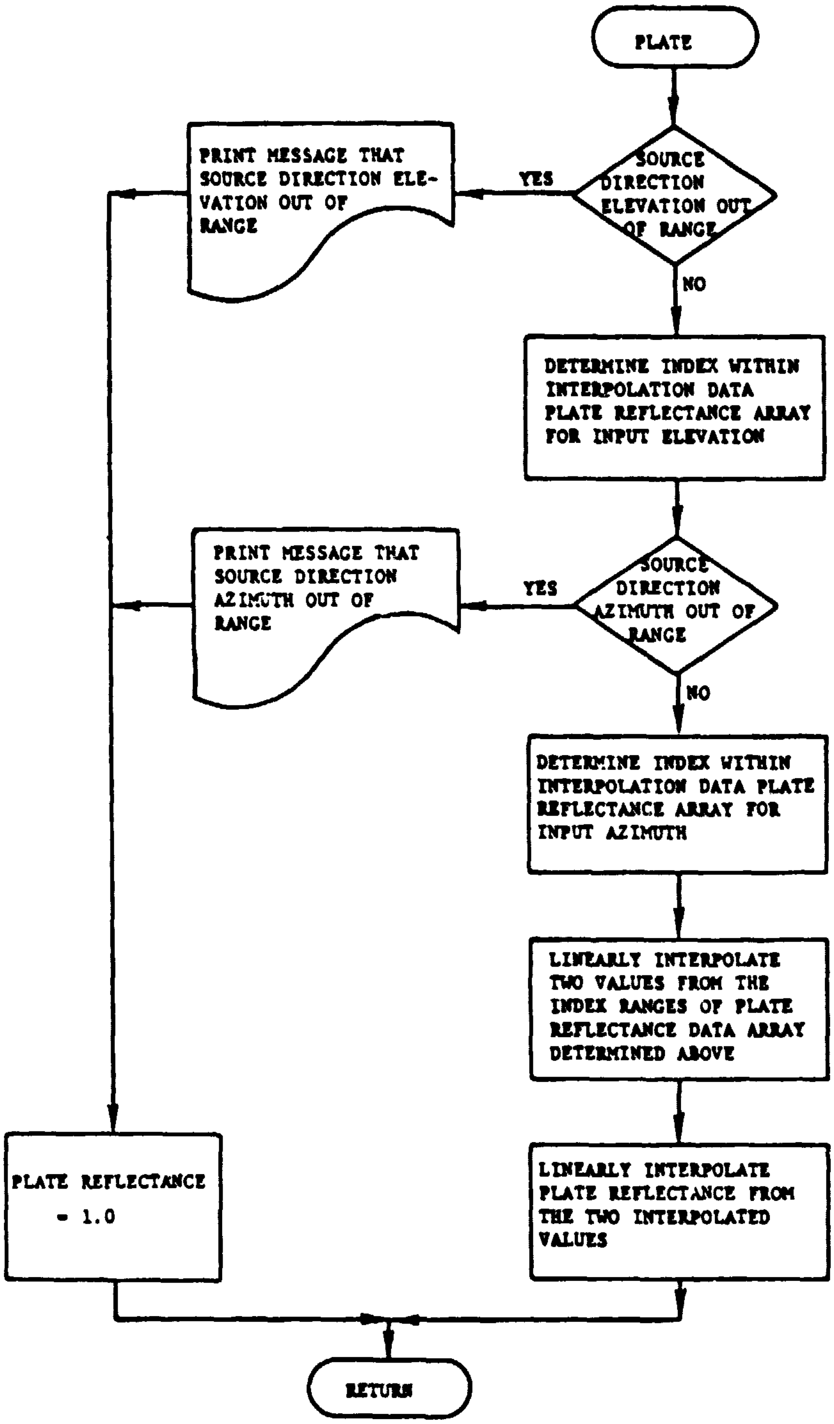


FIGURE 7.6 PLATE Flow Diagram (MATGEN 6.2.17.1)

COMMENTS:

The reflectance radiance are essentially solar blackbody in nature and therefore may be used in the flight calibration of the sensors.

Figure 7.6 shows the PLATE data flow.

7.3.3 LWCAL

Purpose: To determine the slope and intercept of the calibration line from fixed space and internal blackbody views, and to output a statistical summary of them for the orbit.

Method: The long wave channels are calibrated by comparison of counts during views of space and during views of the internal blackbody. Best-fit slopes and intercepts are calculated, along with statistics.

Reference: Subroutine LWCAL in Nimbus-6 software

Program Calling Sequence: Call IWCAL

Figure 7.7 shows the LWCAL data flow.

7.3.4 SPACE

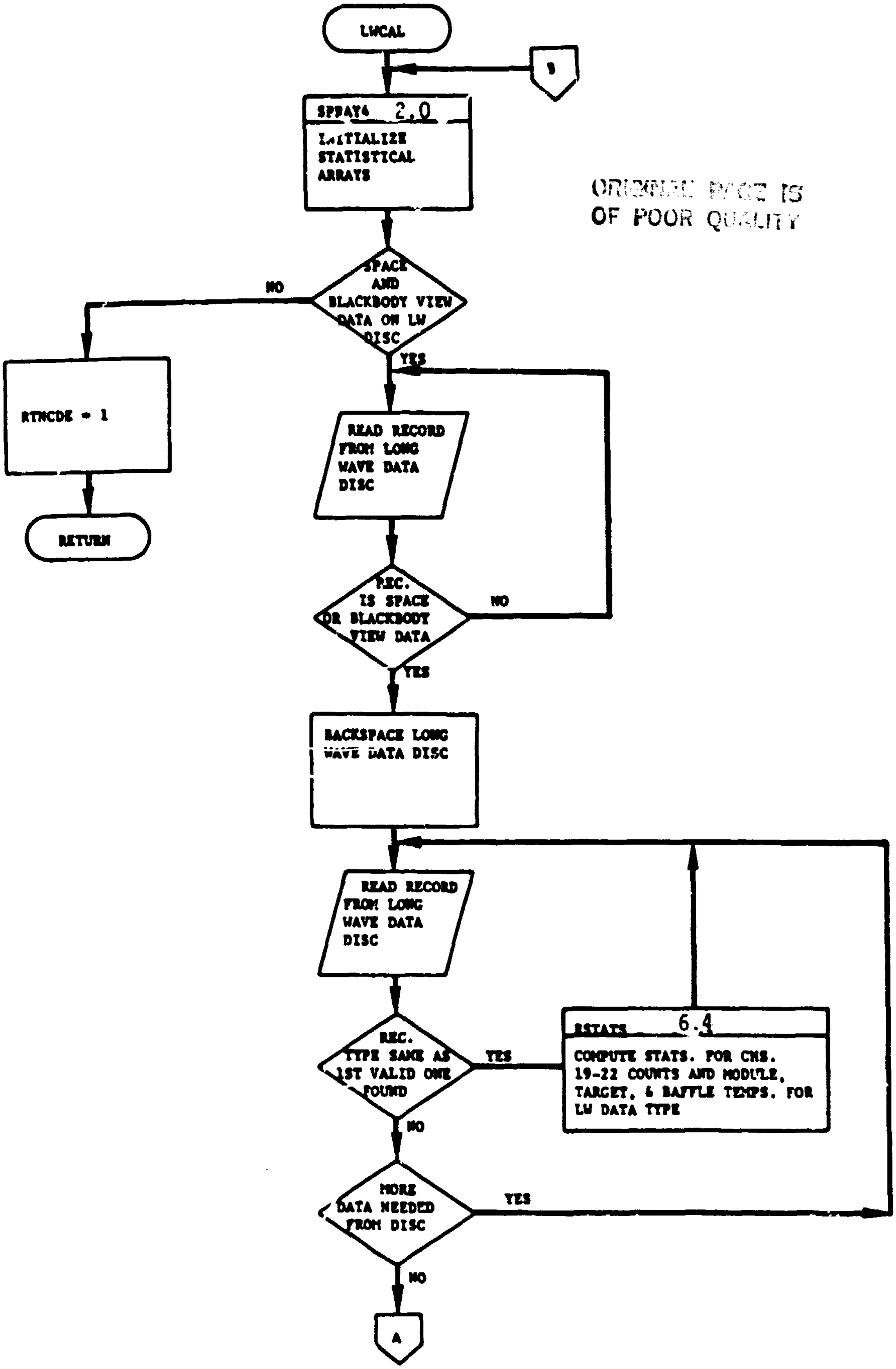
Purpose: Update the statistics for the scanning channel counts during the fixed views of space and write to disk the current major frame average of the mean counts, and mean module, target, PCRT, and baffle temperatures.

Method: Scanning channel statistics are updated in array SCSPVW by subroutine RSTATS. Average assembly temperatures are calculated by subroutine LWSCT, and the data for this major frame are then written out onto disk.

Reference: Subroutine SPACE in Nimbus-6 software

Program Calling Sequence:
Call SPACE (MFTIME, MFNO, ISCANS, JPTM, ITM,
SCSPVW, NSPREC)

Figure 7.8 gives the SPACE data flow.



ORIGINAL PAGE IS
OF POOR QUALITY

FIGURE 7.7 LWCAL Data Flow Chart (MATGEN 6.2.16)

ORIGINAL PAGE IS
OF POOR QUALITY

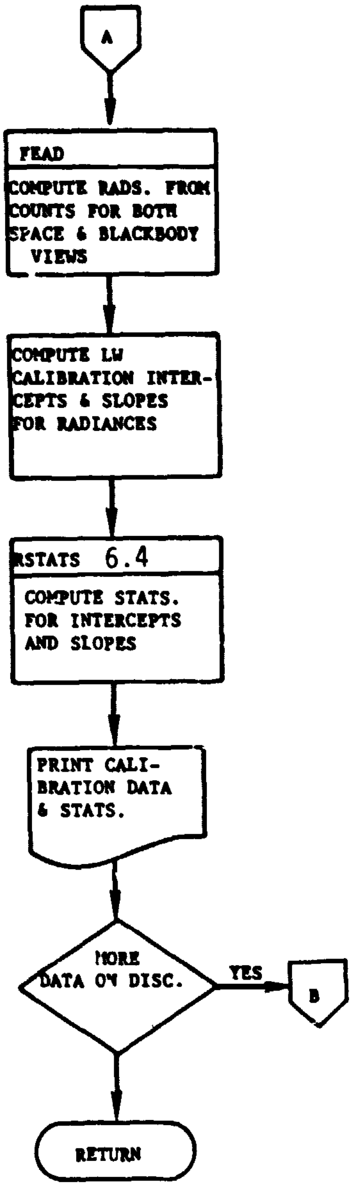


FIGURE 7.7 (CONTINUED)

ORIGINAL PAGE IS
OF POOR QUALITY

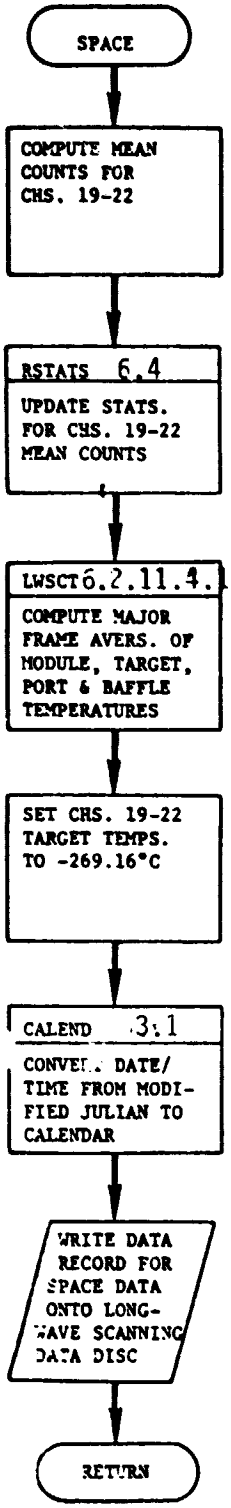


FIGURE 7.8 SPACE Data Flow (MATGEN 6.2.11.4)

7.3.5 SPSCS

Purpose: To update the statistics of detector counts for the eight scanning channels during scans of space.

Method: The subroutine is called if this is the second or the sixth major frame in the scan sequence. It is the second major frame, space scans take place during the ninth and tenth half-seconds. If it is the sixth major frame, space scans take place during the fifteenth and sixteenth half-seconds. Subroutine RSTATS is then called to update the scanning channel counts.

Reference: None

Figure 7.9 shows the SPSCS data flow.

7.3.6 LWCHK

Purpose: Update the statistics for the scanning channel counts during the views of the internal blackbody, and write the data onto disk.

Method: Scanning channels blackbody statistics are updated in array SCBBVW by subroutine RSTATS.

Reference: Subroutine LWCHK in Nimbus-6 software

Figure 7.10 shows the LWCHK flow diagrams.

7.3.7 GONOGO

Purpose: To update statistics during the G0/N0 G0 test for the ten solar channels and four earth flux channels, and to perform the calibration for channel 10C.

Method: The subroutine is called every major frame of the GO/NO GO test, which last 100 major frames. It is called when the G0/N0 G0 heaters are on and until forty major frames after they are turned off. The maximum counts for each channel are determined during the first major frame of the test. On the last major frame that the heaters are on, the minimum counts for each channel are determined. Counts averages are computed for each channel during every fifth major frame, whether or not the G0/N0 G0 heaters are on. After 100 major frames, or after the G0/N0 G0 test is over, these averages are printed and statistics are updated for each channel for the ratio of the difference between the minimum and maximum counts to a prelaunch value for same.

ORIGINAL PAGE IS
OF POOR QUALITY

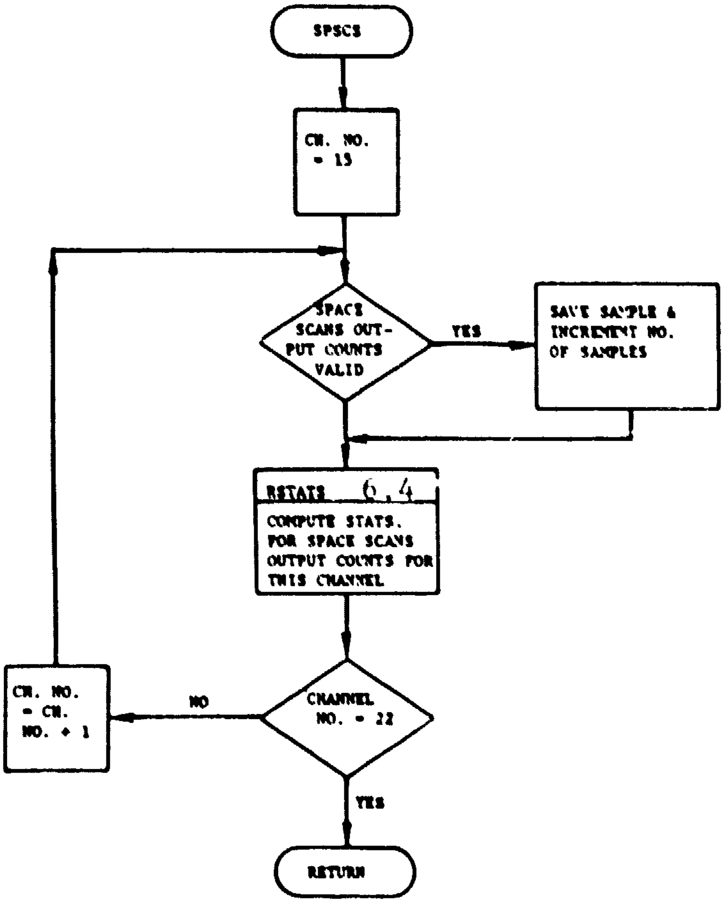


FIGURE 7.9 SPSCS Data Flow Diagram (MATGEN 6.2.9.3)

For the channel 10c calibration during the GO/NO GO test, the output heater current output, and the heater voltage output once per second. These outputs from channel 10c during the GO/NO GO test are tested against the provided limits to determine the type of measurement. The cavity, current, and voltage values for each major frame are averaged and used to compute an average power sensitivity.

Figure 7.11 gives the GONOGO data flow.

7.3.8 ISTAT

Purpose: To determine the statistics (minimum, maximum, mean and standard deviation) of a group of numbers.

Figure 7.12 gives the ISTAT data flow.

ORIGINAL PAGE IS
OF POOR QUALITY

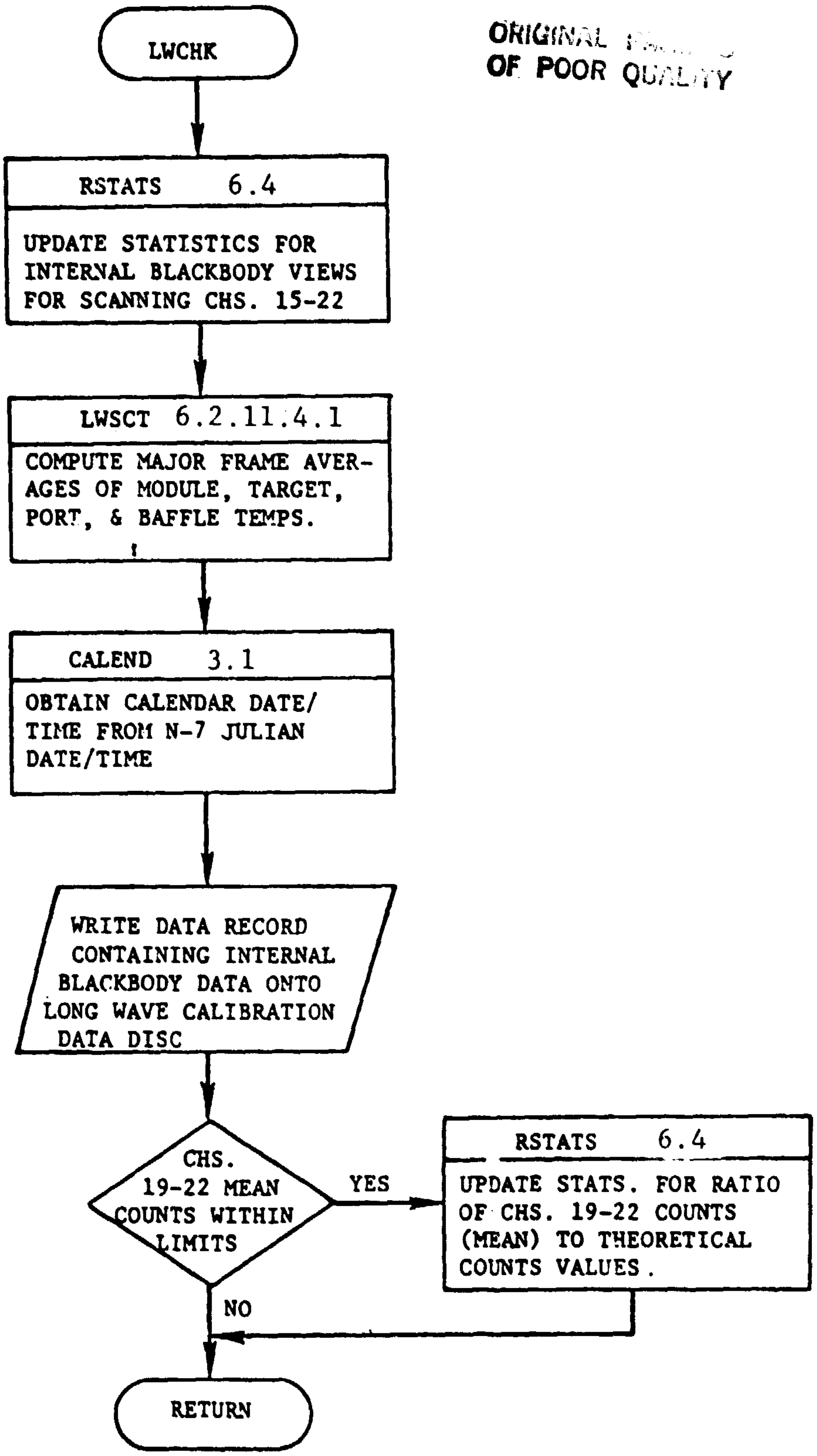


FIGURE 10.0 LWCHK Flow Diagram (MATGEN 6.2.11.6)

ORIGINAL PAGE IS
OF POOR QUALITY

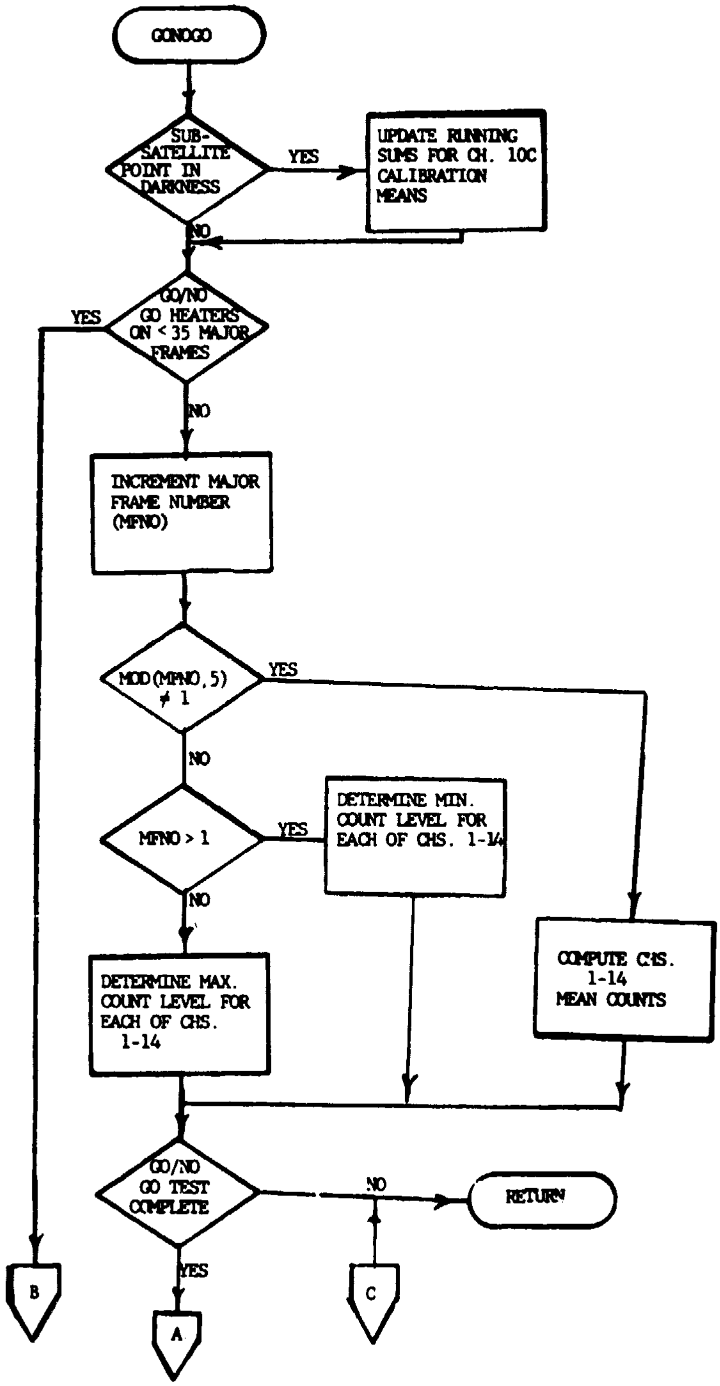


FIGURE 7.11 GONOGO Data Flow (MATGEN 6.2.11.1)

ORIGINAL PAGE IS
OF POOR QUALITY

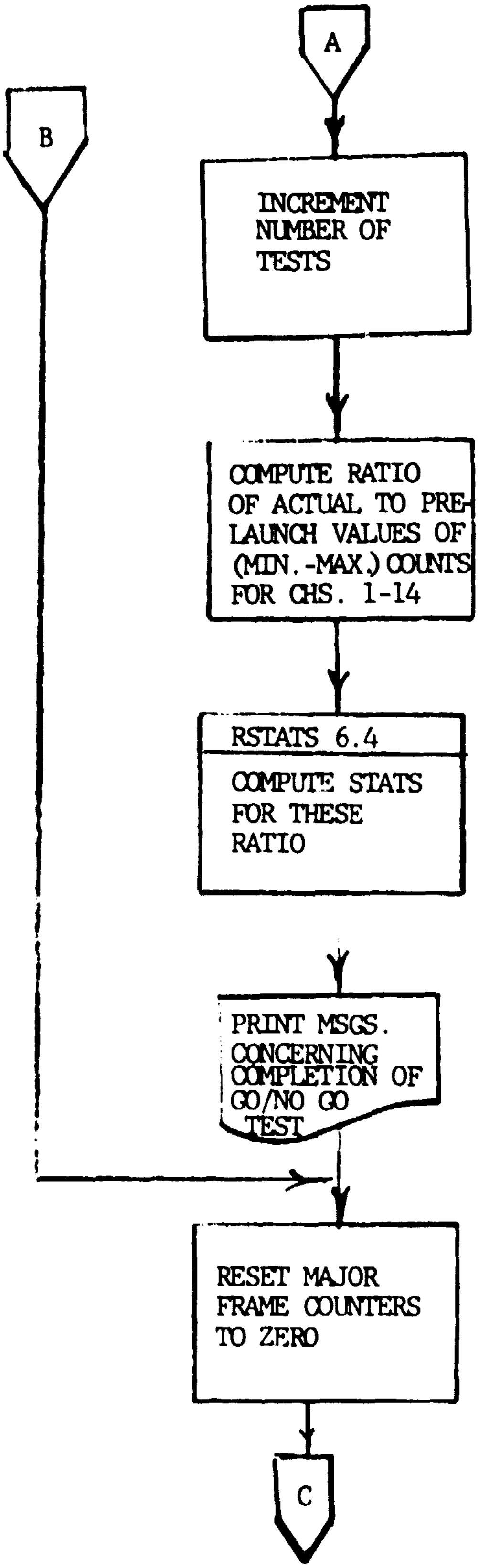


FIGURE 7.11 (CONTINUED)

ORIGINAL PAGE IS
OF POOR QUALITY

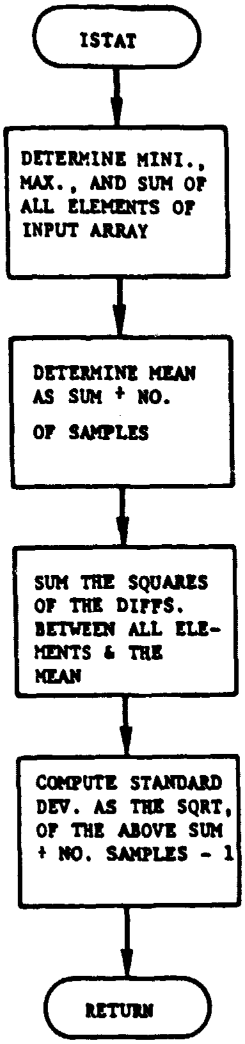


FIGURE 7.12 ISTAT Data Flow (MATGEN 6.2.15.1)

ORIGINAL PAGE IS
OF POOR QUALITY

8.0 SOLAR DATA PROCESSING ALGORITHMS

The solar sensor system does not track the sun throughout the Nimbus orbit. The sensors can be oriented so that they are above to view the sun for only a brief period each orbit at satellite sunrise. Thus the nature of the solar data during the three minutes the sun is in the sensor field of view makes it necessary to use special analysis techniques to determine the exact time at which to determine the on-sun average counts. To determine the correct time at which space and later the sun is viewed the subroutine PROCOR is used (Section 6.4.2).

Before and after solar acquisition (over the South Polar region) the ERB sun sensors view space. This almost constant value is averaged over three major frames at 26 and 13 minutes before and after solar acquisition and used as a reference value for Nimbus-7.

8.1 CHANNELS ALGORITHMS (1-10)

For channels 1 to 9 the following equations are used:

$$H = (V - V_o)/(S_V \cdot f(T_B)) \tag{8.1}$$

$$f(T_B) = 1.0 + 0.01A\,(T_B - 25.0^{\circ}C) \tag{8.2}$$

where

H = Solar irradiance (watts/m^2)

V = Average on sun counts[1]

V_o = Average off-sun counts[2]

S_V = Channel sensitivity at 25°C (counts/watt m^{-2})

A = Temperature correction coefficient (% per °C deviation from 25°C)

T_B = Thermopile base temperature (°C) (Thermister)

For ERB-7 channel 10c is a self-calibrating cavity thermopile. The equations used to convert counts to irradiance for this channel are:

$$H_{10c} = E_m c_f / S_p(T) \tag{8.3}$$

$$E_m = E_{os} - \frac{E(-13) + E(+13)}{2} \tag{8.4}$$

$$S_p(T) = S_0 + ST_H \tag{8.5}$$

ORIGINAL PAGE IS
OF POOR QUALITY

where

H_{10c} = Channel 10c irradiance (watts/m^2)

c_f = Channel 10c correction factor for aperture area and non-equivalence (m^{-2})

E_{os} = Average channel 10c on sun counts

E($\pm$13) = Average channel 10c counts at $\pm$13 minutes from on-sun time.

S_O = Power sensitivity zero level (counts/watt)

S = Power sensitivity slope (counts/watt °C)

T_H = Channel 10c heat sink temperature (°C)

8.2 SOFTWARE AND DATA FLOW

To process the solar data only one subroutine (SOLAR) was required. This routine is described and the data flow shown in Section 2.2.1.

To locate the solar data on the striped out ERB data tape it was necessary to determine the exact Julian time at which it was measured. This program and the data flow diagram is given in Section 2.2.2.

The sensor temperatures also required in the solar count to irradiance equations were also required for the earth viewing sensors. Therefore, this program and its data flow will be found in the general information sections (Section 7.0).

8.2.1 SOLAR

Purpose: Collect process data from ERB solar chs. when N-7 is in the solar collection zone of its orbit.

Method: Solar counts and instrument temperatures are saved for each of the 5 solar zones for later processing. The major frame in solar zone 3 in which the solar minimum occurs is also saved. When solar is called with ISLRZN=6, the stored values are recalled and statistics on the temperatures counts are computed. Normalized solar irradiances are also computed.

Figure 8.1 shows the SOLAR data flow.

ORIGINAL PAGE IS
OF POOR

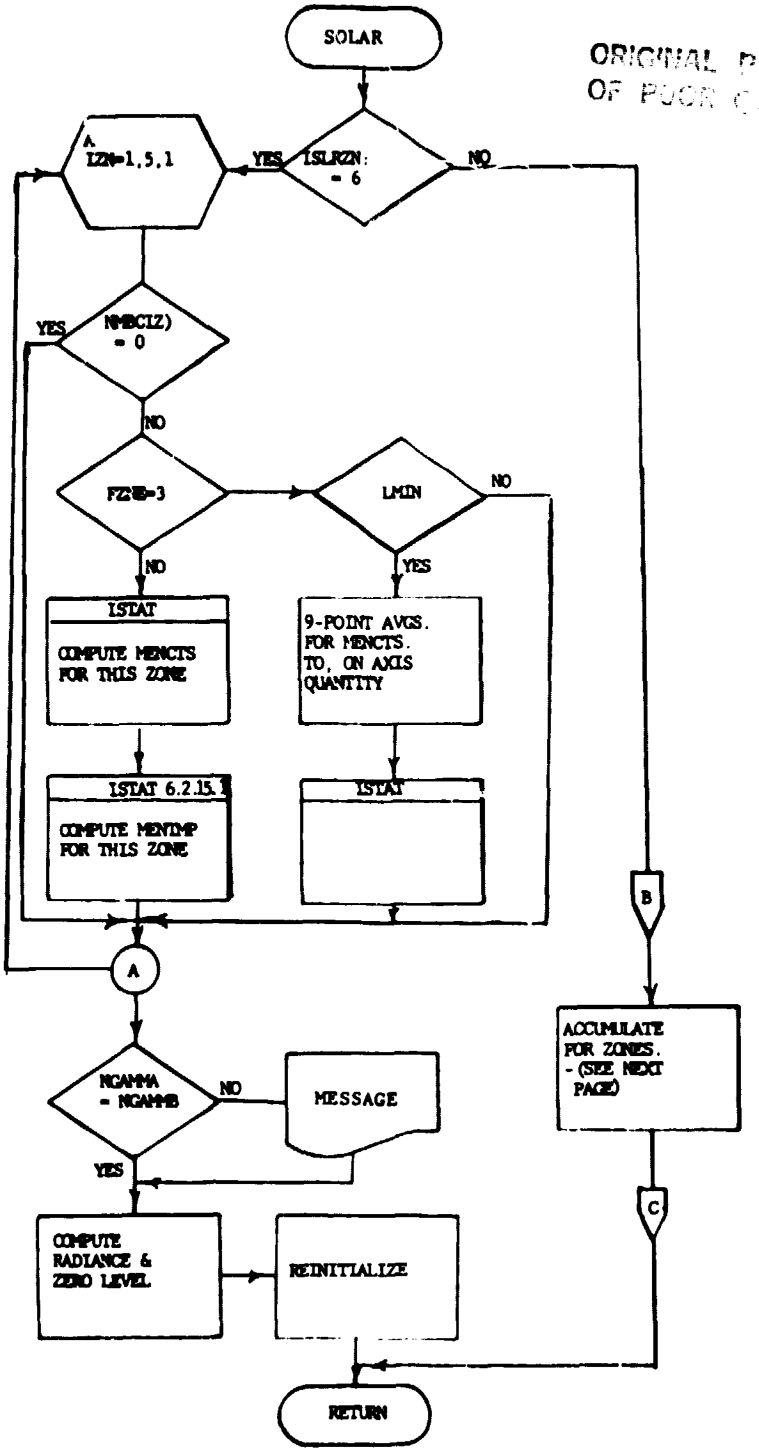


FIGURE 8.1 SOLAR Data Flow (NOPS ERB MATGEN 6.2.15)

OF POOR Q

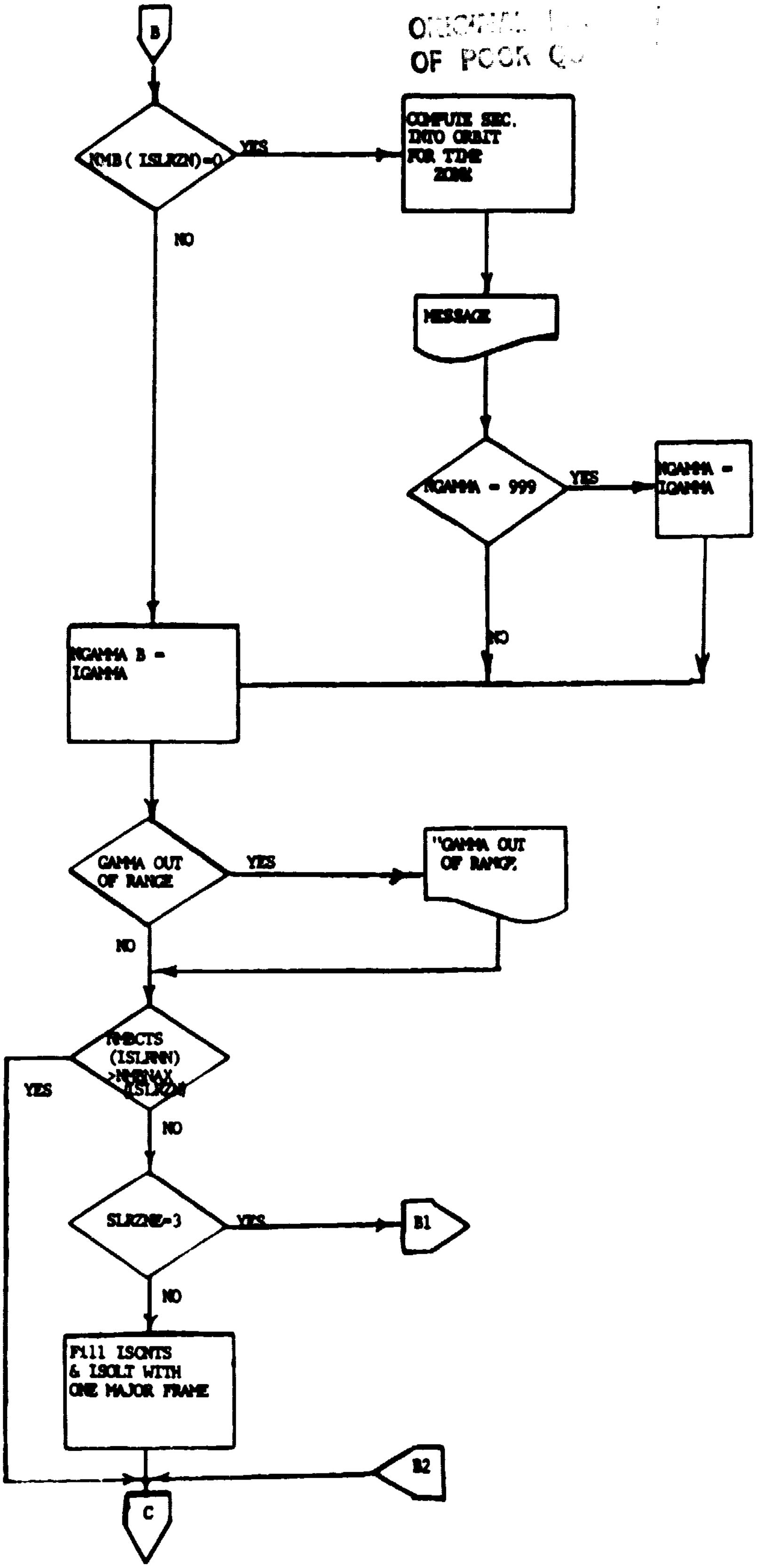
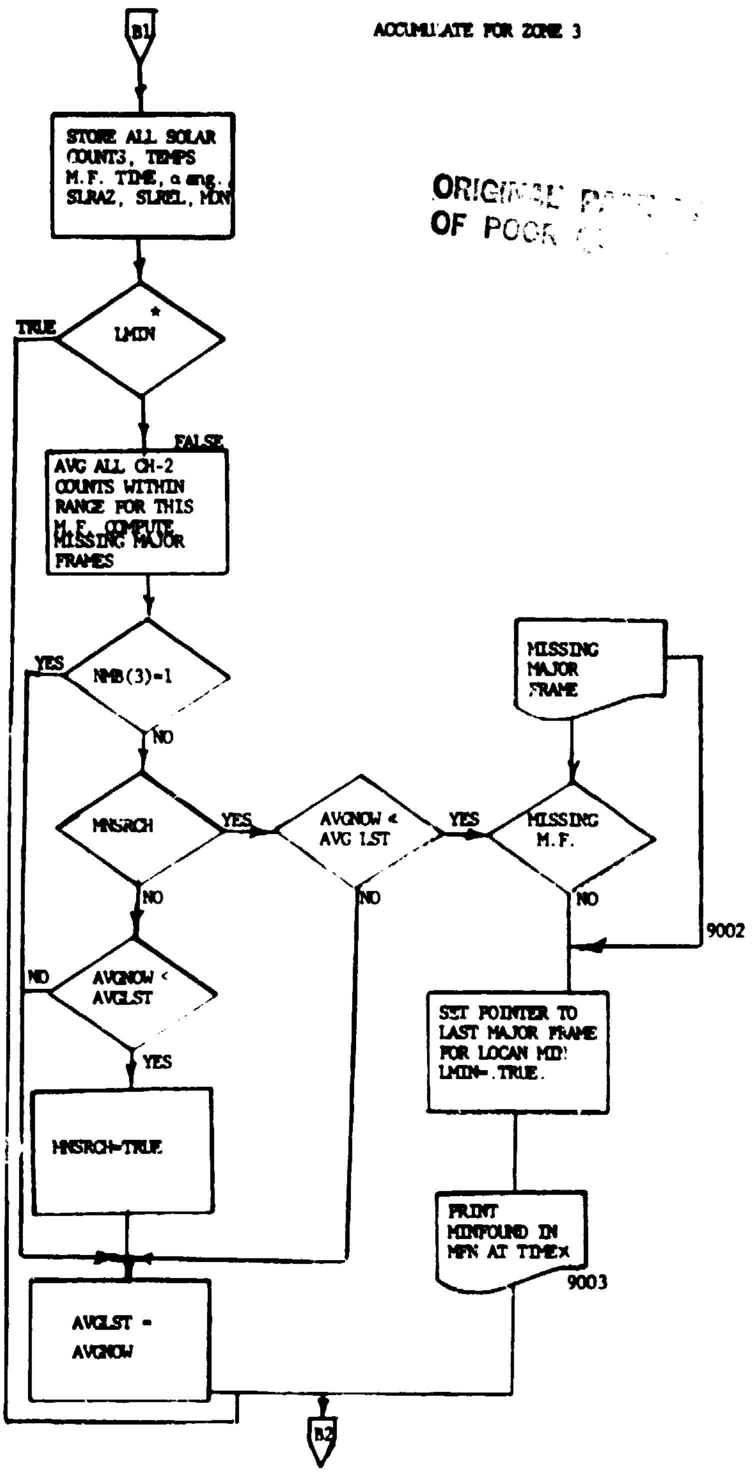


FIGURE 8.1 (CONTINUED)



ORIGINAL PAGE IS
OF POOR QUALITY

FIGURE 8.1 (Continued)

9.0 GENERAL REFERENCES

Ardanuy, P., (1981), "An Estimate of the Effect of Platinum Temperature Monitor Coefficient Errors on the Nimbus-7 Radiance and Irradiance Measurements", Research and Data System Memo, NASA Contract NAS 5-26123, Task 1, March 1981.

Attachment C, Ninth NET Meeting minutes, Dec 1977, and telephone message from J. Hickey to J. Kogut, 11-9-78.

Flynn L.R.M. (1982) "ERB MATGEN Programmer's Manual" SASC contract NAS5-26773 for NASA Goddard (Sept. 1982)

G.E., (1975), "Nimbus 6 Data Catalogue Vol. 1", 12 June 1975-31 August 1975, orbits 1 through 1082.

Gulton (revised 1975) "Operation and Maintenance Manual for ERB Radiometer Subsystem for Nimbus F," Gulton Rept. 13936-970, NOAA Contract 2-35297

Howell, H.B., (1975), "Recalibration of Platinum Resistance Thermoeters (PRT's) in Four ERB Calibration Black Bodies", U.S. Dept. of Commerce, NOAA, National Environmental Satellite Service, 12 September 1975.

Howell, H.B., (1975) "ERB Calibration Coefficients", Letter to record U.S. Dept. of Commerce, Environmental Science Services Administration, National Environmental Satellite Center, 16 May 1975.

Howell, H.B., (1980), "Letter to A. Arking, re: ERB-6 Ingest Program", July 1980.

Jacobowitz, H., "ERB-6 Ingest Print Documentation", NOAA World Weather Building.

Kogut, J.A., (1979), "Current MATGEN Calibration Constants", SASC memo July 1979.

SASC document, "Overall ERB Subsystem Process Flow", MATGEN 5-level summary working paper (subject to change during 1981).

Soule, H.V., (1983), "ERB Calibration Algorithm History", Research and Data Systems, Inc., Contract NAS 5-26123, March 1981.

APPENDIX A

A-1 DIGITAL SOLAR ASPECT SENSOR (DSAS)

A-1.1 ANGLE DEFINITIONS AND COMMENTS

The DSAS sensor system is a separate set of four pairs of orthogonally oriented sensors providing the orientation of the sun with respect to Nimbus-7 and particularly ERB. The four pairs of arrays each have a 62° different field-of-view. Appropriate coordinate computation depends upon the set of sensors receiving the greatest solar illumination.

Referring to Figure A-1 in which the observer is in the plane of the Nimbus orbit; (plane of the paper) it will be noted that the DSAS(α) angle is between the plane of the sun and Nimbus orbit plane through the center of the earth. The descending and ascending nodes about the earth's equator are as noted.

Because of the earth's shape β increases at about one degree a year. For this reason the time at which the satellite crosses the equator changes and a noon crossing in 1975 will become 11:40:30 in 1980.

Sometimes the β angle is called the solar right ascension relative to the spacecraft (S/C). Shown in Figure A-2 is the (S/C) reference system with X, Y and Z coordinates representing the conventional axis. The sun's motion about this system is shown via the dotted line. Here the (β) angle lies between (A), the S/C to sun vector, and the (X) velocity vector.

The DSAS (α) angle is the elevation of the S/C solar vector above the S/C (X,Y) plane. As the Nimbus orbits the earth the (α) angle goes through 2πradians. The (α) angle is considered zero at the time of the ERB solar observation. It then goes negative and becomes $-\pi$ near the North Pole and $+\pi$ just prior to solar observation near the South Pole.

The DSAS (γ) angle gives the azimuth of the solar aspect sensors with respect to the (X) axis in the S/C (X,Y) plane. To correct for the varying angle between the S/C orbital plane and the sun-earth vector, (γ) is adjustable. It is nominally set equal to (β) but with an opposite sign.

1. The " β " angle is the angle between the sun-earth vector and the S/C orbit plane.
2. This angle increases from year to year by about 1° per year. Thus, a sun-synchronous orbit ascending at noon in 1975 will ascend at 11:40:30 AM in 1980.

ORIGINAL PAGE IS
OF POOR QUALITY

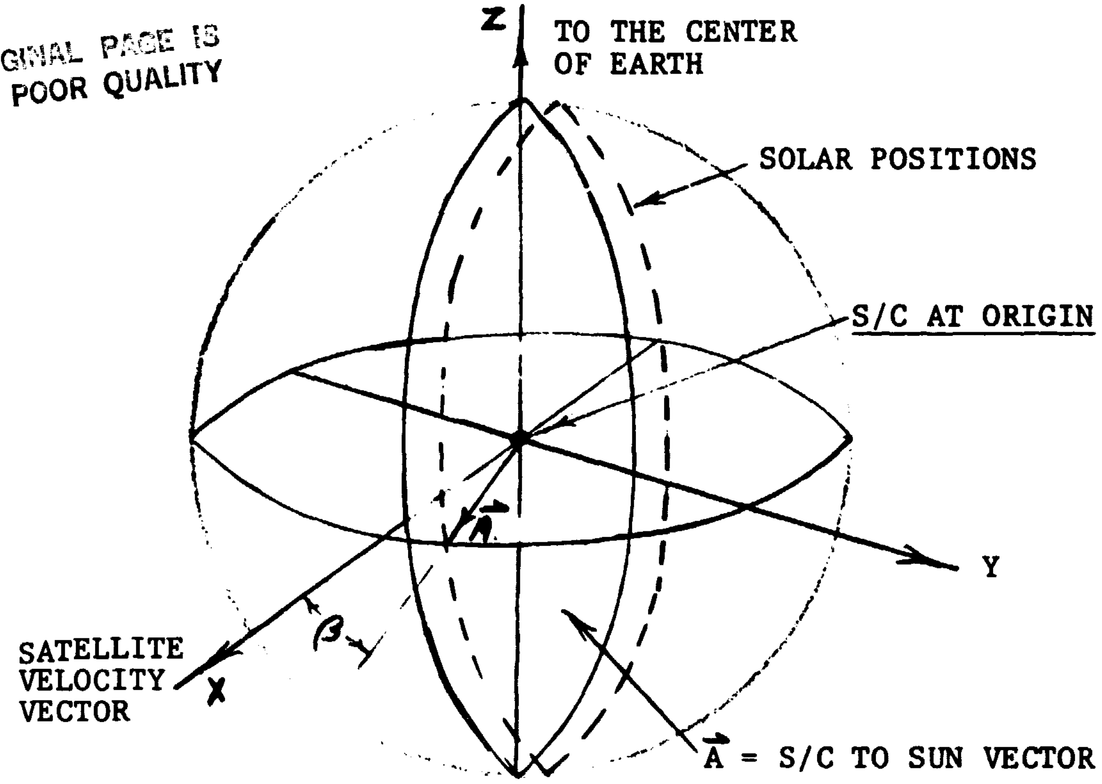


FIGURE A-2 SATELLITE/SUN FRAME OF REFERENCE

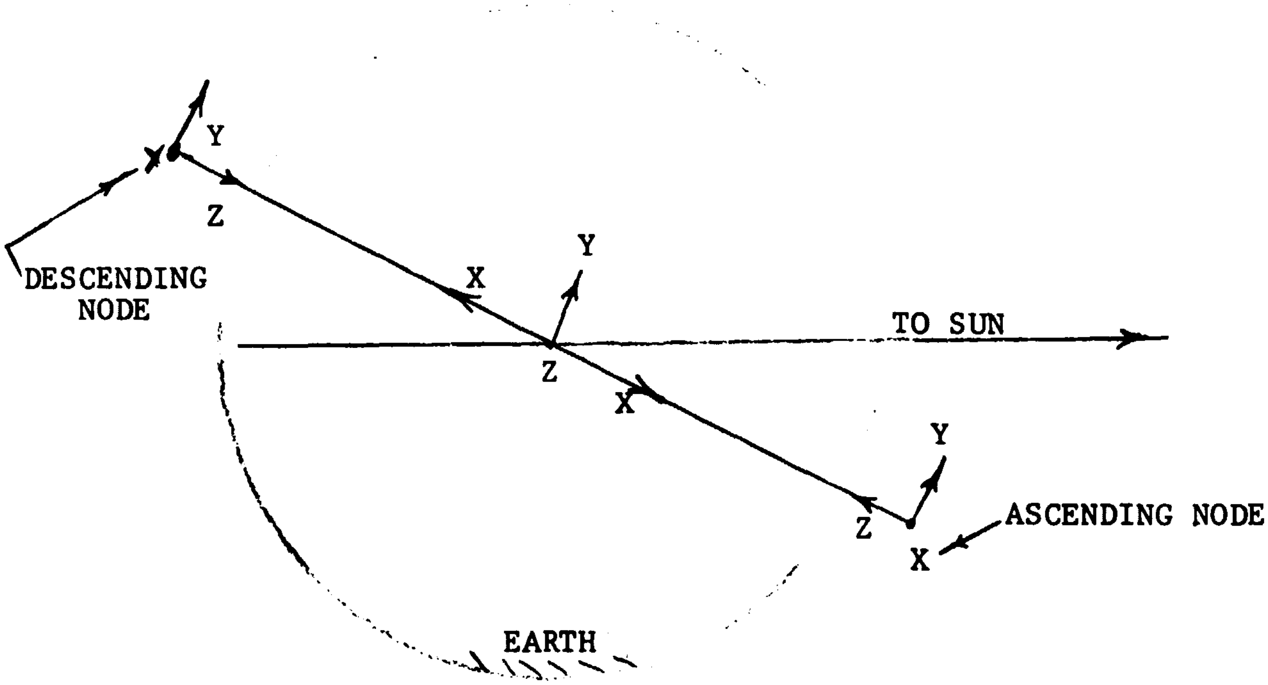


FIGURE A-1 Schematic of the S/C orbital plane angle with respect to the sun about the center of the earth.

3. The DSAS (digital solar aspect sensor) "β " angle is the azimuth angle between the projection of the S/C-solar vector onto the S/C x-y plane and the S/C x-axis. For the N-6 and N-7 S/C it is always positive and varies throughout the orbit. It reaches a minimum when the S/C-solar vector is along the S/C x-y plane near S/C sunrise. This is the time of the solar observation and is the only time for an orbit when the two definitions of the " β " angle coincide. The "β" angle is sometimes also defined as the solar right ascension relative to the S/C.
4. The DSAS " α " angle is the elevation of the S/C-solar vector above the S/C x-y plane. This angle goes through 2 π radians in the time of one orbit period. For ERB-6 this is approximately -.058 radians per second. It is zero at the time of the solar observation and becomes negative immediately after.
5. The S/C " ν " angle measures the azimuth of the solar channel subassembly to the S/C x-axis in the S/C x-y plane. This is adjustable to correct for the varying angle between the S/C orbit plane and the sun-earth vector. This angle is nominally set to a value corresponding to the magnitude of the " β " angle with opposite sign.
6. DSAS " α " and " β " angles are computed from four pairs of orthogonally oriented sensors each angularly separated by 62 degrees. Depending on the pair of sensors most illuminated by the sun, an appropriate coordinate rotation is performed.

TABLE A-1 SOLAR ELEVATION ALGORITHMS

INPUT	PROCESS	OUTPUT
TIME OF FIRST EPHEMERIS DATA DECLINATION OF SUN SATELLITE ATTITUDE DATA $(x,y,z,\dot{x},\dot{y},\dot{z})$ CONST PI = 3.1415926535 GME = GRAVITATIONAL CONST FOR EARTH $= 0.3986032 \times 10^{15}$	3.1.3.1 FOR FIRST ORBIT CALCULATE ORBITAL PERIOD (ORBPER) 3.1.3.2 CONVERT CARTESIAN ORBITAL ELEMENTS TO KEPLERIAN ELEMENTS $RSQ = x^2 + y^2 + z^2$ $R = (x^2 + y^2 + z^2)^{\frac{1}{2}}$ $S = (vx^2 + vy^2 + vz^2)^{\frac{1}{2}}$ $A = (2 \cdot GME - R \cdot S^2)/(GME)^{\frac{1}{2}}$ $DD = (GME)^{\frac{1}{2}} \cdot (1/R - A)$ $EX = ((D^2 \cdot A) + (RSQ \cdot DD^2/GME))^{\frac{1}{2}}$ $P = A(1 - EX^2)$ $H = R - P$ $HD = ((GME)^{\frac{1}{2}} \cdot D)/R$ $PZ = (DD \cdot Z) - (D \cdot VZ)$	

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE A-1 (CONTINUED)

INPUT	PROCESS	OUTPUT
ORBITAL PERIOD	$QZ = ((HD \cdot Z) - (H \cdot VZ))/P^{\frac{1}{2}}$ $W = ARCTAN\ (PZ, QZ)$ 3.1.3.3 COMPUTE THE ORBITS ECCENTRIC ANOMALY FOR VZ = 0 $ECCZ = ARCTAN \left[(1 - Ex^2)^{\frac{1}{2}}, TAN\ (ARCTAN(PZ, QZ))\right]$ 3.1.3.4 FIND THE TIME WHEN VZ = 0 $TZERO = \left[(ECCZ - (Ex \cdot SIN\ ECCZ)) - (ARCTAN\ (D/A^{\frac{1}{2}}, R \cdot DD/(GME)^{\frac{1}{2}} - (D/A^{\frac{1}{2}}))\right]$	
	$\left[((GME)^{\frac{1}{2}}/A^{1.5}) \cdot 86{,}400\right]$ 3.1.3.5 CORRECT FOR LOCATION OF START OF ORBIT 1. IF DN AND BELOW EQ. TMNSEL = TZERO	

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE A-1 (CONTINUED)

INPUT	PROCESS	OUTPUT
	2. IF AN AND BELOW EQ. TMNSEL = TZERO + ORBITAL PERIOD 3. IF AN OR DN AND ABOVE EQUATOR TMNSEL = TZERO + ½ ORBITAL PERIOD 3.1.3.6 CORRECT FOR DECLINATION OF SUN TMNSEL = TMNSEL + (SOLAR DEC/2π) ORBITAL PERIOD	TIME OF MINIMUM SOLAR ELEVATION

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE A-2 ORBITAL PERIOD ALGORITHMS

Calculate orbital period - Calculate the approximate orbital period of a satellite given its state vecotr in cartesian coordinates. Kepler's Laws for two-body motion are used to find the semi-major axis of the orbit and the approximate period. MKS unites are used.

INPUT	PROCESS	OUTPUT
x, y, z POSITION OF SATELLITE IN METERS VALUE OF SATELLITE VELOCITY (vx, vy, vz) IN x, y, z DIRECTION IN M/SEC	$R = (x^2 + y^2 + z^2)^{\frac{1}{2}}$ $V = (vx^2 + vy^2 + vz^2)^{\frac{1}{2}}$ 3.1.3.1.1 CALCULATE THE SEMI-MAJOR AXIS OF THE ORBIT FROM THE EQUATION $A = 1.0/\left[(2/R) - (v^2/GM)\right]$ 3.1.3.1.2 CALCULATE THE APPROXIMATE ORBITAL PERIOD FROM KEPLER'S 1ST LAW $\text{PERIOD} = \left[2\pi\ (A^3)^{\frac{1}{2}}/(GM^{\frac{1}{2}}/86400)\right]$ WHERE $GM = 3.986013 \times 10^{14}$	ORBITAL PERIOD

ORIGINAL PAGE IS
OF POOR QUALITY

APPENDIX B

DATA MANIPULATION SUBROUTINE LIST

The following listing and program descriptions are used in MATGEN to produce the proper operations and data flow. These data flow diagrams will be found in reference 1.

ABCHK	Checks alpha and Beta positions for a major frame to determine scan head position specified by IAR or IBP. If IAP or IBP position maintained then IAY or IBY equals 1. Otherwise they are set to zero (MATGEN 6.2.3.1).
ACTINF	Prints the accounting information for MATGEN. (MATGEN 9.0)
CHKSUM	Compute a 16-bit check sum word for an integer*4 array for length "NIN". The input array is an integer*2 array of dimension (2*NIN). (MATGEN 8.1)
CPYSEF	Mount a new and old SEFDT tape and copy the old SEFDT onto the new. (MATGEN 1.4)
DEFDSR	Inputs arrays, other data is stripped and placed in the daily summary record. (MATGEN 7.1)
DEFOSR	Puts data into the orbital summary data buffer scaling where necessary. (MATGEN 6.3.1)
DLYSUM	Creates and writes the Daily Summary Record on the Master Archive Tape and prints the various other daily averages and statistics. (MATGEN 7.0)
EFLXLR	Writes the earth flux logical record onto the SEFDT tape. It fills the logic record with two major frames of earth flux data and copies it onto the solar earth flux data tape physical record when the logical record is full. (MATGEN 6.2.1.4)
INIORB	Initializes orbital variables and compute the next orbit to be processed. (MATGEN 6.1)
LRMAT	Write a major frame of data onto the MAT tape logical data record. In version 1 data is converted into 16 bit integers with appropriate scaling attempting to store data volume. (MATGEN 6.2.13)
LWSCT	Computes the major frame averages of the ERB module, target, part and buffer temperatures (MATRIX 6.2.11.4.1).
MATREC	Inserts the logical record into the physical record buffer for the MAT tape. When this buffer is filled, it will be written onto the tape. (MATGEN 7.3)

MNOPS	Mounts the appropriate input or output tapes. It contains a program calling sequence. (MATGEN 3.2)
MNTILT	Mount the correct ILT. (MATGEN 1.3)
MNTMAT	Mounts the Master Archival Tape and its copy. It also writes the Standard Header and prints a copy on a shipping label. (MATGEN 3.0)
MNTSEF	Mounts the Solar Earth Flux Data Tape (SEFDT), writes the header, writes the first file and prints the shipping label. (MATGEN 4.0)
MTCHMF	Determine which major frame on the UFO and ILT tapes coincide for a particular time period. It flags sync and data quality errors. (MATGEN 6.2.1).
MNTUFO	Mounts UFO tape, checks correctness, adds header to list used for current months SEFDT. (MATGEN 1.2)
NOPLAB	Determines if the standard header is correct for NOPS input tapes and creates the correct standard header for NOPS output tape. (MATGEN 3.2.1)
NXTILT	Returns the data from the next ILT major frame to be processed. (MATGEN 6.2.1.1)
NXTUFO	Passes to calling routine spacecraft time and a pointer to report UFO digital A data. (MATGEN 6.2.1.3)
ORBSUM	Calls subroutines which define and print the MAT orbital summary record. It also defines and writes the SEFDT solar summary record. (MATGEN 6.3)
PROCDY	Processes a day of ERB data, one orbit at a time. (MATGEN 6.0)
PRTDSR	Sets up daily summary record by inputting the parameters contained in the daily summary record and other averages and statistics. (MATGEN 7.2)
PRTOSR	Prints daily orbital summary record, daily averages and statistics. (MATGEN 6.3.2)
REGLIN	Computes least-squares best fit and correlation coef. for (X,Y) inputs data (MATGEN 6.2.11.2.1).
RESTDY	Read restart information used in the MAT daily summary from the disk if the previous run did not finish a day's processing. (MATGEN 5.0)

RSTATS	Updates statistics (minimum, maximum, mean, std, number of elements and sum of squares) of a group of numbers by adding the effect of NX values of array (X) (real numbers).
RUNINT	Establishes run parameters, mount correct input tapes and copies the input SEFDT. (MATGEN 1.0)
SCTGMT	Converts spacecraft time to modified Julian date using time correction file data (MATGEN 6.2.1.2).
SEFREC	Creates a physical record from the computed logical data and record in the buffer. When the buffer is full it records this data on tape. (MATGEN 8.0)
SETRNP	Sets the day's run parameters. These parameters are read off a logical disc unit and cards and are stored for common use. (MATGEN 1.1)
SOLDLR	Writes the solar data logical record on the SEFDT tape and fill buffer. (MATGEN 6.2.12)
SPRAY2	Sets 2-byte array to some value. (MATGEN 4.1)
SPRAY4	Sets 4-byte array to some value. (MATGEN 2.0)
UNPACK	Unpacks the ERB digital A data, and create variables for the digital A words. (MATGEN 6.2.2)
UNPDQ	Unpacks the data quality information from the ILT tape. (MATGEN 6.2.1.1.1)
UNPILT	Unpack ephemeris data from the ILT tape. (MATGEN 1.5.1)
UNPTCF	Unpack the time correction file from the ILT tape. (MATGEN 1.3.1)

APPENDIX C

ABBREVIATIONS AND TERMINOLOGY

ACS	Attitude Control System
BB	Blackbody
CAT	Calibration Adjustment Tape
CH	Channel
DIG WD	Digital Word
DSAS	Digital Solar Aspect Sensor
DT	Data Tape
E	Earth Flux Channels
ERBMAT	ERB Master Archival Tape
ILT	Image Location Tape
LOS	Line-of-Sight
LSB	Least Significant Bit
MAT	Master Archive Tape
MATGEN	Master Archive Tape Generation
MF	Major Frame
MSB	Most Significant Bit
n	Angle Symbol
NFOV	Narrow Field-of-View
NOAA	National Oceanic and Atmospheric Administration
PRT (PTM)	Platinum Resistance Thermometer
PTM EX	Platinum Thermometer Bridge Excitation Data (plus or minus)
+PTM/-PTM	Platinum Thermometer Data (plus or minus)
QC	Quality Control
S	Solar Channels
S/C	Spacecraft
SEFDT	Summary Earth Flux Data Tape
Sign	Polarity Sign Bits
SSP	Subsatellite Point
UFO	User Formatted Output
VIP	Versatile Information Processor
WFOV	Wide Field-of-View
	Scan Head Angle

APPENDIX C (cont'd)

	Gimbal Angle-or Solar Right Ascension Angle
	Solar Assembly Angle
10 LSB and 10 Sign	Ten least significant bits and ten sign bits of ten preceeding TPM and channel words in chronological order from MSB to LSB.
	6 Bit Gray Code for Solar Channel Assembly Encoder