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DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite Service

Operational Processing of Solar Proton Monitor Data

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WASHINGTON, D.C.
August 1973

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U.S. DEPARTMENT OF COMMERCE
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OPERATIONAL PROCESSING OF SOLAR PROTON MONITOR DATA

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OPERATIONAL PROCESSING OF SOLAR PROTON MONITOR DATA

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ABSTRACT. Described herein is the operational processing of data obtained from the solar proton monitor sensor 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.

I. INTRODUCTION

The examination of large-scale atmospheric phenomena was made more realistic in 1967 by using data from the low resolution infrared radiometer (LRIR) on the environmental survey satellite, ESSA 3 (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 was an archival tape. These taped data were used for further research-oriented data reduction schemes. The launch of the NOAA 2 satellite terminated the processing of FPR data.

The 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. These solar phenomena interfere with high-frequency radio communications and may be hazardous to manned space exploration (Goddard Space Flight Center 1970). The SPM data are "summarized" shortly after being received and are 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 subsequent detailed study.

II. THE SOLAR PROTON MONITOR SENSOR AND DATA

This technical memorandum does not contain a detailed description of the SPM sensor. See Cashion and Gary (1969) for details.

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; detectors 4 and 5 face away from the earth throughout the orbit.

The SPM measures flux in several ranges. Detectors 1 to 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° field-of-view, detects electrons in the 100- to 750-Kev range. Detectors 5 and 6, with 40° 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, an accuracy considered adequate to define the particle flux magnitude (Cashion and Gary 1969). 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 are shifted left, a bit at a time, until a 1 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 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 12.5 seconds (s) of data and is represented by 20 9-bit words; see J of the appendix for the content of each data word (also referred to as a channel).

The ITOS SPM data will be correlated with data from other satellites (such as IMP, VELA, and PIONEER), rocket probes, and with ground based optical/radio sightings. The long term goal of this data-gathering and correlation activity is better understanding of the interaction between solar radiation and the earth's environment. This data gathering provides a means for systematic monitoring of the proton fluxes over an extended period of time, especially during the current solar cycle.

III. DATA RECORDING SYSTEM

There are three scanning radiometer recorders (SRR) aboard the spacecraft. SPM data, VTPR (vertical temperature profile radiometer) data, synchronization (synch) pulses, housekeeping telemetry, and time code data are recorded throughout the orbit. Data are read out of the recorder on 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.

The recording rate is 512 bits/s. A recorder (SRR) can record data for 209 min or approximately two orbital passes (one orbital pass requires about 115 min). The play-back rate is approximately 10,667 bits/s, a ratio of 20.883:1.

IV. RAW-DATA INGESTION

An ingest program determines the binary values of the data samples by examining the portion of the SPM data pulse that 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 telemetry are packed into separate output buffers and written on disk storage for subsequent data processing. The details of the format of this raw-ingest data are given in section A of the appendix.

V. PROCESSING PROCEDURE

The NESS can receive the SPM data in either recorded or direct mode. Recorded mode data are transmitted from the SRR aboard the satellite as described above. In the direct mode operation, the SPM data are recorded on the SRR and simultaneously transmitted to the CDA station while the observation is in progress. When the data recorded on the SRR 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 the following.

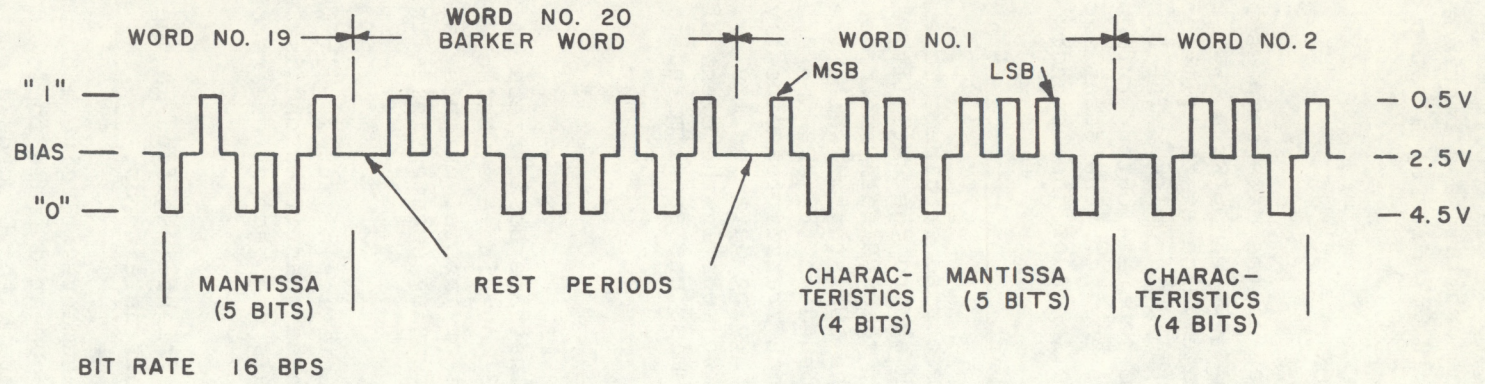
1. The SPM ingested data are created in quantities of 100 24-bit words or 150 16-bit words and are stored on disk. These quantities on disk are referred to as disk segments. One segment equals one record, one record equals six frames (see A in the appendix).

The SPM data are in 9-bit bytes, and are right-justified in the word. Every two 6050 words (24 bits) equal three 16-bit data words.

Each ingested data segment is further documented to give a documented disk segment. Each is composed of a 20-word documented frame followed by four frames of SPM data, thus five frames of data with 20 words per frame total a 100-word documented segment of SPM data (see A in the appendix).

2. An archive tape for SPM data (for formats, see E of the appendix).

a. REAL-TIME WORD FORMAT (RETURN TO BIAS DATA)



b. RECORDED WORD FORMAT (NRZ DATA)

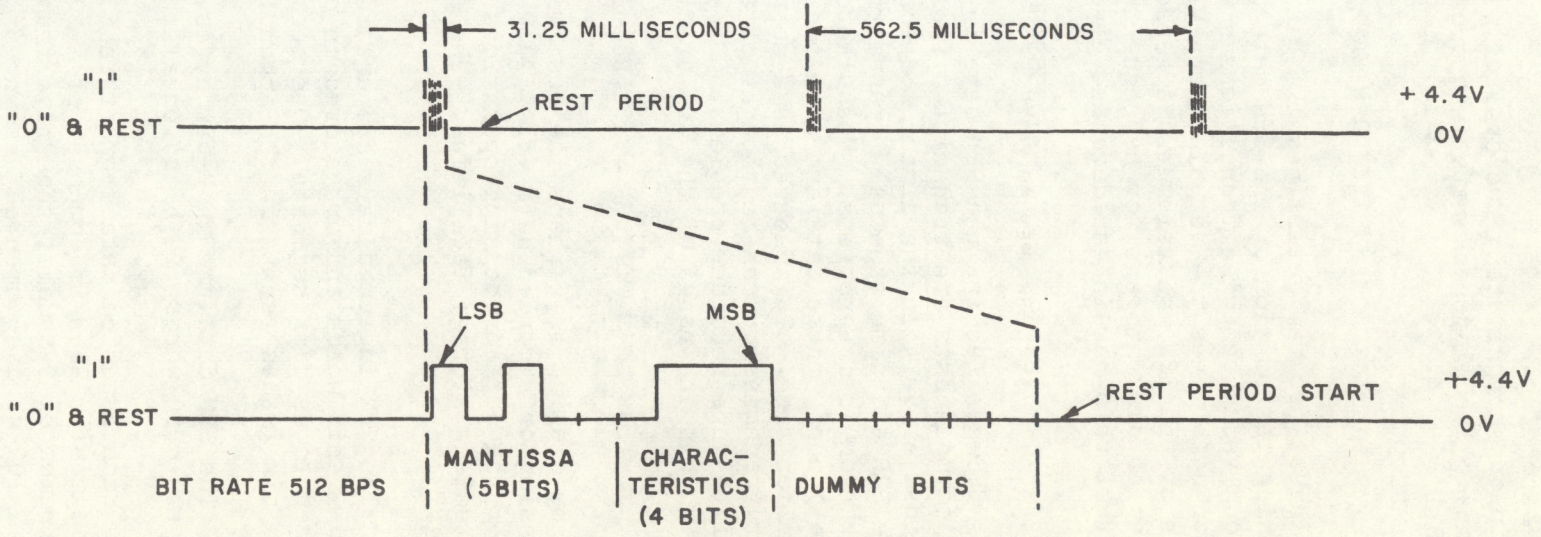


Figure 1. -- SPM Real-time and recorded data word formats.

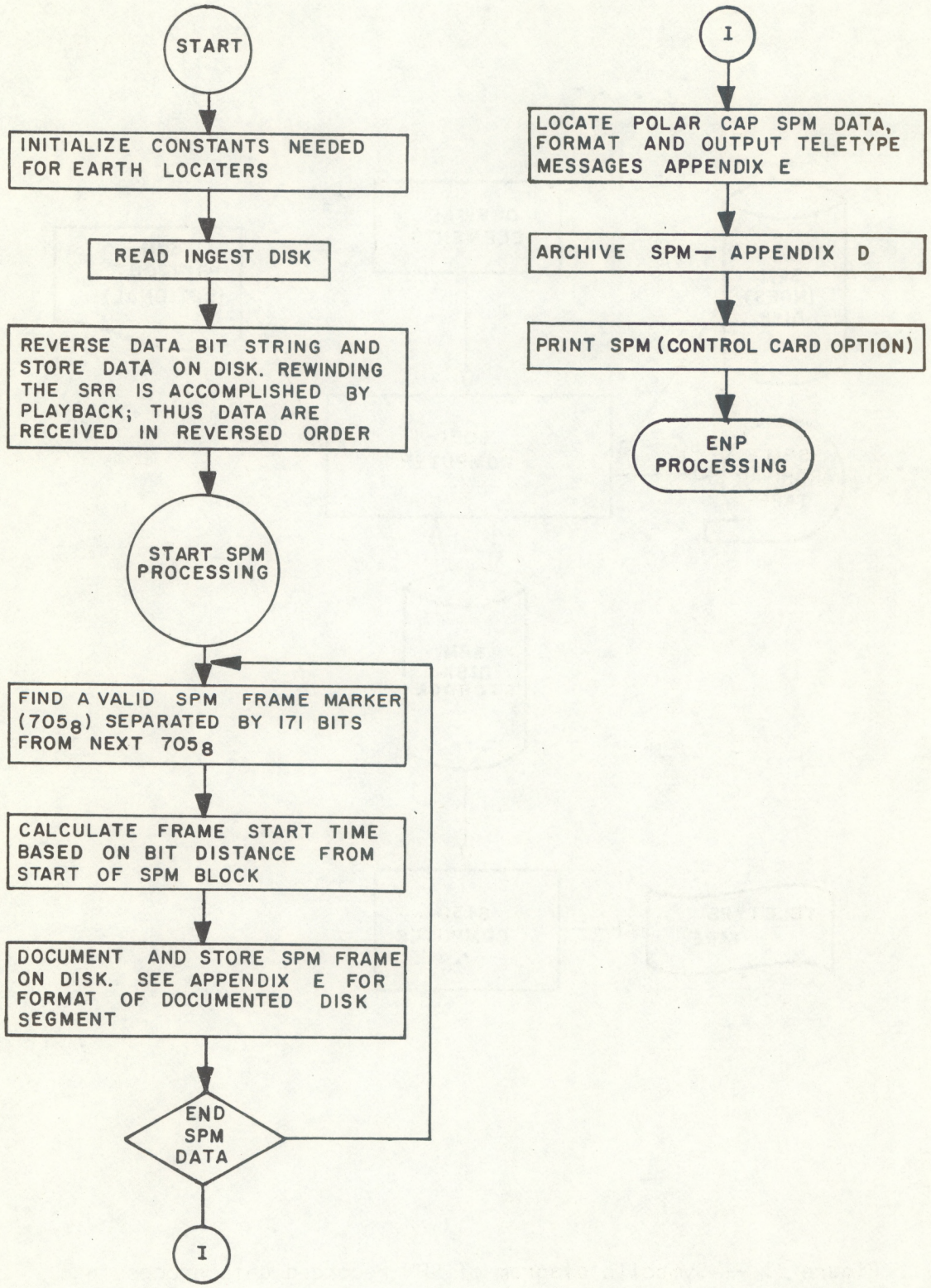


Figure 2. -- Flow diagram of SPM recorded data processing.

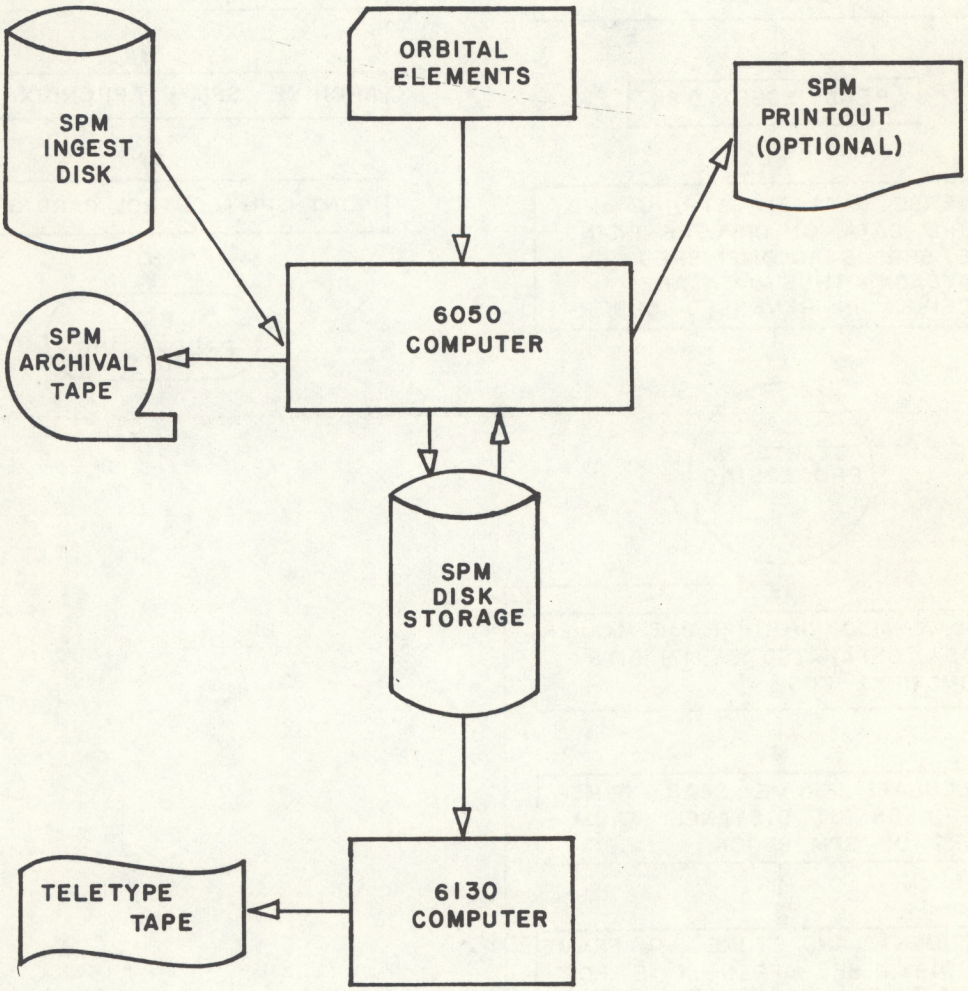


Figure 3. -- Symbolic diagram of SPM recorded data processing

3. 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 50-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).

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

B. Direct (Real-Time) Data

The SPM data transmitted in real time from the satellite to the NESS via the CDA station is stored on a disk for immediate processing (fig. 4). The data processing scheme is 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 of each SPM frame and its associated time.

VI. SUMMARY AND RECOMMENDATIONS

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

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.

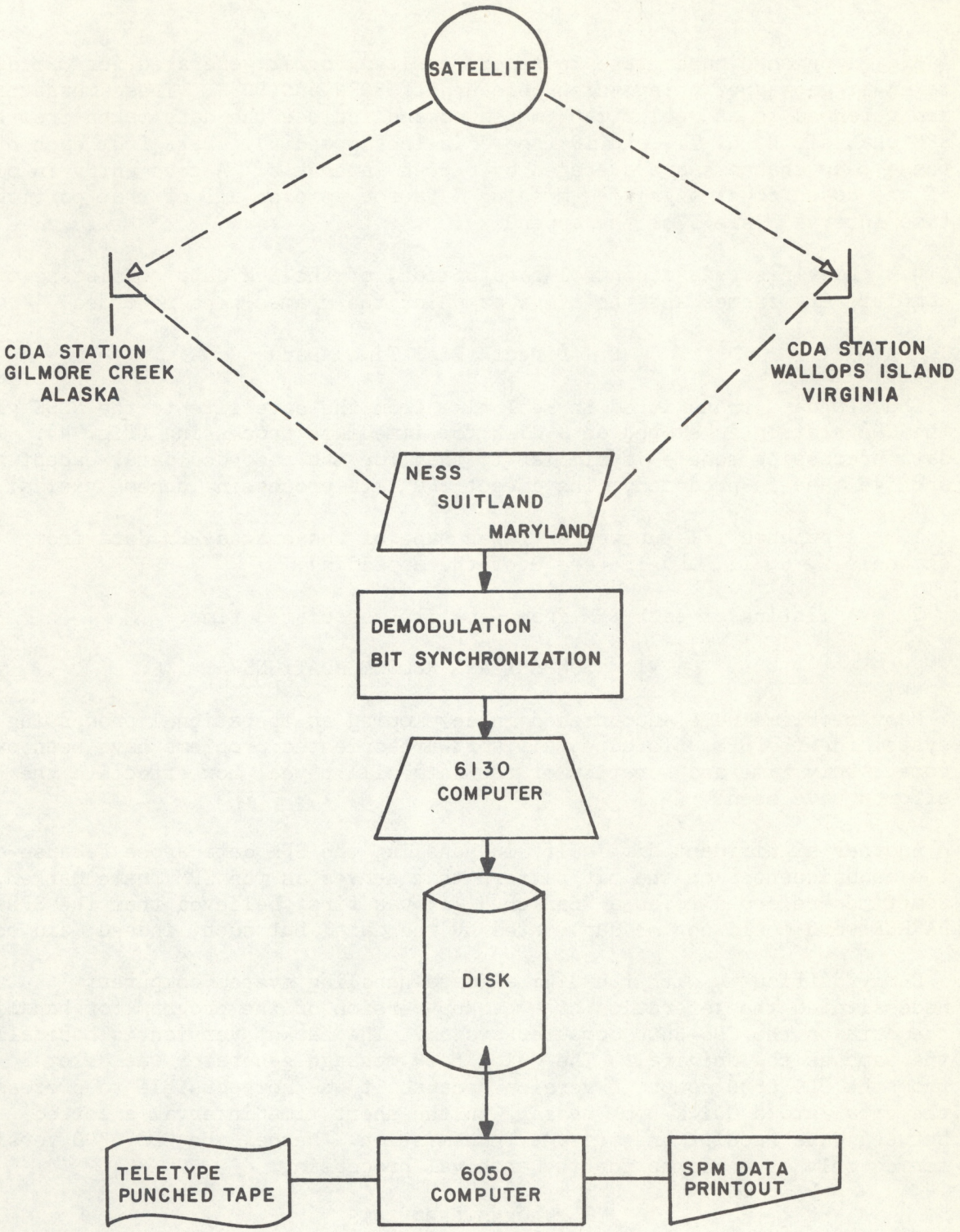


Figure 4. -- Direct (real-time) SPM data processing.

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APPENDIX

A. The Ingest Disk

DOCUMENTATION RECORD
(100 24-bit words)

WORD(s)	DESCRIPTION
1	Zero
2	Octal 123456
3	Zero
4	R/O number
5,6	NASA time code right justified
7,8	Satellite's name 6130 EBCDIC
9 - 100	Zero

SPM DATA RECORD
(100 24-bit words or 150 16-bit words)

FRAME	WORD(s)	DESCRIPTION
	1	Number of 16-bit words in record (excluding this one)
1	2- 23	Frame words
2	24- 45	Frame words
3	46- 67	Frame words
4	68- 89	Frame words
5	90-111	Frame words
6	112-133	Frame words
	134-150	Not used

FRAME WORD
16-bit words, 9-bit bytes
(right justified)

Word(s)	Description	
1	Octal 705	
2-20	SPM data	
21	9 bits, right justified	Quarter seconds
22	15 bits, right justified	Time

B. Documented Solar Proton Monitor Disk Segments

DOCUMENTATION RECORD
(16-bit words)

1	Octal 40000705
2	Day of year for data in 21-40
3	Hour for data in 21-40
4	Minute for data in 21-40
5	Second for data in 21-40
6	R/O for data in 21-40
7	Month for data in 21-40
8	Day for data in 21-40
9	Year for data in 21-40
10	Pass for data in 21-40
11	Ascending longitude east x 100 (integer)
12	FMFL (minutes from launch)
13	FMFL (minutes from launch)
14-16	Zero

17	Quarter second time for words 21-40
18	Quarter second time for words 41-60
19	Quarter second time for words 61-80
20	Quarter second time for words 81-100
21-40*	SPM frame 1-12.5s of data
41-60	SPM frame 2-12.5s of data
61-80	SPM frame 3-12.5s of data
81-100	SPM frame 4-12.5s of data

C. 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)

Words	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 of EBCDIC, for data received after Jan. 1, 1971)

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

Data Record
(1000 24-bit words)
(Approximately 13.2 min of data)

Words	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

D. 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
```

*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.

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)

Data from the satellite are in 9-bit floating point form, the four high-order bits being the exponent n and the five low-order bits being the mantissa m. A 9-bit number converts to $m \times 2^n$. A typical 9-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 9-bit number 307_8 in this form would convert to 7×4^3, since $307_8 = 011/000111_2$ in this format.

In each teletypewriter data line, the first four digits of each line represent a four-digit decimal 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 octal digits. The first three octal digits form an octal number of the form KLL, representing four 12.5-s SPM frames from channel 2 averaged over an interval of 50 s. The next three-digit groups represent channels 6, 11, and 16, respectively, averaged over 50 s. Each data line contains 4.16 min of SPM data. The message terminator is 99999.

**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.

Sample teletypewriter messages:

```
HSAK KSOC 022305
QL/SPM/SH/R00993/EL343.27/P00992/01/02/73/23/06/07.0/
0000-077120120005-027124132137-133132140346-275142154431-334142144427
0410-255132132330-156131126175-017125124006-006124124002-010123121003
0320-006124124001-007123122001-007124126003-010124123001-006123122003
1230-007124121003-006123123001-007125122003-006123122002-007123124001
1640-007126124002-010122121004-004123124002-013122124022-230124126273
2050-327134141426-373165127523-357221157531-263220242522-145150246424
2500-061134257272-142142327233-233220422235-321250455272-350276467320
2910-426322461322-453334455331-99999

HSAK KSOC 022221
QL/SPM/NH/R00993/EL343.27/P00992/01/02/73/22/57.0/
0000-006130126001-006131126003-010126127001-006127127003-011126125001
0410-006130125002-010130125002-007125124002-007126126002-042126125052
0320-223130131247-321133141375-351153144456-325157156455-164141173421
1230-034126144227-123124065121-171122235065-226133244067-254126244045
1640-99999
```

E. 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 50 s of data. The channels used are 2, 6, 11, and 16.

Real-Time Message:

```
HSAK KSOC 101605
QQLSPM/DIRECT/R/O/ 0325 MSTART 11-10-72 HMS 16 05 45.0
0000-070123122016-152125120133-220125126220-230123070250
0050-244127132324-254125127342-266130133366-322133134430
0140-325137146450-331146166470-333156176523-337174131540
0230-340226242560-350240256620-356250250621-344235246566
0320-350236254576-350236242621-350240246621-346422254622
0410-346244321623-350252321625-350260321625-350254320623
0500-99999
```

F. Solar Proton Monitor (Data) Frame Content

The SPM data frame consists of 20 9-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

G. Archived Data

The time periods for which 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 prospective users should use the address below for information on or for obtaining specified data. Some of the data between these intervals are missing because of retrieval problems, noisy data, or for other reasons.

Satellite Name	From		To	
	Date	R/O	Date	R/O
ITOS 1	3/23/70	740	7/19/73	2220
ITOS 1	3/ 8/70	545*	3/14/70	632
NOAA 1	2/ 5/71	697	5/27/71	2098
NOAA 2	10/19/72	44		Present

For information on or for obtaining SPM data, contact:

Space Environment Laboratory, NOAA
Boulder, Colorado 80302

---

*These such data were processed on special request from the Space Disturbance Laboratory at Boulder, Colorado. These data represent a period of maximum solar activity for a 10-yr period.

(Continued from inside front cover)

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