Psyche Mission
Gamma Ray Neutron Spectrometer Instrument (GRNS)

NS Uncalibrated to Calibrated Data Product Software Interface Specification

7506-9075

MO-005-01C

August 1, 2025

Revision: B

Approved by:

Raymond Espiritu
GRNS Science Operations Center Lead

Patrick Peplowski
GRNS Instrument Scientist

Mark LeBlanc
GRNS System Assurance Manager

John Goldsten
GRNS Lead Engineer

David Lawrence
GRNS Instrument Principal Investigator

Michael Cully
GRNS Project Manager

Kathryn Marcotte
GRNS Flight Software Lead

Sam Fix
GRNS DPU Lead

Created under NASA/JPL Psyche Mission Subcontract No. 1569206

Revision Log

Rev	By	Description	Date
-	R. Espiritu	Initial Release	03/04/2022
A	R. Espiritu	Updated based on Preflight PDS Peer Review	07/20/2022
B	R. Espiritu	Update science goals based on new mission orbit; update Time Standards and usage of SPICE kernels for time conversion and update based on feedback from PDS Pipeline Peer Review	08/01/2025

A Release stamp electronically affixed at bottom of the pages of this document certifies that the above personnel or designated alternates have approved this release. Please refer to the JHU/APL Product Lifecycle Management System (PLM) for record of these approvals.

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1 Purpose and Scope

This Data Product Software Interface Specification (SIS) describes the format and content of the Psyche Neutron Spectrometer (NS) Planetary Data System (PDS) data archive. Note that while the full instrument is known as the Gamma-Ray and Neutron Spectrometer (GRNS), the Gamma-Ray Spectrometer (GRS) and NS are archived as two separate bundles. This SIS includes descriptions of the uncalibrated and calibrated data products and associated metadata, the volume archive format, calibration process, and product generation pipeline. The GRS/NS SOC at the Johns Hopkins University Applied Physics Lab (JHU/APL) produces these data products and distributes them to the Psyche Science Data Center (SDC) at the Arizona State University (ASU) which then distributes them to the Psyche science team and the Planetary Data System.

The document is intended to provide enough information to enable users to read and understand the data products. The users for whom this document is intended are the scientists who will analyze the data, including those associated with the project and those in the general planetary science community.

2 Applicable Documents and Constraints

This Data Product SIS is consistent with the following Planetary Data System Documents:

- Planetary Data System Standards Reference, Version 1.22.0, June 4, 2024
- PDS4 Data Dictionary – Abridged – Version 1.22.0.0, June 4, 2024
- PDS4 Information Model Specification, V. 1.22.0.0, June 4, 2024

This Data Product SIS is responsive to the following Psyche documents:

- Psyche Science Data Management Plan, D-100129 - Rev A, Aug 07 2023

Additional information related to the NS instrument can be found in the following documents. This NS SIS is also consistent with these documents.

- Placeholder for GRNS instrument paper
- Placeholder for GRNS calibration paper

3 Relationships with Other Interfaces

Changes to the data products described in this SIS effect the following software, products or documents:

Name	Type
Raw/Calibrated NS Spectra	Product
Raw NS Events	Product

Name	Type
Raw NS Counters	Product
Calibrated NS Count Rates	Product
Raw/Calibrated NS Engineering	Product
NS Data Product Pipeline	Software
Psyche Science Data Management Plan	JPL Document D-100129

4 Roles and Responsibilities

The roles and responsibilities of the Project, Working Groups, Instrument Teams, JHU/APL, SDC, and the PDS are defined in the Psyche Science Data Management Plan.

5 Data Product Characteristics and Environment

5.1 Mission Overview

The Psyche spacecraft was launched on October 13, 2023 and is scheduled to arrive at the Psyche asteroid in August 2029. The science phase is divided into four segments, each in an orbit with a successively smaller semi-major axis; labeled orbits A through D. Each science phase segment has a specific purpose. Between each phase is a period of thrusting designed to move to the next orbit until the final orbit D.

The Psyche mission has the following five science objectives:

1. Determine whether Psyche is a core, or if it is unmelted material
2. Determine the relative ages of regions of Psyche's surface.
3. Determine whether small metal bodies incorporate the same light elements as are expected in the Earth's high-pressure core.
4. Determine whether Psyche was formed under conditions more oxidizing or more reducing than Earth's core.
5. Characterize Psyche's topography.

The Psyche NS contributes to goals 1, 3, and 4 via measurements that are made during the orbit B1-to-D transition, throughout orbit D, the orbit D-to-C transfer, and during orbit C.

5.2 Instrument Overview

The Neutron Spectrometer (NS) consists of three ^{3}He gas proportional counters: one is bare, a second is covered in thin (0.5 mm) Cd wrap, and a third is covered in a 1-cm-thick polyethylene wrap. Each sensor operates in an identical manner wherein a neutron can be absorbed by ^{3}He atoms in the gas volume producing a proton and a triton with a total energy of 764 keV. The proton and triton deposit their kinetic energy in the gas volume, producing a signal corresponding to 764 keV that serves as an unambiguous indicator of a detected neutron. The data from each ^3He sensor are identical, and consist of 256 channels that are accumulated during each accumulation period. Each 256-channel spectrum measures the energy deposition in each ^3He sensor.

The energies are determined by different materials that are wrapped around each sensor. Three energy ranges of thermal and epithermal neutrons are detected with the three separate ^3He neutron sensors. The bare sensor allows both thermal ($E_n < 0.4$ eV) and low-energy epithermal ($E_n > 0.4$ eV) neutrons to be detected. The Cd layer on the Cd-covered sensor blocks thermal neutrons. The count-rate difference between the bare and Cd-covered sensor provides the measurement of thermal neutrons. The polyethylene cover on the third sensor downscatters higher energy epithermal neutrons (approximately 1 – 100 keV) so that they can be efficiently detected in the ^3He gas.

There are two primary goals for Psyche neutron measurements. The first goal is to quantify Psyche's metal-to-silicate fraction using low- and high-energy neutrons. The second goal of Psyche neutron measurements is to provide key correction factors that enable accurate determinations of gamma-ray-derived composition values. These goals are met by producing time-series products of the thermal, epithermal, and high-energy epithermal neutron rates from the three sensors, then plotting these count rates across Psyche's surface.

Further information on the NS instrument can be found in the Psyche GRNS instrument paper (not yet published).

5.3 Data Product Overview

This SIS describes the format and structure of science and state of health (engineering) data acquired by the NS instrument from Raw through Calibrated data processing levels. The 'Raw' and 'Calibrated' designations refer to the processing level of each product using PDS4 terminology. Data are acquired on a schedule as defined in the Psyche Data Management Plan.

5.4 Data Processing Flow

The Psyche Ground Data System (GDS) at JPL receives the NS data packets and processes them into Data Product (DP) files for pickup by the Science Data Center (SDC) at ASU. The SDC converts (where necessary) all input data into formats specified by the investigation teams. The investigation science leads are responsible for retrieving the original or transformed data from the SDC and processing the data at their home institutions. Each data product generated (raw, calibrated, or derived) is then transferred back to the SDC and stored there for use by any member of the Psyche Science Team. Finally, the SDC transfers Standard Data Products to the PDS Small Bodies Node (SBN) on the delivery schedule specified in the SDMP. Figure 1 shows the overall data flow.

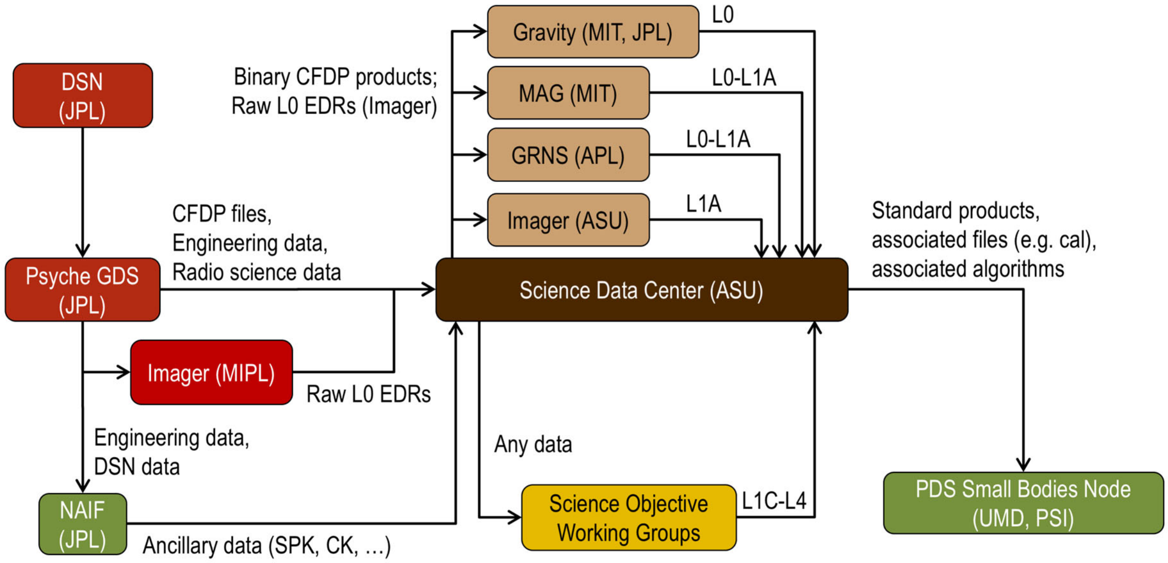

Figure 1. Psyche Data Flow

For the NS data products, the DP files are retrieved from SDC by the GRNS SOC at APL. After download to the SOC the NS data processing pipeline converts the DP files into Raw (Level 0) products. The Raw (Level 0) products are in PDS4 format and consist of a binary data file and associated PDS4 XML label. The Raw product is then transferred to the SDC and stored. The Raw product is also stored in a database at the GRNS SOC to await further processing into Calibrated (Level 1A) data products, which are also in PDS4 format. The Calibrated data products are then transferred to and stored at the SDC as well as stored in a database at the GRNS SOC to await further processing into Derived (Level 3) data products. Derived data products will be in PDS4 format and also transferred to and stored at the SDC. Specifics of the NS Derived data products will be covered in the NS Derived Data Product SIS.

Figure 2 shows the NS data flow between the SDC and the SOC as well as within the NS data processing pipeline. The Raw through Derived data products constitute the GRNS standard data products that will be delivered to PDS.

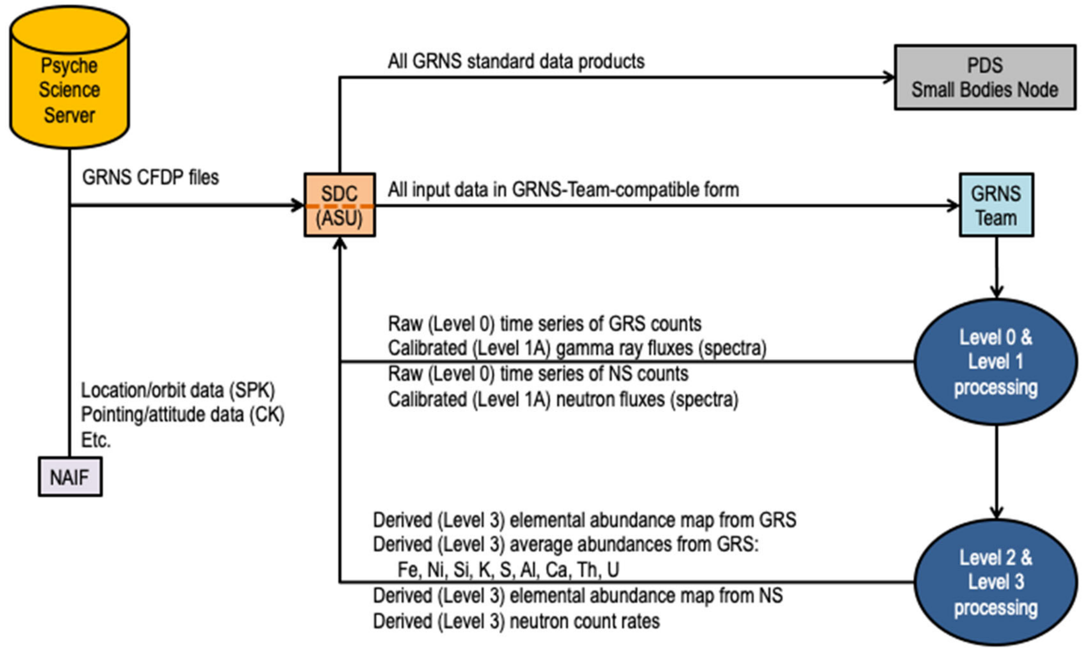

Figure 2. NS Data Flow

5.4.1 Data Processing Level

The following table describes the NS products in terms of their NASA Product processing levels and the organization of an individual NS product. Note that the NS Product name includes the PDS4 Data Processing Level (Raw, Calibrated).

NS Product	NASA Product Level	Description
N/A	Packet data	GRS telemetry
Raw NS Spectra	Level 0	Raw spectra histogram arrays collected from the Bare, Cadmium-, and Poly-wrapped sensors.
Raw NS Events	Level 0	Raw event time series data collected by the NS instrument. Data is contained in the NS Raw Events packet. A given Science Spectra packet may contain from 0-50 events. Events are collected even if they are not considered valid to be included in a spectrum.
Raw NS Counters	Level 0	Contains raw counters of events across the integration period.
Raw NS Engineering	Level 0	Raw measurements of the health and status of the NS instrument

NS Product	NASA Product Level	Description
Calibrated NS Spectra	Level 1A	Calibrated neutron spectra that have the timing, spatial, and engineering readings taken at the beginning of the associated spectral collection period.
Calibrated NS Counts	Level 1A	Calibrated NS count data, extracted from the individual pulse-height spectra, that have the timing, spatial, and engineering readings taken at the beginning of the associated spectral collection period.
Calibrated NS Engineering	Level 1A	Measurements of the health and status of the NS instrument, transformed into engineering units.

5.5 Data Product Generation

CFDP product files are periodically downloaded from the SDC to the GRNS SOC via the ReST API. Requests are sent via the interface for any CFDP products that have been updated since the previous request. This allows the SOC to automatically download newly created products as well as previously downloaded products that were regenerated by the SDC with new information. Once downloaded to the GRNS SOC the CFDP files are used as the basis for the generation of various data products as outlined below.

5.5.1 Raw Science and Engineering Data

Processing of the raw science and engineering data products first consists of organizing the CFDP files by packet type. For example, only CFDP files associated with the NS Science Spectra packet will be used to generate the NS Raw Science Spectra product. Data are then reformatted to match acceptable PDS data types and data type lengths, sorted by the timetag associated with each record, and organized into binary table files separated by collection day (Year and Day of Year).

NS Raw data has no corrections applied. Here data is stored in non-physical units (i.e. voltages and digital numbers) and no calibration is required. One data record is available for each packet generated by the instrument. An associated PDS4 XML label is generated for each binary table file. Raw data products are transferred to the SDC for storage and also stored in the SOC database to serve as the source data for generation of the calibrated products.

5.5.2 Calibrated Science Data

The NS Science Calibrated Data Products are produced by APL and provided to the SDC. Calibration includes implementing gain-shift corrections to individual spectra to enable spectral summing, and the addition of calibration engineering units and spacecraft ephemeris and attitude to the data files. APL is also responsible for generating the PDS4 XML labels. See psyche_ns_processing.pdf in the Documents collection for a detailed description on how science data products are converted into CDRs.

5.5.3 Calibrated Engineering Data

The NS Raw Engineering data are converted into physical units (temperature, voltage, current, etc) and the SCLK timetags are converted into UTC time through the use of SPICE kernels.

An ASCII file containing the table of coefficients for the conversion of engineering data is included in the Documents collection (psyche_ns_raw_engineering_lut.csv). Polynomials (up to 2nd order) are used to generate calibrated engineering data for several raw data fields. The associated algorithm is:

Calibrated Value = $a_0 + a_1x + a_2x^2$

where the a_i values are the coefficients, and **x** is the data field in the NS Raw Engineering table.

Conversion of other NS Engineering fields from DN to voltages is done via the following algorithm:
Calibrated Value = ((int(x)*1e6/1740)*scale)

where int(x) is the integer value of the DN

The scale factor and the fields for which they apply are stored in an NS scale factor lookup table ASCII file stored in the documents collection.

5.6 Product Labeling and Identification

5.6.1 File Naming Convention

The naming convention for NS standard data products from raw through calibrated is as follows (all lower case):

ns_<productType><YYYYDDD><reserved string>_v<version>.<ext>

where

<productType> defines the data as belonging to 'science' or 'state of health (soh)', data product type and processing level:

productType	**Definition**
scil0spec	Raw Spectra Science data product

scil1spec	Calibrated Spectra science data product
scil0evnt	Raw Events science data product
scil0cnts	Raw Counter science data product
scil1cnts	Calibrated Counts science data product
sohl0engn	Raw Engineering status data product
sohl1engn	Calibrated Engineering status data product

<YYYYDOY> defines the four digit year and three digit day of year corresponding to the timetag associated with each data record in the file.

<reserved string> is a reserved character string use during the course of the mission as needed to define “special” data products. Nominal data products are identified by the “zzz” character string.

<version> is the two digit version number associated with the product file. Version numbering starts at 01 and is incremented when a product that has previously been delivered to PDS needs to be regenerated and redelivered. For example, if a new calibration algorithm that yields better data values is applied retroactively to previously delivered data.

<ext> is the three character file extension. The PDS4 naming convention is used, with ‘dat’ to denote binary table files, ‘tab’ for ASCII table files, and ‘xml’ for PDS XML label files.

5.7 Standards Used in Generating Data Products

5.7.1 PDS Standards

All data products described in this SIS conform to PDS4 standards as described in the PDS Standards document noted in the Applicable Documents section of this SIS. Prior to public release, all data products will have passed both a data product format PDS peer review and a data product production pipeline PDS peer review to ensure compliance with applicable standards.

All data products are labeled with PDS4 compliant detached XML labels. These labels describe the content and format of the associated data product. Labels and products are associated by filename with the label having the same base filename as the data product but with a .xml extension.

Labels are constructed with the PDS4 Product class, Product Observational sub-class. The Product observational sub-class contains a set of information objects that describe the content of the data product and how the data product file is formatted. Additional information on PDS4 product labels can be found by selecting “How to Approach a PDS4 Data Set” on the PDS Small Bodies Node website at http://sbn.pds.nasa.gov.

5.7.2 Time Standards

Time standards used by the Psyche mission conform to PDS time standards. The SCLK field in the NS data product tables match the spacecraft time in integer seconds that is transmitted to the NS instrument in a Spacecraft Time Message (STM). This is known as the one pulse per second (1PPS) discrete signal. The SCLK field represents the count of seconds since JPL's J2000 epoch, defined as 01-Jan-2000 12:00:00.00 ET. In addition to the current SCLK value, the NS processor board maintains a high resolution counter which is referenced to the active edge of the 1PPS pulse. This is reported in the SCLK_Sub field as the count of subsecond ticks since the SCLK value, where each tick represents 20 microseconds. The high resolution counter is reset on the active edge of a 1PPS pulse of the most recent valid STM.

Note that the relationship between SCLK and ET or UTC is not accurately described by a linear function. This is a consequence of the fact that the rate at which any spacecraft clock runs varies over time. Thus, accurate conversion from SCLK seconds and subseconds into any other time system should be done using SPICE kernels. SPICE kernels are themselves updated over time, thus the XML labels for each NS data product contain a listing of the kernels that were used to generate any SPICE derived values, including UTC from SCLK. It is recommended to use the SPICE kernel list in the XML label in order to derive the same SPICE values as the data product.

Additionally, the SPICE Psyche SCLK kernel is defined such that each tick on the subseconds portion of the SCLK time string represents 2^{-16} seconds. An extra processing step is required to convert the reported GRNS subsecond values from 20 microsecond ticks to 2^{-16} second ticks before passing it to SPICE. The extra processing step is detailed in the pseudocode below.

The pseudocode shown below is an example of how one would use the SPICE toolkit to load SPICE kernels and convert SCLK and SCLK_Sub values to UTC. The pseudocode uses the CSPICE function and argument naming convention; the exact nomenclature may vary depending on the programming language of the SPICE library being used.

1. First load a Psyche SCLK kernel file.

```
furnsh_c ( <name of SCLK kernel file> );
```

2. Next load the leapseconds kernel file.

```
furnsh_c (<name of Leapseconds kernel file>);
```

3. Create the GRNS SCLK string in the form MMMMMMMMM.NNNNN where:

MMMMMMMMM: the whole seconds value parsed from the SCLK field of the NS data table.

NNNNN: the SCLK_Sub field of the NS data table after performing the following calculation:

a. Multiply the SCLK_Sub field by 2e^-5 to convert from 20 microsecond ticks to units of seconds.

b. Multiply the result from step a by 65536 to convert from seconds to SPICE subsecond ticks.

c. Round to the nearest integer as the subsecond ticks are integer values.

The subeconds portion of the SCLK string is in the range from 0-65535, hence up to 5 digits is allowed for the subseconds portion of the SCLK string. Ex. NS SCLK_Sub value of 49999 is converted to 65535 in SPICE subsecond ticks using the steps above. Also note that the NS SCLK_Sub rollover value of 50000 equates to the SPICE rollover value of 65536 (both equal one second, which results in the SCLK value incrementing by one and the subseconds ticks value rolling over to 0).

4. Convert the SCLK string to a double precision Ephemeris Time (ET) value.

```
scs2e_c (sc, sclkstr, &et);
```

where:
'sc' - NAIF spacecraft ID code. For Psyche it is -255.
'sclkstr' - string containing the SCLK and converted SCLK_sub value as specified in step 3. For example: "685484518.320". The delimiter can either be a '.' or ':' character. Note that the SCLK_sub value represents the number of subsecond ticks. For example, ".320" represents 320 ticks while ".32" represents 32 ticks.

'&et' - pointer to the output in ET

5. Convert the ET to UTC.

```
timout_c (et, pictur, lenout, utc);
```

where:
'et' - ET time output from Step 3.
'pictur' - a string specifying the output format "picture". For example:

```
"MON DD,YYYY  HR:MN:SC.#### (TDB) ::TDB"
```

This specifies the output format as a 3-character month, 2-digit day of month, 4-digit year, hour, minute, second.subseconds in Barycentric Dynamical Time.
'lenout' - maximum allowed length of the output string. If the output string is expected to have N characters, lenout should at least be N+1.
'utc' - output string containing the UTC equivalent to sclkstr from Step 3.

5.7.3 Coordinate Systems

All coordinate systems used by the Psyche mission conform to IAU standards. A complete discussion of the coordinate systems and how they are deployed in the mission can be found in future revisions of the Psyche Science Data Management Plan..

5.7.4 Data Storage Conventions

NS data products are stored as PDS4 binary table data in big-endian (MSB) format with the exception of the calibrated NS Engineering Status data products, which is stored in ASCII fixed-width table format. Data formats are explicitly described in Section 6.

6 Detailed Product Specification

6.1 Data Product Structure and Organization

The Psyche NS bundle shall consist of data products from Raw through Derived Product processing levels. Data product collections within the bundle are organized by processing level, mission phase, year, and day of year. All data products are stored as PDS4 binary tables with detached XML label files.

Note that while the NS bundle will eventually contain a Derived Product collection with an associated SIS, this will not be present until later in the mission. The following shows the organization of the collections within Psyche NS bundle.

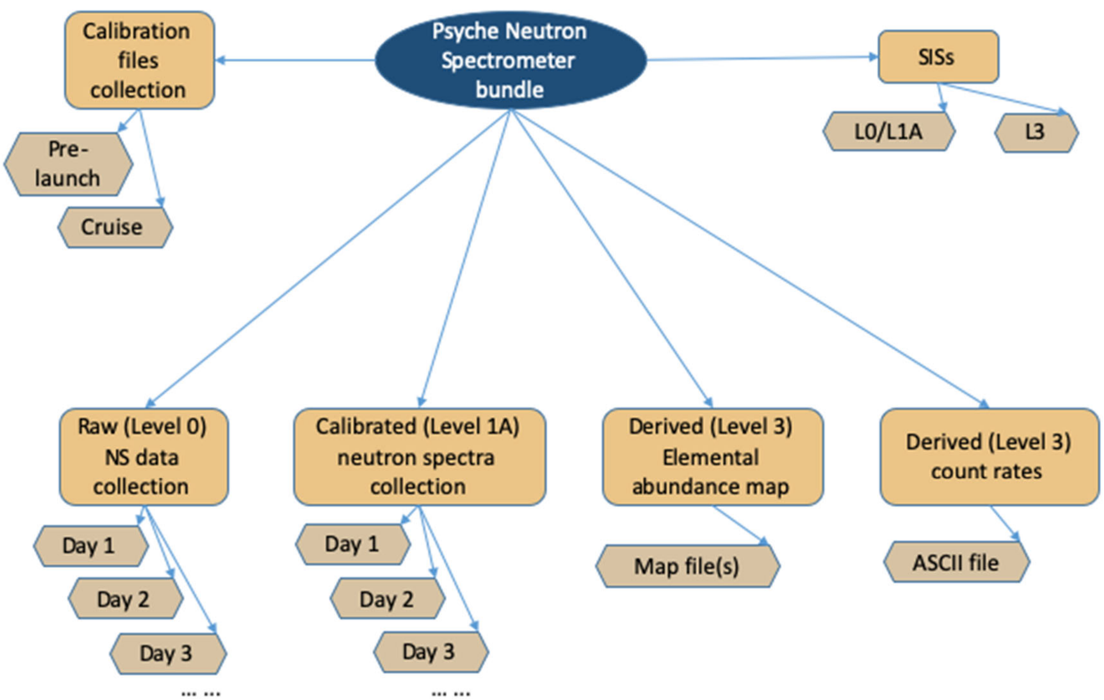

Figure 3. Psyche NS Bundle Layout

6.2 Data Format Descriptions

There are references to channel numbers in some of the following data format descriptions. Below is a lookup table that describes what the channel numbers indicate.

Channel	Description
channel 1 (ch1)	bare sensor
channel 2 (ch2)	cadmium (Cd)-wrapped sensor
channel 3 (ch3)	polyethylene-wrapped sensor

6.2.1 Raw NS Spectra

The raw NS Spectra data product contains three 256-bin histograms, corresponding to the pulse-height measurements made by each of the three ^{3}He gas proportional counters (bare, Cd-wrapped, and Polyethylene-wrapped). The histogram and associated metadata are stored as rows in a fixed-width binary table. The following table shows the format of each row in the binary table.

Field Name	**Length (bytes)**	**Data Type**	**Description**
SCLK	4	Unsigned Integer	Time tag at the start of the histogram integration period in seconds.
SCLK_Sub	2	Unsigned Integer	Subsecond portion of timetag. Units are in subsecond ticks where each tick is 20 microseconds and values range from 0-49999.
AccumPeriod	2	Unsigned Integer	Integration period in seconds.
ConfigChange	2	Unsigned Integer	Indicates whether there was a configuration change during the integration period, which may result in data artifacts. Value corresponds to a bit flag for the following parameters: bit 0 = data products changed. bit 1 = Parameters changed. bit 2 = Pulse Processing configuration changed. For example, if the Parameters and Pulse Processing configuration were changed the value would be 6.
Bare	4 x 256	Unsigned Integer	256 bin histogram of the bare 3He sensor
Cadmium (Cd)	4 x 256	Unsigned Integer	256 bin histogram of the Cd-wrapped 3He sensor.
Polyethylene (Poly)	4 x 256	Unsigned Integer	256 bin histogram of the Poly-wrapped 3He sensor.

6.2.2 Raw NS Events

The Raw NS Events data product contains up to 50 raw events generated per second when integration is enabled. Note that a single timetag is associated with 1-50 events due to the way the data is organized in the downlink telemetry packet. The event data are stored in a fixed-width binary table; the format of each row in the table is shown below.

Field Name	**Length (bytes)**	**Data Type**	**Description**
SCLK	4	Unsigned Integer	Timetag of events in seconds.
SCLK_Sub	2	Unsigned Integer	Subsecond portion of timetag. Units are in subsecond ticks where each tick

			is 20 microseconds and values range from 0-49999.
NumEvents	2	Unsigned Integer	The number of events associated with the SCLK time tag; from 1 to 50 events. This value will also indicate how many rows will have the same SCLK time tag.
EventValid	1	Unsigned Byte	Event word coming out of the file-in file-out (FIFO) is valid. This will always be 1; used by the software to determine if it has read out all the events in the FIFO.
EventDropped	1	Unsigned Byte	Unable to write an event into the FIFO. =1 True, =0 False
EventErr	1	Unsigned Byte	Event has a parity error =1 True, =0 False
EventFull	1	Unsigned Byte	Event FIFO is currently full =1 True, =0 False
Ch1_Event	1	Unsigned Byte	Event present in Ch1. =1 True, =0 False
Ch2_Event	1	Unsigned Byte	Event present in Ch2. =1 True, =0 False
Ch3_Event	1	Unsigned Byte	Event present in Ch3. =1 True, =0 False
Event_Invalid	1	Unsigned Byte	Event is invalid. =1 True, =0 False
Event_OOR	1	Unsigned Byte	Event experienced an ADC OOR. =1 True, =0 False
Max_Value	2	Signed Integer	Amplitude of the positive peak lobe
Min_Value	2	Signed Integer	Amplitude of the negative peak lobe
Delta_Time	2	Unsigned Integer	Duration of time between the max and min lobes (in 100ns clock cycles)
Peak_to_Peak_Value	2	Signed Integer	Min-to-max amplitude

6.2.3 Raw NS Counters

The Raw NS Counts data product contains counters of events across the integration period and is used for diagnostic purposes. The counters and metadata are stored in a fixed-width binary table; the format of each row in the table is shown below.

Field Name	**Length (bytes)**	**Data Type**	**Description**
SCLK	4	Unsigned Integer	Timetag at the start of the histogram integration period in seconds.

SCLK_Sub	2	Unsigned Integer	Subsecond portion of timetag. Units are in subsecond ticks where each tick is 20 microseconds and values range from 0-49999.
AccumPeriod	2	Unsigned Integer	Integration period in seconds.
ConfigChange	2	Unsigned Integer	Indicates whether there was a configuration change during the integration period, which may result in data artifacts. Value corresponds to a bit flag for the following parameters: bit 0 = data products changed. bit 1 = Parameters changed. bit 2 = Pulse Processing configuration changed. For example, if the Parameters and Pulse Processing configuration were changed the value would be 6.
Ch1_Trigger	4	Unsigned Integer	Trigger rate (counts per second) on Channel 1
Ch2_Trigger	4	Unsigned Integer	Trigger rate (counts per second) on Channel 2
Ch3_Trigger	4	Unsigned Integer	Trigger rate (counts per second) on Channel 3
FIFO_Write	4	Unsigned Integer	Number of events written into hardware first-in first-out (FIFO)
SW_Events	4	Unsigned Integer	Number of events software read from hardware FIFO
Ch1_Events	4	Unsigned Integer	Number of Channel 1 events processed by software.
Ch2_Events	4	Unsigned Integer	Number of Channel 2 events processed by software.
Ch3_Events	4	Unsigned Integer	Number of Channel 3 events processed by software.
Ch1_OOR	4	Unsigned Integer	Number of Channel 1 events with ADC out of range
Ch2_OOR	4	Unsigned Integer	Number of Channel 2 events with ADC out of range
Ch3_OOR	4	Unsigned Integer	Number of Channel 3 events with ADC out of range
Ch1_Invalid	4	Unsigned Integer	Number of Channel 1 events flagged as invalid
Ch2_Invalid	4	Unsigned Integer	Number of Channel 2 events flagged as invalid
Ch3_Invalid	4	Unsigned Integer	Number of Channel 3 events flagged as invalid

Ch1_Spec	4	Unsigned Integer	Number of histogrammed Channel 1 events
Ch2_Spec	4	Unsigned Integer	Number of histogrammed Channel 2 events
Ch3_Spec	4	Unsigned Integer	Number of histogrammed Channel 3 events
Ch1_OOB	4	Unsigned Integer	Number of Channel 1 events out of histogram bounds
Ch2_OOB	4	Unsigned Integer	Number of Channel 2 events out of histogram bounds
Ch3_OOB	4	Unsigned Integer	Number of Channel 3 events out of histogram bounds
Ch1_DT_Early	4	Unsigned Integer	Number of Channel 1 events with a delta-time that falls in the early window
Ch2_DT_Early	4	Unsigned Integer	Number of Channel 2 events with a delta-time that falls in the early window
Ch3_DT_Early	4	Unsigned Integer	Number of Channel 3 events with a delta-time that falls in the early window
Ch1_DT_Mid	4	Unsigned Integer	Number of Channel 1 events with a delta-time that falls in the middle window.
Ch2_DT_Mid	4	Unsigned Integer	Number of Channel 2 events with a delta-time that falls in the middle window.
Ch3_DT_Mid	4	Unsigned Integer	Number of Channel 3 events with a delta-time that falls in the middle window.
Ch1_DT_OOB	4	Unsigned Integer	Number of Channel 1 events with a delta-time that is out of bounds.
Ch2_DT_OOB	4	Unsigned Integer	Number of Channel 2 events with a delta-time that is out of bounds.
Ch3_DT_OOB	4	Unsigned Integer	Number of Channel 3 events with a delta-time that is out of bounds.

6.2.4 Raw NS Engineering

The Raw NS Engineering data product contains information about the DPU status, software data, and state of the NS instrument. The data are stored in a fixed-width binary table; the format of each row in the table is shown below.

Field Name	**Length (bytes)**	**Data Type**	**Description**
SCLK	4	Unsigned Integer	Timetag when the source status packet was generated in seconds.
SCLK_Sub	2	Unsigned Integer	Subsecond portion of timetag. Units are in subsecond ticks where

			each tick is 20 microseconds and values range from 0-49999.
SCLK_Last	4	Unsigned Integer	Last SCLK time received.
SCLK_Last_Sub	4	Unsigned Integer	Subsecond portion of last SCLK time received. Units are in subsecond ticks where each tick is 20 microseconds and values range from 0-49999.
Num_SCLK_Rcvd	2	Unsigned Integer	Number of Space Time Messages (STMs) received
SCLK_STM_Status	1	Unsigned Byte	STM bit flag. Bit 0 = reserved Bit 1 = Pulse per second is late Bit 2 = Pulse per second is early Bit 3 = STM needed Bits 4-7 Unused
Cmd_Exec_Count	2	Unsigned Integer	Number of commands executed.
Last_Cmd_Exec	4	Unsigned Integer	SCLK time of last command executed.
Last_Cmd_Exec_Sub	2	Unsigned Integer	Subsecond portion of time of last command executed. Units are in subsecond ticks where each tick is 20 microseconds and values range from 0-49999.
Cmd_Rej_Count	2	Unsigned Integer	Number of commands rejected.
Cmd_Rej_Reason	1	Unsigned Byte	Reason code of last command rejected.
Last_Cmd_Rej	4	Unsigned Integer	SCLK time of last command rejected.
Last_Cmd_Rej_Sub	2	Unsigned Integer	Subsecond portion of time of last command rejected. Units are in subsecond ticks where each tick is 20 microseconds and values range from 0-49999.
Macro_Exec_Count	2	Unsigned Integer	Number of macro commands executed.
Macro_Rej_Count	2	Unsigned Integer	Number of macro commands rejected.
Last_Seq_Count	2	Unsigned Integer	Last sequence count seen.
Queue_Oflow_Count	1	Unsigned Byte	Number of queue overflows.
Last_Queue_Oflow	1	Unsigned Byte	ID of last queue overflow.
Mem_Dwell_Addr	4	Unsigned Integer	Memory Dwell address (peek)
Mem_Dwell_Val	4	Unsigned Integer	Memory Dwell value (peek)
Counter_Dwell_ID	1	Unsigned Byte	Counter Dwell ID (peek)
Counter_Dwell_Val	4	Unsigned Integer	Counter Dwell value (peek)
Crit_ShVar_Stat	1	Unsigned Byte	Status of critical shared variables

LEON_Stat	2	Unsigned Integer	LEON processor status
AHB_Fail_Addr	4	Unsigned Integer	AHB Status
Local_Osc_Count	4	Unsigned Integer	Local oscillator ticks between STM
TLM_Bw	4	Unsigned Integer	Telemetry bandwidth used this second
Bytes_Sent	4	Unsigned Integer	Total bytes sent since power on.
Time_In_App	4	Unsigned Integer	Time spent in application in seconds.
Status_Int	2	Unsigned Integer	Status packet interval.
Sys_TellTales	4	Unsigned Integer	System telltales.
Last_Alarm_SCLK	4	Unsigned Integer	SCLK time of last alarm in seconds.
Last_Alarm_ID	2	Unsigned Integer	ID of last alarm
Alarm_Count	1	Unsigned Byte	Number of alarms.
CPU_Idle_Pct	1	Unsigned Byte	Processor idle percentage.
Macro_Free_Blocks	2	Unsigned Integer	Number of free macro blocks.
Last_Macro_ID	2	Unsigned Integer	Last macro executed.
HK_Raw_or_Avg	1	Unsigned Byte	Housekeeping data is raw or averaged.
LVPS_V_Pri	2	Unsigned Integer	LVPS Primary supply voltage.
LVPS_T_NS_Plate	2	Unsigned Integer	LVPS Plate temperature.
LVPS_V_N12	2	Unsigned Integer	LVPS -12V supply voltage.
LVPS_T_NS_Preamp1	2	Unsigned Integer	LVPS Preamp 1 Temperature.
LVPS_I_N5	2	Unsigned Integer	LVPS -5V supply current.
LVPS_I_N12	2	Unsigned Integer	LVPS -12V supply current.
LVPS_V_P5	2	Unsigned Integer	LVPS +5V supply voltage.
LVPS_V_P6	2	Unsigned Integer	LVPS +6V supply voltage.
LVPS_V_N5	2	Unsigned Integer	LVPS -5V supply voltage.
LVPS_V_P12	2	Unsigned Integer	LVPS +12V supply voltage.
LVPS_V_P33	2	Unsigned Integer	LVPS +3.3V supply voltage.
LVPS_T_NS_Preamp2	2	Unsigned Integer	LVPS Preamp 2 temperature.
LVPS_I_P5	2	Unsigned Integer	LVPS +5V supply current.
LVPS_I_P6	2	Unsigned Integer	LVPS +6V supply current.
LVPS_V_N6	2	Unsigned Integer	LVPS -6V supply voltage.
LVPS_I_Op_Htr	2	Unsigned Integer	LVPS Operational Heater return current.
LVPS_Spare1	2	Unsigned Integer	Spare telemetry field to be used in case a future flight software update adds a telemetry parameter. Field names must be unique, hence this is spare field 1.
LVPS_T_Brd	2	Unsigned Integer	LVPS board temperature.
LVPS_I_Pri	2	Unsigned Integer	LVPS Primary supply current.
LVPS_I_P12	2	Unsigned Integer	LVPS +12V supply current.

LVPS_I_P33	2	Unsigned Integer	LVPS +3.3V supply current.
LVPS_T_NS_Preamp3	2	Unsigned Integer	LVPS Preamp 3 temperature
LVPS_Spare2	2	Unsigned Integer	Spare telemetry field to be used in case a future flight software update adds a telemetry parameter. Field names must be unique, hence this is spare field 2.
LVPS_I_N6	2	Unsigned Integer	LVPS -6V supply current.
HVPS_V_Mon1	2	Unsigned Integer	HVPS Monitor 1 voltage.
HVPS_I_Mon1	2	Unsigned Integer	HVPS Monitor 1 current.
HVPS_V_Mon2	2	Unsigned Integer	HVPS Monitor 2 voltage.
HVPS_I_Mon2	2	Unsigned Integer	HVPS Monitor 2 current.
HVPS_V_ADC_Cal1	2	Unsigned Integer	HVPS ADC Calibration voltage 1
HVPS_V_ADC_Cal2	2	Unsigned Integer	HVPS ADC Calibration voltage 2
HVPS_T_Brd	2	Unsigned Integer	HVPS Board temperature.
HVPS_Seq_En	2	Unsigned Integer	HVPS Power sequence.
PROC_T_Brd	2	Unsigned Integer	Processor board temperature.
PROC_V_P33	2	Unsigned Integer	Processor +3.3V supply voltage.
PROC_V_P25	2	Unsigned Integer	Processor +2.5V supply voltage.
PROC_V_P18	2	Unsigned Integer	Processor +1.8V supply voltage.
PROC_V_P15	2	Unsigned Integer	Processor +1.5V supply voltage.
PROC_I_P25	2	Unsigned Integer	Processor +2.5V supply current.
PROC_I_P18	2	Unsigned Integer	Processor +1.8V supply current.
PROC_I_P15	2	Unsigned Integer	Processor +1.5V supply current.
Op_Htr_State	1	Unsigned Byte	Operational Heater 1 Control state. =0 idle =1 heating =2 at temp =3 fault (temperature sensor failure)
Op_Htr1_Upper_Limit	2	Unsigned Integer	Operational Heater 1 set point upper limit.
Op_Htr1_Lower_Limit	2	Unsigned Integer	Operational Heater 1 set point lower limit.
Op_Htr1_En	1	Unsigned Byte	Operational Heater 1 enable.
Op_Htr2_State	1	Unsigned Byte	Operational Heater 2 Control state. =0 idle =1 heating =2 at temp =3 fault (temperature sensor failure)
Op_Htr2_Upper_Limit	2	Unsigned Integer	Operational Heater 2 set point upper limit.
Op_Htr2_Lower_Limit	2	Unsigned Integer	Operational Heater 2 set point lower limit.

Op_Htr2_En	1	Unsigned Byte	Operational Heater 2 enabled.
HV1_State	1	Unsigned Byte	High Voltage Power Supply (HVPS) 1 state =0 disabled =1 off (enabled at 0V) =2 Ramp1 =3 Hold1 =4 Ramp2 =5 Hold2 =6 Ramp to Goal =7 Ramp Down =8 At Gobal =9 Emergency Shutdown =10 SAFED =11 Fault (temperature sensor failure)
HV1_Volt	2	Unsigned Integer	HVPS1 Commanded voltage
HV1_Goal	2	Unsigned Integer	HVPS1 Setpoint goal
HV1_Max	2	Unsigned Integer	HVPS1 Absolute max allowed voltage.
HV1_Fault_State	1	Unsigned Byte	HVPS1 Fault condition =0 Nominal =1 Safing level 1 =2 Safing level 2
HV2_State	1	Unsigned Byte	High Voltage Power Supply (HVPS) 2 state =0 disabled =1 off (enabled at 0V) =2 Ramp1 =3 Hold1 =4 Ramp2 =5 Hold2 =6 Ramp to Goal =7 Ramp Down =8 At Gobal =9 Emergency Shutdown =10 SAFED =11 Fault (temperature sensor failure)
HV2_Volt	2	Unsigned Integer	HVPS2 Commanded voltage
HV2_Goal	2	Unsigned Integer	HVPS2 Setpoint goal
HV2_Max	2	Unsigned Integer	HVPS2 Absolute max allowed voltage.
HV2_Fault_State	1	Unsigned Byte	HVPS2 Fault condition =0 Nominal

			=1 Safing level 1 =2 Safing level 2
Prisec_Preamp	1	Unsigned Byte	Identifies the Preamp Temperature active sensor. =0 Primary =1 Secondary =2 Both invalid
Dpulser_Status	1	Unsigned Byte	Value corresponds to a bitmapped field, where bit=1 indicates a digital tail pulser channel is enabled, and bit=0 indicates it is disabled. bit 0 (LSB) = Channel 0 bit 1 = Channel 1 bit 2 = Channel 2 bit 3 = Channel 3 bit 4 = Channel 2 CPT. Ex. A value of 10 indicates that Channel 2 and Channel 2 CPT are enabled.
Bare_CPS	4	Unsigned Integer	Bare He3 counts per second
Cadm_CPS	4	Unsigned Integer	Cadmium He3 counts per second
Poly_CPS	4	Unsigned Integer	Poly He3 counts per second
PP_Status	1	Unsigned Byte	Histogramming status =0 Idle (not accumulating) =1 Active =2 Sending histogram; continuing integration
PP_Data_Product_Mask	2	Unsigned Integer	Value corresponds to a bitmapped field, where bit=1 indicates a data product is selected to downlink to ground, bit=0 indicates data is not selected for downlink. bit 0 (LSB) = Bare spectra bit 1 = Cadmium spectra bit 2 = Polyethylene spectra bit 3 = NS Raw Counts bit 4 = NS Raw Events Ex. A value of 23 indicates that the NS Raw Events, Bare, Cadmium, and Poly spectra are all enabled.
PP_Config_Mask	2	Unsigned Integer	NS Pulse Processing configuration. Value corresponds to a bitmapped field, where bit=1 indicates the parameter is enabled,

			bit=0 indicates the parameter is disabled. Configuration settings include whether or not to histogram events that could have poor Data Quality (DQ) and whether or not the delta-time (DT) between minimum and maximum peaks should be used to classify events. bit 0 (LSB) = Ch1 DQ Reject bit 1 = Ch2 DQ Reject bit 2 = Ch3 DQ Reject bit 3 = Unused bit 4 = Ch1 DT Check Option bit 5 = Ch1 DT Check Enable bit 6 = Ch2 DT Check Option bit 7 = Ch2 DT Check Enable bit 8.= Ch3 DT Check Option bit 9 = Ch3 DT Check Enable Ex. A value of 52 indicates that Ch3 DQ Reject, Ch1 DT Check Option, and Ch1 DT Check Enable are all enabled.
PP_DQ_Mask	2	Unsigned Integer	Pulse processing data quality. Indicates whether there was a configuration change during the integration period, which may result in data artifacts. Value corresponds to a bit flag for the following parameters: bit 0 = data products changed. bit 1 = Parameters changed. bit 2 = Pulse Processing configuration changed. For example, if the Parameters and Pulse Processing configuration were changed the value would be 6.
PP_Total_Hist_Int	2	Unsigned Integer	Histogram integration time in seconds
PP_Current_Hist_Int	2	Unsigned Integer	Time into current histogram integration in seconds.

6.2.5 Calibrated NS Spectra

This section will describe the content and structure of the Calibrated NS spectra product. This will be done in time for the Pipeline Peer Review.

6.2.6 Calibrated NS Count Rates

This section will describe the content and structure of the Calibrated NS count rates. This will be done in time for the Pipeline Peer Review.

6.2.7 Calibrated NS Engineering

This section will describe the content and structure of the Calibrated NS Engineering product. This will be done in time for the Pipeline Peer Review.

7 Applicable Software

No software is provided with this data. The PDS has software utilities that use the PDS4 XML label in order to parse the data file and display its contents to the user.

8 Table of Acronyms

Acronym	Name
1PPS	One Pulse Per Second
ACS	Anti-Coincidence Shield
ADC	Analog to Digital Converter
AH	Anneal Heater
AHB	Advanced High Performance Bus
ASU	Arizona State University
CC	Cryocooler
CCBUS	Cryocooler Bus
CCDB	Cryocooler Driver Board
CCPCB	Cryocooler Power Conditioning Board
CCSDS	Consultative Committee for Space Data Systems
CFDP	CCSDS File Delivery Protocol
CK	C-kernel, one of several SPICE kernel files used to derive geometric information contained in calibrated data products
CPS	Counts Per Second
CPT	Comprehensive Performance Test
CR	Charge Reset
CRPS	Charge Resets Per Second
DN	Digital Number
DP	Data Product

DPU	Digital Processing Unit
DQ	Data Quality
DSN	Deep Space Network
EDR	Experimental Data Records (PDS3 terminology; known as 'Raw' data in PDS4)
ET	Ephemeris Time
FIFO	First-in, First-out
FN	Fast Neutrons
FPGA	Field Programmable Gate Array
GCR	Galactic Cosmic Ray; legacy terminology sometimes used when referring to the ACS Low Gain data
GDS	Ground Data System
GRNS	Gamma-Ray and Neutron Spectrometer instrument
GRS	Gamma-Ray Spectrometer
HK	Housekeeping
HPGe	High Purity Germanium
HPGEAC	High Purity Germanium Anti-Coincident data
IDX	Index
JHU/APL	Johns Hopkins University/Applied Physics Laboratory
JPL	Jet Propulsion Laboratory
LEON	Designation of the microprocessor used in the DPU
LVPS	Low Voltage Power Supply
MAG	Magnetometer instrument
MIT	Massachusetts Institute of Technology
NAIF	Navigation and Ancillary Information Facility
NS	Neutron Spectrometer
OOB	Out of Bounds (usually refers to histogram bounds)
OOR	Out of Range
OOR	Out of Range
PDS	Planetary Data System
PP	Pulse Processing
PSI	Planetary Science Institute
PWM	Pulse Width Modulation
SCLK	Spacecraft Clock
SCUM	Sensor Control Unit Module
SDC	Science Data Center (for Psyche Mission)
SIS	Software Interface Specification
SOC	Science Operations Center
SPEC	Short for spectra; used to refer to histogram events in engineering data products
SPICE	Spacecraft, Planet, Instrument, C-matrix, Events; describes the components of the observation geometry information system used to derive geometric and time information
SPK	Spacecraft and Planets Kernel, one of several SPICE kernel files used to derive geometric information contained in calibrated data products

STM	Spacecraft Time Message – digital information sent by the spacecraft to the GRNS instrument containing the SCLK time; used to generate timetags for each GRNS packet
SW	Software
TLM	Telemetry
TTSP	Time to Second Pulse – refers to the time measured between two pulses in the engineering data
TVAC	Thermal Vacuum (refers to a type of ground calibration test)
UMD	University of Maryland
XML	Extensible Markup Language; the format used for PDS4 label files