

*Original contains color
plates: All DTIC reproduction
ions will be in black and
white*

AD-A262 782



2

PL-TR-92-2331

SPREE INTERACTIVE DATA ANALYSIS TOOL (SIDAT)

C. J. Roth
N. A. Bonito

DTIC
ELECTE
MAR 22 1993
S C D

RADEX, Inc
Three Preston Court
Bedford, MA 01730

30 October 1992

Scientific Report No. 6

Approved for public release; distribution unlimited



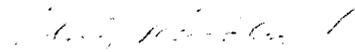
PHILLIPS LABORATORY
Directorate of Geophysics
AIR FORCE MATERIEL COMMAND
HANSCOM AIR FORCE BASE, MA 01731-5000

98 8 19 052

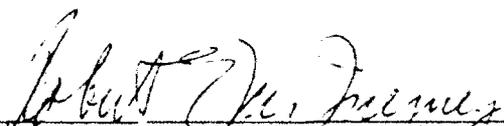
93-05899



"This technical report has been reviewed and is approved for publication"



ROBERT J. RAISTRICK
Contract Manager
Data Analysis Division



ROBERT E. McINERNEY, Director
Data Analysis Division

This report has been reviewed by the ESD Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS).

Qualified requestors may obtain additional copies from the Defense Technical Information Center. All others should apply to the National Technical Information Service.

If your address has changed, or if you wish to be removed from the mailing list, or if the addressee is no longer employed by your organization, please notify GL/IMA, Hanscom AFB, MA 01731. This will assist us in maintaining a current mailing list.

Do not return copies of this report unless contractual obligations or notices on a specific document requires that it be returned.

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF COLOR PAGES WHICH DO NOT REPRODUCE LEGIBLY ON BLACK AND WHITE MICROFICHE.

TABLE OF CONTENTS

1.0 INTRODUCTION	1
1.1 SHUTTLE POTENTIAL AND RETURN ELECTRON EXPERIMENT (SPREE)	1
1.2 SPREE MISSION SUPPORT	2
2.0 COMPUTER PLATFORM ENVIRONMENT	3
2.1 WORKSTATION DESCRIPTION	3
2.2 X-WINDOWS APPLICATIONS	3
2.3 INTERPROCESS COMMUNICATION METHODS	5
3.0 SPREE INTERACTIVE DATA ANALYSIS TOOL REAL-TIME OPERATIONS	6
3.1 REAL-TIME TELEMETRY DESCRIPTION	6
3.2 REAL-TIME DATA ANALYSIS PROCESSES	7
3.2.1 Real-Time Telemetry Data Processing	8
3.2.2 ESA Data Display	9
3.2.3 Orbiter Potential Display	12
3.2.4 Trajectory Display	14
3.2.5 Listener Process Monitors	15
3.2.6 SPREE Status Monitors	15
3.2.7 SPACE Data Displays	15
3.2.8 Partial Orbit ESA Surveys	16
3.2.9 Trending Display	16
4.0 SPREE INTERACTIVE DATA ANALYSIS TOOL POSTFLIGHT OPERATIONS	20
4.1 FLIGHT DATA RECORDER INFORMATION PROCESSING	20
4.2 POSTFLIGHT DATA ANALYSIS PROCESSES	20
4.2.1 Postflight Data Survey Process	21
4.2.2 Postflight ESA Data Display	23
4.2.3 Postflight Orbiter Potential Display	24
4.2.4 Postflight SPREE Status Monitors	24
4.2.5 Postflight SPACE Data Displays	24
4.2.6 Postflight Partial Orbit Surveys	24
4.2.7 Postflight Trending Display	26
REFERENCES	27

LIST OF FIGURES

1. Sample Real-Time SIDAT Workspace	4
2a. Derivation of ESA Zone and Azimuth Parallel to Magnetic Field	10
2b. Derivation of ESA Zone Perpendicular to Magnetic Field	10
3a. Azimuth-Based ESA Data Display	13
3b. Time-Based ESA Data Display	13
3c. Orbiter Potential Display	13
3d. Orbiter Potential Playback Display	13
4a. SPACE Energy versus Pattern Display	17
4b. SPACE Pattern versus Time Display	17
4c. Sample Partial Orbit ESA Survey	17
5a. Trending Process Plot	19
5b. Edited Trending Process Plot	19
6a. Postflight SIDAT Command Panel	22
6b. Postflight Data Survey Panel	22
7a. Postflight ESA Data Display	25
7b. Postflight Partial Orbit ESA Survey	25

ACKNOWLEDGEMENTS

The authors acknowledge Captain Marilyn Oberhardt, SPREE Co-Investigator, for her technical involvement, motivation, and guidance provided during the SIDAT design, development, and application to research. In addition, appreciation is extended to Susan Cline of Radex, Inc. for her effort in the compilation of this report.

Accession to:	
NTIS CRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution /	
Availability Codes	
Dist	Avail and/or Special
AL	

LIST OF ACRONYMS

AITs	-	AFGL Interactive Targeting System
ASCII	-	American Standard Code Information Interchange
CART	-	Captured Real-time Telemetry
CAS	-	Calibrated Ancillary System
DPU	-	Data Processing Unit
ESA	-	Electrostatic Analyzer
FDR	-	Flight Data Recorder
FES	-	Flash Evaporator System
GMT	-	Greenwich Mean Time
GUI	-	Graphical User Interface
IGRF 85	-	International Geomagnetic Reference Field, 1985
IPC	-	Inter-Process Communication
JSC	-	Johnson Space Center
LOS	-	Loss Of Signal
LVLH	-	Local Vertical Local Horizontal
MET	-	Mission Elapsed Time
NASA	-	National Aeronautics and Space Administration
PATH	-	Postflight Attitude and Trajectory History
RTMD	-	Rotary Table Motor Drive
SCSI	-	Small Computer Serial Interface
SIDAT	-	SPREE Interactive Data Analysis Tool
SOC	-	Science Operations Center
SPACE	-	SPREE Particle Correlator Experiment
SPREE	-	Shuttle Potential and Return Electron Experiment
SwRI	-	Southwest Research Institute
TSS	-	Tethered Satellite System

1.0 INTRODUCTION

The SPREE Interactive Data Analysis Tool (SIDAT) is a collection of user-friendly programs that allow users, whether computer-oriented or not, to easily view the SPREE and related experiment data in many different graphical or text forms simultaneously. The SIDAT software user interface was designed to be both simple to understand and to operate. Using standard UNIX interprocess communication methods, each of the active SIDAT displays independently access and process data from the shared data stream, producing the concurrent user-selected data displays for analysis. During real-time SIDAT operations, the data from the current SPREE operations, as well as the related orbiter parameters, could be viewed in real-time via the telemetry data. Postflight SIDAT operations allowed the user to specify the time and data source for surveying the available experiment data, using display processes nearly identical to those used in real-time operations. While surveying the experiment data, the user could build and maintain a working data base of times of interest. The SIDAT software was built using the Xlib and XView X Window System libraries, enabling easy migration to other UNIX-based computer platforms with these standardized graphics libraries.

1.1 SHUTTLE POTENTIAL AND RETURN ELECTRON EXPERIMENT (SPREE)

The Shuttle Potential and Return Electron Experiment (SPREE) measured vehicle potential and return currents and investigated wave-particle interactions. The SPREE hardware consists of two multi-angular, nested, triquadrangular, electrostatic analyzer (ESA) units, each mounted on a Rotary Table Motor Drive (RTMD), a Data Processing Unit (DPU), the SPREE Particle Correlator Experiment (SPACE), and two Flight Data Recorders (FDRs).

SPREE was an experiment provided by the Geophysics Directorate, Phillips Laboratory, as part of the Tethered Satellite System (TSS-1) on the STS-46 Shuttle mission. During the TSS-1 Mission, SPREE was used to study the effects of a potential being induced between the tethered satellite and the Shuttle by the motion of the conductive tether across the Earth's magnetic field lines. Charging of the Shuttle and the interaction of the electron beams with the ambient plasma were examined by SPREE. Many of the effects studied were dependent on the length of the tether, orbital position, solar illumination, the orbiter's ram orientation, and magnetic field orientation. Data obtained from the TSS-1 experiments provided unique and important information as to how large systems are affected by the near Earth plasma environment. Determination of charge-control techniques for large space structures could be made through analysis of SPREE data. Analysis will also determine the effectiveness of using high powered electron beams to probe and modify space plasma [Oberhardt, 1992].

The pair of SPREE ESA units measured the characteristics and quantities of ion and electron particles detected. The ESAs measured ions and electrons from 10eV to 10keV, with a deflection sweep occurring either once per second (slow sweep) or eight times per second (fast mode). Each ESA, mounted on a RTMD, had a full 180 degree range of rotation. The RTMD

units completed a bidirectional sweep in one minute, covering the full 2π steradian field of view out of the shuttle payload bay. While rotating, each ESA unit measured the charged particles in a fan covering a 100×10 degree range, which was divided into ten zones. In the slow sweep mode, particle measurements were made in each of the ten zones once per second. In the fast sweep mode, measurements were made in each of the ten zones eight times per second. Applying the SPREE analyzer data as inputs, an on-board wave-particle correlator (SPACE) performed auto-correlations of the data, and cross correlations with the electron beam information. A neural network processor performed statistical analysis operations, calculating frequency and wavelength. The resulting SPACE statistical data represented the comparative scores versus the known patterns of frequency and wavelength.

1.2 SPREE MISSION SUPPORT

The SPREE Interactive Data Analysis Tool (SIDAT) was used in real-time support of SPREE during the STS-46 shuttle mission. SIDAT captured and processed all of the SPREE and Calibrated Ancillary System (CAS) telemetry data received at the Johnson Space Center (JSC) Science Operations Center (SOC). The SIDAT data analysis display processes allowed the user to view the real-time SPREE and SPACE data in a variety of formats, and the trajectory process displayed the current position and attitude of the orbiter.

SIDAT was also used in the postflight support of SPREE. The SIDAT postflight data display processes, which are nearly identical to those used in the real-time support, were used to review the SPREE and SPACE data gathered during the mission. Two postflight data bases were available: the data captured from the real-time telemetry, and the data archived by the two on-board Flight Data Recorders (FDRs). In the postflight data analysis environment, the user controlled the time and the source of the data being reviewed.

2.0 COMPUTER PLATFORM ENVIRONMENT

2.1 WORKSTATION DESCRIPTION

The SIDAT software was developed on a color SUN SPARCstation 2, operating SUNOS 4.1.1 UNIX and OpenLook Graphic User Interface-compliant Open Windows (Version 3). External Small Computer Serial Interface (SCSI) devices, such as hard disk drives or tape drives, are used for data storage. The SUN workstation uses an ethernet network, to access printers, other computers, and other workstations with large-capacity storage devices. A Tektronix RGB color printer was also adapted for full color hardcopies of the display monitor screen.

2.2 X-WINDOWS APPLICATIONS

The SIDAT software is a collection of graphics and text display processes developed in support of the SPREE real-time and postflight data analysis using the X11 and XView X Window System libraries. Because of the use of the standardized X Window System protocol, the SIDAT software could be easily migrated to other color computer platforms running a UNIX operating system and an X Window System-compliant window manager. All SIDAT display processes utilize the Xlib graphic primitives and the XView Graphical User Interface (GUI) toolkit.

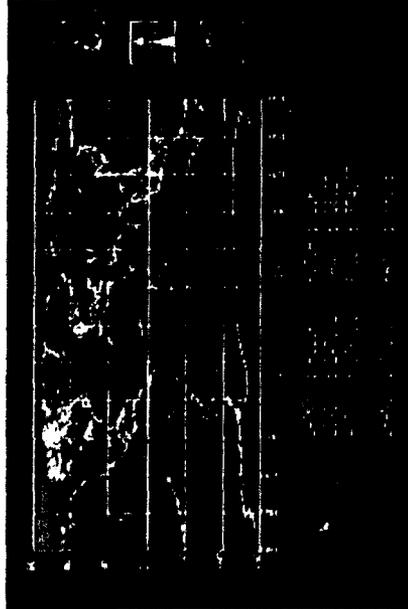
Each of the SIDAT display processes are controlled exclusively by the workstation mouse and mouse buttons. The XView GUI toolkit allowed for the creation of three-dimensional appearing "buttons" on the workstation display. These display buttons are "pressed" by moving the mouse pointer to their location on the screen and depressing one of the mouse buttons. Additional user interface objects available include pull-down menus, scrolling lists, and toggling choice selection buttons. Each process has one or more of these user interface objects, allowing the user to make choices in the operations to be performed and format of the data display. In some of the processes, many options are available, allowing the user to select a greater number of configurations for the data display processing. Depending on the type of data being displayed, either a graphic or text window is used for the presentation.

Each display process window has a specific workstation screen position when invoked. However, the user can move the windows to any position on the screen. Alternatively, the user may change the display process window to a small icon, which consists of a simple picture and text describing the process. This allows the user to set that particular process aside without exiting or stopping. Therefore, the user could have many active processes without filling up the workstation screen. As with the display process windows, the icons could also be moved to any position on the workstation screen. Figure 1 depicts a typical SIDAT workspace.

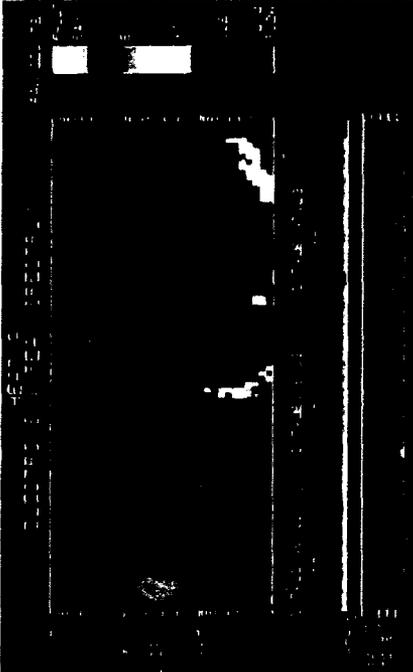
SPREE Data Display System

Quit | SPREE Data Display | Help by Display | External Functions | Status Monitor | SPREE Displays | Playback Displays |

SPREE Vehicle Flight Simulation



CAS Data Display



SPREE Data Display

Detector Particle Data Displayed Calibration
 Head A Electron Sum Spectra Zone I B Raw Counts
 Head B Proton Peak Spectra Zone II B RC - Background
 Auto Count Zone Energy Step Diff Number Flux
 Diff Energy Flux

Apply Cancel Plot vs Arrimuth Time Print Quit

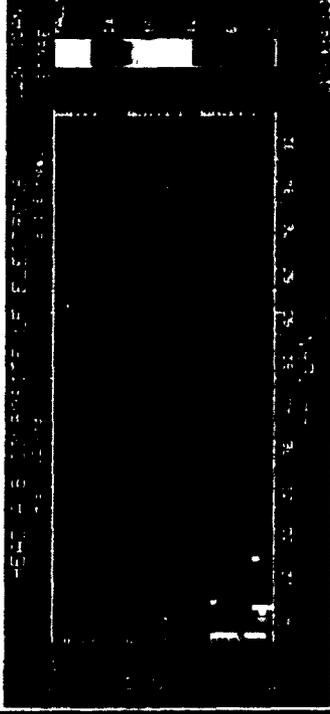
SPREE Flight Data Recorder Status Display

Message Number	Date & Time	Status	Counter	FDR1	FDR2	Quit
00000	217 06:50:20	0000	0000	0000	0000	Quit
00001	217 06:50:30	0000	0000	0000	0000	Quit
00002	217 06:50:40	0000	0000	0000	0000	Quit
00003	217 06:50:50	0000	0000	0000	0000	Quit
00004	217 06:51:00	0000	0000	0000	0000	Quit
00005	217 06:51:10	0000	0000	0000	0000	Quit
00006	217 06:51:20	0000	0000	0000	0000	Quit
00007	217 06:51:30	0000	0000	0000	0000	Quit
00008	217 06:51:40	0000	0000	0000	0000	Quit
00009	217 06:51:50	0000	0000	0000	0000	Quit
00010	217 06:52:00	0000	0000	0000	0000	Quit

SPACEL III Electron Data Time Based Data Display



SPACE II Electron Data Display



Head A Head B Composite Sub Icon Quit

1. Sample Real-Time SIDAT Workspace

2.3 INTERPROCESS COMMUNICATION METHODS

In order to maximize the operations of all processes on the computer platform, one main process performed most of the data processing, and then shared its completed operations with the other display processes by means of the UNIX System V Inter-Process Communication (IPC) Facilities, available under the SUNOS 4.1.1 and other UNIX operating systems. For all SIDAT processes, a combination of the shared memory and semaphore IPC facilities were used.

Shared memory was used to efficiently share large amounts of data between two or more independent processes nearly instantaneously. Each process reading from or writing to this shared memory must first have been "attached" to it, using a specific numeric identifier, called a key. Once attached, each process could read from or write to the shared memory segment as if it were normal process memory. Semaphores act as multi-position flags, able to be set to many different values. As with the shared memory, each process must first have been "attached" to the semaphores with a specific key before the process could access the semaphores. Using specialized system calls, the process could set the value of the semaphore, read the value of a semaphore, or wait until a semaphore reached a specific value. The semaphores were used in this software package as a method for the main process to notify all active display processes when the data contained within the shared memory had been updated. By using this method of interprocess communication and data sharing, each process was wholly independent of other processes and any failure of one display process would not affect further data processing by the others.

3.0 SPREE INTERACTIVE DATA ANALYSIS TOOL REAL-TIME OPERATIONS

3.1 REAL-TIME TELEMETRY DESCRIPTION

The SPREE real-time telemetry contained sets of time-tagged experiment status values, part of the particle data from each of the Electrostatic Analyzer (ESA) units, and a portion of the data from the SPREE Particle Correlator Experiment (SPACE). The SPREE-related status values included the modes and sample rates of the ESA units, the current position of the motorized rotary mounts (RTMDs) of each ESA unit, the determined orbiter potential value, and confidence factor. SPACE status values included the SPACE frame counter, mode, frequency range, and processing monitor values. Hardware status values, relating the voltages, temperatures, and pressures of key hardware components, were also included, as well as the status indicators for the Flight Data Recorders (FDRs).

The SPREE analyzer data consisted of detector particle counts in a log-compressed form, organized by particle type, zone, and energy level. The SPREE Data Processing Unit (DPU) processed analyzer data from both ESA units to determine the peak measurement zone for ions and calculated the summed zone values. Due to space limitations in the real-time telemetry, the full set of analyzer data for a specific ESA unit and species was not available in a one second data segment. To give a representative portion of all the available data, interleaving of the data for the different ESA units and particle species was performed. For example, the ion log-compressed values for only the odd zones were available from the first data set. The following data set contained only the even zones. Although eight times as many data were gathered by the ESA units during the fast ESA zone sweeps, the amount of analyzer data available from the real-time telemetry remained constant. The full set of analyzer data is written to the Flight Data Recorders (FDRs).

SPACE, which received the SPREE analyzer data as input, produced a greater quantity of data, only a portion of which was loaded into the real-time telemetry. SPACE processed the data in one of two modes, slow or fast, similar to the SPREE ESA units. The particle correlator processed the analyzer data in one of three different frequency ranges, each range for a period of 90 seconds. A frequency range cycle was completed in 4.5 minutes. Within each frequency range, the analyzer data being processed was divided into low and high frequencies. Auto-correlations of the ion and electron particle data for each ESA unit were performed to produce the low frequency SPACE ion and electron data. Auto-correlations were performed on the electron particle data from a combination of both ESA units to produce the high frequency SPACE electron data. Analysis by the SPACE neural network processors was performed on each portion of the low and high frequency auto-correlation results to produce the SPACE statistical data. Each set of SPACE statistical data contains a pattern number and associated score for each of the 32 energy steps. Pattern numbers 1-64 refer to a specific frequency according to the current frequency range; pattern numbers 65-98 identify radar returns in the data. The score was a statistical value determined by the SPACE processor. The low frequency SPACE statistical data consist of data sets from only four of the 12 low frequency processor

units, in either fast or slow SPACE data modes. The high frequency SPACE statistical data consist of two data sets in the slow mode, or one data set in the fast mode. Cross-correlation of the electron beam activation and the resulting SPREE particle detection was also performed. Because of size limitations, only the statistical SPACE data were inserted into the real-time telemetry. All of the SPACE data, consisting of the raw SPACE data, cross-correlated beam data, the auto-correlated high and low frequency SPACE data, and the statistical SPACE data, were written to the on-board Flight Data Recorders (FDRs).

The Calibrated Ancillary System (CAS) telemetry data contain values for selected orbiter flight parameters, including the vehicle position and velocity vectors, the associated vector time, and the vehicle attitude values. The CAS telemetry data stream was downlinked from the orbiter at the rate of approximately 1280 bytes per second, and was received by the SIDAT processes via an ethernet link to a National Aeronautics and Space Administration (NASA) network. Specific parameter values were extracted from the telemetry stream and were processed before use by the SIDAT display processes. The CAS data contained epoch-1950 vehicle position and velocity vectors, which were converted to true-of-date position and velocity vectors. Multiple quaternions were used to calculate the Local Vertical Local Horizontal (LVLH) vehicle attitude. The position and attitude of the Shuttle were required for determining the shuttle lighting conditions and the relative orientation of the local magnetic field lines to the SPREE ESA units. Signals for the occurrence of shuttle thruster firings, water dumps, and use of the Flash Evaporator System (FES) were also extracted from the CAS data, as each of these affect the SPREE ESA data.

3.2 REAL-TIME DATA ANALYSIS PROCESSES

All real-time SIDAT display processes were invoked from a master command process panel, located at the top of Figure 1. The user simply selected the desired display process specified on the command panel buttons or in the pull-down menus. In this way, knowledge of the Unix operating system or programming was not necessary. The user only needed to be concerned with the operation of the mouse and buttons in relation to the user interface. When the user invoked a process from this command panel, an informative message was displayed. Some of the real-time processes were allowed only one copy, as multiple copies would contain only repetitive information for the user and would unnecessarily increase the CPU load of the workstation.

Most of the real-time SIDAT processes displayed the telemetry data as they were received via the interprocess communication methods, allowing the user to view the selected data during an experiment in near real-time. These displays allowed support personnel to perform real-time data validation. Based on the results of the experiment seen in the real-time displays, the appropriate replanning actions were able to be performed for the future experiments.

The remaining processes available in the real-time SIDAT software were playback displays. These playback displays could be used during real-time operations for reviewing user-specified

time periods of previously archived Captured Real-time Telemetry (CART) data. These CART data files were generated by the telemetry data receiving process, as described below. Each playback process required the user to specify a starting time. Some also required the choice of an ESA unit. The starting time was specified by the use of a pop-up window containing several scrolling lists. Using the mouse, the user independently selected the year, month, day, hour, minute, and second of the time, each in its own scrolling list. The user could reference the starting time in Greenwich Mean Time (GMT) or Mission Elapsed Time (MET). Each of the playback processes had a button labeled "Go". When pressed, the data access from the CART data base files was initiated, starting at the user-specified time. Because the data is read from files rather than being received in real time via the telemetry, the color raster images of data were rapidly completed. The processing of the data base was halted when specific events occurred, whether related to the display format or the actual data. These events included: a completely filled raster image, a change in the ESA sweep rate, a change in the SPACE mode, a large Loss-of-Signal (LOS) period was detected, or the end of the data base was reached. In all cases, an informative message was posted on the bottom border of the process window. The start time was updated to the time of the last data accessed from the CART data base. Therefore, the user was able to "walk through" the entire data base with a series of single mouse button presses.

The color raster image graphics and text produced by the real-time data analysis display processes were verified for accuracy against the raw SPREE telemetry data obtained during vacuum chamber testing. Several random time segments of data were selected for the verification, some in slow sweep rate and some in fast sweep rate. A telemetry dump, with the aid of the telemetry map, was used to obtain data values for comparison with the values produced in the text display processes, or the corresponding color and placement in the color raster images.

3.2.1 Real-Time Telemetry Data Processing

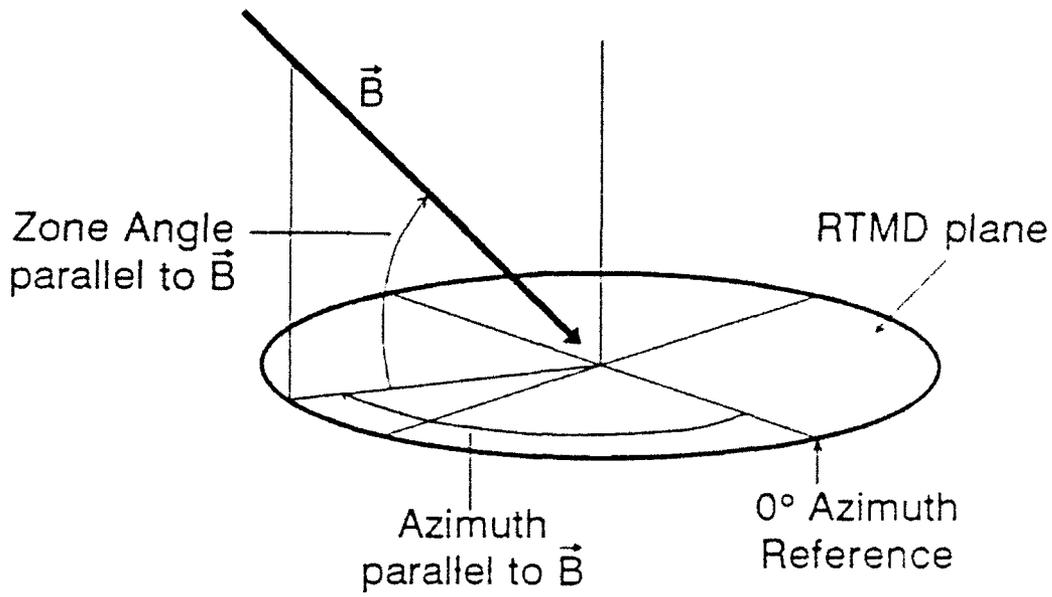
The Network Listener software, originally developed by Southwest Research Institute (SwRI), was the main process receiving the real-time telemetry on a SUN Workstation. The Listener software was enhanced to selectively extract the SPREE and Calibrated Ancillary System (CAS) data from the full telemetry stream in real-time. Shared memory segments and semaphore sets were incorporated to allow the sharing of the telemetry data, one of each for the SPREE data, one of each for the CAS data. As each SPREE or CAS data set is extracted from the telemetry and processed by the modified Listener software, the data was placed in the appropriate shared memory segment and written to the CART files. Minor telemetry verification was performed and the SPREE internal time code was corrected, when possible, in order to maintain the data integrity. When a complete master frame of valid SPREE or CAS data was fully processed, a semaphore was set to notify the display processes. Each of the active graphics processes responded to the semaphore signal by accessing shared memory segments for display processing according to the user options selected.

Additional processing was required for the CAS telemetry, as the epoch-1950 vehicle position and velocity vectors were converted to true-of-date position and velocity vectors, and the LVLH vehicle attitude was calculated from multiple quaternions within the CAS data stream [Kendra, et. al., 1990]. Processing of the CAS data was developed for STS-39 shuttle mission support, with the exception of the added features for the interaction of the magnetic field lines with the SPREE ESA units.

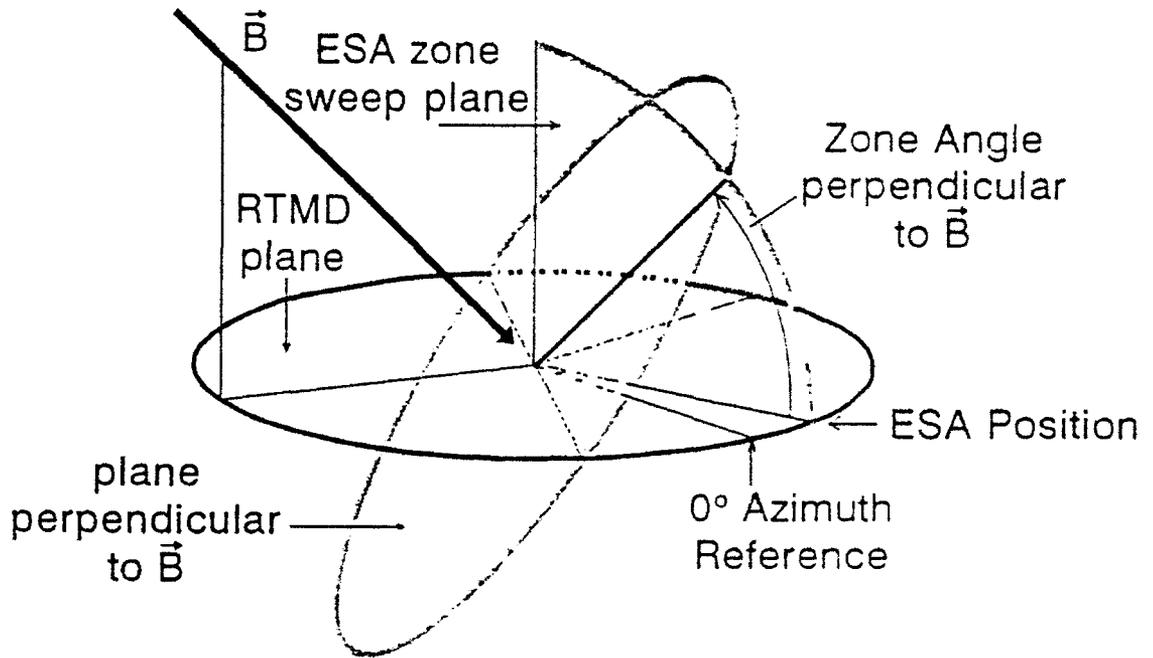
For one of the specialized SPREE data displays, the direction of the magnetic field at the vehicle was determined. The magnetic field line information is calculated using the International Geomagnetic Reference Field 1985 (IGRF 85) model. This internal magnetic field model, using temporally varying coefficients, involves the calculation of an 11x11 spherical harmonic field [IGRF, 1985]. The magnetic field line information was calculated using this model for the current time and vehicle position. With the addition of the current vehicle attitude, the relative orientation of the magnetic field line to the SPREE ESA scanning regions could be determined. The magnetic field lines parallel and perpendicular to the ESA scanning region were of particular interest, as the charged particles have greater tendencies to travel along the magnetic field lines, gyrating about these lines. Once the magnetic field line information is calculated, the orbiter attitude was used to determine the incidence of the magnetic field line on the plane defined by the rotation of the RTMD. As shown in Figure 2a, the ESA zone parallel to the magnetic field line was obtained from the angle between the incident magnetic field line and the RTMD plane; the associated azimuth value was the angle between the projection of the magnetic field line onto the RTMD plane and the zero azimuth reference of the ESA units. The parallel zone/azimuth determination always defines one unique solution. The zone perpendicular to the magnetic field was determined from the intersection of the plane perpendicular to the incident magnetic field line and the quarter-plane defined by the zone sweeping of each ESA unit at its current azimuth, depicted in Figure 2b. The angle between this intersection and the RTMD plane defined the perpendicular zone. The perpendicular zone determination usually produced a valid solution for one ESA unit, and an invalid one for the other. Where an invalid solution was found, the nearest valid zone number was given, either 0 or 9.

3.2.2 ESA Data Display

The SPREE ESA Data Display was the primary real-time ESA data analysis tool. This process produces a color raster image relating the ESA electron or ion particle data values in a variety of formats. The user selected an ESA unit, particle specie, data form, data calibration type, and the x-axis variable, either time or ESA azimuth angle. This type of display is featured in the lower left side of Figure 1. The y-axis variable can either be energy steps or zones, related to the data form selected. To begin the data display processing, the user simply selected the desired options using the mouse and presses the "Apply" button, initializing the graphics window for the user-selected data display options, complete with appropriate annotations. When the semaphore signals were received, the process accessed the shared memory segment and displayed the requested data according to the user selections.



2a. Derivation of zone and azimuth parallel to magnetic field.



2b. Derivation of zone perpendicular to magnetic field.

The raster image is composed of many small colored blocks, each representing one data value. Each color corresponds to a specific range of particle counts or flux value, according to the calibration type selected. The color scale, on the right side of the graphic display, is annotated with the current calibration selection and labeled with several scale values. The user has the choice of three calibration types: Raw Counts (uncalibrated), Raw Counts minus Background, or Differential Flux. The Raw Counts calibration displays the raw counts of particles as received in the data stream. The Raw Counts minus Background calibration subtracts the residual analyzer particle counts from the particle count data, eliminating the noise in the particle counts. The Differential Flux calibrations first subtracts the background from the raw counts, then applies a scale factor. The background values and differential flux scale factors, for each zone and energy step pair, for each ESA unit and particle specie are contained in an external data base in an American Standard Code Information Interchange (ASCII) format. This external calibration file allowed easy adjustment of the data calibration, when required.

All analyzer data displays are dependent on the ESA sweep rate, as the data color scales differ between the slow and fast sweep modes. Under normal conditions, the display process automatically switched between slow and fast sweep color scales whenever a sweep rate change was detected. The user could also manually apply either sweep color scale regardless of the actual sweep rate of the data. The current sweep rate switching mode and sweep rate used are annotated on the bottom right side of the color bar.

The x-axis variable, time or azimuth, determined the manner of construction and display of the color raster image of the data. For both types, azimuth-based and time-based displays, the full raster images were composed of raster image columns several pixels wide, with each column representing one second of data, calibrated according to the current color scale.

The azimuth-based display mimicked the back and forth scanning of the selected ESA unit, building the color raster image column by column in one direction, and then in the opposite direction. At regular intervals, the time was annotated beneath the current data column. Figure 3a is an azimuth-based ESA Data display. The raster image and time labels were cleared each time the ESA scan direction changed. When an LOS period was encountered in the data stream, the corresponding number of blank columns were inserted in the raster image. When the selected ESA RTMD unit was commanded to stop rotating, the raster image column for the current azimuth position was repeatedly redrawn with the current data. When the ESA unit was commanded to rotate to a position outside of its normal 180-degree limits, the display was automatically changed to a time-based presentation.

The time-based display built its color raster image in time-ordered columns, without regard to azimuth position, displaying up to 90 seconds worth of analyzer data. This presentation allowed the user to view the analyzer data being gathered during the current ESA scan and correlate it with the previous 60 seconds of analyzer data. The current time and azimuth were annotated whenever the ESA unit scan direction changed. A time-based display is shown in Figure 3b. The current time and azimuth was also annotated when the selected ESA unit was commanded to stop rotating or to rotate to a position outside of its normal limits. When an LOS period was

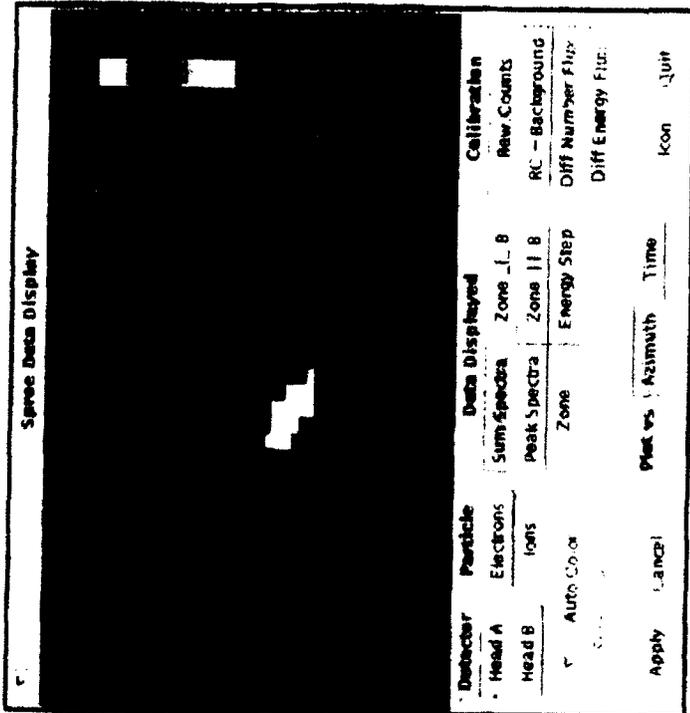
encountered in the data stream, the corresponding columns of the raster image were left blank. When the raster image reached its 90-second capacity, the latter 60 seconds of data in the raster image were scrolled to the left by 30 seconds, and the building of the raster image was continued.

Either of the azimuth-based or time-based ESA display formats could be used in conjunction with any data display configuration. The *Sum Spectra* configuration displays the analyzer data summed over all available zones versus the energy steps. The *Peak Spectra* configuration displays the analyzer data for the peak zone, as determined by the SPREE on-board processors, versus the energy steps. This configuration also contains a histogram which identifies the peak zone and the ESA unit detecting the zone. The *Zone* configuration displays the analyzer data for the user-specified zone number. The two configurations relating to the magnetic field, *Zone || B* and *Zone ⊥ B*, display the analyzer data for the zone determined to be parallel or perpendicular to the local magnetic field at that instant. The magnetic field line interaction with the SPREE ESA units was calculated by the CAS portion of the enhanced Listener process, folding in the orbiter position, orbiter attitude, and direction of the magnetic field for the orbiter position. The current azimuth of each of the ESA units was applied to determine the related zone angle, as described in section 3.2.1. These two configurations also provide a histogram identifying the particular zone number meeting the selected magnetic field orientation requirement. The *Energy Step* configuration displays the analyzer data for a user-specified energy step versus the zones. Alternatively, the analyzer data could be summed over all energy steps and displayed versus the zones.

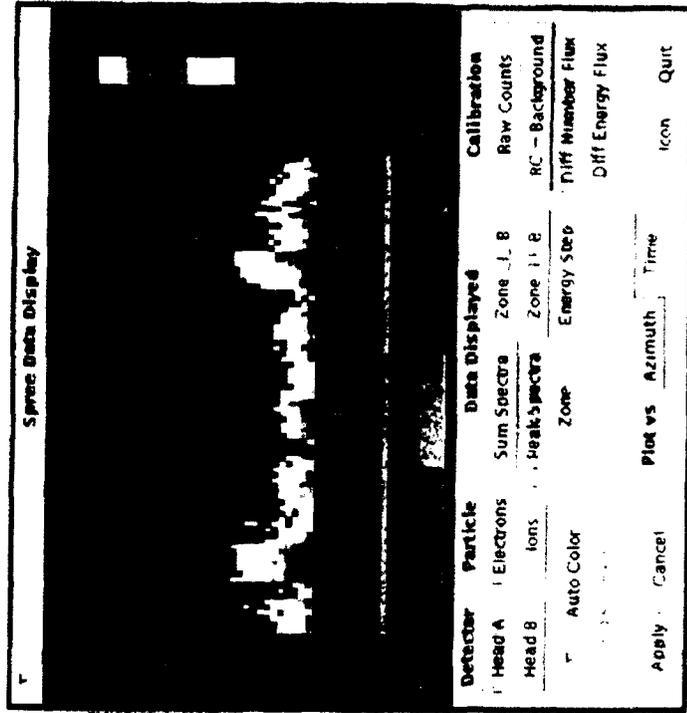
3.2.3 Orbiter Potential Display

The Orbiter Potential Display process presented the real-time on-board determined potential of the orbiter, as a function of time. The determined orbiter potential was displayed at a one second resolution as a single raster block of color, corresponding to the adjacent energy versus color scale. A line plot of the confidence factor for the orbiter potential value was included. The peak zone and ESA histograms, as seen in the Peak Spectrum configuration of the ESA Data Display were also present for correlation. A maximum of 90 seconds of data was displayed. An Orbiter Potential Display is shown in Figure 3c.

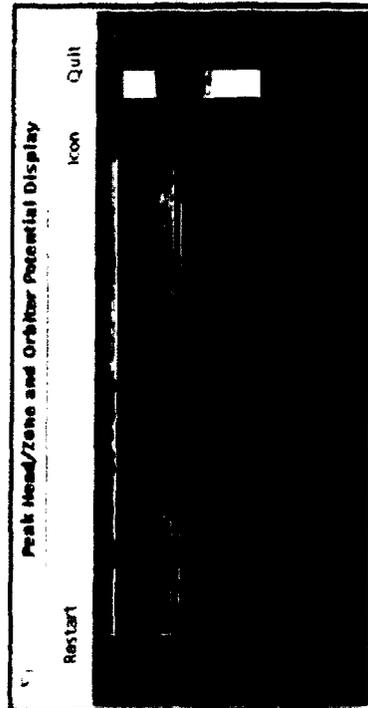
The Orbiter Potential Playback process allows the user to specify times for the review of the previously archived orbiter potential data. This playback process displays the potential of the orbiter in the same format as its real-time counterpart, except that the user supplies the starting time. When the user presses the button labeled "Alter", the standard time selection window appears, allowing the time to be specified via the scrolling lists. Figure 3d shows the Orbiter Playback process with a pop-up time selection window. After a time has been selected, the user presses the button labeled "Go" to begin the data review, accessing data from the CART data base files.



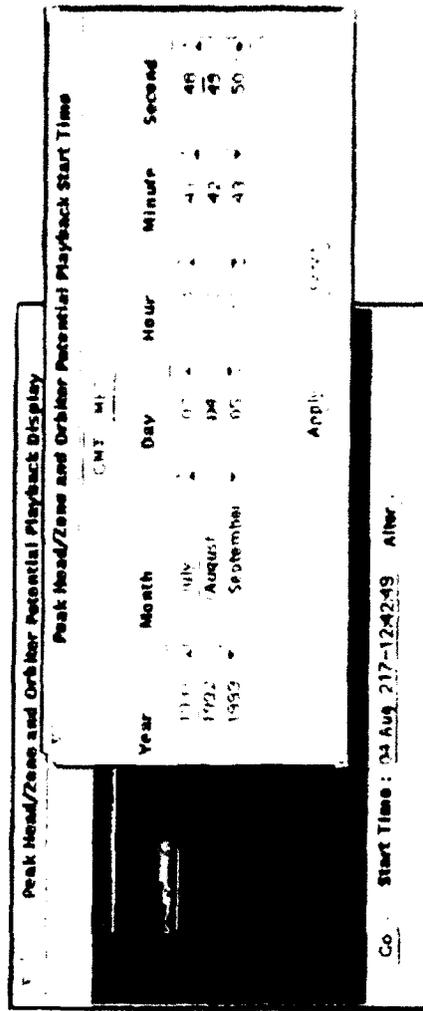
3a. Azimuth-Based ESA Data Display



3b. Time-Based ESA Data Display



3c. Orbiter Potential Display



3d. Orbiter Potential Playback Display

3.2.4 Trajectory Display

The Trajectory display process allowed the user to track, in real-time, the location and attitude of the orbiter. This process received the Calibrated Ancillary System (CAS) data from the NASA telemetry stream via the Listener process. The map showed the current position of the vehicle, the flight path for the previous thirty minutes and future thirty minutes, and the day/night terminators. A Trajectory display is located on the upper left side of Figure 1. For each set of CAS data received, the vehicle position was updated on the map of Earth and the corresponding numeric values were annotated. A simple three-dimensional depiction of the orbiter was presented in relation to Earth, given the processed attitude. Three small pictures lining the right side of the display were indicators for vehicle events: water dumps, thruster firings, or use of the Flash Evaporator System (FES). When these events were not occurring, these pictures were obscured with a red overlay. The occurrence of these events was used in correlation with the SPREE data, which could be affected by each of these. When the CAS data were unavailable, the position of the orbiter was calculated from an orbital element data base, the orbiter was assumed to be in an airplane-like attitude, and the vehicle events were assumed to remain in the state last received.

The CAS data were used to automatically update the orbital element data base. At frequent intervals, the orbiter state vectors from the CAS data stream were saved. Periodically, several of these saved CAS orbiter state vectors were compared to orbiter state vectors as calculated using the orbital element data base, for the identical times. Positional differences within a specific error tolerance were considered acceptable. Positional differences which exceeded the expected error limits indicated that a "bad" CAS state vector, possibly faulty, had been received. Positional differences above the error tolerance, but still within the expected error limits, indicated that an update to the orbiter element data base was needed. In this case, the latest saved CAS state vector exceeding the error tolerance was used in the calculation of the new orbital element, which was then added to the orbital element data base. However, if all of the saved CAS state vectors were determined to be "bad", as might occur following a orbiter thrust event, the latest saved CAS state vector, by default, was used in the calculation of the new orbital element to be added to the data base. In the unlikely event that a truly faulty CAS state vector was used in an update of the orbital element data base, subsequent state vector comparisons would correct the error. This method of orbital element data base update eliminated the need for user interaction, reducing the chances of faulty CAS state vectors being used to update the orbital element data base through the use of multiple vector testing, and was self-correcting following orbital discontinuities.

The vehicle position and velocity values calculated by the Trajectory Display process, using orbital elements, were verified against the AFGL Interactive Targeting System (AITS) Version 2 trajectory process. The trajectory and attitude values derived from the CAS data stream, and the orbital element data base update procedures, were verified against the archived real-time CAS data base from the STS-39 shuttle mission.

3.2.5 Listener Process Monitors

Two processes were available for monitoring the progress of the Listener process. The Listener Monitor process, which simply displayed the current time of each of the SPREE and CAS data sets, allowed the user to verify that the SPREE and CAS data were being properly received and distributed via the interprocess communication facilities. The View Log process allowed the user to view the last ten lines of the Listener process information log. This allowed the user to view various listener messages without a printer or editor for the data file. These log messages included: current process status, data verification information, time code corrections, and SPREE command echo information.

3.2.6 SPREE Status Monitors

The SPREE Status Monitors were used for viewing specific modes or occurrences relating to the on-board SPREE hardware. When particular monitor parameters changed, the status was detected, and a status message was added to the text window. Each status message was tagged with the current date and time, and the SPREE telemetry major frame counter. Each of the SPREE Status Monitor processes placed the status messages in a scrolling text window, which allowed the user to review previous messages without interfering with the real-time updates. The GUN Status process monitored the activity of the four electron guns, while the FDR Status process related the current status codes, error counts, and tape counter values of the two flight data recorders. The Detector Status process sensed mode changes for both ESAs, regarding the power status, the deflection sweep rate, and the rotation status. At regular intervals, the text contained in these scrolling windows was written to disk files, whose filenames were encoded with the last processed data time.

3.2.7 SPACE Data Displays

The SPACE Data Display process depicted the statistical SPACE particle correlator data in two different formats of color raster images, being either energy versus pattern number or pattern number versus time. Both types of displays showed the current data time in the lower right-hand corner. As with the ESA Data Display process, two color scales were used, one for the slow SPACE data mode, and one for the fast. The current SPACE data mode was annotated at the top of the color scale. Different display processes allowed the user to survey each of the three types of SPACE data available, in either display format: Low Frequency Electrons, Low Frequency Ions, or High Frequency Electrons. The data type and display form were chosen via the pull-down menu of the command panel. In the low-frequency electron or ion data display processes, the user had the option to display the data for ESA unit A, ESA unit B, or as a composite of both ESA units. High frequency electron data was displayed as a composite of both ESA units.

The SPACE Data Playback processes allowed the user to specify times for the review of the previously archived SPACE data. These playback processes displayed the SPACE data in the same types and forms as their real-time counterparts, except that the user supplied the starting

time via the standard time selection window. The user then pressed the button labeled "Go" to begin the data review, accessing the data from the CART data base files. In addition to halting the data review at changes in the SPACE data mode, the energy versus pattern number form of the SPACE Data Playback processes also halted at changes in the SPACE frequency. As with their real-time display counterparts, the different data type and display forms of the SPACE Data Playback processes were invoked via a pull-down menu of the command panel.

The energy versus pattern number format of the SPACE particle correlator data display maintained a matrix of the highest scores for each energy and pattern number pair. These scores were displayed as blocks of color, according to the score-color scale. These score blocks were arranged in the raster image as the 32 energy levels versus the 96 pattern numbers, as shown in Figure 4a. When new data were received, the new scores were compared to those already in the matrix. The matrix was then updated when the new data were greater than the present matrix value for the corresponding energy level and pattern number. The raster image was cleared and the matrix was reset whenever a change was detected in either the SPACE particle correlator frequency range or the SPACE data mode. The maximum frequency and wavelength for the current SPACE frequency range were annotated at the top of the raster image.

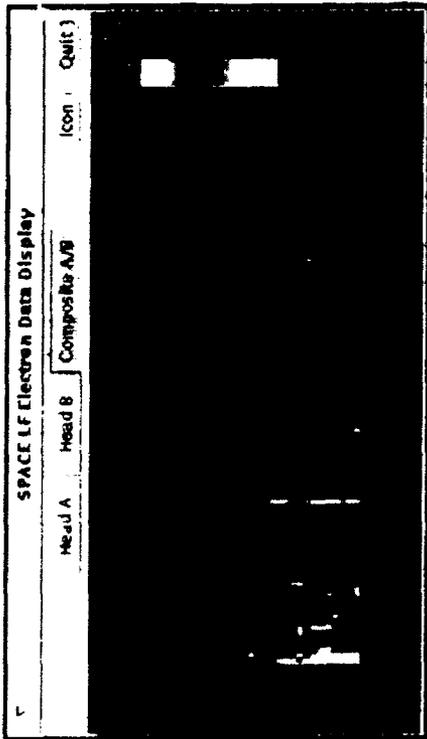
The pattern number versus time SPACE data display raster image was constructed of data columns, several pixels wide, each relating the highest scores for each pattern number over a 3-second time period. This type of raster image displayed the trend of the predominant frequency and wavelength over a long period of time. Each SPACE data frequency range change was annotated with the corresponding time. The full raster image accommodated up to nine minutes of data, representing two full SPACE frequency cycles. Figure 4b depicts a SPACE pattern number versus time display. When totally filled, the raster image was scrolled by 4.5 minutes worth of data, one full frequency cycle. The raster image was cleared when a change in the SPACE data mode had been detected.

3.2.8 Partial Orbit ESA Surveys

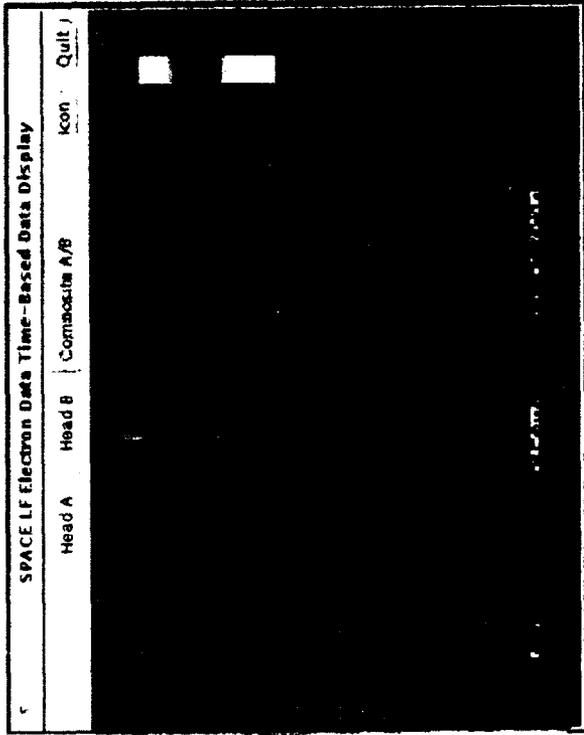
The partial orbit ESA survey processes allowed the user to view the previously archived CART zone-summed electron or ion data as color raster images for the user-specified time period and ESA unit. The starting time was specified using the standard time selection window. A 45-minute time period of data was displayed by the Electron Playback process, and a 15-minute time period of data was displayed by the Ion Playback process. These spectral images were similar to those produced by the SPREE Data Display process for the corresponding options, but for longer time periods. Figure 4c shows an Ion Playback display.

3.2.9 Trending Display

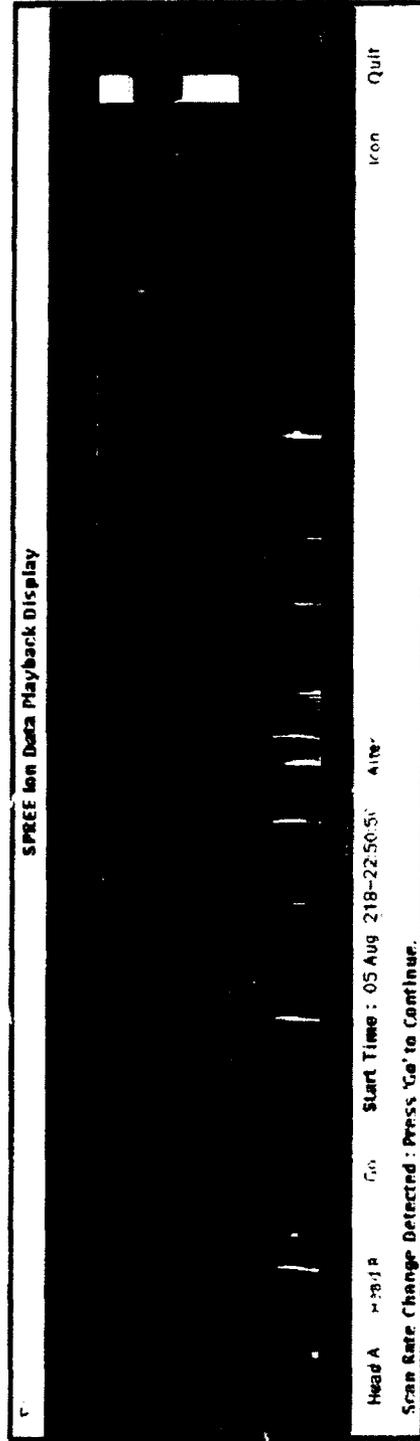
The Trending process produced time-dependent line graphs of a variety of selected data parameters. An external ASCII-format dictionary file was used for the specification of the data parameters available from the CART data base. This dictionary file listed the names of each of the parameters, their location within the data base, the number of bytes occupied in the data



4a. SPACE Energy versus Pattern Display



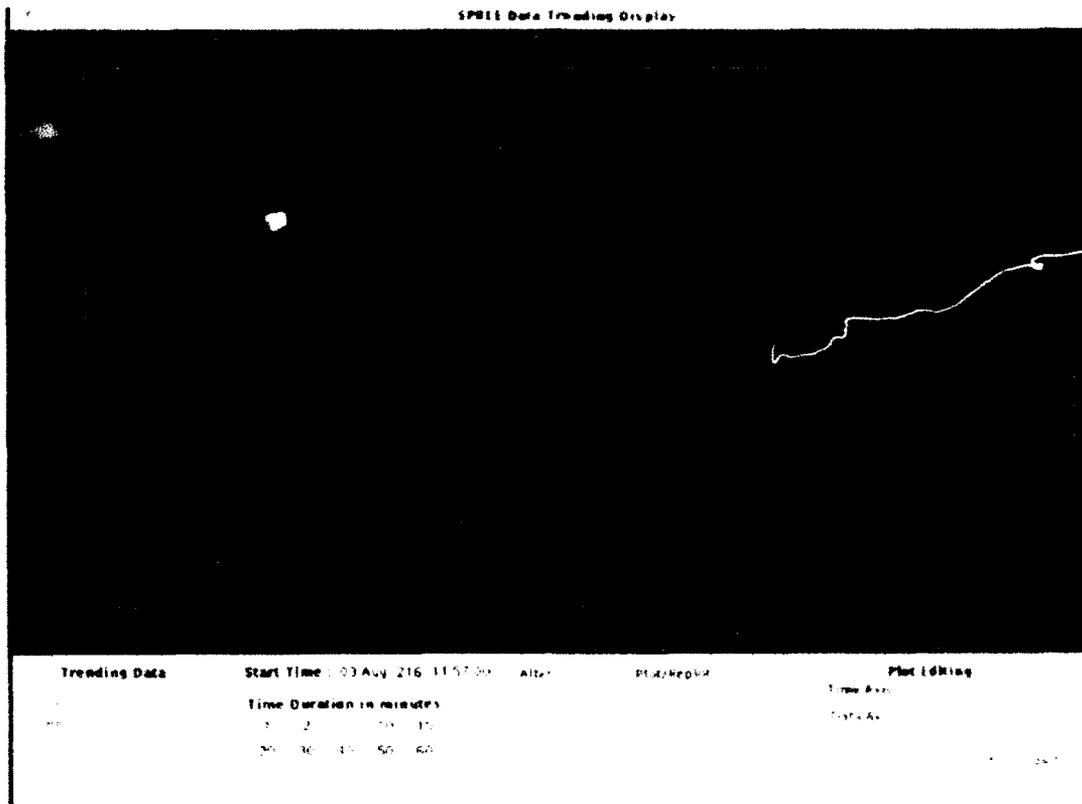
4b. SPACE Pattern versus Time Display



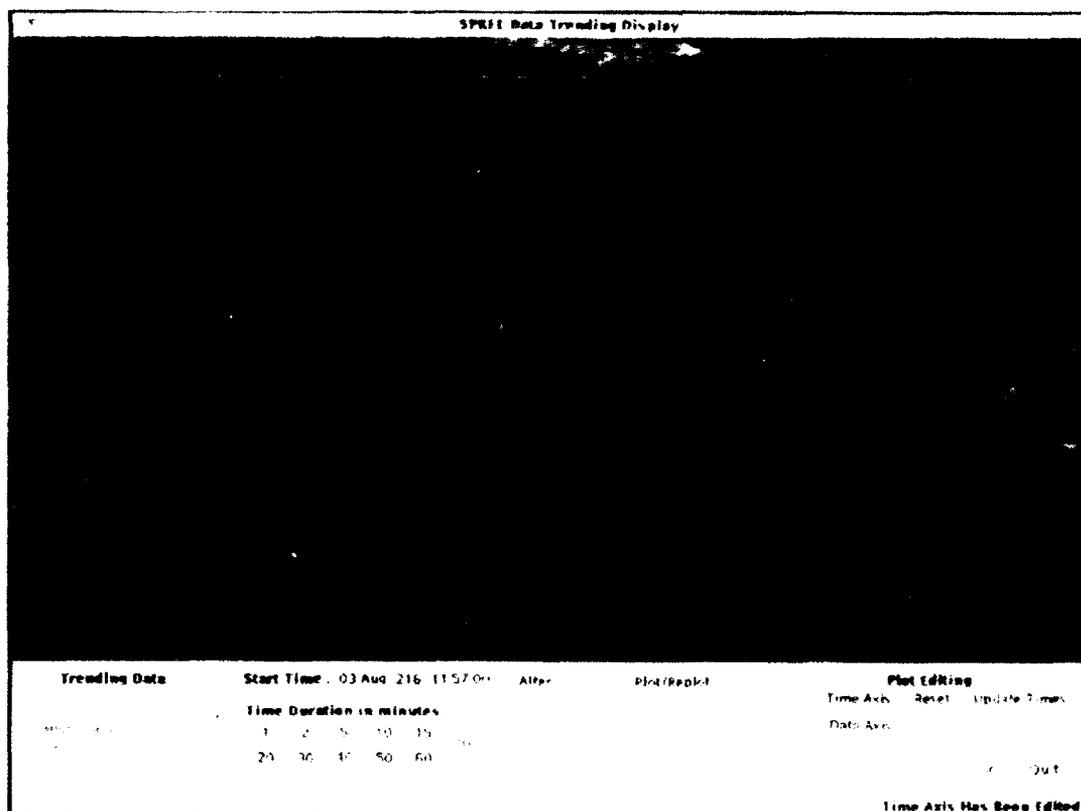
4c. Sample Partial Orbit ESA Survey

base, the data type, a data mask to be applied as needed, and an identifier for the calibration function to be applied. The calibration functions were specified as polynomial equations at the end of the dictionary file. When polynomial equations did not adequately describe the calibration curve, another file was named, containing values for use as a look-up table.

A SPREE data trending graph could be produced with the user selection of an available data parameter from a scrolling list, and specifying a starting time and time duration. A starting time specification is performed using the standard time selection window. A line plot of the data is produced with an automatically scaled data axis accommodating all data values within the selected time period, as shown in Figure 5a. Unlike the other playback displays, the user-specified starting time is not advanced. After the graph has been completed, the user could choose to select another data parameter to plot, alter the time specification, or "edit" the currently displayed line graph. The editing feature could expand a specific region of data values and/or time span for more detailed study, and/or remove spikes in the plotted data. The user performs the axis editing graphically: the first endpoint is picked via the mouse pointer and a left mouse button press, the opposite endpoint is picked with a right mouse button press. Figure 5b shows the graph after a completed editing operation. The user could redraw the trending graph with the original plot axis limits at any time, or could choose the currently edited time axis limits as the new starting time and time duration values for the next trending graph produced.



5a. Trending Process Plot



5b. Edited Trending Process Plot

4.0 SPREE INTERACTIVE DATA ANALYSIS TOOL POSTFLIGHT OPERATIONS

4.1 FLIGHT DATA RECORDER INFORMATION PROCESSING

The Flight Data Recorder (FDR) contained the full SPREE data rate telemetry and was the primary postflight analysis data set. The data were recorded on two on-board flight-qualified Exabyte tape recorders and were in digital format for direct computer access. Each physical tape contained time segmented periods in a near sequential manner on the tape, with a possible two gigabytes per tape. As part of the postflight processing, each tape segment of data was divided into several specialized data bases. The Analyzer data, SPACE data, Flight Data Recorder data, Deflection Plate data, and master frame housekeeping data were separated into independent data streams. The Analyzer Data Base consists of the full set of analyzer data, in either zone sweep mode, with the appropriate header information. The SPACE data were further subdivided into the raw, beam, low frequency, high frequency, and statistical data bases. Each SPACE data type was as described in section 3.1. The Flight Data Recorder Data Base contained all data pertaining to the tape counters, status words, error counts, and hardware temperature of the two recorder units. The Deflection Data Base contained the deflection monitor and beam status. The Major Frame Housekeeping Data Base contained the flight data recorder status information, the housekeeping parameters containing the temperatures and voltages of the various parts of the SPREE instrument, the SPACE and DPU status words, and the SPREE ESA header information, which contained the current azimuth position and status of the ESA units.

4.2 POSTFLIGHT DATA ANALYSIS PROCESSES

All SIDAT postflight processes are invoked from a master command process panel, depicted in Figure 6a, similar to the real-time command panel. The user simply selects the desired display process specified on the command panel buttons or in the pull-down menus. Most of the postflight processes operated nearly identically to their real-time counterparts. Some of the real-time playback processes were either removed or repackaged to streamline operation and eliminate redundant features.

The color raster image graphics and text produced by the postflight SIDAT processes were verified for accuracy against the processed SPREE Flight Data Recorder data obtained during vacuum chamber instrument testing. Several random time segments of data were selected for the verification, some in slow sweep rate and some in fast sweep rate. Where applicable, the text and raster images produced by the postflight display processes were verified against their corresponding real-time SIDAT display process in text or raster image format.

4.2.1 Postflight Data Survey Process

In the postflight data analysis environment, the Data Survey process replaced the functions of the Listener process, placing data in the shared memory segment, and signalling the display processes via semaphore. By emulating the Listener process data communication protocol, most of the postflight display processes were slightly modified versions of the real-time display processes.

A starting time is specified using the standard time selection pop-up window, or selected from one of the user-defined starting times contained in a scrolling list. Each time in this scrolling list has an identifying text label. The user can interactively add or delete times from this list. Each time the user adds or deletes entries in this times list, a confirmation for the operation is requested. When an entry is added to the times list, the time and the specified text label are checked against the entries currently in the list. Any duplication of either causes the new entry to be rejected. When accepted, the entry is inserted into the proper position in the chronologically ordered list. This list of times and text labels is stored in an ASCII-format external file, which is updated with each modification. Figure 6b shows the Data Survey process panel, with the accompanying time list panel. Two other postflight SIDAT processes, the Partial Orbit Survey and the Trending Display, also use a scrolling time list for starting time selection. If the times list is modified by the user in one of these three processes, the scrolling time lists in the other active processes are likewise modified.

To survey the SPREE data, the user first selects the data source. The user may choose to review data from either the Captured Real-time Telemetry (CART) data base, generated by the Listener process during the STS-46 shuttle mission, or from the processed Flight Data Recorder data base. Processing of the selected data is initiated by pressing the button labeled "Go". While processing, the data are read from the appropriate data base files, placed into shared memory, and the semaphore signal is set. The data are processed at a rate of approximately 15 data sets per second. The current loaded time is displayed near the bottom of the Data Survey process panel. The user can halt the data processing at any time by pressing the button labeled "Halt", which replaced the "Go" button during processing.

The processing of the data could be paused briefly at specific events in the data, as specified by the user. The pause could be selected to occur at changes in the sweep rate of the SPREE ESA data, or at mode changes of the SPACE data. Alternatively, the user could decide that no pausing is needed, and to process the data continuously. Additional data events are available for inducing a pause in the data processing. These events include: a user-specified time interval, a change in rotation of either ESA RTMD units, or a change in the SPACE data frequency range. The user specifies the length of time, in seconds, for the pause during the data processing. Status messages, such as "Accessing Data", "Loading Data", "Time Interval Pause", etc., are displayed at the bottom of the Data Survey process panel.

When surveying the processed FDR data, the user should select only those data items required for the active data displays. This selective loading of data expedites the processing, due to the

SPREE Postflight Data Display System

Quit | SPREE Data Displays | Data Survey Process | Status Monitors | SPACE Displays | Playback Displays | RT Playback Displays

Creating Data Survey Process Process

6a. Postflight SIDAT Command Panel

SPREE Data Review

Data Source: Real-Time/Archive: FDR Database

FDR Data to be Loaded: B-field SPACE

Specify Time: From list

Go Start Time: 31 Jul 213-12:00:00 Alter

Pause at Change In: No Pauses ESA Sweep Rate: SPACE Mode

Pause for 2 seconds;

Also Pause at:

Time Interval	of 30 seconds.
ESA A Rotation	5 10 15
ESA B Rotation	30 60 30
SPACE Frequency	Icon Quit

Predefined Start Times

1992 217-06:56:43	H2O 14 start	Add Entry
1992 217-07:00:00	Survey B	Label:
1992 217-07:05:15	FO 1B	Delete Entry
1992 217-07:08:50	3rd FO1B	

6b. Postflight Data Survey Panel

multiple data sources of the FDR data. The user has the choice of loading the analyzer ESA data, the magnetic field information, and/or the SPACE statistical data. Other parameters in the data stream, such as the time, major frame counters, status values, etc., are loaded regardless of these selections.

The magnetic field information is needed for the postflight data survey for one of the specialized options of the SPREE ESA Data Display process. This option allows the user to view the ESA data for the conditions where the ESA scan region is perpendicular or parallel to the direction of the local magnetic field lines. In order to determine the location of these scanning regions, the SPREE postflight data processing requires the orbiter position and attitude at a resolution equivalent to the ESA data rate. When surveying the SPREE CART data, a data base containing processed orbiter position, velocity, and attitude from the CART CAS data base and magnetic field line information is accessed. Surveying of the processed FDR data utilizes a processed Postflight Attitude and Trajectory History (PATH) data base, containing the orbiter position, velocity, attitude, and magnetic field information. With the orbiter attitude and magnetic field information available, the ESA zones parallel and perpendicular to the magnetic field lines were able to be determined, as described in section 3.2.1.

4.2.2 Postflight ESA Data Display

The postflight SPREE ESA Data Display process is nearly identical in function to its real-time counterpart, described in section 3.2.2. The added features of the postflight form include a text label identifying the source of data currently being displayed, and a button labeled "Freeze Display". The "Freeze Display" button allows the user to halt further data processing for that display process only. This ability to "freeze" the data display is especially useful when comparing the data displays for different times and/or data sources. Other alterations enable the full set of SPREE analyzer data from the processed FDR data base to be displayed. Due to the limitations of the workstation display monitor, the analyzer data from each of the eight data sweeps in fast mode could not be displayed separately; instead, four sets of data, obtained by averaging two of the eight sweeps of analyzer data, were displayed as columns just one or two pixels wide. This averaging allowed the fast sweep FDR data to be displayed in the same format as the fast sweep CART data. However, full resolution of the spectra can be obtained using the freeze option, as described below.

Another enhancement of the postflight SPREE ESA Data Display process enabled the user to generate line graphs of the data. This feature allows the user to examine the actual data values of the color raster image for a specific time. The user chose a time for the line graph directly from the color raster image when in the "Freeze Display" mode. This enables the user to select a specific data feature for graphing. A pop-up window appears containing a line graph of the data, drawn according to the user selections for the raster image. If the raster image data was calibrated, the data for the line graph were likewise calibrated. The current time of the data, user selections, ESA azimuth, and zone number as needed, are annotated on the line graph. If the data for the zones perpendicular or parallel to the magnetic field lines were being displayed, the corresponding zone number is also annotated. Moving the mouse pointer across the line

graph window causes the numeric value of the nearest data point to be displayed at the bottom of the graph. Figure 7a shows the postflight SPREE ESA Data Display with corresponding line graph pop-up window. The user can freely step through the data base in one second increments in either direction using the buttons labeled "Forward" or "Backward". Each time either of these buttons are pressed, the line graph is redrawn for the new current time. Alternatively, the user may redraw the line graph for a new time, as selected directly from the color raster graphic image. When displaying FDR data in fast mode, the line graph displays data for only one of the eight sweeps. Additional buttons enable the user to change the sweep number of the data for display. When the user terminates the "Freeze Display" mode or alters the data display configuration, the line graph window is removed.

4.2.3 Postflight Orbiter Potential Display

The postflight Orbiter Potential Display process is identical in function to its real-time counterpart, described in section 3.2.3. The added features of the postflight form include a text label identifying the source of data currently being displayed and a "Freeze Display" button. An Orbiter Potential Playback process was not needed in the postflight data analysis environment, since its functions had been superseded.

4.2.4 Postflight SPREE Status Monitors

The postflight SPREE Status Monitors are identical in function to their real-time counterparts, described in section 3.2.6.

4.2.5 Postflight SPACE Data Displays

The postflight SPACE Data Display processes are identical in function to their real-time counterparts, described in section 3.2.7. The added features of the postflight form included a text label identifying the source of data currently being displayed and a "Freeze Display" button. The SPACE Data Playback processes were not needed, since their functions had been superseded.

4.2.6 Postflight Partial Orbit Survey

The postflight Partial Orbit Survey process is a hybrid of the real-time Ion Playback and Electron Playback processes. This Partial Orbit Survey process produces parallel zone-summed spectral images of both ion and electron data of a specified ESA unit, for a fifteen minute period. Below the parallel spectral images is a small line plot relating the behavior of the ESA during the time period. The data base accessed, CART or processed FDR, is specified when invoking the process via the command panel pull-down menu, and is appropriately annotated on the process display window. A Partial Orbit Survey process is depicted in Figure 7b. The user simply specified the ESA unit and a starting time, and pressed the "Go" button. The starting time could be specified using the standard time selection window, or could be selected from the user-defined times list, as previously discussed. Normally, the zone-summed data were

displayed in the color raster image as one data set per pixel column; however, when displaying fast FDR ESA data, averaging of the data for the eight sweeps was required to be able to display the data in the one-pixel column.

4.2.7 Postflight Trending Display

The postflight Trending Display process is identical in function to its real-time counterpart, described in section 3.2.9. As previously discussed, the starting time could be specified using the standard time selection window, or could be selected from the user-defined times list. The data base accessed, CART or processed FDR, is specified when invoking the process via the command panel pull-down menu. A label on the trending display window identifies the source of the plotted data.

REFERENCES

Oberhardt, M. R., *Private Communication*, February 1992.

International Geomagnetic Reference Field (1985), EOS, June 17, 1986.

Kendra, M. J. and N. A. Bonito, *Coordinate System Software User's Guide For Attitude, Quaternion, M50 and Related Applications*, GL-TR-90-0327, November 1990, ADA234455.