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SCATHA-ANALYSIS SYSTEM

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PREFACE

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I. INTRODUCTION

1.0 OVERVIEW

The Air Force satellite P78-2 was designed to study Spacecraft Charging at High Altitude (SCATHA). The spacecraft contained a number of payloads for the investigation of spacecraft charging phenomenae.

The Air Force Geophysics Laboratory (AFGL) designed and developed three of the payloads.

Due to the volume of data and the complexity of the analysis requirements, a Data Analysis System (DAS) was designed by the Analysis and Simulation section (SUWA) of AFGL. The system, including software interfaces and corresponding analysis, was developed by the Space Data Analysis Laboratory (SDAL) of Boston College under contract (F19628-78-C-0018) to AFGL/SUWA. Implementation of the system fell under the purview of the contract.

1.1 SCATHA Satellite

The Space Test Program (STP) satellite designated P78-2 was launched from the Eastern Test Range (ETR) on 30 January 1979 at 2142: (Z). The space vehicle (SV) was successfully placed in near synchronous orbit for the purpose of investigating spacecraft charging at high altitude. The mission provided data for the study of charging, discharging and plasma interaction phenomenae. Prelaunch objectives included studies of the interaction of charging and discharging phenomenae with SV operations and techniques designed to control SV charge; effects on spacecraft materials due to charging and discharging; studies of various particles over a wide range of energies; and determination of magnetic field intensities due both to the environment and the spacecraft. On-orbit data and command/control communications are being performed by the Air Force Satellite Control Facility (AFSCF). Several remote tracking stations (RTS) are involved in this effort.

Orbital orientation provides two eclipse seasons each year. During these eclipse seasons, the spacecraft experiences a sequence of altitudes near synchronous altitude at local midnight. Approximately 50% of the eclipses occur with the SV above synchronous altitude at local midnight.

During 1979, the two eclipse seasons ran from approximately 17 March through 9 May and 23 September through 10 November.

The final apogee and perigee values are approximately 23, 340 and 14,870 nmi, respectively. The orbital inclination is 7.897 degrees. Thus, the longitudinal drift is eastward at a rate of about 5 degrees/day.

1.2 Satellite Systems

The cylindrical vehicle supports all satellite experiments and subsystems. It also provides for vehicle stabilization; electrical power; data storage and transmission; and the thermal environment for experiments and command control.

The attitude control and determination (AC&D) subsystem is used for attitude sensing and to provide adjustments to attitude, spin rate and velocity. All adjustments are made in real time via ground command. The AC&D system includes 2 steerable horizon crossing indicators, 4 digital sun sensors, 2 nutation dampers and 2 rocket engine modules. The spacecraft spin axis is maintained within $\pm 5^\circ$ normal to the sun and in the orbital plane.

The telemetry subsystem provides for acquisition, storage, formatting and transmission of engineering and science data. This subsystem includes the timing and command distribution unit (TCDU), 2 primary PCM encoders (8192 bps), 1 auxiliary PCM encoder (512 bps), 2 baseband multiplexers, 2 S-Band transmitters, a microwave control assembly and radial and omni antennas.

The TCDU generates timing signals used by the spacecraft and experiments. It also generates the vehicle time code word (VTCW) used in providing a time-tag for the PCM data.

The primary encoders provide data at 8192 $\pm$.01% bps in real time mode. Specifics of the telemetry of the prime encoder are summarized below.

8	bits/word
128	words/mainframe
1024	bits/mainframe
8192	bits/second
8	mainframes/second
.125	seconds/mainframe
128	mainframes/masterframe
16	seconds/masterframe
131072	bits/masterframe

The 128 mainframe words are referenced as word 0 through word 127. The VTCW is located on mainframe words 0 through 3. The synchronization pattern (01147537 octal) is located on mainframe words 125, 126 and 127.

The data rate for the auxiliary encoder is $512 \pm .01\%$ bps. Each mainframe is made up of 64 words (labeled 0 through 63). The synchronization pattern (01147537 octal) is located on mainframe words 61, 62 and 63. No external clock or timing signal exists for this data. The rates for the auxiliary encoder are summarized below.

8	bits/word
64	words/mainframe
512	bits/mainframe
1	mainframe/second
4	mainframes/masterframe
2048	bits/masterframe

The tape recorders onboard the spacecraft record a serial bi-phase-level $8192 \pm .01\%$ bps PCM bit stream using a single data track. The recorders can accumulate approximately 12 hours of 8192 bps data. Tape recorder playback is at a rate of 65536 bps.

Broadband analog data is also transmitted from the vehicle. This provides a means of receiving high data rate information for selected payloads. The Rapid Scan Particles Detectors (SC5) are among the instruments which provide broadband data.

Five combinations of real time, playback and broadband data can be provided by the downlink telemetry. Any one of the five modes may be selected at a given time. The five modes are defined below. (It should be noted that simultaneous downlink transmission of PCM playback and broadband cannot be accomplished.)

Downlink Modes

<u>Transmission Mode</u>	<u>Downlink Data</u>
1	8192 bps real time and 65536 bps playback
2	512 bps real time and one broadband mode
3	8192 bps real time and one broadband mode
4	512 bps real time and 65536 bps playback
5	8192 bps real time only.

1.3 AFGL Experiments

The AFGL payloads which have been successfully operated through nearly 2 years of satellite lifetime are the Particle Beam Systems (SC4) which includes the Electron Beam System (SC4-1) and Positive Ion Beam System (SC4-2); and the Rapid Scan Particle Detectors (SC5).

The Thermal Plasma Analyzer (SC6) experienced difficulties early in the lifetime and hence only a small amount of data was transmitted.

The following sections will provide an overview of the SC4 and SC5 instruments.

1.3.1 Particle Beams Systems (SC4)

The SC4 experiment consists of two independent systems designed to control spacecraft charging. The Electron Beam System (SC4-1) controls the ejection of electrons and the Positive Ion Beam System (SC4-2) controls the positive ion charge (xenon ions).

These systems were developed in order to maintain the space vehicle ground at plasma potential; return a highly negative space vehicle ground to plasma potential; charge the spacecraft to a high positive potential with respect to the plasma (SC4-1); and charge the spacecraft to a high negative potential with respect to the plasma.

Thus, in addition to discharging a charged vehicle, the SC4 systems can be used to charge the spacecraft in a predictable manner. Interpretation of the effects of SC4 operations is accomplished through the use of data from other payloads, e.g. SC5.

The SC4-1 instrument is mounted perpendicular to the spacecraft +X reference spin axis and 189.66° around from the +Z axis (with this angle measured from the +Z axis in the direction of the -Y axis). The line of sight of the SC4-2 instrument is 4.5 degrees from the +Z axis in the direction of the -Y axis and 304° around from the Z axis in the X-Z plane (angle is positive in the +Z through +X direction).

In the SC4-1 system, the electron source is a cathode. Beam currents are selectable through the use of a control grid; the angular spread of the electrons is commandable through the use of a focus element; and the energy of the beam of electrons is also commandable.

There are 6 selectable states for current and energy; and three choices of angular spread.

Commands to the SC4-2 instrument allow for the emission of a positive ion beam, a low energy electron beam, or a plasma of ions and electrons. Basically, a cathode emits electrons which are accelerated toward an anode where they ionize the xenon gas atoms. Thus, a plasma is formed from which ions are extracted. Cylindrical apertures and grids form the beam. The instrument has 2 selectable bias voltages and 3 current levels for each voltage.

Summaries of the SC4-1 and SC4-2 telemetry are included in the appendix.

1.3.2 Rapid Scan Particle Detectors (SC5)

The rapid scan particle detectors were designed to make particle flux measurements of ions and electrons. The approximate energy ranges over which the measurements are taken are 50 eV to 3.5 meV for ions and 50 eV to 1.1 meV for electrons. Ion and electron data is taken simultaneously.

The SC5 package is made up of two identical sets of detectors. One set is mounted to look perpendicular to the reference spin axis of the space vehicle while the other set, perpendicular to the first set, views parallel to the vehicle reference spin axis. Each detector set consists of 2 Electrostatic Analyzers (ESA) and 2 Solid State Spectrometers (SSS).

Each ESA has two Spiraltron Electron Multipliers for detectors; one detector is for ions and the other is for electrons. These detectors have rectangular fields of view. Power control circuitry automatically shuts off the ESAs whenever the flux level exceeds predefined values.

Data is provided by low energy and high energy ESAs. Each ESA accumulates counts at 4 energy levels and also provides a background count measurement. The data are accumulated for 200 ms at each energy level and thus a full set is acquired every second. The Solid State Spectrometers are referred to as anticoincidence and coincidence. The anticoincidence and coincidence detectors respectively perform the lower and higher energy measurements. As with the electrostatic analyzers, there are 5 energy channels for each SSS. The accumulation periods are also 200 ms.

Internal instrument logic provides an output for an energy channel if, and only if, the lower energy threshold for the channel is exceeded and the upper threshold is not exceeded.

The ESAs can be commanded to dwell at an energy range (channel) for up to 1024 accumulation periods (200 ms). Through ground command, the ESA detectors can be turned off while the SSS detectors remain in their normal operational mode.

The counts data for the ESA and SSS detectors is in the form of 12 bit digital readouts. Since the spacecraft has an 8 bit PCM system, each readout is thus split over two mainframe words.

In addition to the counts data, there are 17 housekeeping monitors which provide temperature and voltage data.

A summary of the SC5 telemetry is included in the appendix.

II. SCATHA DATA ANALYSIS SYSTEM

2.0 OVERVIEW

The SCATHA satellite has been, in general, operational 24 hours per day. Due to this volume of data and the diversity of analysis requirements, a SCATHA Data Analysis System (DAS) was defined and developed. The system was designed to allow for maximum data flow; to provide the flexibility necessary in the satisfaction of a variety of requirements; to minimize storage requirements; and to provide a data base for further analysis.

2.1 Functional Flow

Figure 1 depicts the functional flow of data through the system. Succeeding sections will elaborate upon the detailed requirements for each experiment.

Operation of the satellite is performed by the Satellite Control Facility. Telemetry data from the spacecraft is recorded on instrumentation tapes at various remote tracking stations. The instrumentation tapes are then sent to the Eastern Space and Missile Center (ESMC) at Patrick AFB, Florida for digitization. The AFGL digital tape requirements consisted of agency tapes for SC4-1, SC4-2, SC5 and SC9; 100% tapes; and out-of-sync tapes. Each agency tape consists of 5 files: header, event, estimation module, magnetic field and telemetry data. Each telemetry file contains only the parameters specifically requested. The 100% tape contains data from the full telemetry stream for small time periods (which are generally coincident with SC4 operations). The out-of-sync tapes contain data from time periods where out-of-sync, or dropout, occurred during the digitization process. In general, there is one agency tape for SC5 and SC9 as well as one out-of-sync tape for each digitized day of data. SC4 agency tapes are generated only for days on which the SC4 was operated. When generated, there is one SC4-1 (and/or SC4-2) agency tape per day. The 100% tapes cover selected periods which are coincident with SC4 operations and multiple tapes may be received for days on which the SC4 was operated.

The digital data is mailed from ESMC to AFGL/SUWA. Upon receipt of the tapes, they are assigned a number and logged into a cross-reference system. This system allows for look-up by experiment, tape number, or day.

SCATHA Data Analysis System
Functional Flow

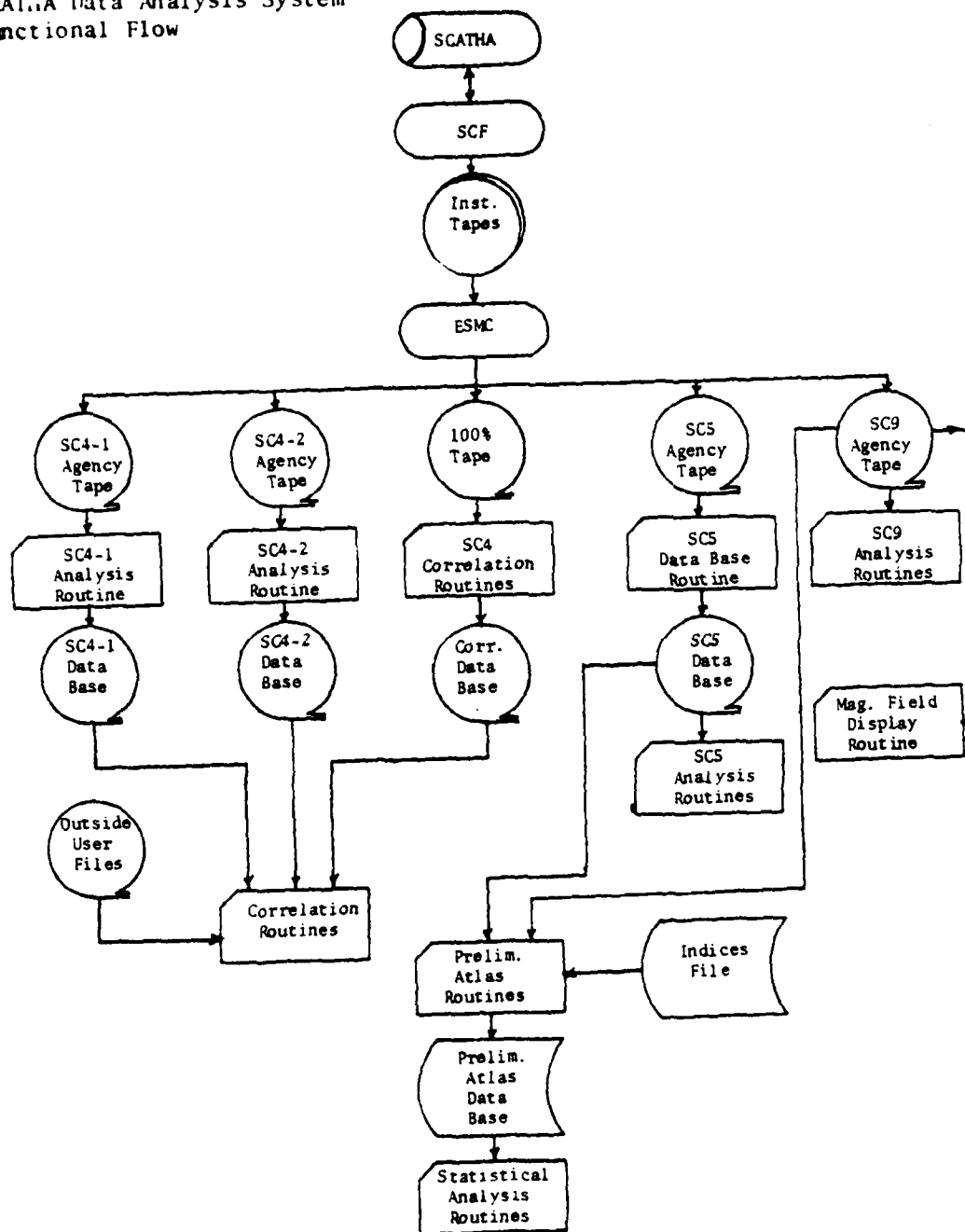


Figure 1

The digital data then flows through the system into analysis and/or pre-process routines designed to satisfy requirements.

The SC4-1 and SC4-2 analysis routines use agency tapes as input and result in a time history of commands sent to the instruments; engineering unit listings and displays; and data bases used for further study in either a stand alone fashion or in conjunction with data from other probes. The data base includes engineering unit parameters and magnetic pitch angle, sun angle and ephemeris data as required.

The 100% tapes are used primarily to provide geophysical unit data from other detectors during SC4 operations. The raw telemetry data for such probes as the SC10 and transient pulse monitor (TPM) is extracted from the 100% tape, calibrated to engineering units, merged with attitudinal and ephemeris data (as required) and listings, plots and data bases created. These correlation data bases are used along with the SC4 and other outside user files, e.g. Surface Potential Monitor, in studying the effects of the SC4 beams systems on the spacecraft and environment.

Due to the extensive and diverse analysis requirements for the SC5, a routine was developed to unpack, edit, reformat, create auxiliary files and create a preprocess data base to be used by the analysis routines. One of the auxiliary files contains the magnetic pitch angle and sun angle for the parallel and perpendicular detectors. The data rate on this auxiliary file is sufficiently high to provide an interpolatable data set. Examples of the types of analysis routines used with the SC5 include contour displays of the velocity distribution at fixed distribution function values; contour integrations resulting in density, temperature and energy parameters; determination of particle flux, and determination of current. The SC5 data was also used in the preliminary atlas.

Information on the SC9 instrument and all SC9 analysis requirements came from the SC5 problem initiator. The SC9 analyses use the agency tape as input. The instrument is a multi-mode particle detector covering the energy range between a few eV and approximately 80 keV. The SC9 analysis routines provide listings and displays of the particle spectra but no data base was required. Typically, displays or listings of differential energy

flux or distribution function as functions of time and energy are required for selected days and time periods. A routine was also developed to search the telemetry stream for commands to the instrument, decode the commands and produce a history of the commands over a one day period.

The magnetic field data on the agency tapes is used in the calculation of magnetic pitch angle. In addition, a routine was developed to extract the field data; optionally leave the reference frame as earth centered inertial (ECI) or map the data into either geocentric solar magnetospheric (GSM) or solar magnetic (SM); and produce displays and listings for selectable time periods.

The preliminary data atlas resulted from a study of the plasma environment encountered by the spacecraft. Data from approximately 45 days of satellite lifetime was included in the study. Input data for the analysis included 10 minute averages of the raw counts from the SC5 and SC9 detectors, the geophysical index Kp and selected ephemeris parameters. The 10 minute averages were used to obtain the moments of the distribution function. A statistical analysis was performed on a data base consisting of the moments, Kp and the ephemeris parameters. The preliminary atlas was published in August 1980 (AFGL-TR-80-0241).

2.2 Agency Tape Structure

The agency tape concept was devised in order to provide a compact file structure containing telemetry and auxiliary data. Telemetry data requirements were specified by the individual experimenters and formats were tailored to satisfy the requirements.

In general, each agency tape contains 24 hours of data running from 0000: to 2400: UT.

Each agency tape contains 6 files which are, in order: header, event, estimation module, ephemeris, magnetic field and telemetry data.

The header file contains general information pertaining to the instrument and day. The file consists of one record containing 15 words. The format of this file is contained in the appendix.

The event file was designed to provide information on SC4 operational status. Basically, this file consists of SC4-1 and SC4-2 on/off status. The format of this file is also contained in the appendix.

The Estimation Module (or EM file) contains coefficients to be used in attitude determination. This file of coefficients is the input to the Output Module (OM) subroutine which performs the attitude calculations.

The ephemeris file has 68 parameters along with UT at a time spacing of one frame per 10 minutes. The file has the standard positional parameters in earth centered inertial (ECI) coordinates but also has several parameters in magnetic, geocentric solar magnetospheric and solar magnetic coordinates. The file format is contained in the appendix.

The magnetic field file contains 15 second averages of the x, y and z components of the magnetic field (in ECI) along with the rms values associated with the averages. The data from the triaxial SC11 magnetometer was mapped into ECI, segmented into 15 second intervals and then averaged. It should be noted that the magnetometer was turned on during day 79053 and hence there is no magnetic field data prior to that day. The format of the magnetic field file is contained in the appendix.

The telemetry files on the agency tapes were tailored for each experiment and contain only the specific mainframe data necessary for analysis. This philosophy results in a compacted data set yet one which contains all the necessary information. The formats of the telemetry files for the SC4-1, SC4-2, SC5 and SC9 agency tapes are contained in the appendix.

2.3 SC4-1 Analysis

For the SC4-1, a cathode is the source of the electrons and a control grid is used to command the current to be drawn from the cathode. The beam current, angular spread (or focus) and accelerating voltage (cathode to anode potential) are selectable by command to the SV.

The 6 selectable beam currents are:

.001	MA
.01	MA
.1	MA
1.0	MA
6.0	MA
13.0	MA

The three angular spreads are:

Sharp	(20%)
Medium	(10%)
Diffuse	(5%)

The six selectable accelerating voltages are:

.05	kv
.15	kv
.30	kv
.5	kv
1.5	kv
3.0	kv

For probe operation, any combination of beam current and accelerating voltage may be selected except for 3 kv with 13 MA.

The beam was designed to be operated in a continuous manner or in pulsed mode.

The continuous mode is referred to as the 100% duty cycle and the pulsed mode (which was successfully used only once in the first year of operations) is called the 6.25% duty cycle.

The SC4-1 is operated only in real time mode.

The SC4-1 routine uses the agency tape as input; determines the status of the instrument; obtains commands sent to the instrument; calculates engineering unit parameters and associated magnetic pitch angle data; and produces listings, plots and a data base.

Command words within the telemetry stream are used to determine the SC4-1 status. In particular, telemetry designations D2001 through D2005

indicate beam current; D2006 reflects beam on/off status; D2007 indicates the duty cycle; D2008 and D2009 give the beam focus status; D2010 through D2013 indicate beam energy; and D2014 is for gun cap deployment.

The following table reflects the instrument status associated with the telemetry bit configurations.

<u>Beam Current</u>	<u>Bit Configuration of D2001 through D2005</u>
13 Ma	01111
6 Ma	10111
1 Ma	11011
.1 Ma	11101
.01 Ma	11110
.001 Ma	11111
<u>Beam On/Off</u>	<u>D2006 Bit</u>
On	1
Off	0
<u>Beam Duty Cycle</u>	<u>D2007 Bit</u>
100% (continuous)	1
6.25% (pulsed)	0
<u>Beam Focus</u>	<u>Bit Configuration of D2008 and D2009</u>
HI (sharp, 20%)	00
MED (10%)	10
LOW (diffuse, 5%)	01
<u>Beam Energy Level</u>	<u>Bit Configuration of D2010 through D2013</u>
3 kv	1100
1.5 kv	1000
.5 kv	0000
.3 kv	0010
.15 kv	0001
.05 kv	0011

Gun Cap Deployment

D2014 Bit

Cap in place	1
Cap deployed	0

Telemetry designations D4001 and D4002 are the beam current monitors and each reads out at 16 points per second.

The computed beam current is a function of the telemetry counts and the beam current indicated by the beam current flags. Other telemetry words converted to engineering units are the high voltage monitor (D4003), the two low voltage monitors (D4004 and D4005), and the temperature monitor (D4007).

Also included on the SC4-1 agency tape are the four command word replicas which reflect the commands sent to the spacecraft. The full set of commands are scanned and all SC4-1 commands, along with their time of occurrence, are extracted.

The listings produced by the SC4-1 routine include the full set of SC4-1 commands, the beam current (all points and one second averages), all remaining engineering unit parameters and the magnetic pitch angle of the SC4-1 instrument.

The plotted displays include:

- i) the time history of the SC4-1 commands for the day
- ii) time history displays of % beam current, beam current (Ma), high voltage monitor (v), focus, beam energy (kV) and magnetic pitch angle. Annotation is provided at the bottom of the displays for latitude, longitude, local time, and the SC4-1 temperature and low voltage monitors.

The files created by the SC4-1 routine consist of three distinct types:

- i) the prime data base
- ii) the time history of SC4-1 commands
- iii) a file constructed for interactive use in providing CRT displays of selected parameters. This file is referred to as the SC4-1 Tektronix file.

The format of the prime data base is contained in the appendix.

2.4 SC4-2 Analysis

The SC4-2 can be commanded to emit beams of three types:

- i) positive ions
- ii) low energy electrons
- iii) admixtures of ions and electrons.

The ion source is a discharge chamber with beam control grids. As electrons are emitted from the cathode, they are accelerated toward the anode by an electric field. The electrons collide with and ionize the xenon gas atoms to form a quasi-neutral plasma from which the ions are extracted and formed into a beam by using cylindrical apertures or grids. The plasma density is controlled by adjusting the anode voltage and cathode emission. The ions are extracted, accelerated and focused by applying voltages to the electrodes. The ion source can be configured by ground command to emit any of the three particle beam types defined above.

This system can be operated only in continuous mode.

For the SC4-2, there are four basic modes of operation. Each mode, however, has options which can be selected by ground command.

A summary of SC4-2 operating modes and options is provided in Table 1.

The SC4-2 is operated only in real time mode.

The SC4-2 routine uses the agency tape as input, extracts commands sent to the instrument; calculates engineering unit parameters and associated magnetic pitch angle; and produces listings, plots and a data base.

The command word replica (which is located on mainframe word numbers 38, 39, 40 and 41) is scanned and all commands to the SC4-2 are extracted.

The high data rate information for the SC4-2 is the beam current monitor (D4008), neutralizer emission monitor (D4009) and SPIBS net current monitor (D4010). Each of these words reads out at 16 pps.

The neutralizer bias polarity flag (D2016) is readout at .5 pps (a 1 bit indicates positive and a 0 bit indicates negative polarity).

Telemetry designations D4011 through D4025 contain the remaining monitor data for the SC4-2.

All telemetry words, rates and locations are contained in the appendix.

Table 1. SC4-2 Operating Modes

Mode	Beam Particles	Ion Source Bias V_i (kv)	Ion Current I_i (mA)	Electron Source Neutral, 5 eV Bias V_e (kv)	Electron Current I_e (mA)
1	Positive Ions	1.0 2.0	.3, 1.0, 1.4 .4, 1.5, 2.0	0 0	0 0
2	Low Energy Electrons	0	0	0	.002, .02, .4, 1.2, 2.2
3	Pos. Ions and Electrons	1.0 2.0	.3, 1.0, 1.4 .4, 1.5, 2.0	0 0	$I_i \leq I_e \leq 2$ $I_i < I_e < 2$
4	Pos. Ions and Electrons from a Biased Source	0. 1.0 2.0	0. .3, 1.0, 1.4 .4, 1.5, 2.0	$\pm .01, \pm .025,$ $\pm .1, \pm .5, \pm 1.0$ As above As above	$I_i \leq I_e \leq 2$ As above As above

Calibration curves were applied to all telemetry designations in order to provide the engineering unit parameters.

Magnetic pitch angle for the SC4-2 is obtained through use of the EM and magnetic field files.

Ephemeris parameters are calculated by means of interpolation on the ephemeris file.

Listings and plots of all engineering unit parameters are produced. In addition, annotation for selected ephemeris parameters is included on the displays. A time history of the commands sent to the SC4-2 is provided on both the listings and the plots.

Four distinct types of files are created by the SC4-2 routine.

- i) The prime data base
- ii) Commands file
- iii) High data rate file for interactive use in creating CRT displays
- iv) Low data rate file for interactive CRT display use.

The format of the prime data base is included in the appendix. This file contains all the SC4-2 data along with ephemeris and magnetic information.

The commands file provides a time history of the commands sent to the SC4-2.

The two files created for interactive CRT use differ in that the high data rate file has the data for only the beam current, neutralizer emission, and SPIBS net current monitors at the full rate of 16 pps; the low data rate file contains averages of the 16 pps monitors and includes all of the remaining SC4-2 monitors.

2.5 SC5 Analysis

The rapid scan particle detectors (SC5) were described in section 1.3.2.

Agency tapes were, in general, received for each day of the first year of satellite lifetime and contain a full 24 hours of data. In 24 hours, the SC5 provides 6,912,000 measurements. Each measurement is made up of 12 bits and hence there are approximately 83 million bits per day. This volume of

data combined with the diversity of requirements dictated the need for a preprocessing routine. Analysis requirements involve energy channel identification; counts calculations; flux and distribution function calculations; calculation of attitudinal data such as magnetic pitch angle and the angle between the SC5 detectors and the sun; and ephemeris information.

The preprocess routine was structured to provide a data base from which all necessary parameters could be retrieved or calculated.

A number of routines were developed which access the data base. Examples of the types of routines developed are as follows:

- i) retrieve counts information for all detectors, calculate magnetic pitch angle and sun angle for each spectra and produce listings;
- ii) calculate flux and/or distribution function along with magnetic and solar angle data - list and plot each spectra;
- iii) calculate and display contours of particle velocity as a function of magnetic pitch angle for fixed distribution function values;
- iv) integrate the distribution function data (with respect to velocity and magnetic pitch angle) over spins of the spacecraft to provide density, temperature and moments parameters;
- v) retrieve counts, average and display results from the parallel detectors;
- vi) retrieve counts, calculate magnetic pitch angle and display these parameters as a function of time (done for both the parallel and perpendicular detectors);
- vii) calculate flux and magnetic pitch angle, bias the flux and display these parameters as a function of time;
- viii) calculate current and magnetic pitch angle on a spectra by spectra basis - list and plot the results;
- ix) retrieve housekeeping data, transform to engineering units - list and display the results;
- x) perform up to a 3 Maxwellian analysis on a spectra by spectra basis thus providing density and temperature components of the plasma
- xi) grey scale the flux data from the parallel and perpendicular detectors and display the grey scale as a function of time.

A more detailed description of the preprocess routine and two of the analysis routines will be provided in succeeding sections.

2.5.1 SC5 Preprocess Routine

The SC5 preprocess routine uses the agency tape as input and writes a data base consisting of seven files. Files 1 through 5 are copied directly from the agency tape and they are, in order: header file, event file, EM file, ephemeris file and magnetic field file. Files 6 and 7 are created by the preprocess routine and are the magnetic/solar angle file and the SC5 preprocess file.

Magnetic and solar angle data is essential to the analysis and interpretation of the SC5 data. Thus, a file of the magnetic pitch angle and SC5/solar angle data was created for the parallel and perpendicular detectors at a rate of one point per second. Interpolation techniques applied to this file are easily implemented within analysis routines. In addition to the pitch and sun angle data, flags are provided to reflect possible problem areas and dummy filled areas. Cases considered include magnetic field data where the time spacing on the magnetic field file is over 45 seconds but less than 180 seconds; time spacing on the magnetic field file in excess of 180 seconds; no magnetic field data; and no EM data.

The SC5 preprocess file consists of a header record followed by data records. The header record has general information relating to the file such as date and the start and end times. The data records have merged ephemeris data (consisting of altitude, L-shell, magnetic local time, geocentric latitude and longitude, geomagnetic longitude and latitude, and invariant latitude) and packed telemetry information from the SC5 detectors. The telemetry data is packed into 12 bit words and structured such that each CDC 6600 word (60 bits) has all five readouts from a particular detector set (e.g. high energy ESA electrons-perpendicular detector). Each record has 16 seconds of the counts and energy channel data followed by the house-keeping monitor information.

Standard routines were developed to provide the magnetic/solar angle interpolation and to unpack the telemetry information in the preprocess file.

The formats of the magnetic/solar angle and preprocess file are contained in the appendix.

2.5.2 SCS Integration Analysis

Integrations are done over each spin. [The spin is defined as running from minimum pitch angle to minimum pitch angle.]

The integrations result in numerical values for:

- i) number density
- ii) energy density
- iii) bulk velocity
- iv) temperature

Only the ESA data (LE and HE) are used in the integrations.

The integrations require velocity values (v and Δv) associated with the ESA energy channels.

The telemetry counts are converted to actual counts by means of an algorithm involving the mantissa (the 9 LSBs of the 12 bit telemetry word) and the exponent (the 3 MSBS of the telemetry word).

Counts are then converted to differential number flux, $D(F)_i$, by multiplying the actual counts times the geometric factor. For the low energy ESA detectors, the background counts must be subtracted from the measured (actual) counts before the geometric factor is applied. The distribution function is then obtained from the differential number flux by the formula

$$f(E) = \frac{D(F) \times K}{E}$$

where

$$k = \begin{cases} .1617 & \text{for electrons} \\ 5.45 \times 10^5 & \text{for ions} \end{cases}$$

and E is the energy.

In the approximations which follow, the subscript i is used in reference to the energy channels ($i=1$ for LE ESA₁, ... , $i=8$ for HE ESA₄). The subscript j is used for the spectra within the vehicle spin, i.e. if there are m spectra within a spin, then $j=1,2,\dots,m$.

Approximations for the integrals are as follows:

i) Number density, n . (scalar)

$$\langle n \rangle = \left[2 \sum_{j=1}^m \left\{ \sum_{i=1}^8 f_j(v_i) v_i^2 \Delta v_i \Delta \rho_j \right\} \right] \times 10^{-15}$$

ii) Energy density, P_E (scalar)

$$P_E = K \sum_{j=1}^m \left(\sum_{i=1}^8 f_j(v_i) v_i^4 \Delta v_i \Delta \rho_j \right)$$

$$\text{where } k = \begin{cases} 5.6 \times 10^{-21}, & \text{elect.} \\ 5.6 \times 10^{-21} \times 1846, & \text{ions} \end{cases}$$

iii) Bulk flow, $\vec{v}_B$ (vector) ; $\vec{v}_B = v_x \vec{i} + v_y \vec{j}$

$$\begin{aligned} \vec{v}_B = & \left[2 \sum_{j=1}^m \left\{ \sum_{i=1}^8 f_j(v_i) v_i^3 \cos \alpha_j \Delta v_i \Delta \rho_j \right\} \right] \hat{i} \\ & + \left[2 \sum_{j=1}^m \left\{ \sum_{i=1}^8 f_j(v_i) v_i^3 \sin \alpha_j \Delta v_i \Delta \rho_j \right\} \right] \hat{j} \end{aligned}$$

$$\text{Then; } \vec{v}_B = \frac{v_x}{\langle n \rangle \times 10^{15}} \vec{i} + \frac{v_y}{\langle n \rangle \times 10^{15}} \vec{j}$$

For i), ii) and iii) above,

$$\Delta \rho_j = \begin{cases} \alpha_{j+1} - \alpha_j, & \text{for } j=1 \\ \frac{\alpha_{j+1} - \alpha_{j-1}}{2}, & \text{for } 1 < j < n \\ \alpha_j - \alpha_{j-1}, & \text{for } j=n \end{cases}$$

where α_j is central pitch angle for the j^{th} spectra within the spin.

iv) Average energy for each spin is defined as $\langle E \rangle$;

$$\langle E \rangle = \frac{P_E}{\langle n \rangle}$$

- v) Temperature values are obtained twice per spin; once at $\alpha = 90^\circ$ (designated $\alpha_{\max}$) and once at the minimum pitch angle ($\alpha_{\min}$). Since there are two sets of $\alpha_{\max}$ and 4 sets of $\alpha_{\min}$ in each spin, the first occurrence of each is selected unless data is missing due to solar interference. Should this occur, the next available minima or maxima is used.

$$T_{\alpha} = \frac{\sum_{i=1}^8 E_i f(E_i) \Delta E_i}{\sum_{i=1}^8 f(E_i) \Delta E_i}$$

where E_i is the energy at channel i and $f(E_i)$ is the distribution function at energy E_i .

Before the integrations were performed, the spectra were cleaned and noise data resulting from solar interference was deleted and interpolated for.

The cleaning of the spectra consisted, basically, of filling the low energy end of the spectra with the first non-zero value $f_j(v_k)$ whenever $f_j(v_i) = 0$ and interpolating (semi-log) for zero distribution function values at energies higher than velocity step v_k .

When the SC5 detector looks toward the sun, erratic spectra result. Thus, a minimum allowable solar/SC5 angle was used to determine areas where erratic spectra should be rejected and recreated by means of interpolation. The interpolation technique used the spectra on either side of the solar interference area.

Listings and displays of the calculated parameters were produced by this analysis routine.

2.5.3 SC5 Maxwellian Analysis

The SC5 Maxwellian analysis was developed in order to provide density and temperature data for low and high energy plasma components.

From the SC5 data, ordered pairs of energy (E_i) and distribution function ($f(E_i)$) are obtained.

The Maxwellian distribution is defined as:

$$f(E) = n \left(\frac{m}{2\pi KT} \right)^{3/2} e^{-E/KT}$$

where n is number density

T is temperature

K is Boltzmann's constant

and m is mass.

Thus,

$$\begin{aligned} \ln(f(E)) &= \ln \left(n \left(\frac{m}{2\pi KT} \right)^{3/2} \right) - \frac{E}{KT} \\ &= \beta - \alpha E \end{aligned}$$

where

$$\begin{aligned} \beta &= \ln \left(n \left(\frac{m}{2\pi KT} \right)^{3/2} \right) \\ \alpha &= \frac{1}{KT} \end{aligned}$$

A least square fit to $(E_i, \ln(E_i))$ was performed (beginning at the high energy end of the spectra) which resulted in the determination of the high energy components of temperature and density. The distribution function values at the low energy end of the spectra were then corrected by subtracting off the high energy components. The fit to the low energy end was then performed.

Spacecraft charging effects result in the necessity to shift the spectra in energy. The analysis took these effects into consideration.

The computer routine developed for this task had options to perform a 3-Maxwellian analysis. The energy ranges over which the analyses were performed are input to the routine. Options exist within the routine to input charging levels. Standard outputs consist of listings and plots of the density and temperature parameters as functions of time.

2.6 Correlation Analysis

The effects of the SC4 beams operations can be determined through the analysis of data from other instruments. In addition to the SC5 and SC9 particle detectors, the SC10 electric field instrument is frequently used. The SC10 common mode data is obtained through use of the 100% tapes. Data has also been received from outside agencies for use in correlation studies. Selected days of Surface Potential Monitor data have been received for this purpose.

The 100% tape format was defined in order to have available the full telemetry stream for selected time periods. Since the SC4 operations are run only in real time, they are of relatively short duration. A 100% tape has, in general, been received for each SC4 operation. This tape contains the full telemetry mainframe along with ground record time (in universal time). The universal time on the agency tapes results from a time/clock correlation procedure and hence the agency tape and 100% tape time tags for the same mainframe may differ by a small amount. (One method of providing time word consistency between the two tapes is to extract the satellite clock word from the 100% tape and use the appropriate clock correlation factors.)

The data on the 100% tape is not clean in the sense that telemetry dropout results in the shifting of word positions, deletion of telemetry words, and/or the insertion of extraneous bits. All information words on the 100% tape are six or 9 bits. A specific bit pattern was inserted into the digitized data at the start of each good telemetry frame.

A computer routine was written which uses the 100% tape as input; decodes the packed data; extracts selectable words from each good (in sync) frame; searches for the beginning of the "in sync" frame following dropout and verifies the pattern by locating the mainframe sync word; and creates a file of the selected mainframe words.

Correlation study files have frequently been created for the SC10 common mode data.

A computer routine was developed to access the SC10 file created from the 100% tape; convert the telemetry information from the common mode channels

CM1-, CM2- and CM3- into voltage; extract the data from the most sensitive yet unsaturated channel; and produce listings, plots and a data base. Analysis routines to provide displays of the SC10 data as functions of magnetic and solar angle data have been developed. These routines access the SC10 data base.

For periods of high interest, special correlation data bases have been necessitated. One such period was pass 4 on day 79089 (usually written as pass 89.4). A direct comparison of the SC4-1, SC10 and SSPM data was to be performed. Thus, a special data base containing parameters from all three instruments was created.

The SC4-1 currents and energies were extracted from the SC4-1 data base; the SC10 common mode voltages were obtained by means of the analysis program requiring the 100% tape; and the SSPM data was received from an outside agency. A merge routine was developed to create the necessary data base. Care was taken to match the data from the 3 instruments on a frame by frame basis since there was no guarantee that missing data (due to dropout) on the agency tape would also be missing on the 100% tape. The merge file was successfully created and several analysis routines were developed to provide the correlation information.

2.7 SC9 Analysis

All information related to the SC9 was received from the SC5 problem initiator through the Contract Monitor.

The SC9 payload returns data from 5 detectors. There are two rotating detector assemblies (RDA) with each assembly housing two detectors; one for negatively charged particles and one for positively charged particles. Each RDA can rotate through approximately 220°. The remaining detector, the Fixed Detector Assembly (FDA), performs measurements on positively charged particles (ions).

All detectors may be stepped through 64 discrete voltage steps. One RDA is a high energy detector with the discrete voltage steps spanning approximately 1 eV to 80000 eV. This detector is referred to as the North-South (NS) detector. The other RDA, called the East-West (EW) detector, and the FDA are low energy detectors (1 eV to 20000 eV).

The FDA is referred to as SC9-1; the NS RDA referred to as SC9-2; and the EW RDA referred to as SC9-3.

The SC9 is controlled by 21 discrete commands (latching commands) and one 22 bit magnitude command.

Rotating detectors can be swept through the full range of angles ($\sim 220^\circ$); wagged between a pair of fixed angles; parked at fixed angles; stopped at any given time; or forced to reverse direction immediately. These options are only executed by ground command.

Detectors can be operated in scan mode; scan-dwell mode; fast proton; fast electron; super-fast proton or electron mode for any of the detectors.

There are 6 accumulators (NS protons, NS electrons, EW protons, EW electrons, and two proton accumulators for the fixed detector). Each detector provides a 16 bit digital readout. For each of the 6 accumulators, the digital readout is converted to counts by a circular notation to the right of one bit.

Bits	1	2	3	4	5	...	14	15	16
								LSB	MSB
Value	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	...	2^1	2^0	2^{15}

Analysis was developed to handle scan mode data and during scan mode, the analyzers scan through 64 discrete energy steps with each energy level maintained for 250 MS. The detector to accumulator relationships are constant during scan modes. These relationships are:

<u>Desig.</u>	<u>Description</u>	
J4501	Accumulator 1	Protons NS detector
J4566	Accumulator 2	Electrons NS detector
J4502	Accumulator 3	Protons EW detector
J4567	Accumulator 4	Electrons EW detector
J4503	Accumulator 5	Protons fixed detector
J4568	Accumulator 6	Protons fixed detector

A computer routine was developed to extract counts data and energy channel information during scan mode operations, convert the counts to

differential energy flux and/or distribution function and produce listings and displays of the engineering unit data as a function of energy on a spectra by spectra basis.

Another SC9 routine which was developed scans the command words and produces a time sequenced listing of the commands.

The SC9 data was used primarily in conjunction with the SCATHA preliminary data atlas.

2.8 Magnetic Field (SC11) Information

The magnetic field file on the agency tapes is used primarily in the determination of magnetic pitch angle. The magnetic field data, however, is also used in a stand alone fashion for geosynchronous environment studies.

In order to provide flexibility in data interpretation, analysis and associated software were developed through which the magnetic field can be obtained and displayed in a choice of coordinate systems. These systems are: earth centered inertial (ECI); solar magnetic (SM); and geocentric solar magnetospheric (GSM).

The data on the magnetic field file is in ECI. Subroutines were developed to provide the mappings into GSM and SM.

All magnetic field displays are done as a function of UT.

2.9 SCATHA Preliminary Atlas Analysis

The provisional atlas effort was completed in June 1980. The following is a description of the analysis used in the development of the atlas data base, data sets selected and the statistical analysis upon the data base.

The two instruments flown aboard the SCATHA spacecraft which were selected for use in the preliminary atlas were the Rapid Scan Particle Detectors (SC5) and the San Diego Particles Detectors (SC9). Each of these detector sets provides ion and electron measurements.

The SC5 package consists of ion and electron sensors mounted parallel to and perpendicular to the spin axis of the vehicle. For the provisional atlas, only the parallel detectors were used. Each element of a detector set (e.g. electron detector mounted parallel to the spin axis) consisted of a low

energy electrostatic analyzer (ESA), a high energy ESA, a coincident solid state spectrometer (SSS) and an anti-coincident SSS. The total energy range spanned by the detectors went from approximately 100 eV to 1 MeV. For the preliminary atlas, the coincident SSS data channels were not used. Thus, the upper energy limits were 500 keV for ions and 335 keV for electrons.

One full spectra (one readout at each energy channel) is completed in a one second period.

The SC9 detector package consists of two detector sets which can be rotated and one fixed detector set. One of the rotatable detector sets, referred to as the North-South (NS) detectors, provides ion and electron measurements between the energy range of .3 eV to 82 keV.

For the preliminary atlas, only the North-South detectors were used.

This detector is programmable by ground command. The only data selected for inclusion in the atlas was from the 'scan' mode whereby the instrument steps through its 64 energy levels in a 16 second period. Data from any incomplete scan mode was deleted.

2.9.1 Overview and Functional Flow

Due to the volume of data associated with the preliminary atlas effort, an analysis system was designed and implemented. The effort was segmented into phases which could be naturally grouped together. Data bases were defined which would provide the flexibility required in an effort such as this.

The functional flow of data through the preliminary atlas system is depicted in Figure 2.

A preprocessed data base exists for the SC5 instrument. This was the initial SC5 file used in the preliminary atlas effort. The initial SC9 input file consisted of the agency tape.

Averaging routines were developed for both detectors. The averaging procedure consisted of a straight 10 minute average of counts. The averaging interval was a period of 10 minutes ending on the even 10 minute part of each hour. For the SC5, only the parallel detectors were used. For the SC9, only complete scans of data from the North-South detectors were used.

Functional Flow - Preliminary Atlas System

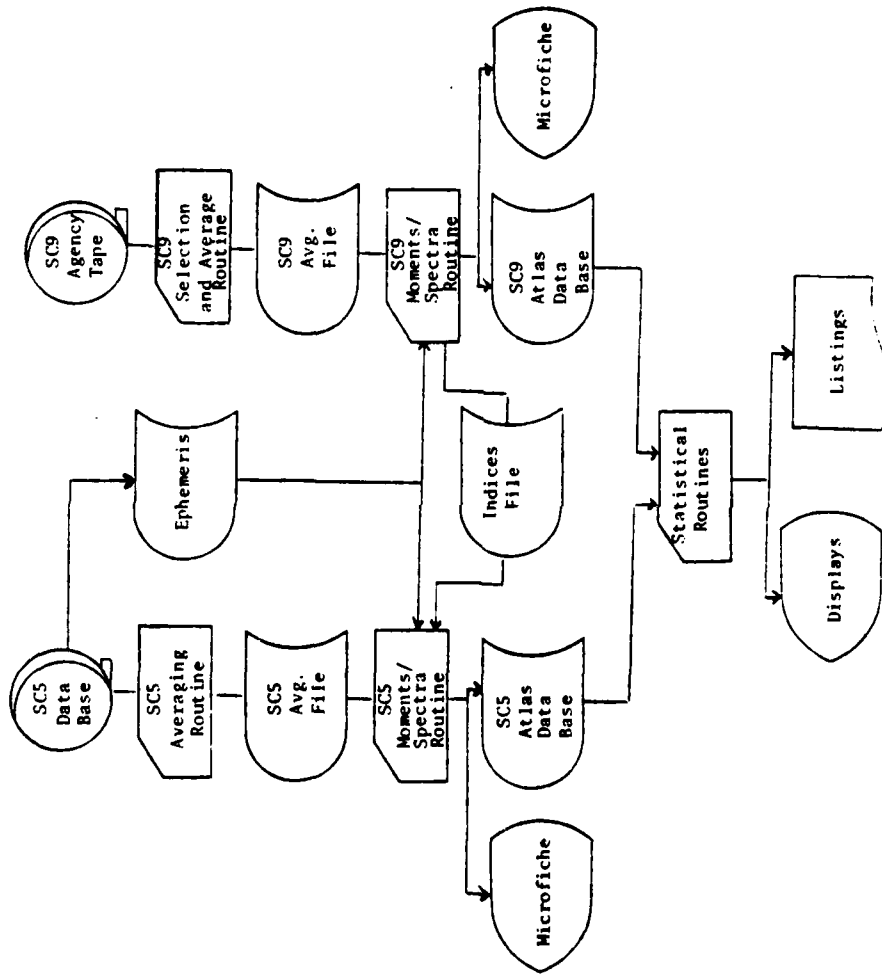


Figure 2

Independent moments routines were developed for the SC5 and SC9 data although several common subroutines were used by the two programs. Basically, the routines computed distribution function; the 4 moments; parameters derived from the moments; and merged ephemeris and geophysical index information. Output from the routines consisted of a data base for use in the statistical analysis and microfiche displays. These displays were in two parts: spectra (derived from the average counts) which consisted of distribution function versus energy along with the 2-Maxwellian curve derived from the data; and time history displays of the moments and parameters derived from the moments.

Several routines were developed to perform statistical analyses upon the data base. In addition, several constraints were applied to the data before acceptance into the statistical analysis. Each routine had its own display and listed outputs.

2.9.2 Data Selection

Due to the volume of available SCATHA data, 65 days were selected as candidates for inclusion in the statistical studies. Data for both detectors was run through the moments routines. The resulting displays were reviewed and from the candidate days, 42 days were selected. The days chosen, all in 1979, are listed below:

40	53	140	164	206
41	54	142	166	208
42	55	144	168	
43	56	146	170	
44	57	152	172	
45	77	154	178	
46	78	156	194	
47	121	158	200	
50	123	160	202	
52	125	162	204	

2.9.3 SC5 Atlas Analysis

The SC5 detectors provide 5 readouts from each of four instruments: low energy ESA, high energy ESA, anti-coincident solid state spectrometer and

coincident solid state spectrometer. Ion and electron detector sets were flown with alignments parallel to and perpendicular to the spacecraft spin axis. For the preliminary atlas only the parallel detectors were used. Further, the SSS coincident data was not used.

Simple 10 minute averages of the counts from each channel were the basic input.

The SC5 instruments can be commanded into states which result in repeating readouts for each of the energy channels. Data included in the averaging procedure was restricted to a repeat factor of 1 (i.e. one readout for each energy step in a 1 second period).

The ESAs (low energy and high energy) each provide a background measurement. The background counts for the low energy ESA (LE ESA) were subtracted from the other four LE ESA values after averaging. The high energy ESA (HE ESA) background measurement was not used.

From the average counts, differential number flux and distribution function were calculated. The distribution function values were then used in the integrations which result in the moments.

Differential number flux, $\left. \frac{d(F)}{dE} \right|_i$, was obtained as follows:

$$\left. \frac{d(F)}{dE} \right|_i = C_i \times K_i$$

where

$$C_i = \begin{cases} \overline{\text{counts}_i} - \overline{\text{background counts}} & \text{for LE ESA} \\ \overline{\text{counts}_i} & \text{for non LE ESA channels} \end{cases}$$

and K_i is the geometric factor. The units for differential number flux are particles/(cm²-sec-ster-eV).

Distribution function (in sec³/km⁶), $f(E_i)$, was obtained by

$$f(E_i) = \frac{\left. \frac{d(F)}{de} \right|_i \times \lambda}{E_i}$$

Table 2. SC5 Energy Channel Information

Channel	Parallel Electrons			Parallel Ions		
	E (KeV)	K	ΔE (KeV)	E (KeV)	K	ΔE (KeV)
LE ESA ₁	.112	588	.138	.145	208	.134
LE ESA ₂	.271	179	.300	.353	116	.34
LE ESA ₃	.679	64.9	.870	.782	36.2	.79
LE ESA ₄	1.5	30.3	1.55	1.706	13.5	1.57
HE ESA ₁	4.57	34.2	6.2	4.5	5.62	4.3
HE ESA ₂	8.97	20.8	8.9	10.4	2.0	8.1
HE ESA ₃	23.2	9.26	25.	25.0	8.62×10^{-1}	20.0
HE ESA ₄	52.7	6.02	53.	59.9	3.65×10^{-1}	47.0
SSS COINC ₀	39	4.13×10^{-1}	12	126	1.52×10^{-2}	49.0
SSS COINC ₁	58	9.77×10^{-2}	24	188	9.96×10^{-3}	75.0
SSS COINC ₂	96	3.47×10^{-2}	48	275	7.47×10^{-3}	100.0
SSS COINC ₃	335	3.28×10^{-3}	430	388	5.98×10^{-3}	125.0
SSS COINC ₄	218	1.48×10^{-2}	95	499	7.76×10^{-3}	97.0

where

$$\lambda = \begin{cases} .1617 & \text{for electrons} \\ 5.45 \times 10^5 & \text{for ions} \end{cases}$$

and E_i is the energy in eV.

Table 2 provides the energies, geometric factors and AE bins (used in the integrations).

2.9.4 SC9 Atlas Analysis

The San Diego Particle Detectors (SC9) consist of 5 instruments. Four of the detectors are contained in a rotating detector assembly. The North-South rotating detector assembly performs ion and electron measurements between approximately 1 eV and 80000 eV. The East-West rotating detector assembly is used for ion and electron measurements between approximately 1 eV and 2000 eV. The fifth detector, called the fixed detector, performs ion measurements in the same range as the East-West detectors.

Commands to the instrument allow for a wide variety of operational modes. One of these modes, called the scan mode, results in the consecutive sampling of each of the 64 energy channels. Time duration of the scan mode is 16 seconds.

Only the North-South detector data was used for the provisional atlas. In the averaging procedure, only complete scans were used.

The energy channels are labeled 0 through 63. The table below provides the energy values associated with each channel.

Chan. No.	E (eV)	Chan. No.	E (eV)	Chan. No.	E (eV)	Chan. No.	E (eV)
0	-4.68	16	119.71	32	1205.49	48	10681.76
1	-2.35	17	140.08	33	1383.30	49	12233.63
2	.32	18	163.41	34	1586.90	50	14010.53
3	3.38	19	190.12	35	1820.02	51	16045.08
4	6.88	20	220.70	36	2086.94	52	18374.64
5	10.89	21	255.72	37	2392.57	53	21041.98
6	15.49	22	295.81	38	2742.51	54	24096.09
7	20.75	23	341.72	39	3143.19	55	27593.05
8	26.77	24	394.29	40	3601.97	56	31597.06

Chan. No.	E (eV)	Chan. No.	E (eV)	Chan. No.	E (eV)	Chan. No.	E (eV)
9	33.66	25	454.45	41	4126.28	57	36181.66
10	41.56	26	523.39	42	4728.76	58	4131.02
11	50.60	27	602.30	43	5147.45	59	47441.54
12	60.95	28	692.62	44	6206.00	60	54323.58
13	72.80	29	796.11	45	7100.89	61	62203.53
14	86.87	30	914.56	46	8142.70	62	71226.06
15	101.97	31	1050.19	47	9326.41	63	81556.86

The average counts were converted to differential energy flux and then to distribution function. The distribution function values were used in the integrations which result in the moments.

Differential energy flux at energy channel i , $\left. \frac{d(EF)}{dE} \right|_i$, was obtained by use of the formula

$$\left. \frac{d(EF)}{dE} \right|_i = \frac{4 c_i}{H \cdot \epsilon_i}$$

where

c_i = counts readout by the detector

$$H = \begin{cases} 1.6 \times 10^{-4} & \text{for electrons} \\ 3.2 \times 10^{-4} & \text{for ions} \end{cases}$$

$$\epsilon_i = \begin{cases} \epsilon_1 \cdot \epsilon_2, & \text{for electrons} \\ \epsilon_3, & \text{for ions} \end{cases}$$

$$\epsilon_1 = 1 - \frac{2}{3 + \frac{6.5}{E_i + .2} + \frac{30}{(E_i + .2)^3}}, \quad E_i \text{ in keV}$$

$$\epsilon_2 = 1 + \frac{2}{\left(\frac{E_i}{.15} \right)^3 + 1}, \quad E_i \text{ in keV}$$

and

$$\epsilon_3 = 1 + \frac{2}{\left(\frac{E_i}{1.5} \right)^3 + 1}, \quad E_i \text{ in keV}.$$

Distribution function is defined by

$$f(E_i) = \frac{\left. \frac{d(EF)}{dE} \right|_i \times \lambda}{E_i^2}$$

where

$$\lambda = \begin{cases} .1617 & \text{for electrons} \\ 5.45 \times 10^5 & \text{for ions} \end{cases}$$

and

E_i is the energy in eV.

It should be noted that only energy channels with $E_i > 100$ eV were used in the moments analysis.

2.9.5 Moments and 2-Maxwellian Parameters

The Maxwellian distribution function, $f(v_i)$ is defined as

$$f(v) = n \left(\frac{m}{2\pi kT} \right)^{3/2} e^{-\frac{mv^2}{2kT}}$$

where

n = number density

m = mass

T = temperature

v = velocity

k = Boltzmann constant

f = distribution function in sec^3/km^6

The first four plasma moments are used (assuming an isotropic distribution) to approximate the following parameters:

$$\text{Number Density } \left(\frac{\text{number}}{\text{cm}^3} \right) = \langle N \rangle = 4\pi \sum_{E_i} \left. \frac{d(EF)}{dE} \right|_i \left(\frac{2E_i}{m} \right)^{-1/2} \frac{\Delta E_i}{E_i}$$

$$\text{Number Flux (number/cm}^2\text{sec-sr)} = \langle Nf \rangle = \sum_{E_i} \left. \frac{d(EF)}{dE} \right|_i \frac{\Delta E_i}{E_i}$$

$$\text{Energy Density (ergs/cm}^2\text{)} = \langle p \rangle = 4\pi \sum_{E_i} \left(\frac{m}{2} \right) \left. \frac{d(EF)}{dE} \right|_i \left(\frac{2E_i}{m} \right)^{1/2} \frac{\Delta E_i}{E_i}$$

$$\text{Energy Flux (ergs/cm}^2\text{sec-sr)} = \langle EF \rangle = \sum_{E_i} \left(\frac{m}{2} \right) \left. \frac{d(EF)}{dE} \right|_i \left(\frac{2E_i}{m} \right) \frac{\Delta E_i}{E_i}$$

where

E_i = energy (in eV)

$$m = \text{mass} = \begin{cases} 9.1 \times 10^{-28} & \text{for electrons} \\ 1.67 \times 10^{-24} & \text{for ions} \end{cases}$$

and

$$\left. \frac{d(EF)}{dE} \right|_i = \text{differential energy flux at } E_i \text{ in eV/eV-sec-ster-cm}^2.$$

Average and root mean square (rms) values of temperature (in eV) were directly obtained from the moments as follows:

$$T(\text{AVG}) = \frac{2}{3} \frac{\langle P \rangle}{\langle N \rangle}$$

$$T(\text{RMS}) = \frac{1}{2} \frac{\langle EF \rangle}{\langle NF \rangle}$$

Current density, in nanoamps/cm², was obtained from number flux by the formula

$$\text{Current Density} = \pi \cdot g \langle NF \rangle$$

$$\text{where } g = 1.6 \times 10^{-10}$$

Assuming that the distribution function is the sum of 2 Maxwellians,

$$f(v_i) = \left(\frac{m}{2\pi K} \right)^{3/2} \left\{ \frac{n_1}{T_1^{3/2}} e^{-\frac{mv^2}{2kT_1}} + \frac{n_2}{T_2^{3/2}} e^{-\frac{mv^2}{2kT_2}} \right\}.$$

The two Maxwellian density (n_1, n_2) and temperature (T_1, T_2) were obtained from the moments.

Due to a truncated energy band pass for the SC9 detector, a correction procedure for Maxwellian and moments parameters was devised by the Atlas initiator.

It was assumed that n_1 and T_1 were correct. Then, n_2 and T_2 were recomputed by means of an approximating polynomial representing the ratio of observed to actual data. Thus, with n_1 , n_2 , T_1 and T_2 known, the moments were recomputed.

2.9.6 Ephemeris and Geophysical Index Parameters

Several ephemeris parameters were selected for inclusion in the preliminary atlas data base. The geophysical index K_p was also selected.

The ephemeris parameters chosen were obtained from the ephemeris file on the SCATHA agency tape. These parameters were local time (hours), geocentric latitude (degrees), altitude (km), L-shell (earth radii), magnetic time (hours), magnetic radius (in earth radii), magnetic latitude and magnetic longitude.

Magnetic time is defined as the angle (in hours) between the meridian planes containing the anti-solar direction and the minimum B point in magnetic coordinates.

The coordinate reference frame for magnetic radius, latitude and longitude is such that the z-axis is parallel to the dipole, and the south geographic pole is in the x-z plane.

Satellite altitude (above the earth) in earth radii was also included in the data base.

The K_p values were taken from an existing file of geophysical indices. The value stored on the data base was $K_p \times 3$. Thus, for example, $K_p = 1$ would be stored as $K_p = 2$.

2.9.7 Statistical Analysis

The SC5 and SC9 data bases were used as input to the statistical analysis. Several constraints were placed upon the data. One such constraint required that valid data exist for both the SC5 and SC9 in order that a point be included in the statistics. There were some periods when the SC5 and SC9

were not on simultaneously. Thus, these periods were eliminated. Other cases existed where data from a detector was rejected due to noise. In that event, data from the other detector was also rejected.

The statistical analysis took four forms:

- i) Histograms of occurrence frequency were generated,
- ii) average values of data base parameters were computed as functions of ephemeris data and K_p
- iii) average values of accepted data base parameters were computed over the full 42 days,
- iv) scatter displays of selected data base parameters were generated.

To aid in interpreting statistical results, cross-correlation information (reflecting the number of points in bins for local time vs. L-shell, K_p vs. local time, and K_p vs. L-shell) was generated.

2.9.8 Rejection Criteria

As noted above, any time period for which simultaneous valid SC5 and SC9 data did not exist was rejected. Several noise point, ephemeris and K_p constraints were also applied to the data. If a value from one detector was rejected due to rejection constraints, the data from the other detector was also discarded.

The constraints applied were as follows:

- i) accept points only if $5.5 \leq \text{L-shell} \leq 9.0$
- ii) reject if $K_p > 6$ -
(i.e. using $3 \times K_p$, reject if $3 \times K_p > 17$)
- iii) reject if SC9 n_1 (ions) $\geq 1.5 \text{ cm}^{-3}$
- iv) reject if SC9 T_2 (ions) $\geq 40 \text{ keV}$
- v) reject if SC9 T_2 (electrons) $\geq 40 \text{ keV}$
- vi) reject if SC9 T(AVG) (electrons) $\geq 15 \text{ keV}$
- vii) reject if SC9 T(RMS) (electrons) $\geq 20 \text{ keV}$
- viii) reject if SC5 n_1 (ions) $\geq 1.5 \text{ cm}^{-2}$

- ix) reject if SC5 T_2 (ions) ≥ 60 keV
- x) reject if SC5 T_2 (electrons) ≥ 60 keV
- xi) reject if SC5 T_1 (electrons) > 7.5 keV
- xii) reject if any of the four moments for either detector is negative.

2.9.9 Histograms

Histograms of occurrence frequency were produced for several parameters. Figure 3 identifies the parameters for which histograms were produced, the range studied and the bin sizes used.

Data for the SC5 and SC9 were plotted together on each histogram. The same ranges and bin sizes were used for both detectors.

2.9.10 Ephemeris and K_p Dependences

To provide an understanding of geophysical unit behavior in the geosynchronous environment an averaging scheme was devised to show variations as functions of local time, L-shell and K_p .

In particular, average values of the moments, current density, average and rms temperatures, 2-Maxwellian densities and temperatures were obtained for fixed ranges of local time, L-shell and K_p . The ranges used were:

- i) Local time, 0 to 24 hours with an average value for every 3 hours
- ii) L-shell, 5.5 to 9.0 with an average value for every change of .5
- iii) K_p bins used were (0,0+,1-), (1°,1+,2-), (2°,2+,3-), (3°,3+,4-), (4°,4+,5-) and (5°,5+,6-)

Displays of the average values were produced. Displays for each of the geophysical unit parameters were created for the 3 sets of dependences. SC5 and SC9 data were plotted on the same grid. Data, however, was plotted separately for the ion and electron measurements.

Parameter	Min	Max	Δ
Local Time (hours)	0	24	3
L-Shell	5.5	9.0	.5
$K_p \times 3$	0	17	3
Number density ($\#/cm^3$) - electrons	0	3	.25
Number density ($\#/cm^3$) - ions	0	3	.25
Energy density (eV/cm^3) - electrons	0	2000	500
Energy density (eV/cm^3) - ions	0	40000	1250
Energy flux ($eV/cm^2\text{-sec-sr}$) - electrons	0	60×10^{11}	2×10^{11}
Energy flux ($eV/cm^2\text{-sec-sr}$) - ions	0	10^{12}	2.5×10^1
Current density ($nanoamps/cm^2$) - electrons	0	.3	.02
Current density ($nanoamps/cm^2$) - ions	0	10^{-2}	5×10^{-4}
T(AVG) (keV) - electrons	0	15	1.25
T(AVG) (keV) - ions	0	25	1.25
T(RMS) (keV) - electrons	0	30	1.25
T(RMS) (keV) - ions	0	30	1.25
n_1 ($\#/cm^3$) - electrons	0	3	.2
n_1 ($\#/cm^3$) - ions	0	3	.2
N_2 ($\#/cm^3$) - electrons	0	3	.2
N_2 ($\#/cm^3$) - ions	0	3	.2
T_1 (keV) - electrons	0	3	.1
T_1 (keV) - ions	0	3	.1
T_2 (keV) - electrons	0	40	1
T_2 (keV) - ions	0	40	1

Figure 3

2.9.11 Scatter Plots

Variation of one geophysical unit parameter as a function of another was displayed through the use of scatter plots.

Fixed x,y pairs were selected and, for the selected pair, all acceptable points in the data base were extracted and plotted. Separate sets of scatter plots were done for the SC5 and SC9 detectors.

Scatter plots done included energy flux vs. number flux, T_1 vs. n_1 , T_2 vs. n_2 , number density vs. $T(\text{AVG})$ and energy density vs. number density.

The concept was then expanded to produce the scatter plots for sets of local time, L-shell and K_p bins.

2.9.12 Atlas Data Base

The atlas data base contained one day of SC5 (or SC9) data per file.

The format of each file is as follows:

<u>Word #</u>	<u>Description</u>
1	Experiment - alphanumeric (SC5 or SC9)
2	Year
3	Month
4	Day
5	Hour
6	Minute
7	GMT (seconds)
8	Day of year
9	Total number density ($\#/cm^3$)
10	2-Maxwellian Low energy density (N_1)
11	2-Maxwellian High energy density (N_2)
12	Total number density ($\#/cm^3$)
13	2-Maxwellian Low energy density (N_1)
14	2-Maxwellian High energy density (N_2)
15	Energy density (eV/cm^3) - electrons
16	Energy density (eV/cm^3) - ions
17	Energy flux ($eV/cm^2\text{-sec-sr}$) - electrons

<u>Word #</u>	<u>Description</u>
18	Energy flux (eV/cm ² -sec-sr) - ions
19	Number flux (#/cm ² -sec-sr) - electrons
20	Number flux (#/cm ² -sec-sr) - ions
21	2-Maxwellian temperature (eV) - low energy electrons
22	2-Maxwellian temperature (eV) - high energy electrons
23	2-Maxwellian temperature (eV) - low energy ions
24	2-Maxwellian temperature (eV) - high energy ions
25	T(AVG) (eV) - electrons
26	T(AVG) (eV) - ions
27	T(RMS) (eV) - electrons
28	T(RMS) (eV) - ions
29	Local time (hours)
30	Altitude (km)
31	R _e
32	Latitude (degrees)
33	L-shell (earth radii)
34	Magnetic time (hours)
35	Radius (magnetic) - earth radii
36	Magnetic latitude
37	Magnetic longitude
38	K _p × 3
39-50	Vacant

For SC5; data stored is from the parallel detectors

For SC9; data stored is from the N-S detectors only.

Dummy filled areas contain the decimal value of -999999.

APPENDIX A
SC4-1 Telemetry Data

SC4-1 TELEMETRY SUMMARY

DESIG	DESCRIPTION	RATE (PPS)	NO. OF BITS	WORD/ BIT	MAINFRAMES	COMMENTS
D2001	Beam Current Flag No. 1	.5	1	103/1	0,16,32,48,64,80,96,112	0=OFF; 1=ON 0=6.25; 1=100%
D2002	Beam Current Flag No. 2	.5	1	103/2	0,16,32,48,64,80,96,112	
D2003	Beam Current Flag No. 3	.5	1	103/3	0,16,32,48,64,80,96,112	
D2004	Beam Current Flag No. 4	.5	1	103/4	0,16,32,48,64,80,96,112	
D2005	Beam Current Flag No. 5	.5	1	103/5	0,16,32,48,64,80,96,112	
D2006	Beam On/Off Flag	.5	1	103/6	0,16,32,48,64,80,96,112	
D2007	Beam Duty Cycle Flag	.5	1	103/7	0,16,32,48,64,80,96,112	
D2008	Beam Focus Flag No. 1	.5	1	103/8	0,16,32,48,64,80,96,112	
D2009	Beam Focus Flag No. 2	.5	1	103/1	1,17,33,49,65,81,97,113	
D2010	Beam Energy Flag No. 1	.5	1	103/2	1,17,33,49,65,81,97,113	
D2011	Beam Energy Flag No. 2	.5	1	103/3	1,17,33,49,65,81,97,113	
D2012	Beam Energy Flag No. 3	.5	1	103/4	1,17,33,49,65,81,97,113	
D2013	Beam Energy Flag No. 4	.5	1	103/5	1,17,33,49,65,81,97,113	
D2014	Gun Cap Deployment Flag	.5	1	103/6	1,17,33,49,65,81,97,113	
D4001	Beam Current Monitor On	16	8	21/ALL	ALL	
D4002	Beam Current Monitor Low	16	8	85/ALL	ALL	0=OFF; 4.5+.2=OPERATE 0=OFF; 4.2+.2=OPERATE
D4003	High Voltage Monitor	.0625	8	53/ALL	ALL	
D4004	Low Voltage Monitor No. 1	.0625	8	117/ALL	ALL	
D4005	Low Voltage Monitor No. 2	.0625	8	102/ALL	55	
D4006	Gun-Cap Current Mon.	.0625	8	102/ALL	56	
D4007	Temperature Monitor	.0625	8	102/ALL	57	
					58	
					59	

APPENDIX B

SC4-2 Telemetry Data

SC4-2 TELEMETRY SUMMARY

DESIG	DESCRIPTION	RATE (PPS)	NO. OF BITS	WORD/ BIT	MAINFRAMES	COMMENTS
D2015	Blow Off Cover Flag	.5	1	103/7	1,17,33,49,65,81,97,113	0=OFF; 1=ON
D2016	Neutral Bias Polarity Flag	.5	1	103/8	1,17,33,49,65,81,97,113	0=OFF; 1=ON
D4008	Beam Current Monitor	16	8	22/ALL	ALL	
D4009	Neutralizer Emission Monitor	16	8	86/ALL	ALL	
D4010	SPIBS Net Current Monitor	16	8	23/ALL	ALL	
D4011	Beam Voltage Monitor	.0625	8	87/ALL	ALL	
D4012	Discharge Current Monitor	.1	8	24/ALL	ALL	
D4013	Discharge Voltage Monitor	1	8	88/ALL	ALL	
D4014	Keeper Current Monitor	.0625	8	102/60	4,12,20,28,36,44,52,60,68,76,84,92,100,108,116,124	
D4016	Keeper High Voltage Monitor	.0625	8	112/ALL	6,14,22,30,38,46,54,62,70,78,86,94,102,110,118,126	
D4016	Keeper Low Voltage Monitor	1	8	111/ALL	63	
D4017	Cathode Heater Current Mon.	1	8	102/ALL	62	
D4018	Accelerator Current Monitor	.0625	8	112/ALL	6,14,22,30,38,46,54,62,70,78,86,94,102,110,118,126	
D4019	Decelerator Current Monitor	.0625	8	113/ALL	7,15,23,31,29,47,55,63,71,79,87,95,103,111,119,127	
D4020	Neutralizer Heater Current Monitor	.0625	8	102/ALL	71	
D4021	Neutralizer Bias Voltage Mon.	.0625	8	102/ALL	72	
D4022	Tank Pressure Monitor	.0625	8	102/ALL	73	
D4023	PWR Proc. Temp. Monitor	.0625	8	102/ALL	74	
D4024	PPA AC Inverter Curr. Mon.	.0625	8	102/ALL	66	
D4025	PPA AC Inverter Voltage Mon.	.0625	8	102/ALL	75	
					64	
					65	

APPENDIX C

SC5 Telemetry Data

SC-5 TELEMETRY SUMMARY

DESIG	DESCRIPTION	RATE (PPS)	NO. OF BITS	INITIAL READOUT WITHIN MASTERFRAME MF WORD/SUBCOMLEVEL (BITS)	MASTERFRAMES
E4001	+3500v Monitor	.0625	8	102/76 (ALL)	76
E4002	+500v Monitor	.0625	8	102/77 (ALL)	77
E4003	+2500v Monitor	.0625	8	102/78 (ALL)	78
E4004	-500v Monitor	.0625	8	102/79 (ALL)	79
E4005	-30v Monitor	.0625	8	102/80 (ALL)	80
E4006	Electron SSD Bias V.	.0625	8	102/81 (ALL)	81
E4007	+15v Monitor	.0625	8	102/82 (ALL)	82
E4008	+10v Monitor	.0625	8	102/83 (ALL)	83
E4009	-5v Monitor	.0625	8	102/84 (ALL)	84
E4010	-10v Monitor	.0625	8	102/85 (ALL)	85
E4011	HE ESA Sweep V. Monitor	.0625	8	102/86 (ALL)	86
E4012	LE ESA Sweep V. Monitor	.0625	8	102/87 (ALL)	87
E4013	Perp. P-SSD Bias V. Monitor	.0625	8	102/88 (ALL)	88
E4014	Par. P-SSD Bias V. Monitor	.0625	8	102/89 (ALL)	89
E4015	DC to DC Conv. Temp. Mon.	.0625	8	102/90 (ALL)	90
E4016	Perp. SSS Temp. Monitor	.0625	8	102/91 (ALL)	91
E4017	Par. SSS Temp. Monitor	.0625	8	102/92 (ALL)	92
E8001	SSS Energy Channel	5	4	18/0 (1-4)	0,8,16,....,120
				95/1 (1-4)	1,9,17,....,121
				44/3 (1-4)	3,11,19,....,123
				121/4 (1-4)	4,12,20,....,124
				70/6 (1-4)	6,14,22,....,126
E8002	ESA Energy Channel	5	4	18/0 (5-8)	0,8,16,....,120
				95/1 (5-8)	1,9,17,....,121
				44/3 (5-8)	3,11,19,....,123
				121/4 (5-8)	4,12,20,....,124
				70/6 (5-8)	6,14,22,....,126

SC-5 TELEMETRY SUMMARY (Continued)

E4503	LE ESA Elect Perp.	5	12	19/001-8)+20/001-4) 96/10-8)+97/10-4) 45/301-8)+46/301-4) 122/401-8)+123/401-4) 71/601-8)+72/601-4) 20/005-8)+44/001-8) 97/105-8)+121/101-8) 46/305-8)+70/301-8) 123/405-8)+15/501-8) 72/605-8)+95/601-8) 45/001-8)+46/001-4) 122/101-8)+123/101-4) 71/301-8)+72/301-4) 18/501-8)+19/501-4) 96/601-8)+97/601-4) 46/005-8)+70/001-8) 123/105-8)+15/201-8) 72/305-8)+95/301-8) 19/505-8)+20/501-8) 97/605-8)+121/601-8) 71/001-8)+72/001-4) 18/201-8)+19/201-4) 96/301-8)+97/301-4) 44/501-8)+45/501-4) 122/601-8)+123/601-4) 72/005-8)+95/001-8) 19/205-8)+20/201-8) 97/305-8)+121/301-8) 45/505-8)+46/501-8) 123/605-8)+15/701-8)	0,8,16,....,120 1,9,17,....,121 3,11,19,....,123 4,12,20,....,124 6,14,22,....,126 0,8,16,....,120 1,9,17,....,121 3,11,19,....,123 4,12,20,....,124 6,14,22,....,126 0,8,16,....,120 1,9,17,....,121 3,11,19,....,123 5,13,21,....,125 6,14,22,....,126 0,8,....,120 1,9,....,121 3,12,....,123 5,14,....,125 6,15,....,126 0,8,....,120 2,10,....,122 3,11,....,123 5,13,....,125 6,14,....,126 0,8,....,120 2,10,....,122 3,11,....,123 5,13,....,125 6,14,....,126 0,8,....,120 2,10,....,122 3,11,....,123 5,13,....,125 6,14,....,126
E4504	LE ESA Elect Par.	5	12		
E4505	HE ESA Elect Perp.	5	12		
E4506	HE ESA Elect Par.	5	12		
E4507	LE ESA Prot. Perp.	5	12		
E4508	LE ESA Prot. Par.	5	12		

SC-5 TELEMETRY SUMMARY (Continued)

E4509	HE ESA Prot Perp.	5	12	96/001-8)+97/001-4) 44/201-8)+45/201-4) 122/301-8)+123/301-4) 70/501-8)+71/501-4) 18/701-8)+19/701-4) 97/005-8)+121/001-8) 45/205-8)+46/201-8) 123/305-8)+15/301-8) 71/505-8)+72/501-8) 19/705-8)+20/701-8) 122/001-8)+123/001-4) 70/201-8)+71/201-4) 18/401-8)+19/401-4) 95/501-8)+96/501-4) 44/701-8)+45/701-4) 123/005-8)+15/101-8) 71/205-8)+72/201-8) 19/405-8)+20/401-8) 96/505-8)+97/501-8) 45/705-8)+46/701-8) 18/101-8)+19/101-4) 95/201-8)+96/201-4) 44/401-8)+45/401-4) 121/501-8)+122/501-4) 70/701-8)+71/701-4) 19/105-8)+20/101-8) 96/205-8)+97/201-8) 45/405-8)+46/401-8) 122/505-8)+123/501-8) 71/705-8)+72/701-8)	0,8,....,120 2,10,....,122 3,11,....,123 5,13,....,125 7,15,....,127 0,8,....,120 2,10,....,122 3,11,....,123 5,13,....,125 7,15,....,127 0,8,....,120 2,10,....,122 4,12,....,124 5,13,....,125 7,15,....,127 0,8,....,120 2,10,....,122 4,12,....,124 5,13,....,125 7,15,....,127 1,9,....,121 2,10,....,122 4,12,....,124 5,13,....,125 7,15,....,127 1,9,....,121 2,10,....,122 4,12,....,124 5,13,....,125 7,15,....,127
E4510	HE ESA Prot. Para.	5	12		
E4511	SSS COINC E Perp.	5	12		
E4512	SSS COINC E Par.	5	12		
E4513	SSS COINC E Perp.	5	12		
E4514	SSS COINC E Par.	5	12		

SC-5 TELEMETRY SUMMARY (Continued)

E4515	SSS <u>COINC</u> Prot Perp	5	12	44/1(1-8)+45/1(1-4) 121/2(1-8)+122/2(1-4) 70/4(1-8)+71/4(1-4) 15/6(1-8)+18/6(1-4) 95/7(1-8)+96/7(1-4) 45/1(5-8)+46/1(1-8) 122/2(5-8)+123/2(1-8) 71/4(5-8)+72/4(1-8) 18/6(5-8)+19/6(1-8) 96/7(5-8)+97/7(1-8) 70/1(1-8)+71/1(1-4) 15/3(1-8)+18/3(1-4) 95/4(1-8)+96/4(1-4) 20/6(1-8)+44/6(1-4) 121/7(1-8)+122/7(1-4) 71/1(5-8)+72/1(1-8) 18/3(5-8)+19/3(1-8) 96/4(5-8)+97/4(1-8) 44/6(5-8)+45/6(1-8) 122/7(5-8)+123/7(1-8) 15/0(1-8) 20/3(1-8) 46/6(1-8)	1,9,....,121 2,10,....,122 4,12,....,124 6,14,....,126 7,15,....,127 1,9,....,121 2,10,....,122 4,12,....,124 6,14,....,126 7,15,....,127 1,9,....,121 3,11,....,123 4,12,....,124 6,14,....,126 7,15,....,127 1,9,....,121 3,11,....,123 4,12,....,124 6,14,....,126 7,15,....,127 0,8,....,120 3,11,....,123 6,14,....,126
E4516	SSS <u>COINC</u> Prot Par. .	5	12		
E4517	SSS <u>COINC</u> Prot Perp	5	12		
E4518	SSS <u>COINC</u> Prot Par.	5	12		
E4519	Auxiliary Counter	3	8		

APPENDIX D

Agency Tape Header File

Agency Tape Header File

<u>Word No.</u>	<u>Description</u>
1	Vehicle ID (P7802 right adjusted)
2	User ID - right adjusted (e.q. SC4-1)
3-6	Vacant
7	Year
8	Day of year
9	GMT at start of data (seconds)
10	GMT at end of data (seconds)
11	Data rate (milliseconds/frame)
12-13	Vacant
14	Total number of SC4-1 events
15	Total number of SC4-2 events

APPENDIX E

Agency Tape Event File

Event File Records

Each record will have 200 words. (50 groups of 4 words.) The 4 words are:

Word 1 = GMT (seconds) (F)

Word 2 = VTCN (I)

Word 3 = Code 1; 1. = SC4-1; 2. = SC4-2 (F)

Word 4 = Code word 2; 1. = on; 2. = off (F)

(The number of SC4-1 and SC4-2 events is contained in the header record. The sum of those values should equal the number of groups (of 4 words) in the event record(s). Should more than 50 groups occur, additional records of 200 words each will be contained on the file).

APPENDIX F

Agency Tape Ephemeris File

Agency Tape Ephemeris File Format

<u>Word</u>	<u>Description</u>
1.	Julian Date
2.	UT (seconds)
3.	Right Ascension of Greenwich (radians)
4.	X, Satellite Position, ECI (km)
5.	Y, Satellite Position, ECI (km)
6.	Z, Satellite Position, ECI (km)
7.	VX, Satellite Velocity, ECI (km/sec)
8.	VY, Satellite Velocity, ECI (km/sec)
9.	VZ, Satellite Velocity, ECI (km/sec)
10.	SX, Sun Position, ECI (km)
11.	SY, Sun Position, ECI (km)
12.	SZ, Sun Position, ECI (km)
13.	MX, Moon Position, ECI (km)
14.	MY, Moon Position, ECI (km)
15.	MZ, Moon Position, ECI (km)
16.	Radius, Earth Center to Satellite (km)
17.	Altitude (km)
18.	Latitude (deg)
19.	Longitude (deg)
20.	Right Ascension (deg)
21.	Velocity (km/sec)
22.	Solar Zenith Angle (deg)
23.	Shadow Angle (deg) (1)
24.	Radius, MAG (ER) (2)
25.	Latitude, MAG (deg)
26.	Longitude, MAG (deg)
27.	Radius, SM (deg) (3)
28.	Latitude, SM (deg)
29.	Local Time, SM (hr)
30.	Radius, GSM (ER) (4)
31.	Latitude, GSM (deg)
32.	Local Time, GSM (deg)
33.	B, (gamma)
34.	L, (ER)
35.	Dipole Radius, R (ER)
36.	Dipole Magnitude, Lambda (deg)
37.	Invariant Latitude, Gamma (deg)
38.	Local Time (hr)
39.	Magnetic Time (hr) (5)
40.	B (gamma) of 100-km North Intercept
41.	Latitude (deg) of 100-km North Intercept
42.	Longitude (deg) of 100-km North Intercept
43.	B (gamma) of 100-km South Intercept
44.	Latitude (deg) of 100-km South Intercept
45.	Longitude (deg) of 100-km South Intercept
46.	B (Gamma) of Equator (Minimum B)
47.	Radius (ER) of Equator (Minimum B)
48.	Latitude (deg) of Equator (Minimum B)

<u>Word</u>	<u>Description</u>
49.	Longitude (deg) of Equator (Minimum B)
50.	Radius (ER) of Mirror Point
51.	Latitude (deg) of Mirror Point
52.	Longitude (deg) of Mirror Point
53.	BX, (Total, ECI (gamma))
54.	BY, (Total, ECI (gamma))
55.	BZ, (Total, ECI (gamma))
56.	BX, (Main Field, ECI (gamma))
57.	BY, (Main Field, ECI (gamma))
58.	BZ, (Main Field, ECI (gamma))
59.	VX, Differential Velocity, ECI (km/sec)
60.	VY, Differential Velocity, ECI (km/sec)
61.	VZ, Differential Velocity, ECI (km/sec)
62.	V, Differential Velocity, (km/sec)
63.	MX, Dipole Moment, ECI (gamma)
64.	MY, Dipole Moment, ECI (gamma)
65.	MZ, Dipole Moment, ECI (gamma)
66.	DX, Dipole Displacement, ECI (km)
67.	DY, Dipole Displacement, ECI (km)
68.	DZ, Dipole Displacement, ECI (km)
69.	Tilt Angle (deg)

- (1) The angle between the satellite-sun line and a line from the satellite tangent to the earth's surface in the plane of the sun, the earth's center and the satellite.
- (2) Magnetic coordinates, MAG; the Z axis is parallel to the dipole, and the south geographic pole is in the +X, Z plane.
- (3) Solar magnetic coordinates, SM; the Z axis is parallel to the dipole, and the sun is in the +X, Z plane.
- (4) Geocentric solar magnetospheric, GSM; the X axis is parallel to the earth-sun line, and the earth's dipole is in the X, +Z plane.
- (5) The angle in hours between the meridian planes containing the anti-solar direction and the minimum B point in magnetic coordinates, MAC.
- (6) The equatorial radius is defined as 6378.135 KM., and the flattening is 298.26.

APPENDIX G

Agency Tape Magnetic Field File

Magnetic Field File (Binary; floating point)

<u>Word #</u>	<u>Parameter</u>	
1	GMT (seconds)	} GMT is associated with center of the 15 second averaging period. B _X , B _Y , B _Z in ECI r _X , r _Y , r _Z are RMS errors.
2	B (gamma)	
3	B _X	
4	B _Y	
5	B _Z	
6	r _X	
7	r _Y	
8	r _Z	

Words 1 thru 8 repeat 59 times in each record.

480 60 bit words/record; covers 900 seconds of data.

APPENDIX H

SC4-1 Agency Tape Telemetry File

SC4-1 Telemetry Records

Data is stored in 8 bit bytes

<u>Byte No.</u>	<u>Description</u>
1-4	GMT (MS) at mainframe word 0 of subcom level 0
5-8	MF words 0-3 + Subcom ID)
9	MF word 21 (D4001)
10	MF word 38 (Subcom)
11	MF word 39 (Subcom)
12	MF word 40 (Subcom)
13	MF word 41 (Subcom)
14	MF word 53 (D4002)
15	MF word 85 (D4001)
16	MF word 102 (Subcom)
17	MF word 103 (Subcom)
18	MF word 117 (D4002)
Data from the Mainframe Containing Subcom Level 0	
Repeat word order of bytes 5-18 for subcom level 1	
Repeat word order of bytes 5-18 for subcom level 2	
⋮	
1769-1782	Repeat word order of bytes 5-18 for subcom level 126
1783-1796	Repeat word order of bytes 5-18 for subcom level 127
1797-1800	Vacant (Zero fill)
1801-3600	Repeat the word order of bytes 1-1800 for the next masterframe.

Two masterframes are stored in each physical record. This will result in 400 60 bit words per physical record. Data should be stored starting 2 masterframes before instrument turn on and extending 2 masterframes after turn off. Telemetry records are written in binary.

APPENDIX I

SC4-2 Agency Tape Telemetry File

SC4-2 Telemetry Records

Data is stored in 8 bit bytes

<u>Byte No.</u>	<u>Description</u>
1-4	GMT (MS) at mainframe word 0 of subcom level 0
5-8	MF words 0-3 (VTCW + Subcom ID)
9	MF word 22 (D4008)
10	MF word 23 (D4009)
11	MF word 24 (D4010)
12	MF word 38 (Subcom)
13	MF word 39 (Subcom)
14	MF word 40 (Subcom)
15	MF word 41 (Subcom)
16	MF word 86 (D4008)
17	MF word 87 (D4009)
18	MF word 88 (D4010)
19	MF word 102 (Subcom)
20	MF word 103 (Subcom)
21	MF word 111 (Subcom)
22	MF word 112 (Subcom)
23	MF word 113 (Subcom)
24-42	Repeat word order of bytes 5-23 for subcom level 1
43-61	Repeat word order of bytes 5-23 for subcom level 2
.	.
.	.
.	.
2399-2417	Repeat word order of bytes 5-23 for subcom level 126
2418-2436	Repeat word order of bytes 5-23 for subcom level 127
2437-2445	Vacant (Zero fill)

Data from the Mainframe
Containing Subcom
Level 0

One masterframe is stored in each physical record. This results in 326 60 bit words per physical record. Telemetry records are stored in binary.

APPENDIX J

SC5 Agency Tape Telemetry File

SC5 Telemetry Records

The telemetry data for SC5 is stored with 1 Masterframe in each physical record.

The last record on the file may require zero fill to keep record sizes consistent throughout the file. Each physical record consists of 400 60-bit words

SC5 Telemetry Records

Data in 8 bit bytes

<u>Byte #</u>	<u>Description</u>
1-4	GMT (MS) at word 0 of Mainframe 0
5	VTCW + Subcom ID
9	Word 15
10	Word 18
11	Word 19
12	Word 20
13	Word 44
14	Word 45
15	Word 46
16	Word 70
17	Word 71
18	Word 72
19	Word 95
20	Word 96
21	Word 97
22	Word 121
23	Word 122
24	Word 123
25	Word 102
26-46	Repeat Word order in bytes 5-25 for data at MF 1
47-67	Repeat Word order in bytes 5-25 for data at MF 2
68-88	Repeat Word order in bytes 5-25 for data at MF 3
89-109	Repeat Word order in bytes 5-25 for data at MF 4
110-130	Repeat Word order in bytes 5-25 for data at MF 5
131-151	Repeat Word order in bytes 5-25 for data at MF 6
152-172	Repeat Word order in bytes 5-25 for data at MF 7
⋮	
2672-2692	Repeat word order in bytes 5-25 for data at MF 127
2693-3000	Vacant

400 60-bit words per physical record

APPENDIX K

SC9 Agency Tape Telemetry File

SC9 Telemetry Record

SC-9 Raw File Format

All bytes are 8 bits - information in binary.

<u>Byte No.</u>	<u>Description</u>
1-4	GMT (MS) at word 0 frame containing subcom level 0
5-8	VTOW + Subcom ID
9	MF word 49
10	MF word 50
11	MF word 51
12	MF word 52
13	MF word 100
14	MF word 102
15	MF word 104
16	MF word 105
17	MF word 106
18	MF word 110
19-32	Repeat word order of bytes 5-18 for subcom level 1
23-46	Repeat word order of bytes 5-18 for subcom level 2
47-60	Repeat word order of bytes 5-18 for subcom level 3
	.
	.
	.
	.
1769-1782	Repeat word order of bytes 5-19 for subcom level 126
1783-1796	Repeat word order of bytes 5-19 for subcom level 127
1797-1800	Vacant (zero fill)
1801-3600	Repeat word order of bytes 1-1800 for next masterframe

Thus, there are two masterframes per physical record and each physical record has 480 60 bit words.

APPENDIX L

SC4-1 Data Base Format

SC4-1 Data Base - Header Record

Word #

0.1	Word count (Integer -10)	
0.2	Group count (Integer =1)	
1	bbbbbb SC4-1	Alphanumeric
2	Day of year	F
3	Month	F
4	Day	F
5	Year (last 2 digits of 19xx)	F
6	Start time of tape (from ETR) sec	F
7	End time of tape (from ETR) sec	F
8	}	Vacant
9		
10		

SC4-1 Data Records

0.1 Word count (13)

0.2 Group count (32) (32 frames/record; 2 masterframes)

<u>Word</u>	<u>Bits</u>	<u>Description</u>
1	1-60	GMT (sec)
2	1-60	Altitude (km)
3	1-36	The 32 bits from mainframe words 38, 29, 40 and 41 (right adjusted) from even frame no.
	37-60	Same TLM words as above from succeeding frame }(**)
4	1-12	
	13-24	Gun cap deployment flag (bit 23) and beam on/off flag (bit 24) (*)
	25-36	Beam current flags (right adjusted) (*)
	37-48	Beam energy flags (right adjusted) (*)
	49-60	Beam duty cycle flat (bit 60) (*)
5	1-12	Beam focus flags (right adjusted) (*)
	13-24	D4001 (from MF 21)
	25-36	D4002 (from MF 53)
	37-48	D4001 (from MF 85)
	49-60	D4002 (from MF 117)
	1-12	D4001 (from MF 21)
	:	:
11	25-36	D4002 (from MF 117)
	37-48	HV Monitor (*)
	49-60	LV Monitor 1 (*)
12	1-12	LV Monitor 2 (*)
	13-24	Gun cap current monitor (*)
	25-36	Temperature monitor (*)
	37-48	Geodetic latitude x 10 (MSB=1 if latitude negative)
	49-60	Geocentric longitude x 10

<u>Word</u>	<u>Bits</u>	<u>Description</u>
13	1-12	Local time in hours and minutes (e.q. $22^H 15^M = 2215$)
	13-24	SC4-1 magnetic pitch angle at GMT tag for this frame
	25-36	SC4-1 magnetic pitch angle at GMT + .5 sec
	37-48	SC4-1 magnetic pitch angle at GMT + 1. sec
	49-60	Vacant

Word order of word 1 thru word 13 repeats for next 31 seconds.
(418 60-bit words/record).

(*) Indicates subcommutated value; if no readout for this 1 second interval, MSB (of the 12 bits) will be set to 1 to indicate dummy fill.

(**) For storage of subcom words 38, 39, 40 and 41; the 8 telemetry frames associated with each 1 second should be scanned and the first non-zero set of readouts from an even frame number (i.e. frame 0, 2, 4,...) stored in bits "1-36" of the 3rd word of the output frame. The data in MF 38, 39, 40 and 41 from succeeding telemetry frame is stored in the next three 12 bit words. Store zeros if no non-zero information in 38, 39, 40 and 41.

APPENDIX M

SC4-2 Data Base Format

SC4-2 Data Base Header Record for Data File

0.1 Word count (10)

0.2 Group count (1)

1	bbbbbbSC4-2	Alphanumeric
2	Day of year	F
3	Month	F
4	Day	F
5	Year (last 2 digits of 19xx)	F
6	Start time of tape (from ETR) - sec	F
7	End time of tape (from ETR) - sec	F
8	} vacant	
9		
10		

SC4-2 Data Records

0.1 Word count (18)

0.2 Group count (16)

<u>Word</u>	<u>Bits</u>	<u>Description</u>
1	1-60	GMT (sec)
2	1-60	Altitude (km)
3	1-12	Bit 11 = blow off cover flag; Bit 12 = neutralizer bias polarity flag (*)
	13-48	Command status (MF 38,39,40,41) right adjusted } (**)
	49-60	Command status (MF 38,39,40,41) right adjusted }
4	1-24	
	25-36	D4008 ₁
	37-48	D4008 ₂
	⋮	⋮
7	25-36	D4008 ₁₆
	37-48	D4011 - Beam voltage Mon. (*)
	49-60	D4012 - Disch. current Mon.
8	1-12	D4013 - Discharge voltage Mon.
	13-24	D4014 - Keeper voltage Mon. (*)
	25-36	D4015 - Keeper HV monitor (*)
	37-48	D4016 - Keeper LV monitor
	49-60	D4017 - Cathode heater current Mon.
9	1-12	D4018 - Accel. current Mon. (*)
	13-24	D4019 - Decel. current Mon. (*)
	25-36	D4020 - Neut. heater current Mon. (*)
	37-48	D4021 - Neut. bias voltage Mon. (*)
	49-60	D4009 ₁
10	1-12	D4009 ₂
	⋮	⋮
	⋮	⋮
12	49-60	D4009 ₁₆
13	1-12	D4010 ₁
	13-24	D4010 ₂
	⋮	⋮
	⋮	⋮
16	1-12	D4010 ₁₆

<u>Word</u>	<u>Bits</u>	<u>Description</u>
16	13-24	D4022 - Tank pressure monitor (*)
	25-36	D4023 - Power processor temp. Mon. (*)
	37-48	D4024 - PPA AC Inv. current monitor (*)
	49-60	D4025 - PPA AC Inv. voltage Mon. (*)
17	1-12	Geodetic latitude x 10 (MSB = 1 if negative)
	13-24	Geocentric longitude x 10
	25-36	Local time (hours and min., e.q. $22^H 15^M = 2215$)
	37-48	SC4-2 magnetic pitch angle at GMT tag for this frame
	49-60	SC4-2 magnetic pitch angle at GMT + .5 sec
18	1-12	SC4-2 magnetic pitch angle at GMT + 1. sec
	13-60	Vacant

Words 1 through 18 will repeat 15 times in each record (16 seconds of data/record)

(*)Subcommutated values; if no readout for this one second interval, MSB will be set to 1 to indicate dummy fill.

Command status words; first second of each record will have values from subcom levels 0 and 1; 2nd second from subcom levels 8 and 9;...

(**)Store the first non-zero information set from MF 38, 39, 40 and 41 from an even frame number followed (in the data base) by the succeeding odd frame.

APPENDIX N

SC5 Magnetic/Solar Angle File Format

SCATHA -- SC 5 Magnetic/Solar Angle File Format

Magnetic pitch angle and sun angle information is stored at even 1 second intervals starting with the start time from the header record and ending with the end time from the header record. A flag word is included in each group of words to indicate reliability of the angular data.

Record Format:

<u>Word #</u>	<u>Description</u>
1	Integer (6) - Number of words in a group
2	Integer (≤ 84)
3	GMT (Seconds)
4	Magnetic pitch angle (SC 5)
5	Sun angle (SC 5)
6	Magnetic pitch angle (SC 5)
7	Sun angle (SC 5)
8	Flag
9	GMT
10	Magnetic pitch angle
	⋮
506	Flag

The value of the flag word is determined as follows.

Flag = 0. ; Normal (magnetic field points less than or equal to 45 seconds apart)

Flag = 1. ; Magnetic field value(s) were between 45 and 180 seconds apart.
($45 < T \leq 180$)

Flag = 2. ; Magnetic pitch angle data is dummy filled with -1. because
magnetic field points greater than 180 seconds apart. ($T > 180$).

Flag = 3. ; Magnetic pitch angle data dummy filled (-1.) due to no EM
coefficients or no magnetic field data

APPENDIX O

SC5 Preprocess File Format

SC5 Preprocess File - Header Record Format

0.1	Integer (number of words in record; 10)	
0.2	Integer (1)	
1	bSC5PREPRO	A
2	bbbbSCATHA	A
3	Month of year	F
4	Day of month	F
5	Year (last 2 digits of 19xx)	F
6	Day of year	F
7	Start time (From AT header) - sec.	F
8	End time (From AT header) - sec.	F
9	} Vacant	
10		

SC5 Preprocess File - Data Record Formats

(each record contains a masterframe)

0.1 Word Count (integer)—number of words/group (31)

0.2 Group Count (integer)— number of groups/record (16)

Word	Bits	Description	
1.	All	GMT (seconds) (at start of mainframe)	
2.		altitude	
3.		L-shell	
4.		magnetic local time (floating point hours)	
5.		geocentric latitude	
6.		geocentric longitude	
7.		geomagnetic longitude	
8.		geomagnetic latitude	
9.		invariant latitude	
10.		vacant	
11.		vacant	
12.	1-12	low energy ESA (electrons) counts (L) E=3MSB's; M = 9 LSB's (for normal ops, bits 1-12 have counts for energy channel 0; 13-24 for channel 1...)	(E4503)
	13-24		
	49-60		
13.	1-12	High energy ESA (electrons) counts (L)	(E4503)
	13-24		
	.		
	49-60		
14.	1-12	SSS <u>coinc</u> counts (electrons; L)	(E4511)
	13-24		
	49-60		
15.	1-12	SSS <u>coinc</u> counts (electrons, L)	(E4513)
	13-24		
	.		
	49-60		
16.	1-12	Low energy ESA (ions); L	(E4507)
	13-24		
	49-60		

17.	1-12 13-24 : : 49-60	Hi Energy ESA (ions) ; $\perp$	(E4509)
18.	1-12 13-24 : : 49-60	SSS <u>coinc</u> (ions) ; $\perp$	(E4515)
19.	1-12 13-24 : : 49-60	SSS coinc (ions) ; $\perp$	(E4517)
20.	1-12 13-24 : : 49-60	Lo Energy ESA electrons ; $\parallel$	(E4504)
21.	1-12 : : 49-60	Hi Energy ESA electrons ; $\parallel$	(E4506)
22.	1-12 : : 49-60	SSS <u>coinc</u> electrons ; $\parallel$	(E4512)
23.	1-12 : : 49-60	SSS coinc electrons ; $\parallel$	(E4514)
24.	1-12 : : 49-60	Lo Energy ESA ; ions ; $\parallel$	(E4508)
25.	1-12 : : 49-60	Hi Energy ESA ; ions ; $\parallel$	(E4510)

<u>Words</u>	<u>Bits</u>	<u>Description</u>	
26.	1-12	SSS <u>coinc</u> - ions ; //	(E4516)
	.		
	49-60		
27.	1-12	SSS <u>coinc</u> - ions ; //	(E4518)
	.		
	49-60		
28.	1-12	ESA energy channel ₁	
	13-24	" " " 2	
	25-36	" " " 3	
	37-48	" " " 4	
	49-60	" " " 5	
29.	1-12	SSS energy channel ₁	
	13-24	" " " 2	
	25-36	" " " 3	
	37-48	" " " 4	
	49-60	" " " 5	
30.	vacant		
31.	vacant		
32-60.	Repeat structure of words 1-31 for the next second		
63-93.	"	" " " " " " " "	
.	.	.	
.	.	.	
-465	"	" " " " " " " "	
466-496			
497	<u>Bits</u>		
	1-12	+3500V Monitor Counts	(E4001)
	13-24	+500V " "	(E4002)
	25-36	+2500V " "	(E4003)
	37-48	-500V " "	(E4004)
	49-60	-30V " "	(E4005)

<u>Words</u>	<u>Bits</u>	<u>Description</u>	
498	1-12	Electron Bias voltage counts	(E4006)
	13-24	+15V monitor counts	(E4007)
	25-36	+10V monitor counts	(E4008)
	37-48	-5V " "	(E4009)
	49-56	-10V " "	(E4010)
499	1-12	HE ESA sweep voltage monitor counts	(E4011)
	13-24	LE " " " "	(E4012)
	25-36	⊥ P-SSD Bias voltage " "	(E4013)
	37-48	" " " "	(E4014)
	49-60	DC-DC Converter Temp. Monitor "	(E4015)
500	1-12	⊥ SSS Temp. Monitor Counts	(E4016)
	13-24	" " " "	(E4017)
	25-36	} Vacant	
	37-48		
	49-60		

(Each record will have 502 words - (500 information words plus the two count words;) 16 seconds of data will be stored in each record).