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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite Service

The Operational Processing of Solar Proton Monitor and Flat Plate Radiometer Data

HENRY L. PHILLIPS AND LOUIS RUBIN

WASHINGTON, D.C.
May 1972

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NESCTM 9 Meso-Scale Archive and Products of Digitized Video Data From ESSA Satellites. Arthur L. Booth and V. Ray Taylor, October 1968. (PB-180 294)

NESCTM 10 Annotated Bibliography of Reports, Studies, and Investigations Relating to Satellite Hydrology. D. R. Baker, A. F. Flanders, and M. Fleming, June 1970. (PB-194 072)

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THE OPERATIONAL PROCESSING OF SOLAR PROTON MONITOR AND FLAT PLATE RADIOMETER DATA

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THE OPERATIONAL PROCESSING OF SOLAR PROTON MONITOR AND FLAT PLATE RADIOMETER DATA

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ABSTRACT. Described is the operational processing of data obtained from the flat plate radiometer and solar proton monitor sensors flown on environmental satellites of the new TIROS (television infrared observation satellite) series named ITOS (improved TIROS operational satellite). Hardware systems aboard the ITOS are discussed; and the software procedures relevant to the data recovery, recording, and transmission problems are described. Included are descriptions of tape formats, message formats, data-location procedures, data-frame contents, and a partial index of processed data available in archival form.

1. INTRODUCTION

The examination of large-scale atmospheric phenomena was made more realistic by using data from the economical LRIR (low-resolution infrared) sensors first flown on ESSA-3 (Environmental Survey Satellite) in 1967 (Rubin 1968 and MacDonald 1970). In 1970, the LRIR experiment was extended into the improved TIROS operational satellite (ITOS) series of environmental satellites using the flat plate radiometer (FPR) as the sensor (Parent and Nelson 1968). The operational FPR product is an archival tape. These taped data are used for further research-oriented data-reduction schemes.

A solar proton monitor (SPM) was introduced at the same time as the FPR. Data from the SPM are used in the preparation of warnings of solar proton storms and in the measurement and prediction of solar flare activity, factors that interfere with high-frequency radio communications and factors which may be hazardous to manned space exploration (Goddard Space Flight Center 1970). The SPM data are "summarized" shortly after being received and are than transmitted as the high-priority coded message "Quick Look" on the solar flare (teletypewriter) network (SOFNET). An archival tape for the SPM is also produced for a subsequent detailed study.

2. SENSORS AND DATA

This technical memorandum does not give detailed descriptions of the FPR and SPM sensors. For detailed descriptions, see Parent and Nelson (1968) and Cashion and Gary (1969).

A. Flat Plate Radiometer

The two main parts of the FPR are (1) the sensor head and (2) the assembly containing associated electronics. The sensor head contains one pair of radiative equilibrium (RE) sensors and one pair of thermal feedback (TF) sensors. All sensors have an earth-facing full hemisphere field-of-view. Each pair consists of a black sensor that measures the shortwave radiant energy emitted and reflected by the earth scene over the range of 0.3 to 30 μm(micrometers) and a white sensor that similarly measures radiation in the infrared range of 7 to 30 μm. The RE sensors, thermally insulated from the sensor head, are cooled by a mirror that reflects into space the heat radiated by the sensors. During normal operation, the sun is not included in the field-of-view of the mirror (Goddard Space Flight Center 1970).

Possible surface degradation to which the TF sensors are subjected in orbit may cause a shift in the infrared response range and, consequently, in the radiative power input; therefore, periodic calibration is required. A heat-controlled isothermal hemisphere within the radiometer housing serves as a calibration standard. The TF sensors, mounted on a motor-driven shaft, are rotated 180^{o} to view the isothermal hemisphere for calibration (Parent and Nelson 1968).

Each FPR data frame represents 32 s (seconds)of data and consists of 60 eight-bit words. See the appendix (I) for the frame contents and the location of the calibration mode flag; see also D of the appendix for the location of the calibration mode flag on the archival tape.

B. Solar Proton Monitor

The two main parts of the SPM are (1) a detector assembly containing six solid-state detectors and (2) an assembly containing associated electronics. Detectors 1, 2, 3, and 6 face away from the sun and are perpendicular to the satellite's direction in orbit. Meanwhile, throughout this orbit, detectors 4 and 5 face away from the earth.

The SPM measures flux in several ranges. Detectors 1 through 3 have full hemisphere fields-of-view and detect protons in ranges centered at 60, 30, and 10 Mev, respectively. Detector 4, with a 13^{o} field-of-view,detects electrons in the 100- to 750- Kev range. Detectors 5 and 6, with 40^{o} fields-of-view, detect alpha particles in the 12.5- to 32-Mev range and protons in the 0.27- to 60-Mev range (Goddard Space Flight Center 1970).

The SPM registers have a counting range from 0 to 2^{20} and an accuracy of 3 percent or one part in 2^{5}, considered adequate to define the particle flux magnitude (Cashion and Gary 1969); whereas the SPM data pulses are counted in a 20-stage-binary counting register. At the end of the accumulation interval, the contents of this register are transferred (in parallel) to a 20-stage-binary shift register. The contents of the shift register are examined to determine if a one appears in bit position 20. If a zero is in bit position 20, the contents are shifted left, a bit at a time, until a one enters position 20 or until a total of 15 shifts have taken place. The number of shifts is subtracted from 15 in an auxiliary subtracting register. At the end of this operation, a value M resides in the five low-order stages of the shift register; and a value N resides in the auxiliary subtracting register. The 20-stage-binary counting register has 1,048,576 different states (0 through 1,048,575). The M register (the five low-order stages of the shift register) has 32 different states (0 through 31), and the N register (the four-stage auxiliary subtracting register) has 16 states (0 through 15). The number of input pulses counted is $M2^N$ (Cashion and Gary 1969).

A SPM data frame represents 12 s of data and is represented by 20 nine-bit words; see J of the appendix for the content of each data word (also referred to as channels).

3. DATA-RECORDING SYSTEM

The incremental tape recorder (ITR) aboard the spacecraft is a miniaturized digital three-track magnetic tape device that serves as a storage and readout facility. FPR and SPM data together with synchronization (synch) pulses, housekeeping telemetry, and time-code data are recorded throughout the orbit. Readout of the ITR is by command from the command and data acquisition (CDA) ground station. The CDA station then transmits the data to a processing division of the National Environmental Satellite Service (NESS) at Suitland, Md. Prior to readout to the CDA station, the message content is processed through the on-board digital format converter (DFC). The DFC is the interface and control unit for the SPM, FPR, ITR, and analog to digital (A/D) converters. All data recordings and readouts are synchronized by the DFC.

The recording rate of the ITR is 15 bits/s ; the packing density is 300 bits/in. The tape reels hold 90 ft of tape. At 324,000 bits per track, a total of 972,000 bits may be stored on the three tracks. This is sufficient to record all data for 355 min or approximately three orbital passes (one orbital pass requiring about 115 min). The playback rate is approximately 2,000 bits/s ; thus, playback of the entire tape requires about 2.7 min (Goddard Space Flight Center 1970).

4. RAW-DATA INGESTION

The incremental tape recorder aboard the satellite records data simulataneously on all three tracks. The SPM data are recorded on one track; the FPR data, the housekeeping telemetry data, and the timecode data are combined and recorded on a second track; and the synch pulses (for the synchronization and timing of the data during ground processing) are recorded on the third track. Upon recorded playback, the three tracks are modulated by three oscillators. The three oscillator signals are combined in the DFC and sent to a multiplexor for transmission to the CDA station (RCA Astro Electronics Division 1970a). The data are transmitted over microwave

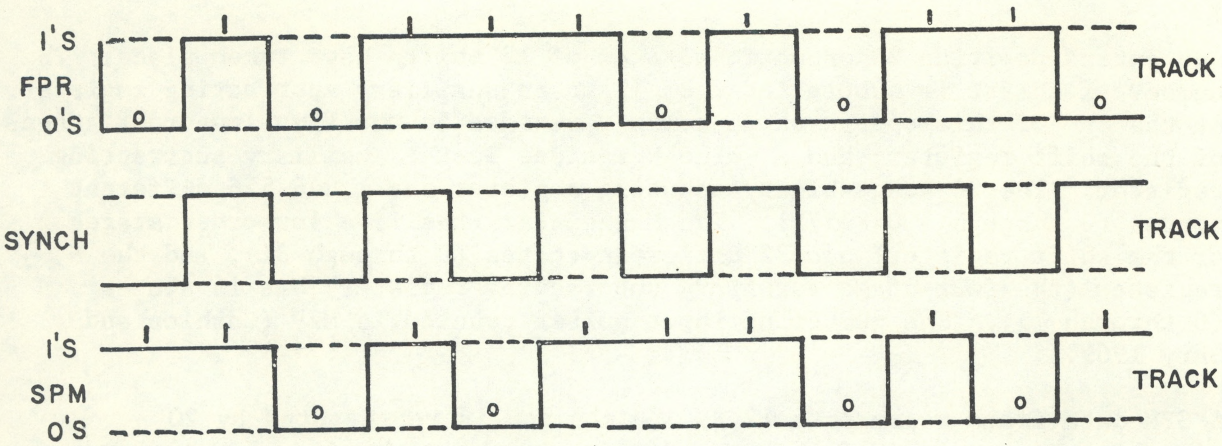

Figure 1.-- **Demultiplexed ITR signal**

communication facilities from the CDA station to the NESS where these data are processed through the digital data handling system (DDHS). The demultiplexed ITR signals appear as shown in figure 1. These signals are then routed to the input channels of an A/D converter programmed to sample each of the three input channels in a time multiplex fashion. The digital samples are then treated by an "ingest" program in a small computer (EMR 6130).

The ingest program determines the binary values of the data samples by examining that portion of the SPM and FPR data pulse which occurs between two consecutive synch pulse transitions. The voltage value, at the time of examination, determines the actual binary value of the data pulse. The binary values of the SPM and FPR telemetry are packed into separate output buffers and eventually written onto a magnetic tape for subsequent data-processing. The details of the format of this raw ingest-data tape are given in the appendix (A).

5. PROCESSING PROCEDURE

The NESS can receive the SPM data in either recorded or direct mode; the FPR data can be received only in the recorded mode. Recorded mode data are transmitted from the ITR aboard the satellite as described above. In the direct mode operation, the SPM data are simultaneously recorded on the ITR and transmitted to the CDA station while the observation is in progress. When the data recorded on the ITR are received on the ground, these data are compared with those transmitted directly at an earlier time. This serves as a means of verifying data quality. The direct transmission can be thought of as a backup mode in the event of satellite tape-recorder problems. Direct transmissions are limited to areas within the range of the CDA station.

A. Recorded Data

A flow diagram is perhaps the best way to illustrate basic steps in the processing of recorded data (fig. 2). Figure 3 contains a symbolic description of the data-processing operations in terms of inputs, outputs, and intermediate storage facilities. The data-processing scheme yields:

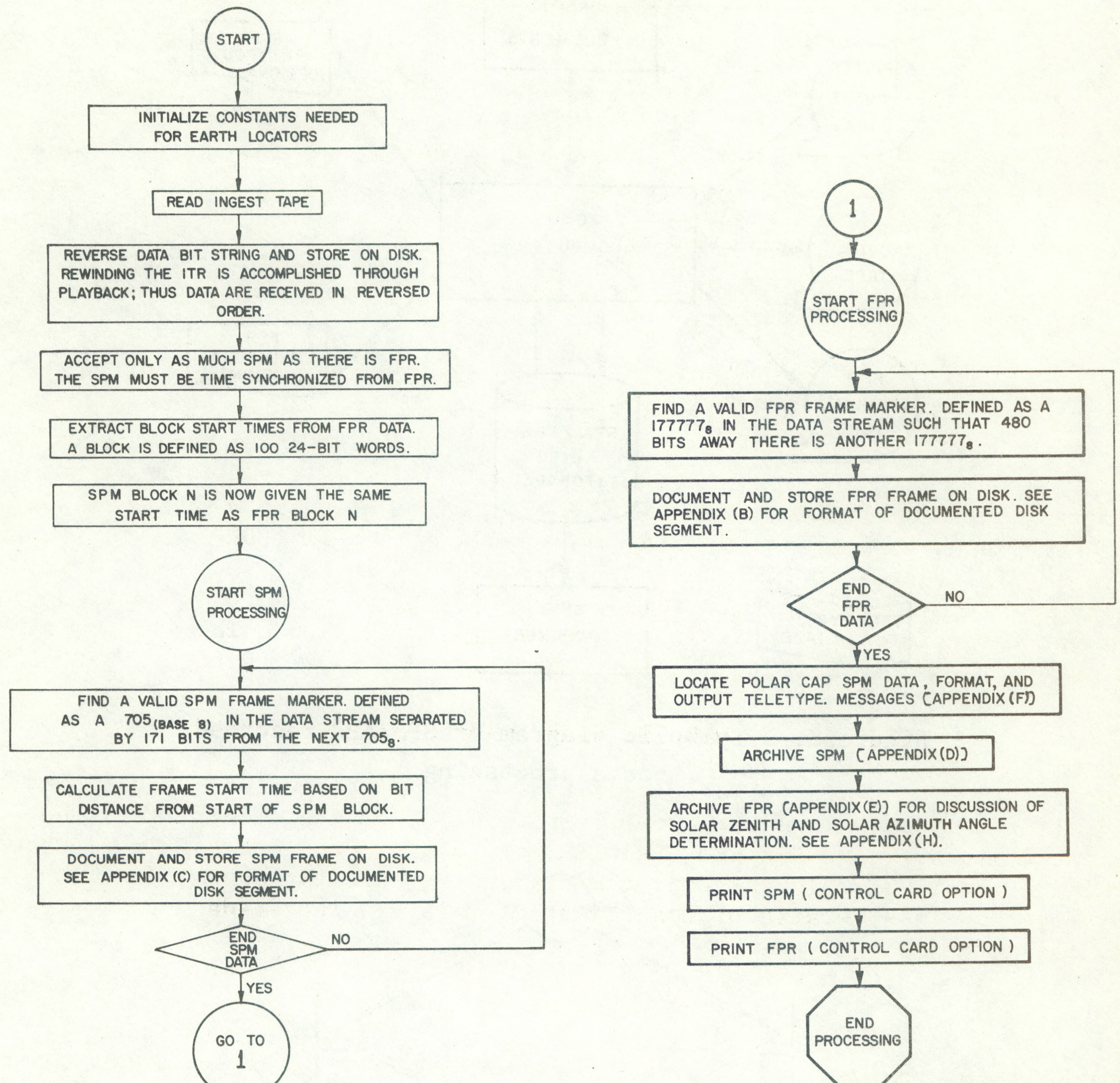

Figure 2.-- **Flow diagram of SPM/FPR recorded data processing**

1. An archive tape for both FPR and SPM data (for formats, see D and E of the appendix).

2. A punched paper tape in teletypewriter format generated for SPM data taken at geomagnetic latitudes poleward of 50°N and 50°S. These messages are referred to as "polar cap" messages and include the data taken from SPM channels 2, 6, 11, and 16 (see J in the appendix). Data from each of these four channels are averaged over 48-s intervals. A zero entry in place of the coded count signifies missing data for some or all of that particular time interval (see F of the appendix).

3. Listings (via a control-card option) of the SPM and FPR data consisting of the complete SPM and FPR frames and the corresponding times at which the frames were recorded.

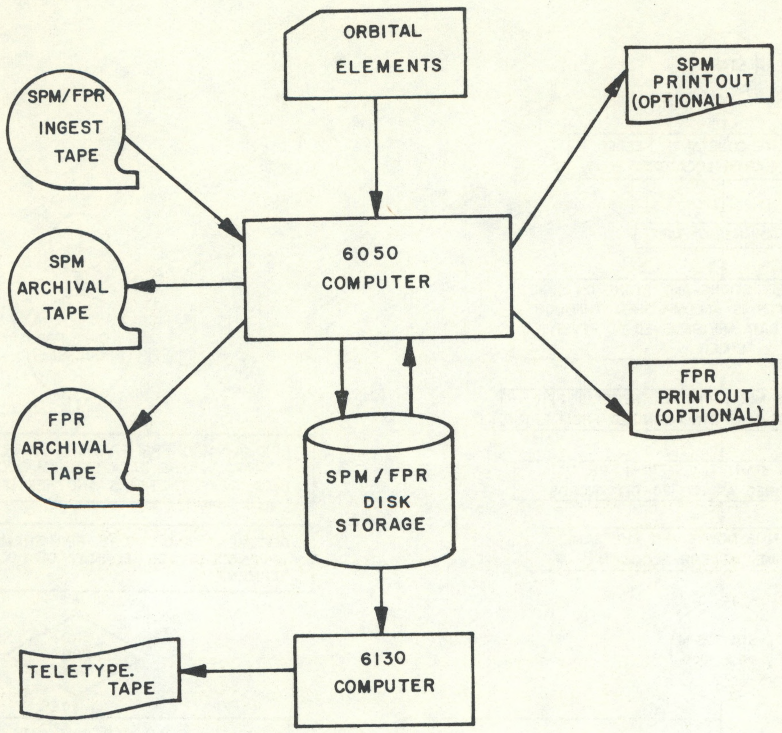

Figure 3.-- **Symbolic diagram of SPM/FPR recorded data processing**

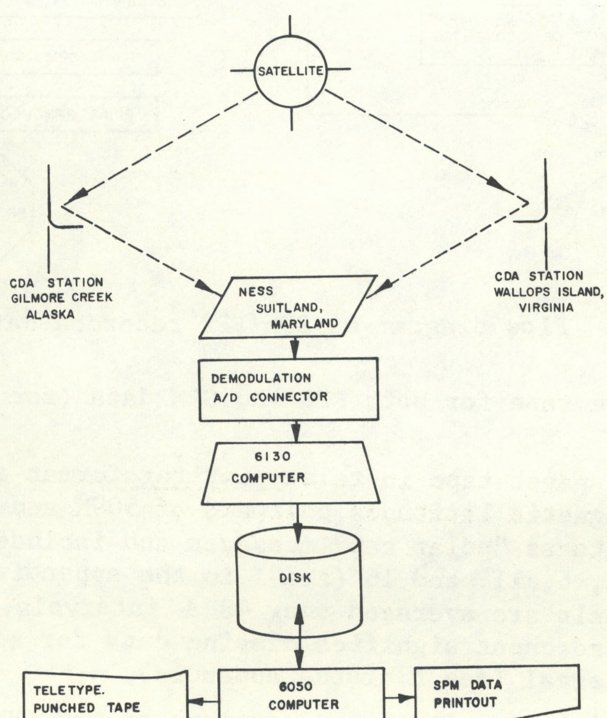

Figure 4.-- **Direct (real-time) SPM data processing**

B. Direct (Real-Time) Data

The SPM data (fig. 4) transmitted directly to the NESS from the satellite via the CDA station is stored on a disk for immediate processing. The data-processing scheme is very similar to that for the recorded data, except no archive tape is produced. The direct SPM data-processing scheme yields:

1. A punched teletypewriter paper tape of unaveraged SPM data from channels 2, 6, 11, and 16 (see G of the appendix).

2. A listing that consists of each SPM frame with its associated time.

6. SUMMARY AND RECOMMENDATIONS

Many problems were encountered in developing an operational processing system for the FPR and the SPM. To date, all software-oriented problems have been overcome. Only time and scrutiny of the data will reveal how effective our efforts have been.

One major problem deserving serious consideration in the future design of similar sensors is data-time synchronization. There is no time indicator in the SPM data stream; thus the SPM data must be time-synchronized from the FPR data. This has caused problems in several cases.

Another significant difficulty in handling the SPM data arose because of the nonuniqueness of the bit pattern that serves as the SPM frame marker, sometimes referred to as a "Barker." It was first believed that the SPM-BARKER word could not be duplicated by the data; but such, indeed, did occur.

Early difficulty with the digital data handling system computer necessitated the generation of a backup version of the program for handling the data on the CDC 6600 computer system. The backup version is basically the same as the original. The Quick Look message generator was deleted from the CDC 6600 computer version because it was not possible to process the data into a Quick Look message in the short time interval allotted between data receipt and message transmission. Hence, the CDC 6600 version served only as a backup for the archival processing.

ACKNOWLEDGMENTS

Special thanks are due Messrs. Dennis Phillips and Levin Lauritson for their assistance in developing or modifying satellite ephemeris routines to our specifications. Thanks are due also to Mr. William Burkhart for his programming of the ingest computer and to Mr. Oscar Stone for his work on the direct ingest-data program.

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APPENDIX

A. The Ingest Tape

The ingest tape consists of a 20-word documentation record and 202-word records of raw FPR and SPM data as explained below. The data records are ordered so that, in every four records appearing after the documentation record, there are two FPR records and two SPM records. The tape terminator consists of a single end-of-file (EOF) mark.

Documentation Record
(20 24-Bit Words)

Word(s)	Description
1	Octal 77777400
2	Octal 705
3	Zero
4	Readout number
5	Zero
6	Zero
7	Zero
8	Month (when word 6 is not zero, otherwise zero)
9	Zero
10	Day (when word 6 is not zero, otherwise zero)
11-12	32-bit NASA* time code (satellite clock reset time)
13	Zero
14	If nonzero --- trouble --- (24-bit time code)
15-18	Zero
19-20	Satellite's name (6 8-bit bytes, extended BCD or EBCDIC for data received after Jan. 1, 1971)

*National Aeronautics and Space Administration

SPM Data Record
(202 24-Bit Words)

Word(s)	Description
1	Octal 00000001 (identifies SPM record)
2	Number of SPM data bits in the record
3-202	SPM data

FPR Data Record
(202 24-Bit Words)

Word(s)	Description
1	Octal 00000000 (identifies FPR record)
2	Number of FPR data bits in the record
3-202	FPR data. (An FPR frame also contains the house-keeping telemetry.)

B. Documented Flat Plate Radiometer Disk Segments (24-Bit Words)

Word(s)	Description
1	Octal 40177777
2	Day of year
3	Hour
4	Minute
5	Second
6	Readout number
7	Month
8	Day
9	Year
10	Pass number
11	Ascending node longitude x 100 in degrees east (0-359.99 expressed as an integer)
12	Minutes from launch (integer)
13	Fractional portion of word 12 (expressed as an integer)
14-15	Floating point minutes from launch
16	24-bit quarter second count
17-18	32-bit NASA time code, left-justified
19-40	Zero
41-100*	An FPR frame (32 s of data)

*In words 41-100, each FPR word (8 bits) is right-justified in a 24-bit computer word.

C. Documented Solar Proton Monitor Disk Segments (24-Bit Words)

Word(s)	Description
1	Octal 400000705
2	Day of year
3	Hour
4	Minute
5	Second
6	Readout number
7	Month
8	Day
9	Year
10	Pass number
11	Ascending node longitude x 100 in degrees east (0-359.99 expressed as an integer)
12	Minutes from launch (integer)
13	Fractional portion of word 12 (expressed as an integer)
14-15	Floating point minutes from launch (frame in 21-40)
16-20	Zero
21-40*	Frame 1 (12s of SPM data)
41-60	Frame 2 (12s of SPM data)
61-80	Frame 3 (12s of SPM data)
81-100	Frame 4 (12s of SPM data)

*In words 21-100, each SPM word (9 bits) is right-justified in a 24-bit computer word.

D. Flat Plate Radiometer Archival Tape

General Description of the Archival Tape:

Tape density - 556 bits/in.
Word size or basic byte size - 24 bits
Mode - binary
Data terminator - One EOF per pass (octal 17)
Tape terminator - Two consecutive EOF's
Words per documented frame - 12
Frames per record - Up to 110
Records per pass - Normally 3 for single readout

FPR Archival Tape Format
Record 1, Documentation Record
(20 24-Bit Words)

Word(s)	Description
1	Octal 00177777
2	Initial pass number
3	Terminal pass number
4	Year of initial pass
5	Month of initial pass
6	Day of initial pass
7	Hour of initial pass
8	Minute of initial pass
9	Second of initial pass
10-11	32-bit time code at T(0) (clock reset time), left-justified

Composition of the 32-bit time code:

Bits used	4	4	4	2	4	3	4	3	4
	100's	10's	1's	10's	1's	10's	1's	10's	1's
	Days			Hours		Minutes		Seconds	

Where (1) January 1 = day 1 and (2) the remaining low-order 16 bits of word 11 are to be disregarded.

Words 12-20 .... Zero-filled

FPR Data Record
(1320 24-Bit Words)
(Approximately 58.6 min of data)
Frame Format

Word(s)	Description
1	24-bit quarter second count from T(0)
2	Subsatellite point (SSP) latitude (+0-89.99...9) x 100 expressed as an integer (sign magnitude, high-order bit on for negative)
3	SSP longitude (+0-359.99...9) x 100 expressed as an integer
4	Solar zenith angle (SZA) x 100 expressed as an integer
5	Solar azimuth angle (SAZ) x 100 expressed as an integer
6	Height (in km) x 100 expressed as an integer
7	Always zero
8*-12	FPR data frame, 3 8-bit bytes per word, high-order bit of each byte equals 0

*Word 8 (24-bit word) bit-position 10 of every data frame (counting left to right) is the calibration mode flag. When flag bit is 1, sensor is in calibration mode; when flag bit is 0, sensor is in data mode.

E. Solar Proton Monitor Archival Tape

General Description of the Archival Tape:

Tape density - 556 bits/in.
Word size - 24 bits
Mode - binary
Data terminator - One EOF per pass (octal 17)
Tape terminator - Two consecutive EOF's
Words per data frame - 15
Frames per record - 66
Records per pass - Normally 10 for single readout

Record 1, Documentation Record
(20 24-Bit Words)

Word(s)	Description
1	Octal 40000705
2	Initial pass number
3	Terminal pass number
4	Year of initial pass
5	Month of initial pass
6	Day of initial pass
7	Hour of initial pass
8	Minute of initial pass
9	Second of initial pass
10-18	Zero
19-20	Satellite's name (6 8-bit bytes, extended BCD or EBCDIC, for data received after Jan. 1, 1971)

Data Record
(1000 24-Bit Words)
(Approximately 13.2 min of data)

Word(s)	Description
1	Octal 40000705
2	Number of frames in record
3-10	Zero
11-25	First frame
26-40	Second frame
.	
.	
.	
.	
.	
986-1000	66th frame (if it exists)

Frame Format

Word(s)

1-2 ...... 48 bits of contiguous time data from left to right:

	Year	Month	Day	Hour	Minute	Second	Pass
Bits used	7	4	5	5	6	6	15

3 ...... Latitude (± 0-89.99...9) x 100, sign magnitude expressed as an integer (high-order bit equals 1 if number negative)

4 ...... Longitude (0-359.99...9°E) x 100 expressed as an integer

5 ...... Height (in km) x 100 expressed as an integer

6-15 ...... SPM data frame*, including the BARKER

*The data frame will be packed one 9-bit data word per 12-bit byte, right-justified, resulting in two 12-bit bytes per 24-bit computer word.

F. Solar Proton Monitor Recorded Data Teletypewriter Messages

Header line for the recorded data teletype message:
1 2 3 4 5 6 7 8 9 10 11 12 13
QL/SPM/NH/Rxxxxx/ELxxx.xx/Pxxxxx/MO/DA/YR/HR/MN/SC/bbbb.......b

Item	Description
1, 2	Basic identification, QL/SPM (Quick Look/Solar Proton Monitor)
3	Sector, NH (Northern Hemisphere), SH (Southern Hemisphere)
4	R (readout identifier followed by 5-digit readout number**)
5	EL (degrees east, 0-359.99, ascending longitude of pass)
6	P (pass identifier followed by 5-digit pass number**)
7	Month, 2 digits, GMT of data start
8	Day, 2 digits, GMT of data start
9	Year, 2 digits, GMT of data start
10	Hour, 2 digits, GMT of data start
11	Minute, 2 digits, GMT of data start
12	Second, 2 digits, GMT of data start
13	b (blanks)

**The readout number refers to the orbital revolution in which the data were acquired at the ground. The pass number refers to the orbital revolution in which the data were taken.

Data from the satellite are in nine-bit floating point form, the four high-order bits being the exponent n and the five low-order bits being the mantissa m. A nine-bit number converts to $m \times 2^n$. A typical nine-bit number 307_8 would thus convert to 7×2^6 since $307_8 = 011000111_2$ or 0110/00111 in this format. The data that comprise the teletypewriter messages are averaged over 48 s and are converted to the form $LL \times 4^K$ or KLL_8 where LL is a two-digit octal number. The nine-bit number 307_8 in this form would convert to 7×4^3 since 307_8 = 011/000111 in this form.

In each teletypewriter data line, the first two digits of each line represent a two-digit <u>decimal</u> number corresponding to elapsed time in minutes from the time in the header line. The remainder of each line is composed of five groups consisting of a hyphen followed by 12 <u>octal</u> digits. The first three octal digits form an octal number of the form KLL, representing four 12-s SPM frames from channel 2 averaged over an interval of 48 s. The next three-digit groups represent channels 6, 11, and 16, respectively, similarly averaged over 48 s. Each data line contains 4 min of SPM data. The message terminator is 99999.

Sample teletypewriter message:

```
HAAK KSOC 141536Z
QL/SPM/NH/R02542/EL358.30/P02542/08/14/70/15/36/36/
00-422221266660-420133220125-352123131033-250122127013-125123224321
04-226225357522-335252366565-371241321571-345220227531-265141154424
08-131122131126-016123131040-003120133036-007122132121-006122132132
12-011123133130-011122131134-011121135134-010073133135-007120134134
16-011120134131-007120131135-007120133140-007075132131-007120133133
20-010067131134-011076131135-006121132127-133076131150-277134153445
24-351176233544-357235325570-271236357535-150157320425-99999

HAAK KSOC 141442Z
QL/SPM/SH/R02542/EL027.07/P02541/08/14/70/14/42/12/
00-241223332525-347232321557-353221231540-323140153442-150072123136
04-010067131064-005071127126-007074130130-012073130131-011071130130
08-010076127132-007121131133-007067130132-005120131130-007074132131
12-006075032131-007074131132-010076132131-005065131131-010070130124
16-004066126041-004075124043-005070124042-044070125121-172071126325
20-325142170464-362223237554-422242277625-422270356634-346322434625
24-266277444556-172224353454-137122240253-237067153043-340054126044
28-424067156133-442124240224-457170327256 99999
```

G. Solar Proton Monitor Real-Time Data Teletypewriter Messages

Header line for the real-time data message:

```
     1     2             3             4            5
QQLSPM/DIRECT/R/Oxxxxx MSTART xx-xx-xx HMS xx-xx-xx
```

Item	Description
1, 2	QQLSPM DIRECT (basic message identifier)
3	Readout number (pass in which data were observed and acquired at ground)
4	GMT of the starting message 2-digit month, 2-digit day, 2-digit year
5	GMT of the starting message 2-digit hour, 2-digit minute, 2-digit second

The difference between direct and recorded messages is that the direct data are unaveraged. Each three-digit group in the body of these messages (see appendix (F)) represents a 12-s sample; each line contains 1 min of data. The channels used are 2, 6, 11, and 16.

```
Real-time message:

HAAK KSOC 201916Z
QQLSPM/DIRECT/R/0/ 5271 MSTART 03-20-70 HMS 19-16-22
00-000000000000-004122120002-005121072002-003120121000-004074120003
01-003121121002-003120074002-005121120001-005120122002-002120120001
02-001122074002-002-74-62003-003122076002-002120121002-004072076001
03-004120074000-006121006002-005064120001-003074074000-006064074002
04-004123076005-003070076002-000000000000-000000000000-002120072002
05-003120121003-005122064003-005066072003-003120074002-005121076002
06-005120066002-005120700007--17120120022-126120070125-170124121164
07-162120120156-000000000000-227076120221-233074122234-246123124260
08-264122126331-324130154421-334137224450-350166236523-362221252540
09-374227272562-422246325621-422254335625-000000000000-421270346631
10-420276352631-364266344624-344244326562-324227254533-244164227456
11 99999
```

H. Locators

Subsolar Point Determination

To associate the FPR data with the appropriate SZA and SAZ, one must determine the subsolar point for each FPR frame. A subsolar point is computed for each frame by a combination of system library functions and subroutines SUBSOL and SUNVEC. The only input requirements are the Julian time (in min) and DREF (day of reference of launch). The unit sun vector direction cosines are computed, and the subsolar latitude and longitude are derived from them. SUNVEC performs the following calculations: time converted to centuries; mean anomaly; geocentric longitude of the sun; obliquity of the ecliptic; and the sun vector's direction cosines.

Subroutine SUNVEC is derived from subroutine SUN1 --calculation of sun vector and longitude. For details and discussion of actual equations, see IBM Federal Systems Division(1964).

SUBSOL interprets the direction cosines in terms of latitude $\pm \pi/2$ rad and longitude Ø to 2π rad east. The principal FORTRAN (formula translator) equations used by SUBSOL are

$$SUBLAT = ASIN (UZ)$$

and

$$RL = ATAN (UY/UX).$$

The arctan function (ATAN) returns a signed angle to SUBSOL (fig. 5) based on UX, UY, and UZ. The program ignores this sign and performs a quadrant check based on the original components UY and UX (e.g., let UX/UY = γ, RL = right ascension of sun vector). Thus,

for quadrant I, RL = $|\gamma|$;

for quadrant II, RL = π rad - $|\gamma|$;

for quadrant III, RL = π rad + $|\gamma|$; and

for quadrant IV, RL = 2π rad - $|\gamma|$.

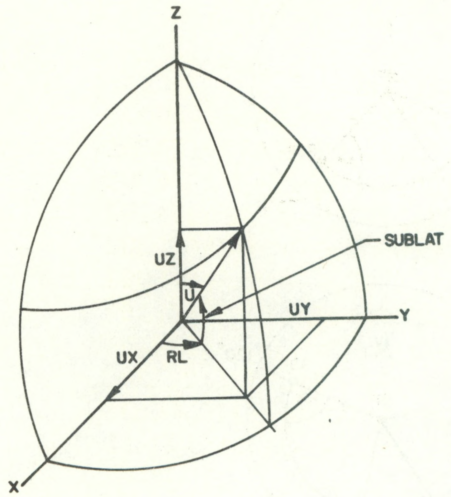

Figure 5.-- Direction cosines (UX,UY,YZ) furnished by SUNVEC

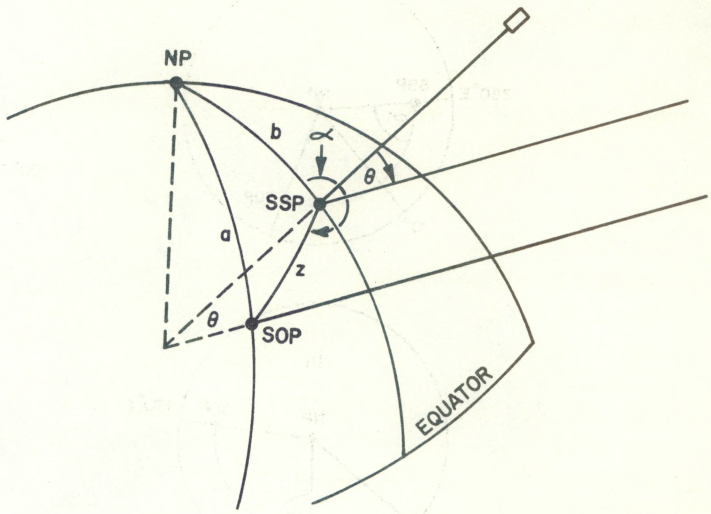

Figure 6.-- Angles used in computing the SZA and the SAZ

RL is then converted to an earth longitude, and the program computes subsolar latitude ($\pm\pi/2$ rad) and longitude (0 to 2π rad east).

Solar Zenith and Azimuth Angle Determination

A SZA and a SAZ are computed for each frame by subroutine SUN in which the input requirements are the latitude and longitude of the subsolar point (SOP) and the subsatellite point (SSP). SUN sets up and solves a spherical triangle with the North Pole (NP), the SOP, and the SSP as vertexes.

In figure 6, θ is the SZA; α is the SAZ; and the SSP and SOP are given. Solve spherical triangle abz to obtain θ and α. The law of cosines for spherical triangles is used to compute the SAZ. The smallest triangle is always selected, and the final value (azimuth) is determined by the relation of the triangle to the Greenwich Meridian as shown in figure 7. In this figure, four cases of solar azimuth determination (I through IV) are respectively:

$$SAZ = \alpha \text{ if } LOSOP-LOSSP = (-) \text{ and } |LOSOP-LOSSP| > 180^\circ,$$

$$SAZ = 360^\circ - \alpha \text{ if } LOSOP-LOSSP > 180^\circ,$$

$$SAZ = \alpha \text{ if } LOSOP-LOSSP < 180^\circ \text{ but } > 0^\circ, \text{ and}$$

$$SAZ = 360^\circ - \alpha \text{ if } LOSOP-LOSSP = (-) \text{ and } |LOSOP-LOSSP| < 180^\circ$$

where

LOSOP is longitude of the SOP,

and

LOSSP is longitude of the SSP.

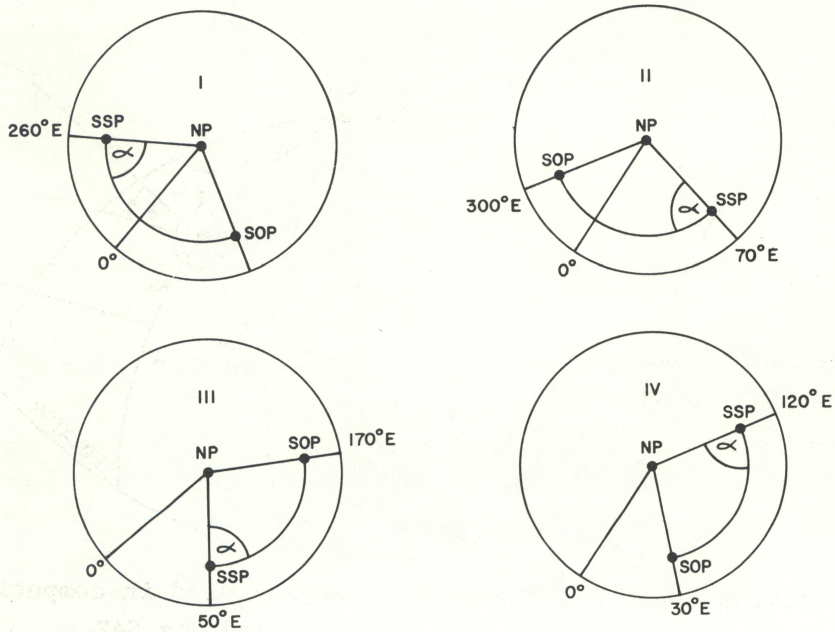

Figure 7.-- Solar azimuth determination

In addition to the normal determination of the SAZ, the special cases considered are DLO = 180° and 0°, DLO is the difference longitude between the SOP and the SSP. When both points are in the NH and DLO = 180°, SAZ = 360°.

When both points are in the SH, SAZ = 180°. If the points are in different hemispheres, the latitude of the SOP determines SAZ [e.g., (1) SSP latitude = 80°N, SOP latitude = 10°S, SAZ = 180°; (2) SSP latitude = 10°S, SOP latitude = 80°N, SAZ = 360°; and (3) when DLO = 0, SAZ is determined by the latitude of the SOP].

I. Flat Plate Radiometer (Data) Frame Content

The FPR data frame consists of 60 eight-bit words (also referred to as channels). The content of each word is given.

Words 3, 4, 5, and 6 are combined to produce a 24-bit quarter second count. Thus each data frame is time synchronized as follows:

Present time = (quarter second count) + (NASA 32-bit time code).

Bits 5-8 of word 6 and bits 5-7 of word 8 contain no relevant data. Bit 8 (F) of word 8 is the calibration mode flag. When F equals 1, the sensor is in the calibration mode; when F equals zero, the sensor is in the data mode. Words 22-60 of the FPR frame (not shown above) contain housekeeping telemetry values (RCA Astro Electronics Division 1970b).

FPR FRAME CONTENT									
WORD	FUNCTION	NOTES							
1	Frame synch	Bits 1-8 (all 1's)							
2	Frame synch	Bits 1-8 (all 1's)							
		Bits in Word							
		1	2	3	4	5	6	7	8
3	Time code	0	2^0	2^1	2^2	2^3	2^4	2^5	2^6
4	Time code	0	2^7	2^8	2^9	2^{10}	2^{11}	2^{12}	2^{13}
5	Time code	0	2^{14}	2^{15}	2^{16}	2^{17}	2^{18}	2^{19}	2^{20}
6	Time code	0	2^{21}	2^{22}	2^{23}	X	X	X	X
7	FPR RE white sensor	0	2^0	2^1	2^2	2^3	2^4	2^5	2^6
8	FPR RE white sensor	0	2^7	2^8	2^9	X	X	X	F
9	FPR RE black sensor	data format same as 7, 8							
10	FPR RE black sensor	"							
11	FPR RE calibration	0	2^0	2^1	2^2	2^3	2^4	2^5	2^6
12	FPR RE (white) mount temp.	bit value same as eleven							
13	FPR RE (black) mount temp.	"							
14	FPR TF white sensor	"							
15	FPR TF black sensor	"							
16	FPR TF sensor mount temp.	"							
17	FPR TF cal. source (white)	"							
18	FPR TF cal. source (black)	"							
19	FPR TF surface temp. (white)	"							
20	FPR TF surface temp. (black)	"							
21	FPR Electronics temp.	"							

J. Solar Proton Monitor (Data) Frame Content

The SPM data frame consists of 20 nine-bit words (also referred to as channels). The content of each word is given below.

SPM Data Frame		
Word	Detector code	Primary energy response (Mev)
1	00	Synch word, always 111000101_2 or 705_8
2	41	$Ee \geq 0.14$ (electrons)
3	51	$0.27 \leq E_p \leq 0.56$ (protons)
4	52	$0.56 \leq E_p \leq 1.05$
5	53	$1.05 \leq E_p \leq 3.2$
6	10	$E_p \geq 60$
7	42	$E_p \geq 2.37$
8	54	$3.2 \leq E_p \leq 60$
9	55	$12.5 \leq E \leq 32$ (alpha particles)
10	56	Background
11	20	$E_p \geq 30$
12	41	$E_e \geq 0.14$
13	61	$0.27 \leq E_p \leq 0.56$
14	62	$0.56 \leq E_p \leq 1.05$
15	63	$1.05 \leq E_p \leq 3.2$
16	30	$E_p \geq 10$
17	42	$E_p \geq 2.37$
18	64	$3.2 \leq E_p \leq 60$
19	65	$12.5 \leq E_\alpha \leq 32$
20	66	Background

K. Archived Data

The time periods for which FPR and SPM data have been processed and archived are shown below for both the ITOS 1 and NOAA 1 satellites. These taped archived data are now available, and perspective users should use the addresses below for information and/or obtaining specific data. Some of the data between these intervals are missing due to retrieval problems, noisy data, etc.

ITOS 1

From R/O Number	Date	To R/O Number	Date
FPR			
740	3/23/70	2220	7/19/70
SPM			
740	3/23/70	2220	7/19/70
545*	3/ 8/70	632	3/14/70

*These data were processed on special request from the Space Disturbance Lab. (SDL) at Boulder, Colo. These data represent a period of maximum solar activity for a 10-yr period.

NOAA 1

FPR			
693	2/ 4/71	2097	5/27/71
SPM			
697	2/ 5/71	2098	5/27/71

For information on and/or obtaining FPR data, a prospective user should contact:

National Environmental Satellite Service,
National Oceanic and Atmospheric Administration,
Washington, D.C. 20233.

A prospective SPM user should contact:

Space Environment Lab., NOAA,
Boulder, Colo. 80302.

(Continued from inside front cover)

NESCTM 11 Publications by Staff Members, National Environmental Satellite Center and Final Reports on Contracts and Grants Sponsored by the National Environmental Satellite Center 1968. January 1969. (PB-182 853)

NESCTM 12 Experimental Large-Scale Snow and Ice Mapping With Composite Minimum Brightness Charts. E. Paul McClain and Donald R. Baker, September 1969. (PB-186 362)

NESCTM 13 Deriving Upper Tropospheric Winds by Computer From Single Image, Digital Satellite Data. Charles S. Novak, June 1969. (PB-185 086)

NESCTM 14 Study of the Use of Aerial and Satellite Photogrammetry for Surveys in Hydrology. Everett H. Ramey, March 1970. (PB-191 735)

NESCTM 15 Some Aspects of the Vorticity Structure Associated With Extratropical Cloud Systems. Harold J. Brodrick, Jr., May 1969. (PB-184 178)

NESCTM 16 The Improvement of Clear Column Radiance Determination With a Supplementary 3.8μ Window Channel. William L. Smith, July 1969. (PB-185 065)

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NESCTM 18 On the Statistical Relation Between Geopotential Height and Temperature-Pressure Profiles. W. L. Smith and S. Fritz, November 1969. (PB-189 276)

NESCTM 19 Applications of Environmental Satellite Data to Oceanography and Hydrology. E. Paul McClain, January 1970. (PB-190 652)

NESCTM 20 Mapping of Geostationary Satellite Pictures -- An Operational Experiment. R. C. Doolittle, C. L. Bristor, and L. Lauritson, March 1970. (PB-191 189)

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NESS 26 Potential of Satellite Microwave Sensing for Hydrology and Oceanography Measurements. John C. Alishouse, Donald R. Baker, E. Paul McClain, and Harold W. Yates, March 1971. (COM-71-00544)

NESS 27 A Review of Passive Microwave Remote Sensing. James J. Whalen, March 1971.

NESS 28 Calculation of Clear-Column Radiances Using Airborne Infrared Temperature Profile Radiometer Measurements Over Partly Cloudy Areas. William L. Smith, March 1971. (COM-71-00556)