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THE PASPLUS SURVEY GRAPHICS PACKAGE -- APPLICATIONS AND DESIGN ELEMENTS

John R. Palys
Dennis E. Delorey

Boston College
Institute for Scientific Research
Chestnut Hill, MA 02167

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ALAN R. GRIFFIN
Contract Manager
Data Analysis Division

ROBERT J. RAISTRICK, Acting Director
Data Analysis Division

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John R. Palys
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This report describes the PASPlus Survey Graphics Package, which displays data from the full complement of instrumentation comprising the PASPlus payload, along with ephemeris and spacecraft state-of-health information. Graph types include instantaneous I-V curves for all sixteen of the research solar arrays, along with derived and ancillary information; biased-array current-loss data, as a time series; all parameters from the data-rich Transient Pulse Monitor, from which can be derived arcing rates for individual arrays; high-energy particle flux and dose data, from the Dosimeter, along with time-correlated single event upset data from the state-of-health file; nonthermal electron and ion energy spectra, from the Electrostatic Analyzer; thermal plasma density and temperature, from the Langmuir Probe; solar array and other instrumentation temperatures, along with the outputs of contamination monitors; emitter and grid currents, with ancillary monitor outputs; and ephemeris parameters in geographic and geomagnetic coordinates, along with sun sensor data and parameters characterizing the performance of the satellite's own solar arrays, including applied voltage, array temperatures, and output currents.

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1.0 Introduction

The Photovoltaic Array and Space Power Plus Diagnostics (PASPlus) experiment has characterized the in-flight performance of a variety of solar cell arrays of varying design and composition, under a wide range of conditions in the near-earth environment. Environmental effects such as radiation-induced degradation of solar cells and other instrumentation, power loss mediated by space plasmas, and arcing between differentially-charged spacecraft components, have been studied in conjunction with environmental sensors (Dosimeter, Electrostatic Analyzer, Langmuir Probe). These sensors provide spacecraft power system designers with information of immediate interest, such as high-energy particle fluxes and energies (responsible for solar cell degradation), plasma densities and temperatures (which are implicated in arcing and plasma-mediated power loss), and they contribute to long-term studies of the near-Earth environment, supplementing in significant ways the data sets garnered by the CRRES and DMSP vehicles.

Many of the solar arrays are regularly operated at various potentials ranging to five hundred volts above or below the spacecraft potential, to simulate the operating conditions of high-voltage systems which have been proposed for use in future space power systems, and in particular for the space station. Simultaneously, the payload's orbit (perigee at 360 km, apogee at 2500 km, inclination 70°) extends well into the radiation belts at high altitudes, exposing solid-state components to fluxes of highly energetic particles, and drops into regions of appreciable plasma density at low altitudes, at which plasma-mediated power loss becomes significant.

Results from preliminary analyses of comparative solar cell degradation rates, negative-potential solar array arcing rates, single-event upset (SEU) correlations with highly energetic protons from the radiation belts, and other efforts have been presented at the PASPlus Post-Launch Analysis Meeting (29 November 1994) and at other meetings, and there are several PASPlus-related research papers currently in press.

PASPlus, which was launched aboard the APEX satellite on 3 August 1994, has completed its first full year of data collection and has begun its second, having amassed a data base which is unparalleled in the field of space power.

2.0 PASPlus Data Acquisition

PASPlus data is continually acquired onboard the spacecraft, and is periodically telemetered to ground stations in "major frame" format, with data from all instruments interleaved in blocks spanning 30 seconds. On the ground, the analog data tapes are digitized and the resulting major-frame-format files are reorganized into a number of individual file types. Data from several orbits are consolidated into files spanning a single day (more precisely, the interval 00:00—24:30 UT, with the overlap ensuring continuous coverage). Several file types are post-processed, either because of the intrinsic complexity of their data-reduction algorithms (as for Langmuir Probe and attitude/magnetic field data) or to reduce the sheer volume of data that must be retained (by averaging, as for electrostatic analyzer and dosimeter data). The final output is retained in the form of binary bit stream files, for maximal storage efficiency.

Even with averaging, PASPlus generates between 10 and 12 megabytes per day of reduced time-series data from its full complement of instrumentation. Data types include solar array current as a function of voltage curves (for all 16 research arrays), electrostatic analyzer data, high-energy particle flux and dose data, Langmuir Probe data, power-loss ("leakage-current" or "parasitic-current") data, transient pulse monitor data, emitter data, sun sensor and ephemeris data, housekeeping data, attitude/magnetic field data, and spacecraft state-of-health data. The daily volume of data is variable because not all instrumentation is always utilized, and because some modes of operation are inherently more data-rich than others.

3.0 The PASPlus Survey Graphics Package

3.1 Purpose, Host Platform and Implementation Environment

The Survey Graphics Package (SGP) was designed to fulfill specific requirements within the PASPlus program. First and foremost, the package is a *survey* utility, intended to enable a rapid and comprehensive overview of the processed satellite data. It is not an analysis package *per se*, although data output through its charts and tabular listings have been used in preliminary analyses of a variety of phenomena.

Secondly, the package is intended to be freely dispersed to all those interested in PASPlus data, including personnel at Phillips Laboratory Geophysics Directorate, Phillips Laboratory Space and Missiles Technology Directorate, NASA Lewis Research Center, the Aerospace Corporation, MIT, the S-Cubed Division of Maxwell Laboratories, SRI International, and others, notably the solar array fabricating subcontractors. This open-ended distribution places practical limits on the type of computing platform and operating environment that can be employed, i.e. that the platform be widely available and familiar, and that the operating environment impose no restrictions on the distribution of executable code. These constraints led to the adoption of the PC as the computing platform, and to the decision to develop the software *ab initio*, rather than modifying (by supplying application-specific templates for) any of the graphical display environments which are commercially available, but which require registration and licensing fees to be paid for every CPU on which applications are hosted.

Finally, the large volume of data acquired (10—12 megabytes per day, for 300+ days and counting) along with the magnitude of the requirements—which encompass the access, display, and in some cases the tabulation of data from eleven dissimilar file structures and thence the generation of approximately fifty-five individual display types, each comprised of up to seven panels of single or overplotted time-series data—dictate the use of a robust implementation language along with a 32-bit addressing mechanism, to facilitate the storage of large blocks of data and to accelerate operations overall. Such considerations led to the adoption of DOS-hosted FORTRAN as the implementation language. The compiler was obtained from an established vendor, and is distributed with a memory management utility which enables the use of extended memory. These tools were supplemented by a graphics library, a set of scaleable screen fonts, and a printer graphics library with printer drivers, particularly PostScript utilities, for monochrome, greyscale, and full-color hard copy.

Time marches on and progress persists. Certainly at this writing, two years after the commencement of development and one year post-launch, the increasingly wide availability of 32-bit windowed operating systems for the PC would result in different choices of operating environment and implementation language: but the implementation decisions made at the start of the project were appropriate for the technologies in general use at that time.

3.2 Design Considerations and the User Interface

A package intended for extensive distribution must be easy to use and largely self-documenting, replete with user interface mechanisms such as pull-down menus and menu bars, dialog boxes, and mouse-button selection of operations. A graphical user interface embodying all these features was developed for the SGP. This interface is a custom implementation of the more or less ubiquitous elements noted above, along with a mechanism specifically tailored to the problem of data file inventory and access for an active, ongoing scientific satellite experiment.

With a projected mission lifetime of 1—3 years, with occasional loss of days or weeks of data due to unanticipated anomalies in satellite operations, and with a data processing system that can output up to eleven different file types per day (although not all file types are always written), one of the requisites for a survey graphics package is an inventory of the currently-available data sets, along with a display of these files, ordered in a comprehensible way. The file-inventory task must be repeated frequently, because satellite data is continually acquired and regularly processed, and because it is often the most recently acquired data that is of greatest interest to researchers and operations personnel.

Thus, the introductory screen of the SGP is an explicit representation of the available PASPlus data files, ordered by (five-digit) Julian day and instrument type. By scrolling through this display, the availability of files from the entire flight history may be determined, and gaps in coverage may be identified at a glance (Figures 1 and 2). Scrolling is accomplished by mouse clicks to the buttons in the menu bar at the top of the screen (indicated by the arrow in Figure 2). Three buttons scroll to absolute positions (*"Top"* moves to the earliest data, *"Bot"* to the latest, and *"Day..."* opens a dialog box and then moves directly to the day requested by the user) and two scroll to relative positions (*"Up"* moves fourteen days prior to the current position, and *"Dn"* moves fourteen days hence).

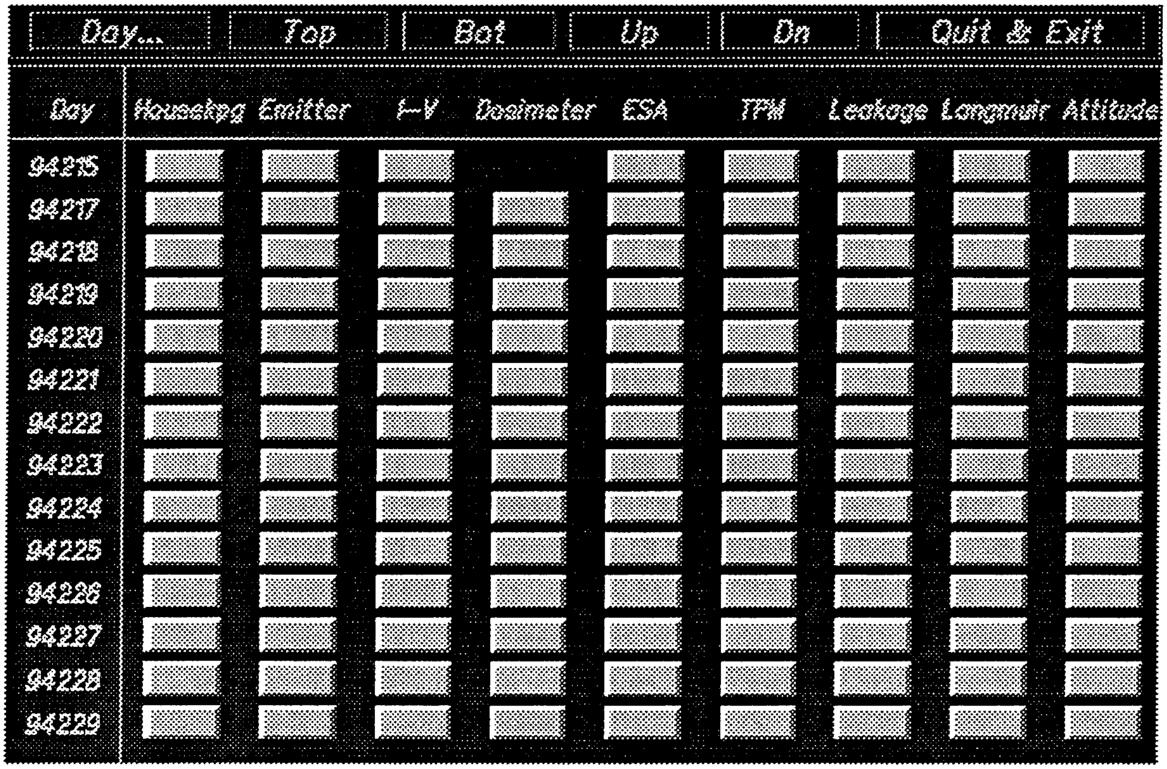

Figure 1. The SGP's opening screen, displaying the available files of PASPlus data for the first fourteen days of satellite operation. Files are organized by instrument type (Housekeeping, Emitter, I—V,...) across the top of the screen and Julian Day number, commencing at 94215, down the left hand side. Each brightly-shaded button represents a single PASPlus data file.

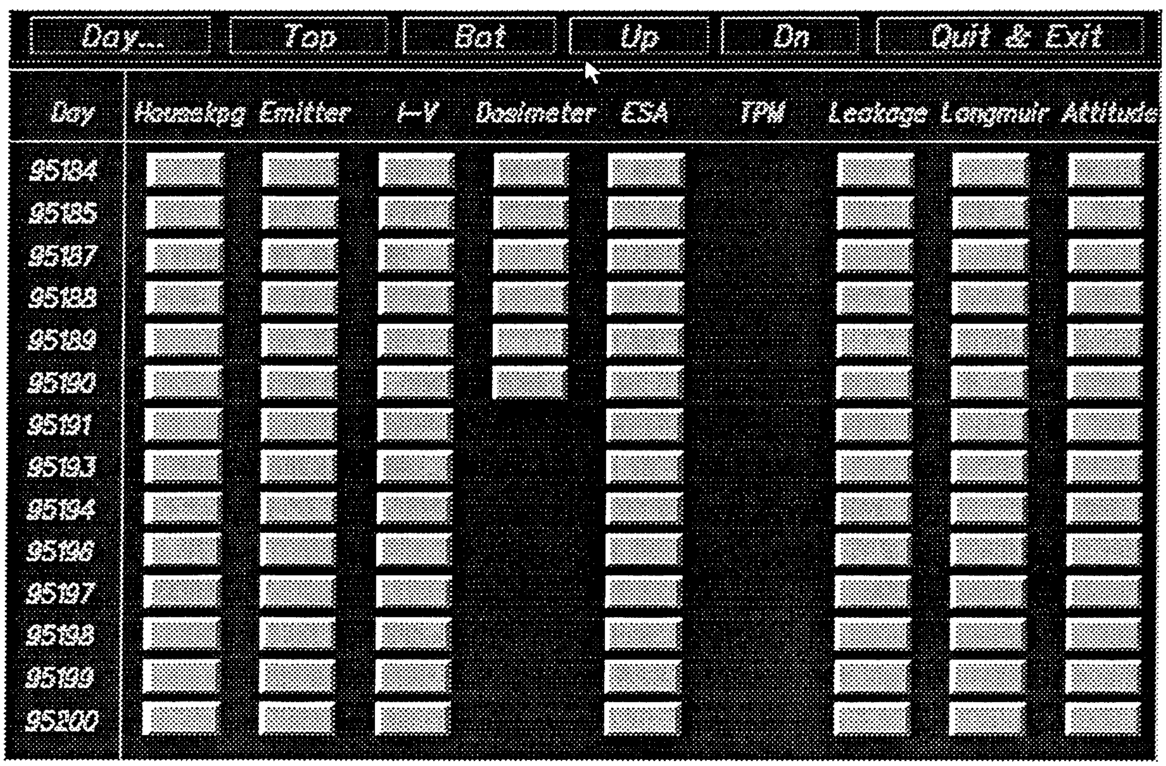

Figure 2. The same screen as in Figure 1, after scrolling to the "bottom", to display the most recently acquired data sets.

At this writing, the data-inventory process occurs anew with each invocation of the program. However, as the number of data files increases, so increases the computational burden, and therefore this task may in the future be performed by supplemental software, regularly and independently executing and making its results available to the SGP.

3.3 Viewing PASPlus Data

A mouse-button click to any file token in the SGP's opening screen initiates the display of the corresponding file. Data from the ESA, Leakage current, and Langmuir probe instruments are displayed immediately, whereas the remaining instruments require multiple screens, and in these cases an instrument-specific menu prompts for the desired display type (Figures 3, 4, and 5).

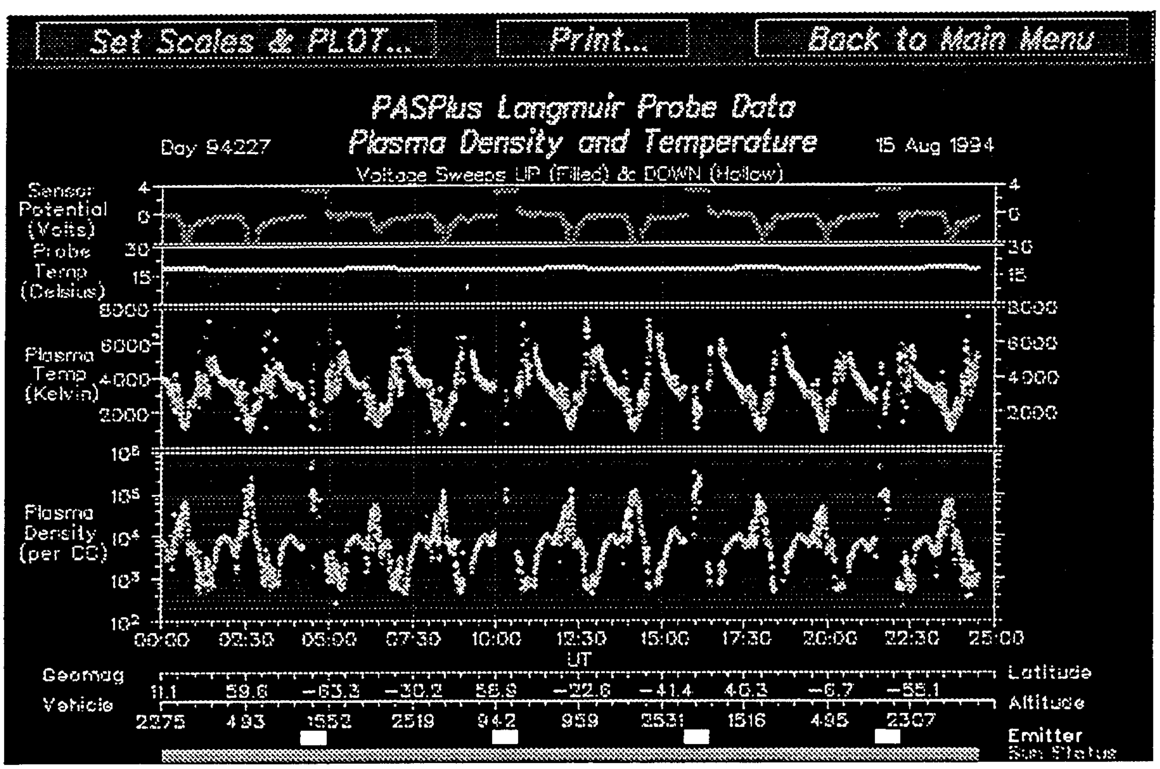

Figure 3. Langmuir Probe data is displayed immediately upon clicking a Langmuir file token in the SGP's opening screen, whereas...

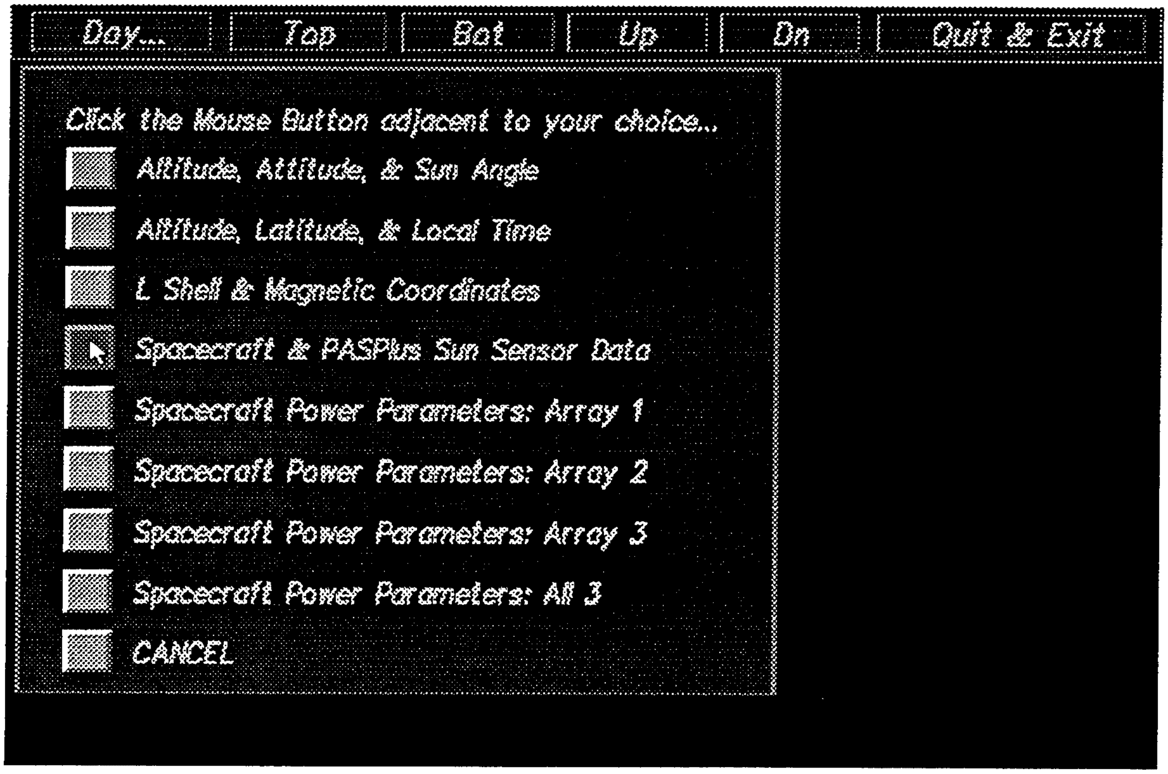

Figure 4. ...the large number of parameters in the Attitude/Ephemeris files are distributed over eight different screens. This menu is used to select the screen of interest...

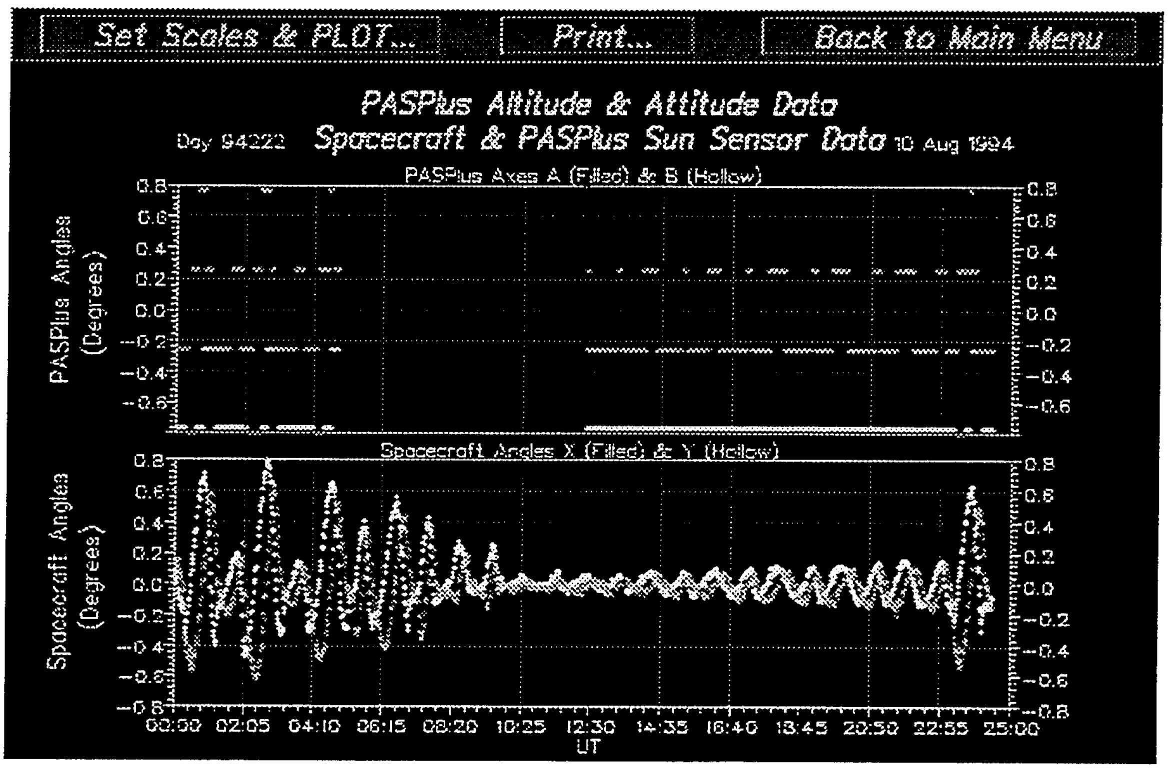

Figure 5. ...so that the desired parameters may be charted.

3.4 Viewing PASPlus Data in Detail

Figures 3 and 5 are fairly typical of the screen displays produced by the SGP: time series data is charted in one or more panels, for a default time interval and one or more default ordinate ranges. The initial default time interval is the entire data file (0:00—25:00 UT) and the default ordinates are initially supplied by the SGP.

Both the default time interval and ordinates may be modified by the use of the *Set Scales & Plot...* menu, activated by clicking the appropriate button in the menu bar (see Figure 6). There are nine options in this menu:

- *Set the Start Time [hh:mm]*

  This option controls the start time of the chart, and supplies the currently-active value [hh:mm]. To change this value, click on the button and type a new value, using one of the formats **h**, **hh**, **:mm**, or **hh:mm**.

- *Set the Stop Time [hh:mm]*

  This option controls the stop time of the chart, and functions similarly to its companion.

- *Set the Ordinate Scales*

  This option enables the modification of the ordinate scales. To change any of these values, click on this button: a set of tokens will be superimposed on the rightmost axis (or axes). Click any of these to modify the corresponding value, and then enter a new value in exponential or floating-point notation, as convenient.

- *Restore to Default Ordinates*

  This option restores any modified ordinate values to the program defaults **if it is invoked before exiting the chart**. Otherwise, the modified values are retained and used throughout the session.

- *PLOT*

  This option redisplays the chart with any modifications that may have been made to the time interval or ordinate interval(s).

- *Plot Next Interval*

  This option is useful when studying small subintervals of a day. Once such a subinterval is defined (by the use of ***Set the Start Time*** and/or ***Set the Stop Time***, e.g. by selecting and viewing a 1-hour period) then successive intervals of this duration may be viewed by clicking this button.

- *Plot Previous Interval*

  This option works as its companion, above, displaying **preceding** intervals.

- ♦ *Skip to NEXT AVAILABLE DAY [YYDDD]*

  This option enables a quick jump to the next day's data, bypassing the top-level menu and retaining the currently-defined ordinate settings.

- ♦ *CANCEL*

  Closes the current display and returns to the opening screen.

A refinement of this control structure has been defined for two specific instrument types, the dosimeter and electrostatic analyzer, to enable access to these types by orbit number as well as by start and stop times. The corresponding menu is seen in Figure 7: it is analogous to its time-interval companion, and its usage is similar.

As the SGP has the property of retaining start and stop time specifications within all data sets for a single day, it is possible to review all data types by orbit, not merely those for which the mechanism is explicitly defined. To view Langmuir probe data, for example, by orbit, open either the dosimeter or ESA file for the day of interest, skip to the appropriate orbit, and then go back to the main (file-select) menu and open the Langmuir probe file. Langmuir probe data will be plotted for the start and stop times corresponding to the orbit just viewed (in the dosimeter or ESA file). Preceding or succeeding orbits may be viewed by selecting the ***Plot Next Interval*** or ***Plot Previous Interval*** options.

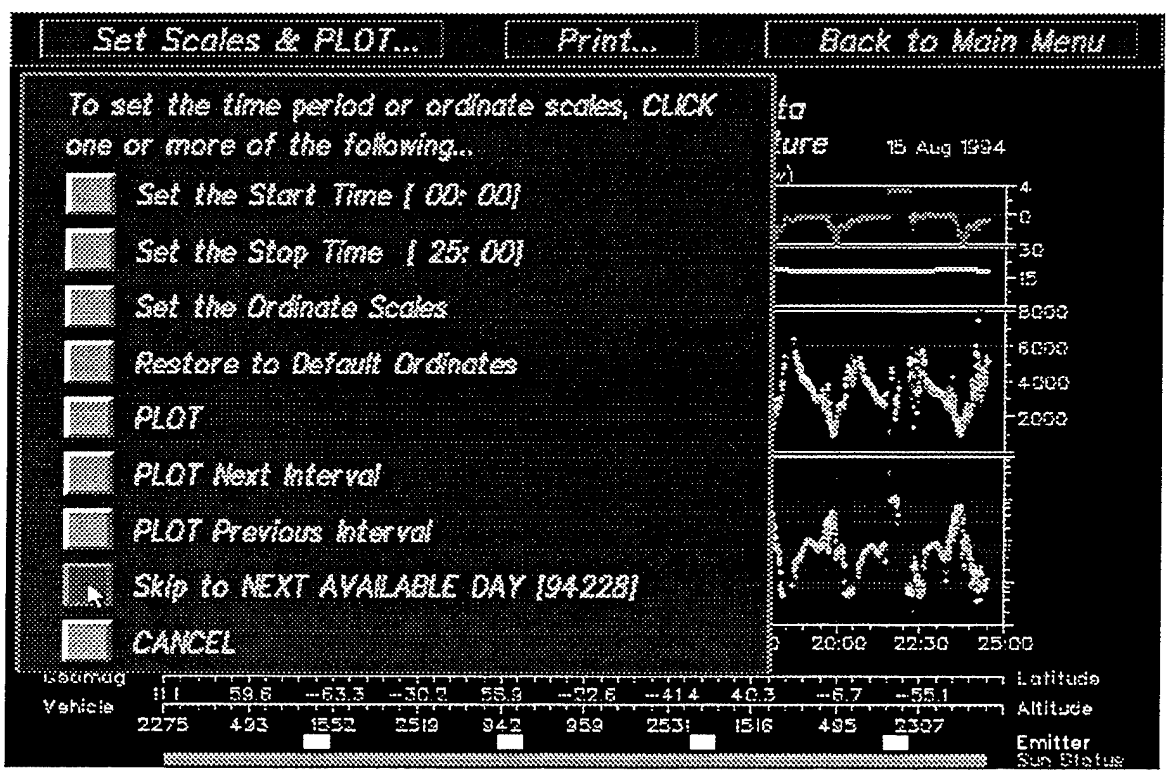

Figure 6. The *Set Scales & Plot...* menu enables the modification of the abscissa and ordinates.

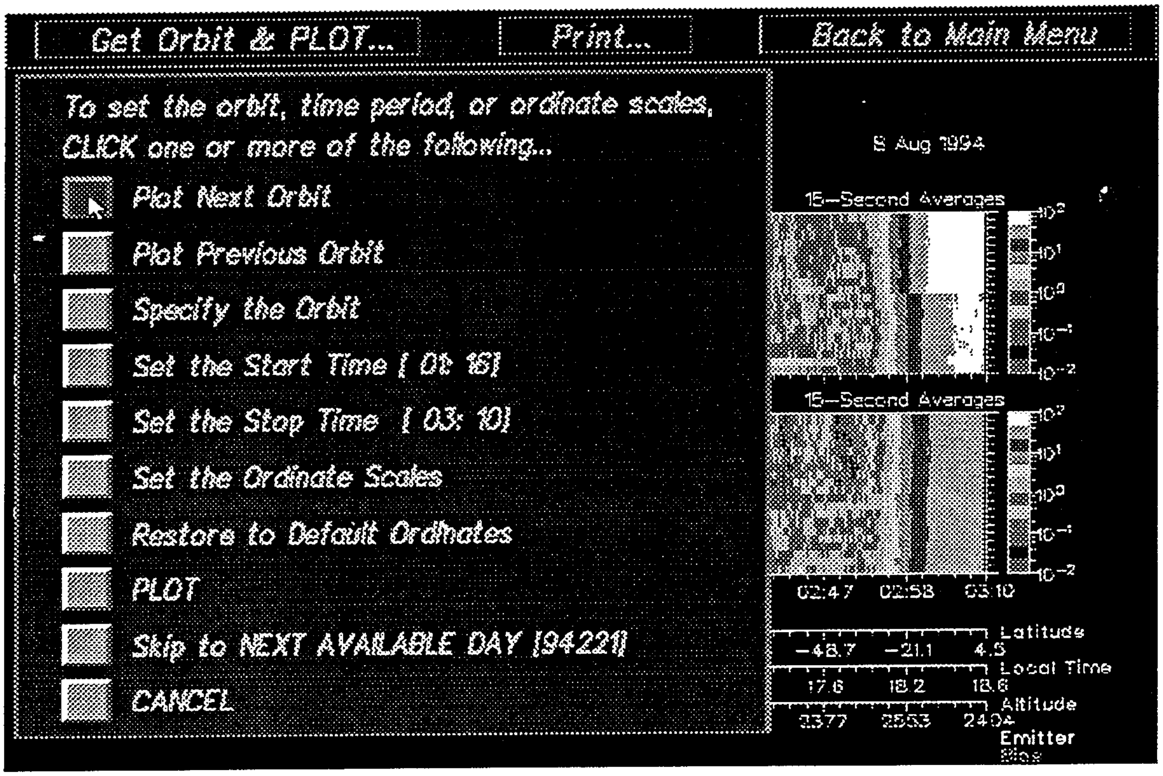

Figure 7. Similarly, the ***Get Orbit & Plot...*** menu enables modifications of the chart's scaling, but with explicit access to the data by orbit.

3.5 Printing PASPlus Charts and Tabulating PASPlus Data

On-screen displays are useful for overviews, for the rapid assessment of data, and for searches for phenomena of interest. For more deliberate analysis, for the dissemination of results, and for publication, high-quality prints are essential.

All of the chart types produced by the SGP may be printed. Although the screen displays make extensive use of color for emphasis and for the coordination and grouping of related elements on a chart, as well as for visual appeal, a color hard copy device is not required for reproducing the SGP's graphics. Even the false-color images (color spectrograms) may be rendered on a monochrome device, in gray scale.

But by itself, charted data is insufficient. Calibrated data in digital form is essential for post-survey analysis. Thus, for several of the data types (research solar array data, power-loss, i.e. "leakage current" data, and attitude/ephemeris information) it is possible to copy calibrated data to tabulation files, for examination, analysis, and import into analysis software.

Both of these functions—printing charts and tabulating data—are accessed through the ***Print...*** button, which is part of the menu bar displayed when a chart is active (see Figure 6 or Figure 7).

When the ***Print...*** button is selected, the menu bar changes to offer the options ***Print Graph to Metafile, Print Data to Text File,*** and ***Cancel.*** On selection, these buttons function in a predictable manner, with the possible exception of ***Print Graph to Metafile***: on first invocation within a session, this button will offer the options of printing in a low-resolution (raster) graphics mode or a high-resolution (vector) graphics mode. Use the high-resolution mode except under highly unusual circumstances, and never when printing to a PostScript printer.

3.6 PASPlus and PostScript

PostScript is a graphics language (its developers refer to it as a "page description language") which is optimized for high-quality printed output. It has become a *de facto* standard for the production of quality graphics in technical and non-technical disciplines alike.

Although the SGP's printer graphics subsystem can produce output on a variety of printers, PostScript devices are the printers of choice, and are recommended over all others. A pair of utilities has been written to facilitate the production of PostScript prints of SGP charts, enabling a convenient specification of color model (black & white, gray scale, and full color), number of copies desired, etc. These utilities are available on request.

3.7 The PASPlus Data Types

The following is an exhaustive list of the SGP display types, ordered by instrument. Display screens are given in boldface text, to distinguish them from instrument types and menu group designations. The character "A" in the left-hand margin indicates that this data may also be tabulated to an ASCII file for export to other packages.

Housekpg (Housekeeping Parameters)

Calorimeter Temperatures CAL1, CAL2, CAL3, plus the ESA Temperature
QCM Frequencies & Temperatures: DP Temp, DP Freq, PS Temp, PS Freq
Array RTDs from TLM mf 9 (array temperatures)

Emitter

Voltage, Current Analogs: Grid Current, Heater, Bias, Emission, LV, A/B Monitors
Grid Current, HV Bias Voltage

I—V (Research Array I-V Curves)

A **I-V Curves**
Bias Voltage
Isc, Voc, Pmax, RTD, Fill Factor

Dosimeter

FLUX or Delta DOSE for all Domes...
LoLet Flux (.05 - 1 MeV), all Domes (D1A, D1B, D2A, D2B, D3, D4)
HiLetA Flux (1 - 3 MeV), all Domes
HiLetB Flux (3 - 10 MeV), all Domes
Hilet Flux (1 - 10 MeV), all Domes
VHiLet Flux (10+ MeV), all Domes
Total Flux (.05 - 10+ MeV), all Domes
LoLet Dose (.05 - 1 MeV), all Domes
HiLet Dose (1 - 10 MeV), all Domes
FLUX & Delta DOSE for Individual Domes...
D1A Flux & DeltaDose: .029 g/cm^2 moderator (small area)
D1B Flux & DeltaDose: .029 g/cm^2 moderator (large area)
D2A Flux & DeltaDose: .550 g/cm^2 moderator (small area)
D2B Flux & DeltaDose: .550g/cm^2 moderator (large area)
D3 Flux & DeltaDose: 1.55 g/cm^2 moderator
D4 Flux & DeltaDose: 3.05g/cm^2 moderator
DOSE & Delta DOSE for all Domes...
LoLet Dose & DeltaDose (.05 - 1 MeV)
HiLet Dose & DeltaDose (1 - 10 MeV)
FLUX or Delta DOSE for all Domes, with SEUs...
LoLet Flux (.05 - 1 MeV), all Domes, with SEUs
HiLetA Flux (1 - 3 MeV), all Domes, with SEUs
HiLetB Flux (3 - 10 MeV), all Domes, with SEUs
Hilet Flux (1 - 10 MeV), all Domes, with SEUs
VHiLet Flux (10+ MeV), all Domes, with SEUs
Total Flux (.05 - 10+ MeV), all Domes, with SEUs
LoLet Dose (.05 - 1 MeV), all Domes, with SEUs
HiLet Dose (1 - 10 MeV), all Domes, with SEUs
LoLet DeltaDose (.05 - 1 MeV), with SEUs
HiLet DeltaDose (1 - 10 MeV), with SEUs

ESA (Electrostatic Analyzer)

Electron & Ion Spectra

TPM (Transient Pulse Monitor)

Pulse Counts, Threshold, & Bias
All Parameters for a Single Sensor...
Sensor 0: +- Amplitude, +- Derivative, Integral Counts, & Bias
Sensor 1: +- Amplitude, +- Derivative, Integral Counts, & Bias

Sensor 3: +- Amplitude, +- Derivative, Integral Counts, & Bias
Sensor 4: +- Amplitude, +- Derivative, Integral Counts, & Bias
Sensor 5: +- Amplitude, +- Derivative, Integral Counts, & Bias

One Parameter for All Sensors...

Positive Amplitude for all Sensors, & Bias
Negative Amplitude for all Sensors, & Bias
Positive Derivative for all Sensors, & Bias
Negative Derivative for all Sensors, & Bias
Integral for all Sensors, & Bias

All Parameters (Counts) & Bias

Leakage (Leakage Current)

A **Grid Current, Leakage Current, Biased Array Number, & Bias Voltage**

Langmuir (Langmuir Probe)

Plasma Density and Temperature, Probe Temperature, & Sensor Potential

Attitude (Ephemeris & Attitude)

A **Vehicle Altitude, Attack Angle (RAM angle), and Solar Offset**
Vehicle Altitude, Geocentric Latitude, and Local Time
A **L Shell, Magnetic Latitude, & Magnetic Local Time**
A **Sun Sensor Angles (PASP & Spacecraft)**
Spacecraft Power Array #1 Current, Temperature, and Voltage
Spacecraft Power Array #2 Current, Temperature, and Voltage
Spacecraft Power Array #3 Current, Temperature, and Voltage
Spacecraft Power Array Current, Temperature, and Voltage: All 3 Arrays