Venus Express ASPERA-4 ELS PAD Data

Software Interface Specification

for

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PI: Shaousi Xu, University of California at Berkeley, Berkeley, CA

Prepared by:

Rudy A. Frahm, Southwest Research Institute, San Antonio, TX

Reviewed by:

Sandee J. Jeffers, Southwest Research Institute, San Antonio, TX

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Document Review

This document and the archive it describes were submitted to PDS April 24, 2023. A peer review was conducted supervised by PDS beginning on 7 August 2023 through 22 September 2023 with a compilation of lies from the peer review on 11 October 2023. All liens were addressed and this document was resubmitted for acceptance into the PDS archive.

For this NASA Grant (80NSSC21K015) the PI is Shaousi Xu (University of California at Berkeley). The PDS4 Data Production generator is Rudy A. Frahm, ELS instrument scientist and ELS Pitch Angle Data (PAD) creator (Southwest Research Institute at San Antonio). Sandee J. Jeffers is the chief reviewer and ELS software engineer (Southwest Research Institute at San Antonio). All have approved this document.

Joe Mafi, PDS Planetary Plasma Interactions (PPI) Node Representative, has reviewed and approved this document December 29, 2023.

Document Change History

Revision	Revision Date	Section(s)	Remarks
1.0	29 December 2023	All	Initial Version

Table of Contents

1.0 Introduction

The Electron Spectrometer (ELS) instrument is a part of the Analyzer of Space Plasmas and Energetic Atoms (ASPERA-4) experiment [6] on the European Space Agency’s (ESA's) Venus Express (VEx) mission. The ELS instrument measured the *in situ* electron plasma in the Venus environment and the solar wind from April 2006 through 2014. Due to the complexity of generating the Pitch Angle Distribution (PAD), which uses measurements from the VEx magnetometer (MAG) [7] and ELS, generation of the PAD could not be accomplished during the mission.

1.1 Overview of the Venus Express Mission

The VEx spacecraft orbited Venus sampling data from a polar orbit with a periapsis which varied between 250 km and 300 km, and an apoapsis of about 66,000 km. The VEx orbit was polar with pericenter about the north pole of Venus and the apocenter about the south pole of Venus. The VEx orbit precessed, taking 120 days to precess 180° about its semimajor axis.

The VEx mission was constructed from flight spare instrumentation left over from the ESA Mars Express (MEx) mission. In the USA, NASA was a participant in the ESA MEx program. Through the first Discovery program Mission of Opportunity (MO), NASA supported Southwest Research Institute (SwRI) to participate in the Analyzer of Space Plasmas and Energetic Atoms (ASPERA-3) experiment on the MEx program. This included instrument construction (different components of the ASPERA-3 contingent as well as the entire ELS instrument), archiving of all MEx ASPERA-3 data in the ESA PSA/NASA PDS, and to participate in the science investigation of the ASPERA-3 experiment at Mars. SwRI constructed a flight and a flight spare unit of ASPERA-3 ELS which was supplied to the PI institution, Swedish Institute of Space Physics (IRF), for the ASPERA-3 experiment on MEx. After the successful launch of the MEx spacecraft in 2003 from Baikonur by a Russian Soyuz rocket, ESA decided to conduct a similar mission to Venus. ESA decided that rather than build new instrumentation for the VEx mission, it would modify the left over MEx spare instrumentation for the higher radiation environment expected at Venus. At this time, the ESA member countries all supported the VEx mission; however, NASA opted to only allow the flight spare instrumentation from MEx to be included as part of the VEx mission without support from the USA. Thus, the unused flight spare ELS unit was modified in Europe for the extra radiation shielding needed for the Venus environment and this became the ASPERA-4 ELS [6] unit which was flown on VEx.

As a consequence of the NASA decision, data from the VEx mission was archived by the Europeans in the European Planetary Science Archive (PSA) without guidance from NASA or SwRI. Data from the VEx mission is now all publicly available. For VEx ELS, this data is archived at https://www.cosmos.esa.int/web/psa/venus-express. The PSA ELS data consists of the telemetered ELS science packets in ASCII form, and the calibration factors needed to construct the electron spectrum in geophysical units.

1.1.1 Overview on the Electron Spectrometer on Venus Express

ELS is a spherically symmetric top hat spectrometer which weighs 300 g and operates on 650 milliwatts of power. The shape of ELS is roughly cylindrical with a height of 41 mm and a diameter of 111 mm. ELS measures electron plasma through an inlet opening in the side of the detector from an azimuth of 360°. This azimuth is segmented into 16 sectors, each 22.5° wide (numbered 0-15). The elevation acceptance angle is ± 2°.

The plasma passes through the collimator region, where the plasma from angles beyond the acceptance range is removed. The collimator also traps stray light (particularly UV) with its 5 baffle design. Plasma then enters the top hat region where spherical deflection plates separate out the electron plasma of specific energy. Five light traps at the entrance to the deflection region also trap light, preventing it from generating bounces which generate secondary electrons. The selected electrons which pass through the deflection plates are then focused on to a microchannel plate (MCP) sensor. The electron signal is multiplied by the MCP and passed to an anode. Electrons are collected on the anode, and amplified by a charge sensitive amplifier, and then counted.

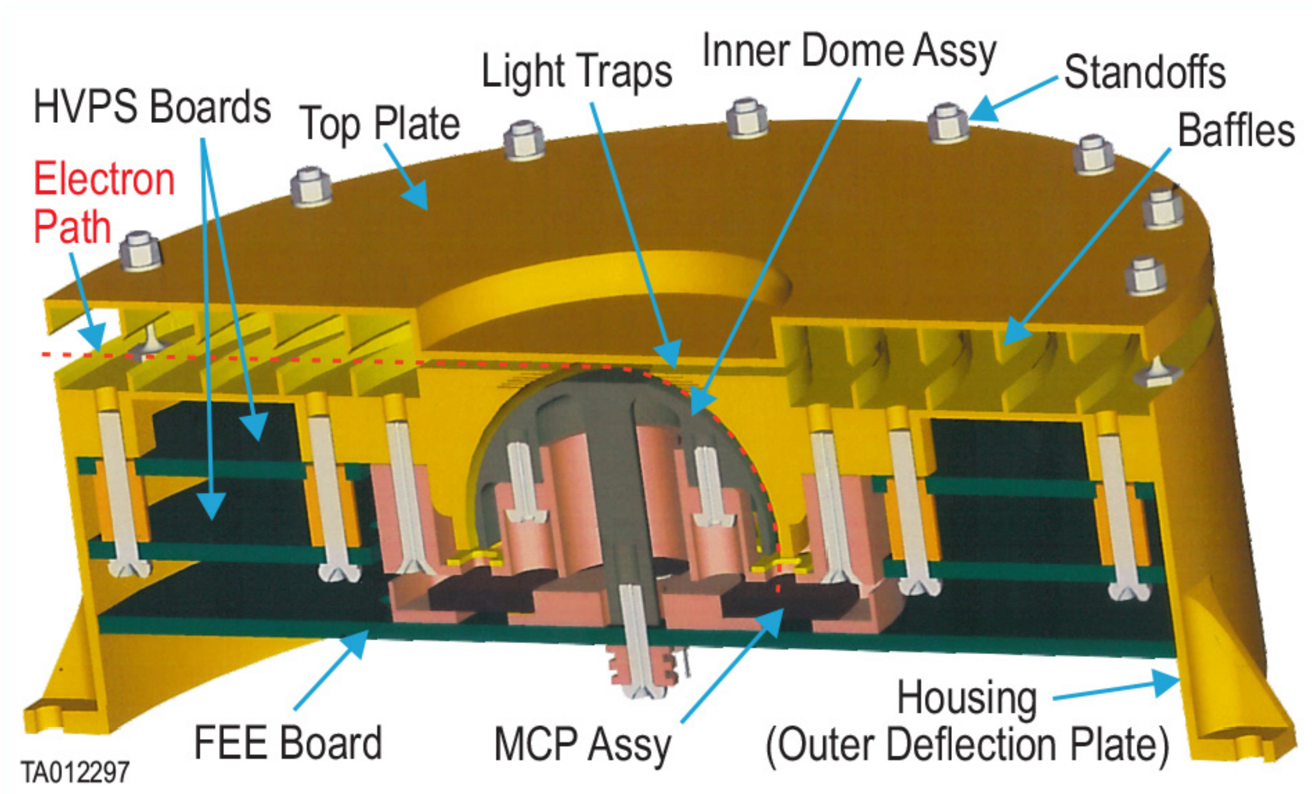

Figure 1. Cross-section of the VEx ELS instrument showing the internal geometry. Plasma enters through the sides of the housing and travels between the collimator baffles which refine the plasma into a beam. A high voltage power supply (HVPS) generates an electric field between the top plate/outer plate and the inner dome which selects electrons. Energy selection occurs further as the electrons travel between the inner and outer domes, eventually striking the MCP assembly where they are magnified and turned into an electronic signal by the front-end electronics (FEE). Contamination protection by ultraviolet light (UV) is shown as baffles in the collimator and light traps at the entrance to the deflection domes.

The ELS sensor had several operational modes, only three classes were used on ASPERA-4. The three classes are described by the energy sweep: 128-step, 32-step, and 1-step. The 1-step sweep monitors one energy level continually at a rate of 32 measurements each second. The 32-step sweep measures a 31-point energy spectrum (with one additional step for flyback) from about 9 eV to about

200 eV every second. The 128-step sweep measures a 127-point energy spectrum (with one additional step for flyback) from about 0.6 eV to about 30 keV every 4 seconds.

A cut away view of the VEx ELS sensor is shown in Figure 1. The ELS data stored in the PSA public archive is raw data in units of counts/sample from the ELS spectrometer on the VEx spacecraft. This raw data contains the environment signal from the Venus plasma and the internal signals generated in the instrument. There is no discussion or description of signals from penetrating radiation, or how to recover the plasma signal from the ELS data in the PSA archive.

1.1.2 Overview of ELS Background

Throughout its lifetime, the ELS detector experienced an energy independent background. The ELS energy independent background signal is the portion of the raw data which is internally generated within the instrument and does not reflect the Venus plasma. The ELS instrument experienced several different types of contamination which altered the electron spectrum from Venus. These signals include external fluxes due to penetrating radiation caused by geophysical events like Solar Energetic Particles (SEPs), cosmic rays that penetrate through the instrument, as well as internal effects due to thermal noise generated within the MCP, outgassing of the MCP, and electronic noise. All these sources are **independent of the energy of an incoming electron** (energy independent) from the Venus environment, but these sources are **time dependent**.

The VEx ELS energy independent background was generated on a 5-minute cadence and archived independently at NASA PDS PPI under https://doi.org/10.17189/5ngj-s536. Procedures were followed in the documentation [9] to generate three other background data products: at the 4-second resolution of the instrument, a 1-minute average, and a 25-minute average. Each of these four background products are examined to compare their intensity with their duration to dynamically remove the appropriate amount of background data from the ELS measurements.

1.1.3 Overview of the Venus Express Magnetometer

VEx was not a magnetically clean spacecraft. As such, VEx used a two triaxial fluxgate sensor system to remove spacecraft generated magnetic fields from the magnetic field generated by the Venus interaction with the interplanetary magnetic field (IMF) and solar wind [8]. Both sensors were mounted on a 1 m boom, with the inboard sensor mounted within 10 cm of the spacecraft and the outboard sensor mounted at the tip of the boom, generating the VEx magnetometer (MAG) experiment. VEx MAG data is stored in the ESA PSA at: https://www.cosmos.esa.int/web/psa/venus-express.

The VEx MAG measured data at a 1 Hz rate for most of the orbit, but also sampled data at a high rate of 32 Hz about pericenter and 128 Hz during burst mode operations. The 32 and 128 Hz rates were found to be unstable, and thus, were not archived. In addition to the 1 Hz rate, the magnetometer also generated measurements at an independent 4 Hz rate. The 1 Hz and 4 Hz measured data are not synchronized and the 4 Hz data can not be derived from the 1 Hz data. Both 1 Hz and 4 Hz MAG data are returned from the VEx spacecraft and are archived in the ESA PSA. There was no attempt to synchronize the magnetometer with operation of the plasma instruments on VEx, so both resolution modes are independently collected data. Thus, MAG data processing uses only the 1 Hz and/or 4 Hz data.

1.2 The Purpose and Scope of this Document

The purpose and goal of this document is to provide the users of the Venus Express Electron Spectrometer (VEx ELS) data with detailed descriptions of the ELS PAD data products. These data products are meant to aid in the science analysis of the ELS data by orientating the ELS data relative to the magnetic field. This document is intended for those wishing to read and understand the format and content of the VEx ELS PDS data product archive collection. This typically includes scientists, PDS staff, data analysts, and software engineers.

1.3 Applicable Documents

[1] Planetary Data System Standards Reference, JPL D-7669, Part 2, Version 1.19.0, DOI: 10.17189/02p7-vj89, October 1, 2022.

[2] The PDS4 Data Provider's Handbook: Guide to Archiving Planetary Data Using the PDS4 Standard, Version 1.19.0, DOI: 10.17189/d466-nk02, October 1, 2022.

[3] PDS4 Concepts, Data Design Working Group, Version 1.19.0, DOI: 10.17189/6h0f-ng87, October 1, 2022.

[4] PDS4 Data Dictionary Abridged, Version 1.19.0.0, Generated from Information Model Version 1.19.0.0 on Monday September 19, 2022 at 10:35:38 EDT 2022.

[5] PDS4 Information Model Specification, PDS4 Information Model Specification Team, Version 1.19.0.0, Monday, September 19, 2022 at 10:35:38 EDT.

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[9] Frahm, R. A., Venus Express ASPERA-4 ELS Background Data Description Document, NASA Planetary Data System Planetary Plasma Interactions Node, https://doi.org/10.17189/y84k-dj44, 2021.

[10] Fatemi, S., NPI and NPD field of view obstructions on Mars and Venus Express, INSTITUTET FÖR RYMDFYSIK, IRF Technical Report 050, ISSN 0284-1738, 2009.

[11] Xu, S., R. A. Frahm, Y. Ma, J. G. Luhmann, and D. L. Mitchell, Magnetic topology at Venus: New insights into the Venus plasma environment. Geophysical Research Letters, 48, e2021GL095545. https://doi.org/10.1029/2021GL095545, 2021.

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1.4 Document Content Overview

The following is an overview of what this document contains:

Section 2 describes the relationships with other interfaces as they relate to the data generation and archiving of the Venus Express ELS PAD data.

Section 3 describes the roles and responsibilities of the cognizant personnel in generating, delivering, and archiving of the VEx ELS PAD data.

Section 4, Data Product Characteristics and Environment, provides an overview of the data products in this archive, details the data processing flow and generation of the data products, and describes the standards used in generating the data products.

Section 5 describes the archive organization, identifiers, and naming conventions for the bundle, data collections, data products, and document collection.

Section 6 gives the details of the archive data formats.

Appendix A has a table of acronyms and abbreviations with their meanings and a list of glossary terms with their definitions.

Appendix B contains sample PDS product labels for each of data products in this archive.

2.0 Relationships with other Interfaces

The interfaces that could have an impact on the ASPERA-4 ELS PAD data product generation, packaging, distribution, and documentation include:

SPICE Data file set for Venus Express: These data are derived for the Venus Express spacecraft and stored at the PDS Navigation and Ancillary Information Support Node (NAIF). They are used to determine the location of the solar array and offset of the ASPERA-4 scanner relative to the ELS field of view. This relationship determines which ELS sectors are blocked by the spacecraft or its appendages. Any changes to the kernels could affect selection of unblocked ELS sectors, which could impact the ASPERA-4 ELS PAD data products and collections. Data produced before 1 February 2015 was used for processing.

PSA MAG Data: These data were produced by the Venus Express Magnetometer and represent both 1-second and 4-second data products which have been corrected to remove the effects of spacecraft magnetic fields. Any changes to the MAG data files could affect the generation of the PAD data, which could impact the ASPERA-4 ELS PAD data products and collections. Version 1 data was used for processing.

ASPERA-4 IDFS (Instrument Data File Set) ELS Data: These data are produced from telemetry and are used as the basis for determining the PAD data. If these data are reprocessed for any reason, there could be a direct impact on the generation of the ASPERA-4 ELS PAD data products and collections. Data produced before 1 January 2019 was used for processing.

ASPERA-4 IDFS MAG Data: These data are produced from the PSA MAG data and are used as the basis for orienting the PAD data. If these data are reprocessed for any reason, there could be a direct impact on the generation of the ASPERA-4 ELS PAD data products and collections. Data produced before 1 January 2019 was used for processing.

ASPERA-4 IDFS ELS Background Data: These data are produced from telemetry and are used to correct the ELS science data for an energy independent background. If these data are reprocessed for any reason, there could be a direct impact on the generation of the ASPERA-4 ELS PAD data products and collections. Data produced before 1 January 2019 was used for processing.

getdata PAD Generation Software: This software reads the IDFS ELS data, IDFS MAG data, IDFS background data, and the results of the SPICE data analysis to determine the PAD distribution. This software generates the ASPERA-4 IDFS PAD. Modifications of this software could directly impact the generation of the ASPERA-4 ELS PAD data products and collections. October 20, 2021 version was used to generate files in this archive.

CreateASCIIDump CSV HEAD and DATA Generation Software: This software reads the ASPERA-4 IDFS ELS PAD data products and generates the HEAD (TXT) and DATA (CSV) files which are PDS4-compliant for submission to PDS. Modifications of this software could directly impact the generation of the ASPERA-4 ELS PAD data products and collections. April 13, 2023 version was used to generate files in this archive.

CreatXMLLabel XML HEAD and DATA Label Generation Software: This software reads the HEAD and DATA files to generate PDS4-compliant XML label files for archive into the PDS. Any changes to this software could impact the generation of the PDS4 collection files. January 18, 2023 version was used to generate files in this archive.

The probability of these interfaces changing causing impact to the ASPERA-4 ELS PAD data products and collections is very low.

3.0 Roles and Responsibilities

The grant PI for this program is Ms. Shaousi Xu from the University of California at Berkeley (SSW Grant 80NSSC21K0151) for which Southwest Research Institute (SwRI) received a sub-award. SwRI is responsible for the production and delivery to the PDS-PPI node of documented VEx ELS PAD data collections using PDS4 standards. In addition, SwRI interfaces with PDS-PPI to ensure PDS4-compliance of the VEx ELS PAD data archive. It is SwRI's responsibility to resolve any change requests (liens) as a result of the PDS peer review.

The specific SwRI personnel are Dr. Rudy A. Frahm (Co-I of SSW Grant 80NSSC21K0151), Ms. Sandee J. Jeffers (Data Manager), and Ms. Carrie A. Gonzalez (Software Engineer). Ms. Gonzalez is responsible for creation software that generates PDS4-compliant XML labels. Ms. Jeffers is responsible for reviews of the following: PAD generation software, all PDS4 documents, infrastructure, and the data collections and archive bundle. Dr. Frahm is responsible for generating and validating the VEx ELS PAD data in IDFS format, creation of all PDS4 documents, generation of CSV, TXT, and XML files, infrastructure, and the data collections and archive bundle. He is also responsible for validating the collections and delivery to PDS-PPI. Ms. Jeffers and Dr. Frahm are the SwRI participants of the PDS peer review and Dr. Frahm is responsible for lien resolution for PDS-PPI approval.

The PDS is the primary organization within NASA responsible for archiving planetary data, and thus, the designated point of contact for archive-related issues. PDS-PPI personnel participate in archive planning efforts to ensure that archives are planned, generated, and reviewed using PDS4 standards. PDS standards require that all archive products undergo a peer review (PR) cycle, much in the way a journal article is reviewed. The peer review is a coordinated effort between PDS-PPI and SwRI personnel, and the PDS-PPI assists SwRI with resolving any PR liens. Once SwRI delivers the data, PDS-PPI is responsible for distributing VEx ELS PAD data to the broad science community.

4.0 Data Products Characteristics and Environments

Throughout the nine-year Venus Express mission (launched in late 2005, arrived at Venus in 2006, and ended late 2014), all the VEx ELS data were automatically processed and stored at SwRI in the Instrument Data File Set (IDFS) format. The VEx ELS data have been and are used for collaborative studies; however, charged particles respond to and are organized by the magnetic field. Attempts were made to reorganize the ELS data relative to the magnetic field in order to generate a pitch angle distribution (PAD) of electrons. The results of these studies made no scientific sense until a spacecraft model could be employed which accounted for the ASPERA-4 scanner position and the position of the spacecraft solar array. This showed that early attempts at creating a PAD included ELS data from sectors which were blocked by the spacecraft and/or its solar array. Inclusion of different sectors relative to spacecraft boundaries were investigated in order to determine how much influence inclusion of data from ELS sectors near or at the edge of the spacecraft affected the PAD. It was determined that a proper PAD could be generated by including ELS data from sectors which did not contain the spacecraft, its edge, or the solar array. PAD data stored in this archive are generated from ELS sectors which include no spacecraft influence.

The pitch angle array chosen to best express the ELS sorted electron distribution data is shown in Table 1. Since it is not known *a priori* the relation between the ELS sector and the pitch angle, mapping of the ELS sector to the proper pitch angle bin must occur at each time when the data is processed. In addition, the ELS sector boundaries do not have to align with pitch angle bins. Even though ELS sectors from opposite sides of the instrument are separated by180°, they do not have to map to the same pitch angle bin. Sector pitch angle positions could be separated by half of the sector angular width, or 11.25°, which was felt best represents the smallest pitch angle resolution. Thus, 10° wide bins were chosen for the PAD.

Table 1. Definition of the Pitch Angle Scan for the PAD.

Pitch Angle Bin				
Number (Index)	Start (deg)	Center (deg)	Stop (deg)	Width (deg)
0	0	5	10	10
1	10	15	20	10
2	20	25	30	10
3	30	35	40	10
4	40	45	50	10
5	50	55	60	10
6	60	65	70	10
7	70	75	80	10
8	80	85	90	10

Pitch Angle Bin				
Number (Index)	Start (deg)	Center (deg)	Stop (deg)	Width (deg)
9	90	95	100	10
10	100	105	110	10
11	110	115	120	10
12	120	125	130	10
13	130	135	140	10
14	140	145	150	10
15	150	155	160	10
16	160	165	170	10
17	170	175	180	10

The getdata routine maps the fraction of the subdivided pixel which falls into each pitch angle bin. Normalization to 100% coverage occurs after all bins have been mapped. See section 4.2.2 Data Product Generation for a more detailed discussion on how the PAD was generated.

The following sections give an overview of the data products and describe the data processing and standards used in generating the data products.

4.1 Data Product Overview

There are two types of VEx ELS PAD data in this archive: (1) ELS PAD Mode and (2) ELS PAD Data. PAD data generation requires that ELS and MAG data exist at the same time. After VEx arrival at Venus, the MAG and ELS instruments operated sequentially. Simultaneous operation of MAG and ELS did not occur until 14 May 2006 (134) 00:54 UT. The Mode and Data products are described in the following subsections (a brief name for each column is noted in the first three lines of each data product file).

4.1.1 ELS PAD Mode

The Venus Express ELS PAD Mode file contains information which allows one to determine what files were used during the PAD processing. The ELS PAD Mode file is an ASCII text file that contains the first three lines as short column descriptors. These are the same for each Mode file and are included for the convenience of the user. They are: Start Time, End Time, Pitch Angle Range (Minimum and Maximum columns), Sweep Type, Individual Pitch Angle for Anode (16 columns, one per sector), Number of Used Sectors, Background Type Used for Anode (16 columns, one per sector), MAG Type, and Software Version. Below is a brief description of the columns:

Start Time – Time when the spectral sample begins in the format YYYY-DDDTHH:MM:SS.SSS. In the time format YYYY represents the year, DDD represents the day of year, T is the separator between the date fields and the time fields, HH is the hour of the day, MM is the minute of the hour, and SS.SSS is the seconds of the minute with the fractional part showing the milliseconds.

End Time – Time when the spectral sample ends in the format YYYY-DDDTHH:MM:SS.SSS. In the time format YYYY represents the year, DDD represents the day of year, T is the separator between the date fields and the time fields, HH is the hour of the day, MM is the minute of the hour, and SS.SSS is the seconds of the minute with the fractional part showing the milliseconds.

Pitch Angle Range – Abbreviated by PA Range, there are two columns associated: minimum (MIN) and the maximum (MAX). This is the approximate pitch angle range based on the mapping of active sectors into the pitch angle array. The units are in degrees. A value of 255 indicates the field is filled. These fields are meant to give some information about how much of the pitch angle range is covered by the PAD without having to read the data file.

Sweep Type – Abbreviated by ST TYP, represents the number of energy steps in the electron spectrum and has three values: 0, 1, 2. A value of 0 means a 127-step sweep in the electron spectrum. A value of 1 means a 31-step sweep in the electron spectrum. A value of 2 means that the instrument is sampling a constant energy 32 times each second. This field is meant to determine how many steps were in the spectrum which generated the PAD.

Individual Pitch Angle for Anode – There is one column per sector of ELS (labeled 00 to 15) with the value of 255 meaning that sector was excluded from the PAD determination. The units are in degrees. These fields tell you which ELS sectors were included in the creation of the PAD and where they fall within the pitch angle array.

Number of Used Sectors – Abbreviated by USD SEC, this field represents the number of sectors used to determine the PAD (1 to 16). A special case of 0 means that no ELS sector was used and a value of 255 means that it was filled.

Background Type Used for Anode – There is one column per sector of ELS (labeled 00 to 15) with the value of 255 meaning that sector was excluded from the PAD determination. Additional values are 0, 1, 2, 3, 4. A value of 0 means that no background was subtracted from the data. A value of 1 means that background was determined at the rate of the spectrum. A value of 2 means that a 1-minute average was used to determine background. A value of 3 means that a 5-minute average was used to determine background. A value of 4 means that a 25-minute average was used to determine background. These values are meant to show which sectors removed background and the type of background removed.

MAG Type – Values are either a 0 meaning 4-second magnetometer resolution was used, 1 meaning 1-second magnetometer resolution was used, or 2 meaning high resolution magnetometer data was used to determine the PAD. This field shows the resolution of the magnetometer used to generate the PAD.

Software Version – Abbreviated by SW VER, this field reflects the version of the software which created the data file.

For more detailed descriptions of the Mode fields, please see the ASCII text document ASCII_ELS_PAD_Fields.txt.

4.1.2 ELS PAD Data

The Venus Express ELS PAD Data file contains the PAD data. The ELS PAD Data file is an ASCII CSV file that contains the first three lines as short column descriptors. These are the same for each Data file and are included for the convenience of the user. They are: Start Time, End Time, Scan Index, Center Energy, Velocity, and ELS PAD Distribution Function Data. Below is a brief description of the columns:

Start Time – Time when the spectral sample begins in the format YYYY-DDDTHH:MM:SS.SSS. In the time format YYYY represents the year, DDD represents the day of year, T is the separator between the date fields and the time fields, HH is the hour of the day, MM is the minute of the hour, and SS.SSS is the seconds of the minute with the fractional part showing the milliseconds.

End Time – Time when the spectral sample ends in the format YYYY-DDDTHH:MM:SS.SSS. In the time format YYYY represents the year, DDD represents the day of year, T is the separator between the date fields and the time fields, HH is the hour of the day, MM is the minute of the hour, and SS.SSS is the seconds of the minute with the fractional part showing the milliseconds.

Scan Index – Abbreviated by SCN INX, is an integer index that begins at 0 and sequentially increments until the number of steps in the sweep are counted (see Sweep Type in the Mode file). ELS is a decay sweep, so small index numbers refer to larger energy values.

Center Energy – This is the value of the center energy which is represented by the Scan Index. The unit is in eV. The value of the Center Energy is not the same for different scans and is dependent on the instrument configuration.

Velocity – This field represents the Velocity of an electron with the value of the Center Energy field. This field changes with the value of the Center Energy represented by the Scan Index. Units are given in meters/sec.

ELS PAD Distribution Function Data – There are 18 columns, each representing a pitch angle bin with width of 10 degrees, representing pitch angle sorted data. Bins are marked with their center pitch angle. ELS PAD Distribution Function Data units are in $sec^3/m^6/sr$. A value of -3.400e+38 is used to represent a filled value. Negative values represent fluxes which are less than the amount of background predicted and are statistical in nature. They should be kept until the final processed product is determined so that the statistical nature of the data is maintained.

For more detailed descriptions of the Data fields, please see the ASCII text document ASCII_ELS_PAD_Fields.txt.

4.1.2.1 PAD Energy Steps

The energy steps of each ELS sector differ due to applying their unique calibration. The energy steps for each of these sectors is mapped to a standard energy grid and the data value adjusted accordingly to map to a standard energy grid. The standard energy grid is a function of the active sectors. Energy steps are compared for those sectors which are not blocked. Average ranges are determined using only active sectors and the number of energies in a sweep, then a new scale is determined by logarithmic spacing. Mapping of the data for each sector is determined proportionally. Thus, the center energy for each step could differ if different sectors are included in the PAD.

4.1.2.2 PAD Data Units

The ELS PAD Data is archived in Distribution Function units of $sec^3/m^6/sr$. For a gyrotropic electron distribution, apply the Gyrotropic Weight from Table 2 to the appropriate pitch angle bin to integrate across the angular area of each bin. The angular area is in steradian units represented by the gyrotropic weight column. So the integrated electron distribution function in sec^3/m^6 is just the distribution obtained from the data file multiplied by the appropriate gyrotropic weight from Table 2.

Table 2. The angular weights for each pitch angle bin. The gyrotropic weight is in units of steradians (sr) whereas the theta and phi weights are in units of radians (rad).

Pitch Angle Bin (deg)			Cosine of Angle			Theta Weight (rad)	Phi Weight (rad)	Gyrotropic Weight (sr)
Start	Center	Stop	Start	Center	Stop			
0	5	10	1.000000	0.992404	0.984808	0.015192	6.283185	0.095456
10	15	20	0.984808	0.962250	0.939693	0.045115	6.283185	0.283467
20	25	30	0.939693	0.902859	0.866025	0.073667	6.283185	0.462865
30	35	40	0.866025	0.816035	0.766044	0.099981	6.283185	0.638199
40	45	50	0.766044	0.704416	0.642788	0.123257	6.283185	0.774446
50	55	60	0.642788	0.571394	0.500000	0.142788	6.283185	0.897161
60	65	70	0.500000	0.421010	0.342020	0.157980	6.283185	0.992617
70	75	80	0.342020	0.257834	0.173648	0.168372	6.283185	1.057912
80	85	90	0.173648	0.086824	0.000000	0.173648	6.283185	1.091064
90	95	100	0.000000	-0.086824	-0.173648	0.173648	6.283185	1.091064
100	105	110	-0.173648	-0.257834	-0.342020	0.168372	6.283185	1.057912
110	115	120	-0.342020	-0.421010	-0.500000	0.157980	6.283185	0.992617
120	125	130	-0.500000	-0.571394	-0.642788	0.142788	6.283185	0.897161
130	135	140	-0.642788	-0.704416	-0.766044	0.123257	6.283185	0.774446
140	145	150	-0.766044	-0.816035	-0.866025	0.099981	6.283185	0.638199
150	155	160	-0.866025	-0.902859	-0.939693	0.073667	6.283185	0.462865
160	165	170	-0.939693	-0.962250	-0.984808	0.045115	6.283185	0.283467
170	175	180	-0.984808	-0.992404	-1.000000	0.015192	6.283185	0.095456

4.1.3 Browse PAD

In the Browse collection there are two types of PNG image files. One shows the Data and the other shows the Mode. These images were created using an image tool which collects data and registers them in time sequence. Since ELS has a duty cycle where every eighth spectrum is missing, it could create a blank as the last value placed into a pixel, showing on the image. If the data shown on the spectrum is below the lowest color represented on the color bar, the data is drawn in white, giving the appearance that no data exists at that location. This is not necessarily true. One should interrogate the data to determine the existence of data.

These browse data products are not intended for scientific research. They are meant to aid the user in locating data of interest. For detailed analysis, the user should interrogate the data files themselves.

The browse images do not cover the entire time range of the data. They are meant to cover only the region near the planet. Images were not generated at times when no PAD data was available near the planet. Image files may span across data files. Thus, the images do not correspond in a 1-for-1 fashion with the data files.

4.1.3.1 Browse Data Images

A sample Data image is shown in Figure 2 and consist of three panels. The data from the VEx magnetometer in 1-second and 4-second resolutions in the top panel. Magnetometer components are drawn against the left axis (Bx, By, Bz in VSO coordinates) and magnitudes are drawn against the right axis. VEx MAG data is archived in the ESA PSA at: https://www.cosmos.esa.int/web/psa/venus-express and is not included within this PAD archive. Without the magnetometer data, no PAD can be generated. Thus, gaps in the magnetometer data are reflected in the PAD data.

The line colors are meant to draw attention to whether 1-second resolution magnetometer data is present, with primary colors used for the 1-second data and pastel colors used for the 4-second data. PAD creation prioritizes the use of the 1-second magnetometer data above the 4-second data. Thus, if primary colors are observed, the PAD data was generated with 1-second magnetometer resolution, but if pastel colors are observer, the PAD was generated with 4-second resolution magnetometer data. In large time images such as in Figure 2, the 1-second resolution magnetometer data will dominate over the 4-second resolution data.

The center panel shows the approximate pitch angle range of the PAD. The approximate pitch angle range is determined at spectral resolution (4-second shown in Figure 2) from the maximum and minimum of the ELS sectors used to generate the PAD. The used sectors do not have to form a continuous pitch angle distribution. Gaps in the pitch angle distribution can occur when sectors are blocked.

The bottom panel shows the energy-time spectrogram in terms of differential energy flux (units of ergs/[cm^2 s sr eV]) for the 90°-100° pitch angle electrons. Gaps in the data which are traced up the image can be seen to be due to missing magnetometer data. Other gaps could be due to sector blockage by the spacecraft or duty cycle affects. Overlaid on top is the spacecraft altitude in km drawn against the right vertical axis and at the bottom are noted values of VEx orbit parameters: Planetodetic Latitude (PdLat) in degrees, Planetodetic Longitude (PdLon) in degrees, the VSO X, Y, and Z positions in km, and the Solar Zenith Angle (SZA) in degrees. These values were generated for the VEx SPICE kernels located at the NAIF PDS node https://naif.jpl.nasa.gov/pub/naif/VEX/kernels/ using the SPICE software tookkit located at https://naif.jpl.nasa.gov/pub/naif/toolkit/.

As an aid to the reader of this document, above the third panel in Figure 2, are markings for the major regions crossed: Solar wind, Magnetosheath, and Ionosphere (Iono.).

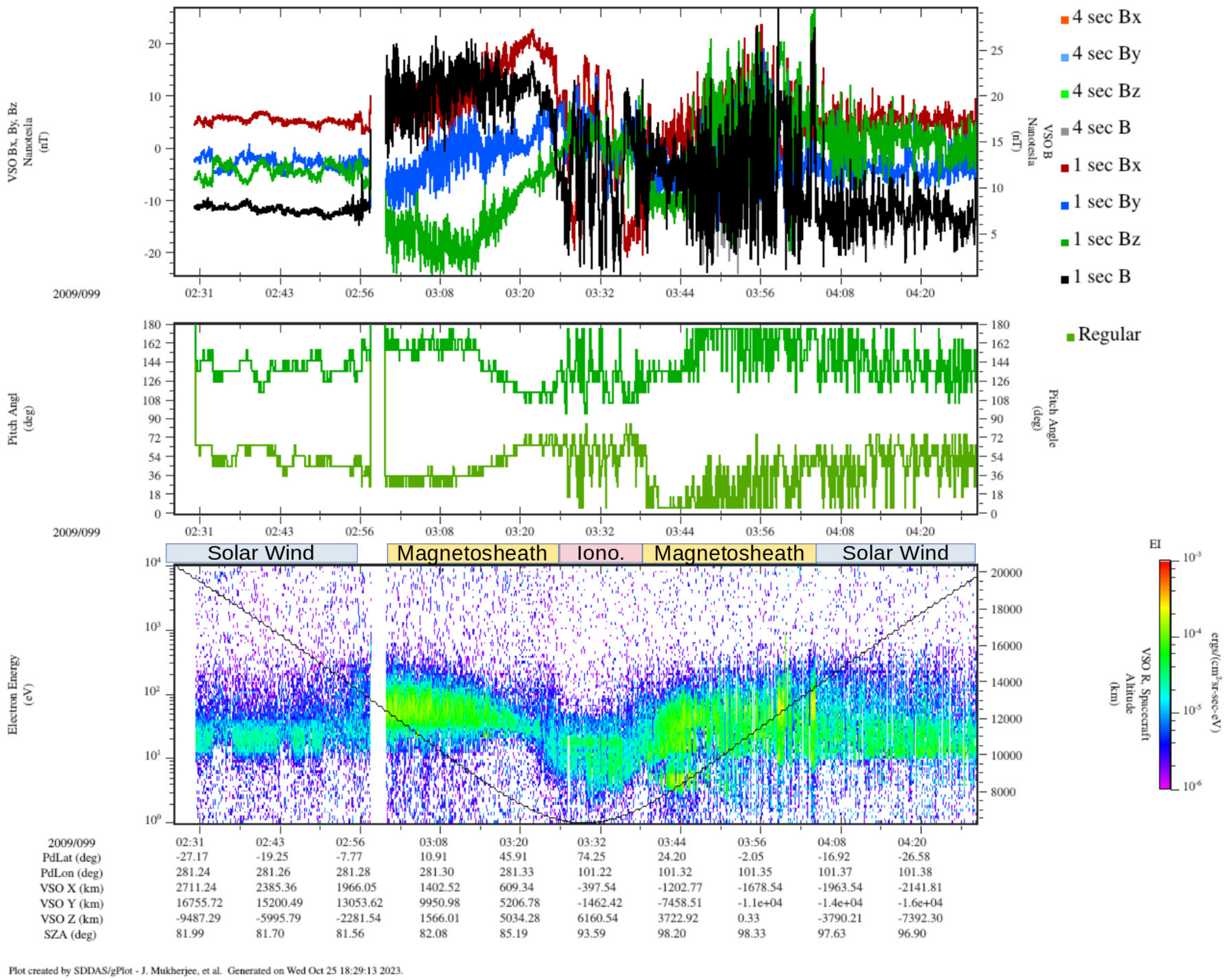

Figure 2. ASPERA-4 ELS PAD Data from 2009 (099) from 02:28:09 UT to 04:29:10 UT. Shown are three panels. The top panel shows the VEx magnetometer data at 1-second and 4-second resolution. Components are marked with the line color on the right. The second panel shows the approximate pitch angle range of the PAD data. The bottom panel shows the energy-time spectrogram of the differential energy flux for the 90°-100° pitch angle electrons.

4.1.3.2 Browse Mode Images

Mode images supply information about how the PAD was generated. Figure 3 shows an example of the mode image which corresponds to the data image shown in Figure 2. There are four panels shown in Figure 3. In the upper left, a line plot describes the number of sectors used in generating the PAD and how that can change with time. This is mainly due to rotation of the ASPERA-4 scanner coupled with the movement of the solar array. This can also be seen in the lower left panel as those ELS sectors which view the spacecraft or the solar array are blocked from observing the space environment and are not included in the PAD determination. Locations where sectors are not included for other reasons are also blocked out. For example, the red lines over the entire range of ELS are seen in the data plot to be caused by missing magnetometer data, even though the upper left panel indicates there were unblocked sectors.

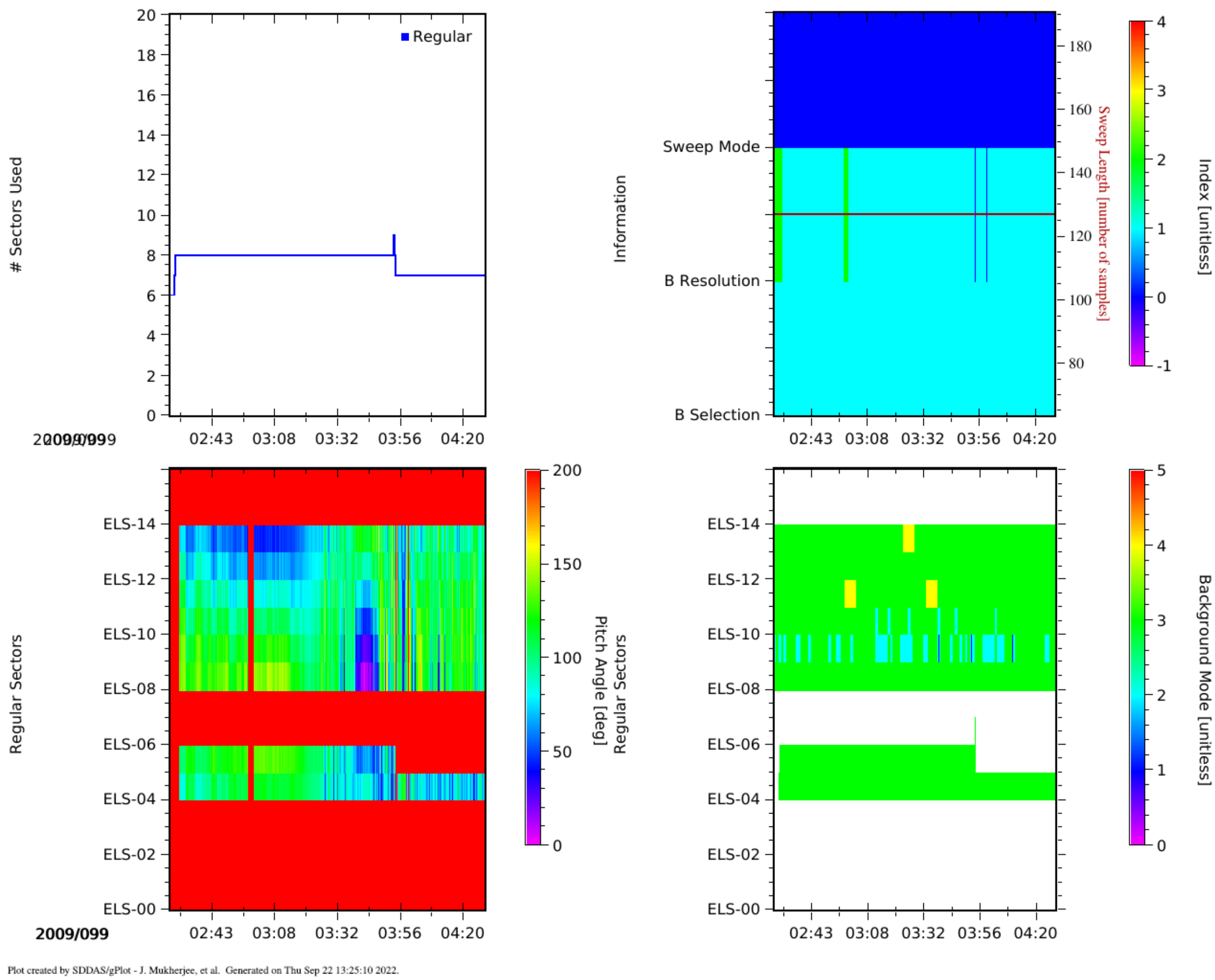

Figure 3. ASPERA-4 ELS PAD Data from 2009 (099) from 02:28:09 UT to 04:29:10 UT. The upper left panel shows a timeline of how many sectors were used in generating the PAD. The lower left panel shows how the sectors vary in time, which sectors were used to generate the PAD, and for the used sectors, their average pitch angle. The upper right panel indicates what B resolution dominates in the PAD determination, the time resolution of the magnetic field actually used in determining the PAD, and the mode the ELS sweep was in when the PAD was generated on the left, while the length of the energy sweep is shown on the right axis. The lower right image shows what type of background was removed from the ELS sector.

Data at the upper right panel shows which type of magnetic field measurement is set to dominate (lower left axis). In this case, the 1-second resolution magnetometer is set at the highest priority (cyan value of 1). Different measurement resolutions can be set to dominate; however, this can be overridden during PAD processing depending on the availability and quality of the magnetometer data. This information is shown by the center left axis, which drops into using the 4-second resolution (green) and no magnetometer data (blue) at times. The sweep mode is shown to take 4-second to generate an energy sweep by the upper left axis, and the right axis indicates that there are 127 energy steps in the sweep.

The image on the lower right indicates what type of background was removed from the ELS data. The amount of removed background is sector dependent. Areas where no background data is removed is shown in white where different resolutions of background removal is indicated by the color. Blue indicates the most noise in a sector and is the most frequent being at the spectral resolution, whereas cyan indicates a 1-minute average background was removed, green a 5-minute average background was removed, and yellow indicates that a 25-minute average background was removed. The larger the average typically means the lower the background and the quieter the sector.`

4.1.4 Miscellaneous PAD

The amount of blockage that each sector of ELS sees is a function of the rotation angle of the ASPERA-4 scanner and the rotation angle of the -Y axis solar array of the VEx spacecraft. These blockage factors are not necessary when using the PAD data; however, they are used during the construction of the PAD. If it is desired to reconstruct the PAD using the same or different pitch angle bins, the files under the miscellaneous PAD collection should be used to determine the amount of blockage experienced by each ELS sector.

There are two ASCII files in the miscellaneous PAD collection: one contains the documentation for the blockage tables while the other contains the blockage tables.

4.1.4.1 Blockage Documentation

The documentation file ASPERA4Scanner_NYSA_Blockage.txt describes the structure and use of the blockage tables in the miscellaneous PAD collection. The document is written in ASCII text. The document file explains how to generate the ASPERA-4 scanner angle and the -Y solar array angle, which are key to finding the appropriate blockage factors within the table file. The document also explains where to find data in the massive table list.

4.1.4.2 Blockage Tables

The blockage tables are contained within a separate ASCII file in the miscellaneous PAD collection. There are two sections to this file. The first section contains 52 lines of content information before the second section where the tables begin. In this file, comment lines begin with the pound, or number, character (“#”). In the table section, there are 361 tables representing 1° increments of the -Y solar array offset angle, from 0° to 360°. Each table has three header lines where the first line contains the -Y solar array offset angle after the leading pound sign. The -Y solar array offset angle is in units of deg. The second and third header lines are column information.

After the header lines of a table, there are 181 lines containing 17 columns. Each line represents the ASPERA scanner angle offset in 1° increments ranging from 0° to 180°. The first column is the ASPERA-4 scanner offset angle in units of deg. The next 16 columns are the percent of blockage for each ELS sector. A 0 means that the sector is viewing open space and a 100 means that all of the sector (100% of it) is viewing the spacecraft. A number less than 100 means that the sector partly views the spacecraft. When viewing the spacecraft, the sector is viewing electrons which have interacted with the spacecraft surface and are not pristine.

4.2 Data Processing

The ELS PAD data is a derived data product. Inputs are (1) IDFS ELS science data files separated for High and Low range power (the ELS science data is archived in CSV format at https://www.cosmos.esa.int/web/psa/venus-express), (2) IDFS magnetometer 1- and 4-second science data products (archived in ASCII format at https://www.cosmos.esa.int/web/psa/venus-express), (3) IDFS ELS background data determined for 4-second, 1-minute, 5-minute, and 25-minute resolution following the procedure described in [9] (the 5-minute averaged background data is archived in CSV format at https://pds-ppi.igpp.ucla.edu/search/view/?f=yes&id=pds://PPI/vex-aspera4-els and https://doi.org/10.17189/w6en-f049), (4) SPICE navigation data for the VEx spacecraft archived at https://naif.jpl.nasa.gov/pub/naif/pds/data/vex-e_v-spice-6-v2.0/vexsp_2000/, and (5) VEx spacecraft blockage data file determined from [10] and the results may be found in the miscellaneous_pad collection of this archive.

4.2.1 Data Processing Levels

Data processing levels in this document refer to PDS4 processing levels. Table 3 provides a description of the data processing levels along with the equivalent designations used in the PDS3 and NASA systems. The VEx ELS products described in this document include derived data.

4.2.2 Data Product Generation

Throughout the nine-year Venus Express mission (launched in late 2005, arrived at Venus in 2006, and ended late 2014), all VEx ELS data were automatically processed and stored at SwRI in the Instrument Data File Set (IDFS) format. Periodically, the VEx MAG team would produce a 4-second data set which was converted to IDFS format and stored at SwRI. Upon request, the VEx MAG team furnished 1-second magnetometer data and rarely, 128 samples/sec data to SwRI for different studies. SwRI converted this data into IDFS format for use with ELS data.

At the end of the VEx mission, the VEx MAG team decided to archive their holdings of the 1-second data product. SwRI converted the 1-second MAG data into IDFS, compared the 1-second and 4-second data, and worked with the MAG team to solve discrepancy issues related to the 1-second and 4-second MAG data, and their agreement with ELS data. Collaborative studies have been performed.

During the VEx mission, ELS and MAG data were used to generate a PAD data product. This PAD data computed the pitch angle by generating a dot product between the inverse of the outward pointing ELS sector vector normal and the magnetic field vector normal. Results proved unsatisfactory, and at times, confusing. Four improvements lead to reliable and consistent PAD results. These were (1) subdividing ELS sectors, (2) removal of energy independent background from

ELS data, (3) improved pitch angle accuracy, (4) identification and removal of sectors containing reflected electrons, and (5) determination of the limit on secondary scatter.

The ELS PAD data is generated by the program getdata. All PAD data generated by getdata is stored at SwRI in IDFS format. The IDFS format is incompatiable with PDS archive formats because it is a development format and not an archive format. IDFS format contains pieces of information and extra information needed to influence data in real time, so that results can be easily modified with a minimum amount of reprocessing. As a result, the program CreateASCIIDump applies the appropriate pieces of data and extracts the appropriate ELS PAD data and information to generate the CSV Data and TXT Mode files for storage in PDS4-compliant formats for archival in the public data system.

Table 3. Data Processing Level Definition

PDS4 Level	PDS4 Level Description	CODMAC Level (used in PDS3)	NASA Level
Raw	Original data from an experiment. If compression, reformatting, packetization, or other translation has been applied to facilitate data transmission or storage, those processes are reversed so that the archived data are in a PDS approved archive format. Often called EDRs (Experimental Data Records).	1	0
Partially Processed	Data that have been processed beyond the raw stage but which have not yet reached calibrated status. These and more highly processed products are often called RDRs (Reduced Data Records).	2	1A
Calibrated	Data converted to physical units, which makes values independent of the experiment.	3	1B
Derived	Results that have been distilled from one or more calibrated data products (for example, maps, gravity or magnetic fields, or ring particle size distributions). Supplementary data, such as calibration tables or tables of viewing geometry, used to interpret observational data should also be classified as ‘derived’ data if not easily matched to one of the other three categories.	4+	2+

4.2.2.1 Subdividing ELS Sectors

The ELS sector is 22.5° in azimuth and ±2° in elevation. The ELS pitch angle binning was originally set to reflect the azimuth pixel size, with the outward pointing ELS sector vector normal taken at the center of the sector. This was found to give inaccurate information about the width of the pitch angle range. Sectors are now subdivided into 2.5° in azimuth and 2° in elevation (one above and one below 0° elevation). For each of these sub-pixels, its outward pointing vector normal is generated and the pitch angle for a sub-pixel is determined on a 10° width pitch angle array. Outward pointing vector normals at the centers, corners, and edges of each subdivided pixels were generated and mapped to the pitch angle array after removal of duplicate vector normals from adjacent sub-pixels.

4.2.2.2 Energy Independent Background Removal

An energy independent background is removed by generating the average count above 10 keV. The background removal process is described by [9]. Background averages of 1-minute, 5-minutes, and 25-minutes are used along with a background at the instrument sample rate (4-second), to remove an energy independent background. Removal occurs at the count level before data is converted into distribution function units. The getdata routine automatically chooses which type of background to remove based on the criteria found in Table 4. The type of background value chosen should be the largest number of counts in the shortest accumulation time possible to ensure that the best statistics are achieved. For example, a count of 20 in the 5-minute average background (22% uncertainty) means that at the same time, the 25-minute average has 100 counts (10% uncertainty). Even though statistically the 25-minute background average is better, the accumulation time for the 25-minute average background is five times longer than the accumulation time for the 5-minute average background and may not capture the variability in the spectra.

Because background is subtracted from the count spectra before conversion to the electron distribution function, it is possible to have negative numbers. This result is statistical and based on average values. These negative numbers should be retained and used until all averaging has been completed. They should be converted to zero just before writing out the final product.

Table 4. Count limit of transition for background use. A transition in background value occurs from longer averages to shorter averages when the smallest count limit is reached for each successive background type. When the transition limit is reached (smallest number in column), longer average background shows equivalent count (e.g., 20-counts in the 1-minute average equates to 100-counts in the 5-minute average and 500-counts in the 25-minute average).

Background Type	Transition Count Limit				Frequency Range	
	4 second	1 minute	5 minute	25 minute	Maximum	Minimum
4 second	6	-	-	-	117 kHz	21.4 Hz
1 minute	90	20	-	-	21.4 Hz	5.42 Hz
5 minute	450	100	20	-	5.42 Hz	1.08 Hz
25 minute	2250	500	100	1	1.08 Hz	0.0108 Hz

4.2.2.3 Identification and Removal of Sectors

Mounting of the ASPERA-4 unit on the VEx spacecraft is described by [10]. Some slight modifications and improvements to the descriptions of spacecraft obstructions were made based on photographs of spacecraft appendages. The spacecraft operation was modeled by using SPICE software to access the SPICE navigation files which describe the rotation of the VEx solar arrays and the ASPERA-4 scanner rotation. Tables of pixel blockages were then generated for each degree of scanner and solar array rotation. The results of these tables were used to exclude ELS sectors as containing contaminated data. As a convenience, these tables are included in this archive as a miscellaneous collection.

4.2.2.4 Secondary Scatter Limit

Pixel blockage maps were used to define four PAD products to study the effect of secondary electron scatter. These PADs were termed All, Wide, Regular, and Narrow. The All designation referred to PADs which were generated using all ELS sectors. The Wide designation referred to PADs which were generated using pixels which contained the spacecraft edge or the edge of an appendage, but not the body of the spacecraft or body of an appendage (e.g., the full pixel viewed the solar array). The Regular designation was chosen as the closest pixel to the spacecraft body or appendage which totally viewed into space. The Narrow designation was chosen as the second pixel away from the spacecraft or its appendages, similar to the Regular designation.

Comparisons of All and Wide PADs showed secondary electron scatter while Regular and Narrow PADs were clear of secondary electrons. The largest pitch angle extent was observed with All sectors and was severely restricted with the Narrow PADs. This archive contains only data from the Regular PAD calculation, which shows a better pitch angle coverage range than Narrow PADs.

4.2.3 Data Flow

Figure 4 is a graphical overview of the inputs involved in generating the VEx ELS PAD data archive. The VEx ELS PAD data are locally archived in the IDFS format, generated by the GetData program. The SwRI CreateASCIIDump conversion tool extracts the VEx ELS Regular PAD data from the SwRI IDFS database and converts it to PDS4-compliant data files. In a separate process, their corresponding XML labels are generated with CreateXMLLabel. The PDS4 ELS PAD documentation describes the ELS PAD Data and Mode files. The Documentation PAD, Data PAD, Browse PAD, and Miscellaneous PAD components comprise the VEx ELS PAD data archive collections and bundle. The spacecraft model is not part of this archive and is based on Fatemi, 2009 [10].

4.3 Standards Used in Generating Data Products

All the Venus Express ELS data product files and labels included in this archive comply with the Planetary Data System standards, specifically the PDS4 standard as referenced in the document: Planetary Data System Standards Reference, Version 1.19.0, October 1, 2022 [1].

4.3.1 Coordinate Systems

The Venus Express ELS measurements are *in situ* and the resulting PAD data are in the VEx ELS instrument reference frame as defined in the SPICE (Spacecraft, Planet, Instrument, C-matrix, and Event) instrument kernel, VEX_ASPERA4_V03.TI. The ELS is mounted on a rotating scanner to give a 360° field of view with a ±2° deviation out of viewing plane (elevation). The 16 ELS sectors are each 22.5°. The Venus Express SPICE kernels should be used for translating/rotating to other reference frames, which are defined in the frames kernel, VEX_V11.TF. The orientation of the ASPERA-4 scanner is given in the CK kernel, VEX_ASPERA_SAF_051109_1.BC, found on the NAIF (Navigation and Ancillary Information Facility) website: https://naif.jpl.nasa.gov/pub/naif/VEX/kernels/.

The Venus Express Magnetometer measurements are also i*n situ* and are used to generate the PAD. The Magnetometer data (both the 1-second and 4-second) are available from ESA Planetary Science Archive (PSA) at https://archives.esac.esa.int/psa/ftp/VENUS-EXPRESS/MAG/ and were used to generate PAD data. The magnetometer instrument frame is described by the instrument kernel VEX_VMC_V05.TI . The VEx magnetometer data was rotated from the magnetometer instrument frame to the frame of ELS using the instrument frame definitions and incorporating the ASPERA-4 scanner's ck kernel VEX_ASPERA_SAF_051109_1.BC under the SPICE toolkit N065.

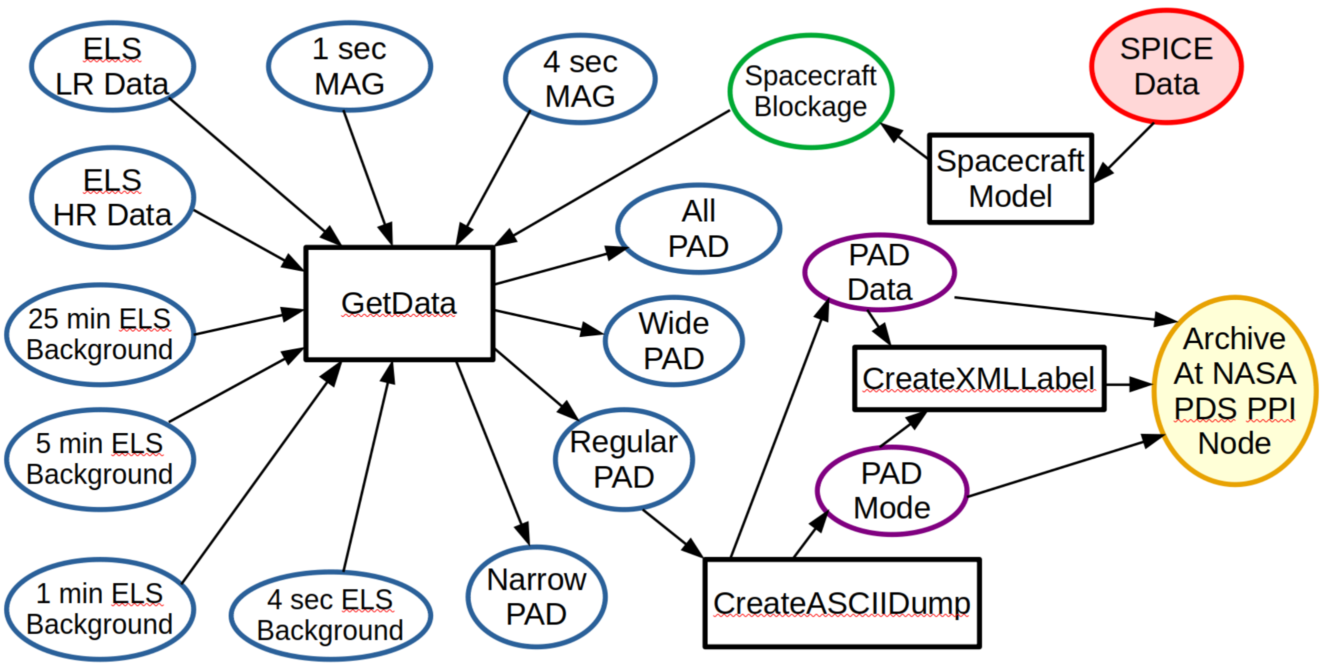

Figure 4. Flow schematic for PAD generation and preparation of data files for NASA PDS. Items in boxes represent processes, circles represent data (borders: blue are IDFS files, green are ASCII, purple are PDS-4 files), red circles are government supplied data, and gold circles represents where data files are ultimately archived.

4.3.2 Geometric Elements

All geometry information is archived along with the ASPERA-4 ELS data at the ESA PSA and can be found in the GEOMTRY subdirectory associated with each data set. FTP access to the PSA ASPERA-4 data archive is at: https://archives.esac.esa.int/psa/ftp/VENUS-EXPRESS/ASPERA4/.

Table 5. Estimated Data Volumes for the Data PAD Collection

File Type	Data Products	Estimated Volume
PAD Mode	PAD Mode ASCII Tables	5 GB
PAD Data	PAD Data ASCII CVS Files	435 GB

4.3.3 Data Storage Conventions

The Venus Express ELS Data PAD Mode are stored in PDS4-compliant ASCII table format. The Venus Express ELS Data PAD Data are stored in PDS4-compliant ASCII CSV format. Table 5 shows the estimated data volume for the data collection.

4.3.4 Data Validation

The VEx ELS data are validated by Dr. Rudy Frahm for science content and for compliance with PDS4 archive standards. Additionally, data was checked and used to develop PAD data statistics [12] and perform individual case studies [11] by Dr. Shaosui Xu. All data and documentation are submitted to a peer review committee for science review according to PDS policy.

4.3.5 Software

All data are in ASCII form so they are readily and easily readable using almost any text editor. In addition, the PDS labels include complete software-readable descriptions of the data file formats for custom-software development if warranted. The CSV files can be read using spreadsheet software (e.g., Microsoft Excel), but users should be aware of row/column limitations of the various software versions.

5.0 ELS PAD Archive Organization, Identifiers and Naming Conventions

This section describes the basic organization of the Venus Express ELS data archive, and the naming conventions used for the bundle, collections, and data products.

5.1 Logical Identifiers

Every product in PDS is assigned an identifier, which allows it to be uniquely identified across the system. This identifier is referred to as a Logical Identifier or LID. A LIDVID (Logical Identifier plus Version Identifier) includes product version information and allows different versions of a specific product to be referenced uniquely. A product's LID and VID are defined as separate attributes in the product label. LIDs and VIDs are assigned by the entity generating the labels and are formed according to the conventions described in sections 5.1.1 LID Formation and 5.1.2 VID Formation below. The uniqueness of a product's LIDVID may be verified using the PDS Registry and Harvest tools.

5.1.1 LID Formation

LIDs take the form of a Uniform Resource Name (URN), and are restricted to ASCII lower case letters, digits, dash, underscore, and period. Colons are also used, but only to separate prescribed components of the LID. The dash, underscore, or period are used as separators within these prescribed components. LIDs are limited in length to 255 characters. Venus Express ELS PAD LIDs are formed according to the following conventions:

Bundle LIDs are formed by appending a bundle specific ID to the PDS base ID:
urn:nasa:pds:<bundle ID>. The VEx ELS PAD bundle ID is: vex-aspera4-els-pad. Thus, the bundle LID is: urn:nasa:pds:vex-aspera4-els-pad. Since all PDS bundle LIDs

are constructed this way, the combination of vex-aspera4-els-pad must be unique across all products archived with the PDS.

Collection LIDs are formed by appending a collection specific ID to the collection's parent bundle LID: urn:nasa:pds:<bundle ID>:<collection ID> or urn:nasa:pds:vex-aspera4-els-pad:<collection ID>. For example, the Data PAD collection LID is: urn:nasa:pds:vex-aspera4-els-pad:data_pad. Collection LIDs are based on the bundle LID, which is unique across PDS, so the only additional condition is that the collection ID must be unique across the bundle. Collection IDs correspond to the collection type (e.g. "data", "document", etc.). Additional descriptive information may be appended to the collection type (e.g. "data_pad", "browse_pad", etc.) to ensure that multiple collections of the same type within the bundle have unique LIDs.

Basic product LIDs are formed by appending a product specific ID to the product's parent collection LID: urn:nasa:pds:<bundle ID>:<collection ID>:<product ID> or urn:nasa:pds:vex-aspera4-els-pad:<collection ID>. For example, the basic Data PAD product LID is generated as: urn:nasa:pds:vex-aspera4-els-pad:data_pad:<product ID> or urn:nasa:pds:vex-aspera4-els-pad:data_pad:vexelspadrg_2009312_data. Since the product LID is based on the collection LID, which is unique across PDS, the only additional condition is that the product ID must be unique across the collection. For VEx ELS data products, the product LID is the same as the data file name without the extension.

5.1.2 VID Formation

Product version IDs consist of major and minor components separated by a "." (x.y). Both components of the Version Identifier (VID) are integer values. The major component is initialized to a value of "1", and the minor component is initialized to a value of "0". The minor component resets to "0" when the major component is incremented. The Planetary Data System Standards Reference [1] specifies rules for incrementing major and minor components.

5.1.3 File Naming Conventions

Multiple similar files exist within the Data PAD and Browse PAD collections. Files within the Data PAD collection are Data and Mode files which contain data and information on how that data was generated. Files within the Browse PAD collection contain images of the data. Separate naming conventions are applied to files within these collections.

5.1.3.1 Data PAD Naming Conventions

Files within the Data PAD collection contain approximately 1 day of data. Since the accumulated spectrum may cross a day boundary, data from the entire spectral sweep is included within the day in which the start time of the spectrum accumulation occurs.

Each file name begins with "VExELSPADRG". The "VEx" means that this data was generated from the Venus Express spacecraft, the "ELS" means that this data was generated from the ELS instrument, the "PAD" means that the data is a sorted Pitch Angle Distribution for electrons, and "RG" means that the data came from the ReGular definition of blockage, e.g. no ELS sector used to generate the PAD included blockage by the spacecraft or its appendages. The ELS PAD Mode files are PDS4 ASCII tables and are named as follows:

VExELSPADRG_YYYYDDD_Mode.TXT

where YYYY is the year and DDD is the day of year.

The ELS science data are in PDS4-compliant CSV format and are named as follows:

VExELSPADRG_YYYYDDD_Data.CSV

where YYYY is the year and DDD is the day of year.

5.1.3.2 Browse PAD Naming Conventions

Files within the Browse PAD collection contain images with a random amount of data. Browse products are meant to be quick look images which can be used to search for data. Images are formed only in the ionosphere of Venus around perigee and may also include images from the magnetosheath and bow shock. Images can vary with the time the spacecraft was within the ionosphere. Browse files are not included for times when PAD data does not exist or have zero (or less) values. Image files are generated in PNG format.

Each file name begins with “VExELSPADRG”. The “VEx” means that this image was generated from data obtained by the Venus Express spacecraft, the “ELS” means that this image was generated from data taken by the ELS instrument, the “PAD” means that the image is from a sorted Pitch Angle Distribution of electrons, and “RG” means that the data came from the ReGular definition of blockage, e.g. no ELS sector used to generate the PAD included blockage by the spacecraft or its appendages. The ELS PAD images for Mode files are PDS4-compliant PNG images and are named as follows:

VExELSPADRG_YYYYDDD_HHMMSS_yyyydddd_hhmmss_Mode.png

where YYYY is the beginning year, DDD is the beginning day of year, HH is the beginning hour of the day, MM is the beginning minute of the hour, SS is the beginning second of the minute, yyyy is the ending year, ddd is the ending day of the year, hh is the ending hour of the day, mm is the ending minute of the hour, and ss is the ending second of the minute.

File names for Data images are formed similarly:

VExELSPADRG_YYYYDDD_HHMMSS_yyyydddd_hhmmss_Data.png

where YYYY is the beginning year, DDD is the beginning day of year, HH is the beginning hour of the day, MM is the beginning minute of the hour, SS is the beginning second of the minute, yyyy is the ending year, ddd is the ending day of the year, hh is the ending hour of the day, mm is the ending minute of the hour, and ss is the ending second of the minute.

5.2 Bundles

The highest level of organization for a PDS4 archive is the bundle. A bundle is a set of one or more related collections which may be of different types. A collection is a set of one or more related basic products which are all of the same product type (not necessarily the same format). Bundles and collections are logical structures, not necessarily tied to any physical directory structure or organization. This Venus Express ELS archive is organized into one bundle: urn:nasa:pds:vex-aspera4-els-pad.

5.3 Collections

Collections consist of basic products all of the same product type (not necessarily the same format). The Venus Express ELS PAD bundle contains the collections listed in Table 6. There are four ELS PAD collection LIDs:

(1) urn:nasa:pds:vex-aspera4-els-pad:data_pad
  The VEx ELS PAD is stored in files with the naming convention described in section 5.1.3.1. There are two types of VEx ELS PAD files, the Mode and the Data files. Mode files contain information describing how the PAD was generated; whereas, Data files contain the actual PAD values.

(2) urn:nasa:pds:vex-aspera4-els-pad:browse_pad
  Images of the VEx ELS PAD are stored in files with the naming convention described in section 5.1.3.2. There are two types of VEx ELS PAD image files: Mode images and Data images. Mode images show information describing how the PAD was generated; whereas, Data images show the actual PAD values.

(3) urn:nasa:pds:vex-aspera4-els-pad:document_pad
  VEX_ASPERA-4_ELS_PAD_Spec.pdf is the software interface specification (this document) which contains information about the archive.
  VEX_ASPERA-4_ELS_PAD_Fields.txt is a document containing definitions of the fields in the Data and Mode files.

(4) urn:nasa:pds:vex-aspera4-els-pad:miscellaneous_pad
  ASPERA4Scanner_NYSA_Blockage.txt is a document describing the miscellaneous product which contains information about the creation, use, and format of the blockage tables.
  ASPERA4Scanner_NYSA_Blockage_Tables.txt contains the blockage tables including their descriptions.

Table 6: VEx ELS PAD Collections, Products, and Estimated Volumes.

Collection	Data Products	Estimated Volume
data_pad	VExELSPADRG Mode – information describing how the PAD was generated VExELSPADRG Data – values of the energy [eV], Velocity [m/s], and the pitch angle sorted electron distribution function [$s^3/m^6/sr$]	440 GB

Collection	Data Products	Estimated Volume
browse_pad	VExELSPADRG Mode – mode data shown in estimated perigee region VExELSPADRG Data – magnetic field and pad data shown for the estimated perigee region	640 MB
document_pad	VEX_ASPERA-4_ELS_PAD_Spec.pdf - Software Interface Specification VEX_ASPERA-4_ELS_PAD_Fields.txt – Definition of fields included in Data and Mode files.	3MB
miscellaneous_pad	ASPERA4Scanner_NYSA_Blockage.txt – documentation describing the tables document. ASPERA4Scanner_NYSA_Blockage_Tables.txt – tables of blockage factors used to generate the ELS PAD.	5.4 MB

5.4 Products

A PDS product consists of one or more digital objects and an accompanying PDS label file. PDS labels provide identification and description information for labeled objects. The PDS label includes a Logical Identifier (LID) by which any PDS labeled product is uniquely identified throughout all PDS archives. PDS4 labels are XML-formatted ASCII files. The LID for a product in all the collections consists of the collection LID concatenated with the file name, without the extension. Example LID for an ELS low energy range background corrected number flux product: urn:nasa:pds:vex-aspera4-els-pad:data_pad:vexelspadrg_2009312_data.

5.5 Data Collection

Data are considered products by PDS and have LIDs, VIDs, and PDS4 labels. The VEx ELS PAD bundle includes a Data PAD Collection, which consists of two types of data products: Data and Mode. The Data PAD collection has the following LID: urn:nasa:pds:vex-aspera4-els-pad:data_pad.

5.6 Document Collection

Documents are also PDS products and have LIDs, VIDs, and PDS4 labels similar to the data products. The VEx ELS PAD bundle includes a Document PAD Collection, which consists of documents relevant to this archive. This archive contains two documents: VEX_ASPERA-4_ELS_PAD_Spec.pdf and VEX_ASPERA-4_ELS_PAD_Fields.txt. The Document PAD Collection has the following LID: urn:nasa:pds:vex-aspera4-els-pad:document_pad.

5.7 Browse Collection

Images of data are also PDS products and have LIDs, VIDs, and PDS4 labels similar to the data products. The VEx ELS PAD bundle includes a Browse PAD Collection, which consists of images relevant to this archive. This archive contains two types of browse products: Data and Mode. The Browse PAD Collection has the following LID: urn:nasa:pds:vex-aspera4-els-pad:browse_pad.

5.8 Miscellaneous Collection

Miscellaneous items are also considered PDS products and have LIDs, VIDs, and PDS4 labels similar to the data products. The VEx ELS PAD bundle includes a Miscellaneous PAD Collection, which consists of items relevant to this archive. This archive contains two miscellaneous products: ASPERA4Scanner_NYSA_Blockage.txt and ASPERA4Scanner_NYSA_Blockage_Tables.txt The Miscellaneous PAD Collection has the following LID: urn:nasa:pds:vex-aspera4-els-pad:miscellaneous_pad.

5.9 Archive Organization and Directory Structure

The Venus Express ELS PAD archive is organized into one bundle with four collections: data_pad, document_pad, browse_pad, and miscellaneous_pad. This section describes the overall directory structure.

```
vex-aspera4-els-pad – top level directory
    bundle_vex-aspera4-els-pad.xml
    readme_vex-aspera4-els-pad.txt
    browse_pad – subdirectory containing the browse collection
        collection_browse_pad.csv
        collection_browse_pad.xml
        ......
    data_pad – subdirectory containing the data collection
        collection_data_pad.csv
        collection_data_pad.xml
        ......
    document_pad – subdirectory containing the document collection
        collection_document_pad.csv
        collection_document_pad.xml
        VEX_ASPERA-4_ELS_PAD_Fields.txt
        VEX_ASPERA-4_ELS_PAD_Fields.xml
        VEX_ASPERA-4_ELS_PAD_Spec.pdf
        VEX_ASPERA-4_ELS_PAD_Spec.xml
    miscellaneous_pad – subdirectory containing the miscellaneous collection
        collection_miscellaneous_pad.csv
        collection_miscellaneous_pad.xml
        ASPERA4Scanner_NYSA_Blockage.txt
        ASPERA4Scanner_NYSA_Blockage.xml
        ASPERA4Scanner_NYSA_Blockage_Tables.txt
        ASPERA4Scanner_NYSA_Blockage_Tables.xml
```

The subdirectories of each of the data and browse directories have the same structure. These subdirectories are broken into year in which the data was taken, formulated: YYYY (indicating year).

<type>_pad – where <type> is either browse or data
2006
2007
2008
2009
2010
2011
2012
2013
2014

The files (ASCII tables and CSV) along with their associated labels (XML) for the data_pad collection are located in their respective subdirectories. The files (PNG images) along with their associated labels (XML) for the browse_pad collection are located in their respective subdirectories.

6.0 ELS PAD Archive Data Formats

Data that comprise the VEx ELS PAD archive are formatted in accordance with PDS4 specifications (see the Planetary Data System Standards Reference [1], PDS4 Data Provider's Handbook [2], and PDS4 Data Dictionary [4]). This section provides details on the formats used for each of the products included in the archive.

Table 7. The column format of the PAD Data file.

Field Name	Data Type/Format	Units	Description
Start Time	ASCII_Date_Time_DOY YYYY-DOYTHH:MM:SS.mmm	UTC	Start date/time of the data
Stop Time	ASCII_Date_Time_DOY YYYY-DOYTHH:MM:SS.mmm	UTC	Stop date/time of the data
Scan Step Number	ASCII_Integer xxx	Number	Sequential scan step number
Energy of Scan Step	ASCII_Real **s**x.xxx**e**±yy	eV	Center energy of scan
Velocity of Scan Step	ASCII_Real **s**x.xxx**e**±yy	m/s	Center velocity of scan
Pitch Angle Distribution	ASCII_Real **s**x.xxx**e**±yy	$s^3/m^6/sr$	Pitch angle distribution for pitch angle bin z z = 0 to 17 18 fields (columns)

6.1 PAD Data Formats

The PAD Data files begin with 3 header lines which describe the contents of each column. The VEx ELS PAD Data files are stored in ASCII CSV files with a total of 23 columns per row: two for start and stop date/times, a scan step number, an energy value, a velocity value, and 18 values that correspond to each pitch angle bin. The PAD Data file is meant to hold the information required to define the PAD. Table 7 describes the 23 fields (columns).

6.2 PAD Mode Formats

The PAD Mode files begin with 3 header lines which describe the contents of each column. The VEx ELS PAD Mode files are stored as an ASCII table with a total of 40 columns per row: two for start and stop date/times, two for the pitch angle range, one for the sweep type, 16 for the pitch angle for each of the ELS sectors, one for the number of used ELS sectors, 16 indicating the type of background removed from the data of each ELS sector, one for the magnetic field resolution, and one for the software version constructing the PAD. The PAD Mode file is meant to hold a description of how the PAD was generated. Table 8 describes the 40 fields (columns).

Table 8. The column format of the PAD Mode file.

Field Name	Data Type/Format	Units	Description
Start Time	ASCII_Date_Time_DOY YYYY-DOYTHH:MM:SS.mmm	UTC	Start date/time of the data
Stop Time	ASCII_Date_Time_DOY YYYY-DOYTHH:MM:SS.mmm	UTC	Stop date/time of the data
Pitch Angle Range: Minimum	ASCII_Integer xxx	index	Index to pitch angle bin
Pitch Angle Range: Maximum	ASCII_Integer xxx	index	Index to pitch angle bin
Type of Scan	ASCII_Integer xxx	index	0 = 127 step, 1 = 31 step, 2 =1 step
ELS pitch angles	ASCII_Integer xxx	degree	Center pitch angle for ELS sector w w = 0 to 15 16 fields (columns)
Number of Used ELS Sectors	ASCII_Integer xxx	number	Count of the ELS sectors used to generate the PAD
ELS Sector Specific Background Removal	ASCII_Integer xxx	index	Background removal for sector w: 0 = no removal, 1 = spectral resolution, 2 = 1 min average, 3 = 5 min average, 4 = 25 min average w = 0 to 15 16 fields (columns)
Magnetometer Resolution	ASCII_Integer xxx	index	0 = 4 sec, 1 = 1 sec, 3 = high resolution (128 samples/sec)
Software Version	ASCII_Integer xxx	number	Version of the software which generated the PAD

6.3 Browse Product Formats

All browse products in the VEx ELS PAD archive are provided in PNG file format as quick look images of either the PAD Data or Mode files. The images do not cover all time ranges, pitch angle sectors, or all PAD Data/Mode files.

6.4 Document Product Formats

Some document products in the VEx ELS PAD archive are provided in PDF/A file format while others are provided in ASCII text format (file extension is txt).

6.5 Miscellaneous Product Formats

The miscellaneous products in the VEx ELS PAD archive are provided in ASCII text format (file extension is txt). The file ASPERA4Scanner_NYSA_Blockage_Tables.txt is unique and requires special notes. The file ASPERA4Scanner_NYSA_Blockage_Tables.txt contains 52 comment lines and then 361 tables describing the amount of blockage that each ELS sector experiences for a given offset angle of the -Y solar array. The formats of all 361 tables are the same. The format of one of the tables is described in Table 9.

Table 9. Format of a table (repeated 361 times) in the Miscellaneous Tables file.

Number of Lines (Rows)	Field Name	Data Type/Format	Units	Description
1	Comment Line	ASCII_String %s	N/A	Leading '#'
	NYSA Offset	ASCII_Integer xxxx	degrees	Offset angle of the -Y solar array
	NYSA Text	ASCII_String %s	N/A	Text descriptor
2	Comment Lines	ASCII_String %s	N/A	Column descriptors with leading '#'
181	ASPERA-4 Scanner Offset	ASCII_Integer xxxx	degrees	Offset angle of the ASPERA-4 scanner
	Blockage Factors	ASCII_Integer xxxx	percent	Amount of blockage from the spacecraft for ELS sector w w = 0 to 15 16 fields (columns)

6.6 PDS Labels

There is a PDS4 label for each VEx ELS PAD product. PDS4 labels are ASCII text files written in the eXtensible Markup Language (XML). All product labels are detached from the files they describe (except the Product_Bundle label). There is one label for every product. A PDS4 label file usually has the same name as the data product it describes, but always with the extension ".xml".

For the Venus Express ELS PAD archive, the structure and content of the PDS labels conform to the PDS master schema and schematron based upon the PDS4 Information Model Specification, Version 1.19.0.0 [5]. By use of an XML editor the schema and schematron may be used to validate the structure and content of the product labels.

See Appendix B: ELS PAD PDS4 Sample Label Files for examples of PDS labels for the VEx ELS data products.

Appendix A: Acronyms, Abbreviations, and Glossary

A.1 Acronyms and Abbreviations

Table 10. Acronyms and Abbreviations

Acronym or Abbreviation	Meaning
ASCII	American Standard Code for Information Interchange
ASPERA-3	Analyzer of Space Plasma and Energetic Atoms (3rd Version), experiment on the Marx Express spacecraft
ASPERA-4	Analyzer of Space Plasma and Energetic Atoms (4th Version), experiment on the Venus Express spacecraft
CK	C-matrix Kernel (NAIF orientation data)
Co-I	Co-Investigator
CODMAC	Committee On Data Management and Computation (of NRC)
CSV	Comma Separated Values (PDS Spreadsheet Object ASCII format)
DOY	Day Of Year (Julian date, 3 digits)
EDR	Experiment Data Record
ELS	Electron Spectrometer (instrument of the ASPERA-3 or ASPERA-4 experiment)
ESA	European Space Agency
FK	Frames Kernel (NAIF orientation data)
FTP	File Transfer Protocol
GB	Gigabyte(s)
IDFS	Instrument Data File Set or Instrument Description File Set
IK	Instrument Kernel (NAIF orientation data)
IRF	Swedish Institute of Space Physics (Kiruna, Sweden)
JPL	Jet Propulsion Laboratory
LID	Logical Identifier
LIDVID	Versioned Logical Identifier
MB	Megabyte(s)
MEx	Mars Express
NAIF	Navigation Ancillary Information Facility
NASA	National Aeronautics and Space Administration
PAD	Pitch Angle Distribution
PDF	Portable Document Format
PDS	NASA Planetary Data System
PDS4	NASA Planetary Data System, Version 4
PI	Principal Investigator
PNG	Portable Network Graphic

Acronym or Abbreviation	Meaning
PPI	Planetary Data System, Planetary Plasma Interactions Node
PR	Peer Review
PSA	ESA Planetary Science Archive
RDR	Reduced Data Record
SIS	Software Interface Specification
SPICE	Spacecraft, Planet, Instrument, C-matrix, Events files and software
SwRI®	Southwest Research Institute®
TB	Terabyte(s)
TXT	Standard Text File
URN	Uniform Resource Name
UTC	Universal Time Coordinated
VEx	Venus Express

A.2 Glossary

Many of these definitions are from Appendix A of the PDS4 Concepts Document [3], pds.nasa.gov/pds4/doc/concepts. See this document for more information.

Archive – A place in which public records or historical documents are preserved; also the material preserved – often used in plural. It may be capitalized when referring to all of PDS holdings – the PDS Archive.

Basic Product – The simplest product in PDS4; one or more data objects (and their description objects), which constitute (typically) a single observation, document, etc. The only PDS4 products that are not basic products are collection and bundle products.

Bundle Product – A list of related collections. For example, a bundle could list a collection of raw data obtained by an experiment during its mission lifetime, a collection of the calibration products associated with the experiment, and a collection of all documentation relevant to the first two collections.

Class – The set of attributes (including a name and identifier) which describes an item defined in the PDS Information Model. A class is generic – a template from which individual items may be constructed.

Collection Product – A list of closely related basic products of a single type (e.g. observational data, browse, documents, etc.). A collection is itself a product (because it is simply a list, with its label), but it is not a basic product.

Data Object – A generic term for an object that is described by a description object. Data objects include both digital and non-digital objects.

Description Object – An object that describes another object. As appropriate, it will have structural and descriptive components. In PDS4 a ‘description object’ is a digital object – a string of bits with a predefined structure.

Digital Object – An object that consists of electronically stored (digital) data.

Identifier – A unique character string by which a product, object, or other entity may be identified and located. Identifiers can be global, in which case they are unique across all of PDS (and its federation partners). A local identifier must be unique within a label.

Label – The aggregation of one or more description objects such that the aggregation describes a single PDS product. In the PDS4 implementation, labels are constructed using XML.

Logical Identifier (LID) – An identifier which identifies the set of all versions of a product.

Versioned Logical Identifier (LIDVID) – The concatenation of a logical identifier with a version identifier, providing a unique identifier for each version of product.

Manifest - A list of contents.

Metadata – Data about data – for example, a ‘description object’ contains information (metadata) about an ‘object.’

Object – A single instance of a class defined in the PDS Information Model.

PDS Information Model – The set of rules governing the structure and content of PDS metadata. While the Information Model (IM) has been implemented in XML for PDS4, the model itself is implementation independent.

Product – One or more tagged objects (digital, non-digital, or both) grouped together and having a single PDS-unique identifier. In the PDS4 implementation, the descriptions are combined into a single XML label. Although it may be possible to locate individual objects within PDS (and to find specific bit strings within digital objects), PDS4 defines ‘products’ to be the smallest granular unit of addressable data within its complete holdings.

Tagged Object – An entity categorized by the PDS Information Model, and described by a PDS label.

Registry – A data base that provides services for sharing content and metadata.

Repository – A place, room, or container where something is deposited or stored (often for safety).

XML – eXtensible Markup Language.

XML schema – The definition of an XML document, specifying required and optional XML elements, their order, and parent-child relationships.

Appendix B: ELS PAD PDS4 Sample Label Files

The ELS PAD VExELSPADRG Data and Mode XML label are combined such that the Mode file is a slave to the Data file. The XML label describes the Data as the master product and is labeled with the Data name; however, the Mode label definition is included as the slave to the Data. An example (VExELSPADRG_2009312_Data.xml) of the XML label combining the Data and Mode files are shown below:


```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-model href="https://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1J00.sch"
schematypens="http://purl.oclc.org/dsdl/schematron"?>
<?xml-model href="https://pds.nasa.gov/pds4/particle/v2/PDS4_PARTICLE_1J00_2010.sch"
schematypens="http://purl.oclc.org/dsdl/schematron"?>
<Product_Observational xmlns="http://pds.nasa.gov/pds4/pds/v1"
   xmlns:particle="http://pds.nasa.gov/pds4/particle/v2"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xsi:schemaLocation="http://pds.nasa.gov/pds4/pds/v1
                   https://pds.nasa.gov/pds4/pds/v1/PDS4_PDS_1J00.xsd
                   http://pds.nasa.gov/pds4/particle/v2
                   https://pds.nasa.gov/pds4/particle/v2/PDS4_PARTICLE_1J00_2010.xsd">
   <Identification_Area>
      <logical_identifier>urn:nasa:pds:vex-aspera4-els-
pad:data_pad:vexelspadrg_2009312_data</logical_identifier>
      <version_id>1.0</version_id>
      <title>VEX ELS Pitch Angle Sorted Data 2009-11-08 02:31</title>
      <information_model_version>1.19.0.0</information_model_version>
      <product_class>Product_Observational</product_class>
      <Citation_Information>
         <author_list>Frahm, Rudy</author_list>
         <publication_year>2023</publication_year>
         <description>
            The product contains pitch angle sorted ELS data which excludes data from sectors
which view the spacecraft.
         </description>
      </Citation_Information>
      <Modification_History>
         <Modification_Detail>
            <modification_date>2023-01-18</modification_date>
            <version_id>1.0</version_id>
            <description>Initial version</description>
         </Modification_Detail>
      </Modification_History>
   </Identification_Area>
   <Observation_Area>
      <Time_Coordinates>
         <start_date_time>2009-11-08T02:31:04.181Z</start_date_time>
         <stop_date_time>2009-11-08T21:10:38.280Z</stop_date_time>
      </Time_Coordinates>
      <Primary_Result_Summary>
         <purpose>Science</purpose>
         <processing_level>Derived</processing_level>
         <Science_Facets>
            <discipline_name>Particles</discipline_name>
            <facet1>Electrons</facet1>
```

```
            <facet2>Plasma</facet2>
         </Science_Facets>
      </Primary_Result_Summary>
      <Investigation_Area>
         <name>Venus_Express</name>
         <type>Mission</type>
         <Internal_Reference>
            <lid_reference>urn:esa:psa:context:investigation:mission.venus_express</
lid_reference>
            <reference_type>data_to_investigation</reference_type>
         </Internal_Reference>
      </Investigation_Area>
      <Observing_System>
         <Observing_System_Component>
            <name>VEX</name>
            <type>Host</type>
            <Internal_Reference>
               <lid_reference>urn:esa:psa:context:instrument_host:spacecraft.vex</lid_reference>
               <reference_type>is_instrument_host</reference_type>
            </Internal_Reference>
         </Observing_System_Component>
         <Observing_System_Component>
            <name>ASPERA4-ELS</name>
            <type>Instrument</type>
            <Internal_Reference>
               <lid_reference>urn:esa:psa:context:instrument:vex.aspera4-els</lid_reference>
               <reference_type>is_instrument</reference_type>
            </Internal_Reference>
         </Observing_System_Component>
      </Observing_System>
      <Target_Identification>
         <name>Venus</name>
         <type>Planet</type>
         <Internal_Reference>
            <lid_reference>urn:nasa:pds:context:target:planet.venus</lid_reference>
            <reference_type>data_to_target</reference_type>
         </Internal_Reference>
      </Target_Identification>
      <Mission_Area>

      </Mission_Area>
      <Discipline_Area>
         <particle:Particle_Observation>
            <particle:energy_range_minimum
unit="keV">0.0005</particle:energy_range_minimum>
            <particle:energy_range_maximum unit="keV">40</particle:energy_range_maximum>
            <particle:Particle_Parameter>
               <particle:particle_type>Electrons</particle:particle_type>
               <particle:particle_measurement_type>Pitch Angle
Distribution</particle:particle_measurement_type>
            </particle:Particle_Parameter>
         </particle:Particle_Observation>
      </Discipline_Area>
   </Observation_Area>
   <File_Area_Observational>
```

```
    <File>
      <file_name>VExELSPADRG_2009312_Data.csv</file_name>
      <local_identifier>VExELSPADRG_2009312_Data</local_identifier>
      <creation_date_time>2023-01-18T16:07</creation_date_time>
      <file_size unit="byte">145488358</file_size>
      <records>542867</records>
      <comment>
        This table contains the pitch angle sorted ELS data which excludes data from sectors
which view the spacecraft for all 16 ELS anodes.
      </comment>
    </File>
    <Header>
      <offset unit="byte">0</offset>
      <object_length unit="byte">806</object_length>
      <parsing_standard_id>PDS DSV 1</parsing_standard_id>
      <description>This file header describes data columns in the Data CSV file.</description>
    </Header>
    <Table_Delimited>
      <offset unit="byte">806</offset>
      <parsing_standard_id>PDS DSV 1</parsing_standard_id>
      <records>542864</records>
      <record_delimiter>Line-Feed</record_delimiter>
      <field_delimiter>Comma</field_delimiter>
      <Record_Delimited>
        <fields>23</fields>
        <groups>0</groups>
        <Field_Delimited>
          <name>Start Time</name>
          <field_number>1</field_number>
          <data_type>ASCII_Date_Time_DOY</data_type>
          <maximum_field_length unit="byte">21</maximum_field_length>
          <description>The start time of the data spectrum in UTC.
                The Start Time and Stop Time fields define
                the time range covered by the data spectrum.
                The format is YYYY-DDDTHH:MM:SS.SSS.
          </description>
        </Field_Delimited>
        <Field_Delimited>
          <name>Stop Time</name>
          <field_number>2</field_number>
          <data_type>ASCII_Date_Time_DOY</data_type>
          <maximum_field_length unit="byte">21</maximum_field_length>
          <description>The end time of the data spectrum in UTC.
                The Start Time and Stop Time fields define
                the time range covered by the data spectrum.
                The format is YYYY-DDDTHH:MM:SS.SSS.
          </description>
        </Field_Delimited>
        <Field_Delimited>
          <name>Scan Index</name>
          <field_number>3</field_number>
          <data_type>ASCII_Integer</data_type>
          <maximum_field_length unit="byte">3</maximum_field_length>
          <field_format>%3d</field_format>
          <description>A pure number which ranges from 0 to 30 when the
```

```
                electron instrument is in the 1 sec/sweep mode and
                from 0 to 126 when the electron instrument is in the 4 sec/sweep mode.
                The scan is a decay sweep, which means that a low scan index
                value represents a large energy.  The Scan Index, Electron Energy,
                and Velocity fields describe the energy scan of the data.
    </description>
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    <name>Electron Energy</name>
    <field_number>4</field_number>
    <data_type>ASCII_Real</data_type>
    <maximum_field_length unit="byte">10</maximum_field_length>
    <field_format>%10.3e</field_format>
    <unit>eV</unit>
    <description>The energy for each Scan Index, which depends on the
                instrument configuration; therefore, the same scan index
                does not always correspond to the same energy value.
                The Scan Index, Electron Energy, and Velocity fields describe
                the energy scan of the data.
    </description>
</Field_Delimited>
<Field_Delimited>
    <name>Velocity</name>
    <field_number>5</field_number>
    <data_type>ASCII_Real</data_type>
    <maximum_field_length unit="byte">10</maximum_field_length>
    <field_format>%10.3e</field_format>
    <unit>m/sec</unit>
    <description>The electron energy converted into velocity.
                The Scan Index, Electron Energy, and Velocity
                fields describe the energy scan of the data.
    </description>
</Field_Delimited>
<Field_Delimited>
    <name>5 deg PA</name>
    <field_number>6</field_number>
    <data_type>ASCII_Real</data_type>
    <maximum_field_length unit="byte">10</maximum_field_length>
    <field_format>%10.3e</field_format>
    <unit>sec**3/(m**6 sr)</unit>
    <description>The electron Pitch Angle Distribution value
                for the pitch angle bin that runs from
                0 degrees to 10 degrees.
    </description>
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    </Special_Constants>
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<Field_Delimited>
    <name>15 deg PA</name>
    <field_number>7</field_number>
    <data_type>ASCII_Real</data_type>
    <maximum_field_length unit="byte">10</maximum_field_length>
    <field_format>%10.3e</field_format>
    <unit>sec**3/(m**6 sr)</unit>
```

```
    <description>The electron Pitch Angle Distribution value
              for the pitch angle bin that runs from
              10 degrees to 20 degrees.
    </description>
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    </Special_Constants>
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    <field_format>%10.3e</field_format>
    <unit>sec**3/(m**6 sr)</unit>
    <description>The electron Pitch Angle Distribution value
              for the pitch angle bin that runs from
              20 degrees to 30 degrees.
    </description>
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    </Special_Constants>
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  <Field_Delimited>
    <name>35 deg PA</name>
    <field_number>9</field_number>
    <data_type>ASCII_Real</data_type>
    <maximum_field_length unit="byte">10</maximum_field_length>
    <field_format>%10.3e</field_format>
    <unit>sec**3/(m**6 sr)</unit>
    <description>The electron Pitch Angle Distribution value
              for the pitch angle bin that runs from
              30 degrees to 40 degrees.
    </description>
    <Special_Constants>
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    </Special_Constants>
  </Field_Delimited>
  <Field_Delimited>
    <name>45 deg PA</name>
    <field_number>10</field_number>
    <data_type>ASCII_Real</data_type>
    <maximum_field_length unit="byte">10</maximum_field_length>
    <field_format>%10.3e</field_format>
    <unit>sec**3/(m**6 sr)</unit>
    <description>The electron Pitch Angle Distribution value
              for the pitch angle bin that runs from
              40 degrees to 50 degrees.
    </description>
    <Special_Constants>
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    </Special_Constants>
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    <name>55 deg PA</name>
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<field_number>11</field_number>
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<field_format>%10.3e</field_format>
<unit>sec**3/(m**6 sr)</unit>
<description>The electron Pitch Angle Distribution value
for the pitch angle bin that runs from
50 degrees to 60 degrees.
</description>
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</Special_Constants>
</Field_Delimited>
<Field_Delimited>
<name>65 deg PA</name>
<field_number>12</field_number>
<data_type>ASCII_Real</data_type>
<maximum_field_length unit="byte">10</maximum_field_length>
<field_format>%10.3e</field_format>
<unit>sec**3/(m**6 sr)</unit>
<description>The electron Pitch Angle Distribution value
for the pitch angle bin that runs from
60 degrees to 70 degrees.
</description>
<Special_Constants>
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</Special_Constants>
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<Field_Delimited>
<name>75 deg PA</name>
<field_number>13</field_number>
<data_type>ASCII_Real</data_type>
<maximum_field_length unit="byte">10</maximum_field_length>
<field_format>%10.3e</field_format>
<unit>sec**3/(m**6 sr)</unit>
<description>The electron Pitch Angle Distribution value
for the pitch angle bin that runs from
70 degrees to 80 degrees.
</description>
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<Field_Delimited>
<name>85 deg PA</name>
<field_number>14</field_number>
<data_type>ASCII_Real</data_type>
<maximum_field_length unit="byte">10</maximum_field_length>
<field_format>%10.3e</field_format>
<unit>sec**3/(m**6 sr)</unit>
<description>The electron Pitch Angle Distribution value
for the pitch angle bin that runs from
80 degrees to 90 degrees.
</description>
<Special_Constants>

<invalid_constant>-3.400e+38</invalid_constant>
</Special_Constants>
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<description>The electron Pitch Angle Distribution value
for the pitch angle bin that runs from
90 degrees to 100 degrees.
</description>
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</Special_Constants>
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<field_number>16</field_number>
<data_type>ASCII_Real</data_type>
<maximum_field_length unit="byte">10</maximum_field_length>
<field_format>%10.3e</field_format>
<unit>sec**3/(m**6 sr)</unit>
<description>The electron Pitch Angle Distribution value
for the pitch angle bin that runs from
100 degrees to 110 degrees.
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</Special_Constants>
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<Field_Delimited>
<name>115 deg PA</name>
<field_number>17</field_number>
<data_type>ASCII_Real</data_type>
<maximum_field_length unit="byte">10</maximum_field_length>
<field_format>%10.3e</field_format>
<unit>sec**3/(m**6 sr)</unit>
<description>The electron Pitch Angle Distribution value
for the pitch angle bin that runs from
110 degrees to 120 degrees.
</description>
<Special_Constants>
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</Special_Constants>
</Field_Delimited>
<Field_Delimited>
<name>125 deg PA</name>
<field_number>18</field_number>
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<maximum_field_length unit="byte">10</maximum_field_length>
<field_format>%10.3e</field_format>
<unit>sec**3/(m**6 sr)</unit>

<description>The electron Pitch Angle Distribution value
for the pitch angle bin that runs from
120 degrees to 130 degrees.
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<name>135 deg PA</name>
<field_number>19</field_number>
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<field_format>%10.3e</field_format>
<unit>sec**3/(m**6 sr)</unit>
<description>The electron Pitch Angle Distribution value
for the pitch angle bin that runs from
130 degrees to 140 degrees.
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<description>The electron Pitch Angle Distribution value
for the pitch angle bin that runs from
140 degrees to 150 degrees.
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<unit>sec**3/(m**6 sr)</unit>
<description>The electron Pitch Angle Distribution value
for the pitch angle bin that runs from
150 degrees to 160 degrees.
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          <description>The electron Pitch Angle Distribution value
                    for the pitch angle bin that runs from
                    160 degrees to 170 degrees.
          </description>
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          </Special_Constants>
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        <Field_Delimited>
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          <data_type>ASCII_Real</data_type>
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          <field_format>%10.3e</field_format>
          <unit>sec**3/(m**6 sr)</unit>
          <description>The electron Pitch Angle Distribution value
                    for the pitch angle bin that runs from
                    170 degrees to 180 degrees.
          </description>
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          </Special_Constants>
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      <creation_date_time>2023-01-18T16:07</creation_date_time>
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      <records>12835</records>
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      <parsing_standard_id>7-Bit ASCII Text</parsing_standard_id>
      <description>This file header describes data columns in the Mode TXT file.</description>
    </Header>
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      <offset unit="byte">590</offset>
      <records>12832</records>
      <description>
        This table describes how the pitch angle sorted ELS data was generated.
      </description>
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    <field_number>11</field_number>
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