New Horizons SWAP Pluto Encounter Calibrated Data Overview

During the migration to the Planetary Data System's (PDS) PDS4 data standards, this current description was adapted from the PDS3 dataset catalog file, including updates found in the KEM1 Encounter phase version, providing light edits to the text, format, flow, and to make the description to better conform to this PDS4 data collection.

Abstract

This data set contains Calibrated data taken by the New Horizons Solar Wind Around Pluto (SWAP) instrument during the PLUTO ENCOUNTER mission phase.

This data set contains SWAP observations taken during the Approach (Jan-Jul, 2015), Encounter, Departure, and Transition mission sub-phases, including flyby observations taken on 14 July, 2015, and departure and calibration data through late October, 2016. This data set completes the Pluto mission phase deliveries for SWAP.

Changes since the prior version include the addition of data downlinked between the end of January, 2016 and the end of October, 2016, completing the delivery of all data covering the Pluto Encounter and subsequent Calibration Campaign.

Finally, downlink data several days beyond the end of the nominal end of mission phase were included in this data set in an attempt to fill out the products at the nominal end of mission phase.

These data were migrated from the previously released PDS3 data set NH-P-SWAP-3-PLUTO-V3.0.

Data Set Overview

This data set contains Calibrated data taken by the New Horizons Solar Wind Around Pluto (SWAP) instrument during the PLUTO ENCOUNTER mission phase. The closest approach to Pluto occurred on July 14, 2015, at approximately 11:50 UTC.

SWAP comprises electro-optics and detectors to obtain count rate measurements of the solar wind; measuring the solar wind before, during and after the Pluto encounter will allow characterization of the atmospheric escape rate of Pluto. The SWAP electro-optic elements select the angles and energies of the solar wind and pickup ions to be measured; ions thus selected are registered with a coincidence detector system. SWAP measures the energy spectrum of ions in its environment by varying (also called scanning or sweeping) voltages of the electro-optics over many steps during a short time period. SWAP can also immediately follow a sweep of coarse voltage steps with a sweep of finer steps, centered on the peak measurement of the coarse sweep, to obtain a higher resolution of that portion of the energy spectrum.

There are three types of SWAP science data: real-time; summary; histogram. Real-time data, at rates up to 1Hz, provide the most detailed science measurements since they contain the full count rate distribution as a function of energy (speed). For science summary and science histogram modes, the full distribution is not recorded. Instead, parameters are derived from the count rate distribution stored by SWAP. These derived parameters require less memory than storing the whole distribution. The science summary and science histogram modes are primarily used during the cruise phase of the mission. For science data, the common data product is usually a binary table; for calibrated real-time data, spectrograms as images are also provided. Typically the tables have instrument parameters and measurements in the columns and measurement times in the rows, but the actual format depends on the type of data and the processing level (raw vs. calibrated). Other tables containing housekeeping and other parameters are also provided. Documentation for all data types and formats can be found in the Science Operations Center (SOC) Instrument Interface Control Document (ICD) found within the PDS (see PDS4 LID `urn:nasa:pds:nh_documents:mission:soc_inst_icd`).

During the Pluto Charon Encounter mission phase starting in January, 2015, there were several sub-phases: three Approach sub-phases, (AP1, AP2 and AP3); a CORE sequence for the Pluto flyby on 14.July, 2015 (Day Of Year 195), sometimes also referred to as NEP (Near-Encounter Phase); three Departure sub-phases (DP1, DP2, DP3); a Transition sub-phase closing out the mission phase in October, 2016. For this final SWAP delivery for the Pluto mission phase, this data set includes all data for the Pluto Encounter mission phase, downlinked through late October, 2016.

SWAP was turned on for nominal operations throughout approach, other than powering off and on around trajectory correction maneuvers. It was operating as a ridealong during the PEPSSI plasmarolls, on DOY 107, 115, 121, 128, 148, 156, and 176. There were two other dedicated SWAP and PEPSSI rolls on DOY 163 and 171. SWAP gain functional testing occurred on DOY 016 and 137.

Note: Sub-phases AP1, AP2 and AP3 started on 2015-01-15, 2015-04-05 and 2015-06-23, respectively. Sub-phases DP1, DP2 and DP3 started on 2015-07-16, 2015-08-04 and 2015-10-22, respectively.

Every observation provided in this data set was taken as a part of a particular sequence. For this data set, these sequences can be found in the SWAP document collection under PDS4 LID `urn:nasa:pds:nh_documents:swap:seq_swap_pluto`. Please note that some sequences provided may have zero corresponding observations.

Version History

Each subsection below details the major changes between the prior versions of this data set, listing the newest versions before older versions.

PDS4 v1.0 (migration from PDS3 V3.0)

This data collection was migrated from Planetary Data System's (PDS) PDS3 archive standards to the PDS4 archive standards, which involved changing the PDS formatted product labels. The

products themselves have remained unchanged. The major changes from the PDS3 V3.0 data set are:

- the calibration files, documents, and data products were reorganized into separate collections of calibration files, documents, data product summary plots, spacecraft trajectory tables, and data products, instead of being in a single package as it was in prior PDS3 data set versions.
- the geometry keyword values found within the PDS4 labels were calculated using the most recent SPICE kernels available at label creation. Note that the FITS headers have not been updated and their geometry keyword values therefore remain unchanged.
- the PDS4 data labels were produced using the PDS3 data labels and/or FITS headers, and so any fixes and/or updates to the PDS3 label pipeline as found in future mission phases may not have been implemented here.

There is a slight overlap of a few days of data between the end of the Pluto Encounter and the beginning of KEM Cruise 1 PDS3 delivered data sets. No attempt to sort out these data were made during the migration of the PDS3 data sets to the PDS4 standards. Some data files may supersede others. This is due to data being replayed after the Pluto Encounter PDS Deliveries. As a result, the product identifiers (LIDVIDs) may not reflect one product superseding the other. Note that file names may change between deliveries if the start/stop times are updated when additional data were later downlinked.

PDS3 V3.0 (NH-P-SWAP-3-PLUTO-V3.0)

This is VERSION 3.0 of this data set. This P3 Pluto Encounter dataset release includes all data from the previous two Pluto deliveries and adds data that was downlinked from 1/31/2016 through 10/31/2016. This dataset completes delivery of all data covering the Pluto Encounter and subsequent Calibration Campaign. For SWAP, most of the Pluto Encounter data was downlinked in the 15229 load in August 2015. Since then, SWAP has stayed on and taken data continuously, other than a few power cycles around spacecraft events such as 3-Axis operations and trajectory correction maneuvers.

Downlink data several days beyond the end of the nominal end of mission phase were included in this data set in an attempt to fill out the products at the nominal end of mission phase; refer to the CONFIDENCE_LEVEL_NOTE in this data set catalog for more details.

There have been several changes to the PDS data labels, mostly involving improved values for the NAME, AXIS_NAME, and DESCRIPTION keywords in ARRAY OBJECTs in SWAP Histogram products. As part of that work, the count rate HISTOGRAM has been converted to an ARRAY object to take advantage of the improvements.

PDS Citation Information: McComas, D., NEW HORIZONS CALIBRATED SWAP PLUTO ENCOUNTER V3.0, NH-P-SWAP-3-PLUTO-V3.0, NASA Planetary Data System, 2018.

PDS3 V2.0 (NH-P-SWAP-3-PLUTO-V2.0)

This is VERSION 2.0 of this data set. This P2 Pluto Encounter dataset release provides updates to the Pluto dataset between P1 (data on the ground by 7/31/2015) and P2 (data on the ground

by 1/31/2016). All liens from the initial Pluto delivery have also now been resolved. For SWAP, most of the Pluto Encounter data was downlinked in the 15229 load in August 2015. Since then, SWAP has stayed on and taken data continuously, other than a few power cycles around spacecraft events such as 3-Axis operations and trajectory correction maneuvers.

PDS Citation Information: McComas, D., NEW HORIZONS CALIBRATED SWAP PLUTO ENCOUNTER V2.0, NH-P-SWAP-3-PLUTO-V2.0, NASA Planetary Data System, 2017.

PDS3 V1.0 (NH-P-SWAP-3-PLUTO-V1.0)

This is VERSION 1.0 of this data set. For this first SWAP delivery for the Pluto mission phase, this data set includes only the Approach data plus the subset of the CORE sequence data that was downlinked through the end of July, 2015.

Liens were never resolved for this data set version but will be in the next version.

PDS Citation Information: McComas, D., NEW HORIZONS CALIBRATED SWAP PLUTO ENCOUNTER V1.0, NH-P-SWAP-3-PLUTO-V1.0, NASA Planetary Data System, 2016.

General statement about data set versions after V1.0

The pipeline (see Processing below) was re-run on these data for each version since the first (V1.0). A pipeline rerun usually changes the FITS headers but not the FITS data of raw data sets. In some cases, calibrated FITS data may change because the calculated geometry of an observation has changed. See data set version-specific sections above for significant exceptions to this general statement, i.e., changes to pipeline processing, calibration processing, and data delivered.

An all-instrument Calibration Campaign occurred in July 2016. For most instruments, calibrations were updated as of April 2017 which changed the data in the calibrated data sets. Calibration changes are described in the data set version-specific sections.

Note that even if this is not a calibrated data set, calibration changes are listed as the data will have been re-run and there will be updates to the calibration files, to the documentation and to the steps required to calibrate the data.

Also note that file names may change between versions if start/stop times are updated when additional data are downlinked.

Processing

The data in this data set were created by a software data processing pipeline on the Science Operations Center (SOC) at the Southwest Research Institute (SwRI), Department of Space Operations. This SOC pipeline assembled data as FITS files from raw telemetry packets sent down by the spacecraft and populated the data labels with housekeeping and engineering values, and computed geometry parameters using SPICE kernels. The pipeline did not resample the data.

Data

The observations in this data set are stored in data files using standard Flexible Image Transport System (FITS) format. Each FITS file has a corresponding detached PDS label file, named according to a common convention. The FITS files may have image and/or table extensions. See the PDS label plus the document collection for a description of these extensions and their contents.

This Data section comprises the following sub-topics:

- Filename/Product IDs
- Instrument description
- Other sources of information useful in interpreting these Data
- Visit Description, Visit Number, and Target in the Data Labels

Filename/Product IDs

The filenames and Local product Identifiers (LID) of observations adhere to a common convention, e.g.:

```
swa_0123456789_0x584_sci.fit
^^^ ^^^^^^^^^^ ^^^^^ ^^^\__/
|         |       |     |  ^^
|         |       |     |   |
|         |       |     |   +--File type (includes dot)
|         |       |     |      - .FIT for FITS file
|         |       |     |      - .LBLX for PDS label
|         |       |     |      - not part of LID
|         |       |     |
|         |       |     +--ENG for CODMAC Level 2 data
|         |       |        SCI for CODMAC Level 3 data
|         |       |
|         |       +--Application ID (ApID) of the telemetry data
|         |          packet from which the data come
|         |          N.B. ApIDs are case-insensitive
|         |
|         +--MET (Mission Event Time) i.e. Spacecraft Clock
|
+--Instrument designator
```

Instrument Designator(s):

Instrument Designator	Description
SWA	SWAP

See SOC Instrument Interface Control Document (ICD) within the PDS for more details (PDS4 LID `urn:nasa:pds:nh_documents:mission:soc_inst_icd`).

Mission Event Time (MET)

Note that, depending on the observation, the Mission Event Time (MET) in the data filename and in the LID may be similar to the MET of the actual observation acquisition, but should not

be used as an analog for the acquisition time. The MET is the time that the data are transferred from the instrument to spacecraft memory and is therefore not a reliable indicator of the actual observation time. The PDS labels are better sources to use for the actual timing of any observation. The specific keywords for which to look are:

- start_date_time
- stop_date_time
- start_clock_count
- stop_clock_count

Application ID (ApID)

Here is a summary of the types of files generated by each ApID (N.B. ApIDs are case-insensitive) along with the instrument designator that go with each ApID:

ApIDs	Data product description/Prefix(es)
0x584	SWAP Science Real-Time/SWA
0x585	SWAP Science Summary/SWA
0x586	SWAP Science Histogram Header/SWA
0x587	SWAP Science Histogram Data/SWA

Note that the CODMAC Level 3 NH SWAP data sets produced after April, 2016 do not have 0x585 (Science Summary data); in-flight and in practice, 0x585 data are used only for health and safety and not for science.

There are other ApIDs that contain housekeeping values and other values. See SOC Instrument ICD for more details: `urn:nasa:pds:nh_documents:mission:soc_inst_icd`

Please note that not all ApIDs may be found in this data set.

Instrument description

Refer to the following files for a description of this instrument:

- New Horizon SWAP instrument overview: `urn:nasa:pds:nh_documents:swap:swap_inst_overview`
- SWAP Space Science Review (SSR) paper: `urn:nasa:pds:nh_documents:swap:swap_ssr`
- SOC Instrument ICD: `urn:nasa:pds:nh_documents:mission:soc_inst_icd`
- SWAP SPICE Instrument Kernel: `urn:nasa:pds:nh_documents:swap:nh_swap_ti`

Other sources of information useful in interpreting these Data

Refer to the following files for more information about these data:

- NH Mission Trajectory Table: `urn:nasa:pds:nh_documents:mission:nh_mission_trajectory`
- New Horizons Spacecraft Trajectory Tables: `urn:nasa:pds:nh_swap:trajectory`
- Field of View Illustration: `urn:nasa:pds:nh_documents:mission:nh_fov`
- SWAP SPICE Instrument Kernel: `urn:nasa:pds:nh_documents:swap:nh_swap_ti`

- SWAP Data Summary Plots: `urn:nasa:pds:nh_swap:pluto_data_summary_plots`

Visit Description, Visit Number, and Target in the Data Labels

The observation sequences were defined in Science Activity Planning (SAP) documents and grouped by Visit Description and Visit Number. The SAPs are spreadsheets with one Visit Description & Number per row. A nominal target is also included on each row and included in the data labels but does not always match with the target name field's value in the data labels. In some cases, the target was designated as right_ascension_angle, declination_angle pointing values in the form "right_ascension_angle, declination_angle =123.45,-12.34" indicating Right Ascension and Declination, in degrees, of the target from the spacecraft in the Earth Equatorial J2000 inertial reference frame. This indicates that either the target was a star, or the target's ephemeris was not loaded into the spacecraft's attitude and control system which in turn meant the spacecraft could not be pointed at the target by a body identifier and an inertial pointing value had to be specified as Right Ascension and Declination values. PDS-SBN practices do not allow putting a value like right_ascension_angle, declination_angle =... in the PDS target name keyword's value. In those cases, the PDS target purpose value is set calibration. Target name may be None for a few observations in this data set; typically, that means the observation is a functional test so None is an appropriate entry for those targets, but the PDS user should also check the nh:observation_description and nh:sequence_id keywords in the PDS label, plus the provided sequence list (`urn:nasa:pds:nh_documents:swap:seq_swap_pluto`) to assess the possibility that there was an intended target. These two keywords are especially useful for star targets as often stars are used as part of instrument calibrations and are included as part of the sequencing description which is captured in these keywords.

Ancillary Data

The geometry items included in the data labels were computed using the SPICE kernels archived in the New Horizons SPICE data set, NH-J/P/SS-SPICE-6-V1.0, https://doi.org/10.17189/1520109.

Every observation provided in this data set was taken as a part of a particular sequence. A list of these sequences has been provided within the NH SWAP document collection (PDS4 LID `urn:nasa:pds:nh_documents:swap`) within the PDS, one file for each mission phase. The sequence identifier and description are included in the PDS label for every observation.

N.B. While every observation has an associated sequence, every sequence may not have associated observations. Some sequences may have failed to execute due to spacecraft events (e.g., safing). No attempt has been made during the preparation of this data set to identify such empty sequences.

Time

There are several time systems, or units, in use in this dataset: New Horizons spacecraft MET (Mission Event Time or Mission Elapsed Time), UTC (Coordinated Universal Time), and TDB (Barycentric Dynamical Time).

This section will give a summary description of the relationship between these time systems. For a complete explanation of these time systems the reader is referred to the documentation distributed with the Navigation and Ancillary Information Facility (NAIF) SPICE toolkit from the PDS NAIF node, (see http://naif.jpl.nasa.gov/).

The most common time unit associated with the data is the spacecraft MET. MET is a 32-bit counter on the New Horizons spacecraft that runs at a rate of about one increment per second starting from at value of zero at "19.January, 2006 18:08:02 UTC" or "JD2453755.256337 TDB."

The leapsecond adjustment (DELTA_ET = ET - UTC) was 65.184s at NH launch, and the first four additional leapseconds occurred at the ends of 12/2009, 06/2012, 06/2015, and 12/2016. Refer to the NH SPICE data set, NH-J/P/SS-SPICE-6-V1.0, https://doi.org/10.17189/1520109, and the SPICE toolkit documentation, for more details about leapseconds.

The data labels for any given product in this dataset usually contain at least one pair of common UTC and MET representations of the time at the middle of the observation. Other portions of the products, for example tables of data taken over periods of up to a day or more, will only have the MET time associated with a given row of the table.

For the data user's use in interpreting these times, a reasonable approximation (+/- 1s) of the conversion between Julian Day (TDB) and MET is as follows:

```
JD TDB = 2453755.256337 + ( MET / 86399.9998693 )
```

For more accurate calculations the reader is referred to the NAIF/SPICE documentation as mentioned above.

Reference Frame

Geometric Parameter Reference Frame

Earth Mean Equator and Vernal Equinox of J2000 (EMEJ2000) is the inertial reference frame used to specify observational geometry items provided in the data labels. Geometric parameters are based on best available SPICE data at time of data creation.

Epoch of Geometric Parameters

All geometric parameters provided in the data labels were computed at the epoch midway between the start_date_time and stop_date_time label fields.

Software

The observations in this data set are in standard FITS format with PDS labels and can be viewed by a number of PDS-provided and commercial programs. For this reason, no special software is provided with this data set.

Confidence Level Overview

During the processing of the data in preparation for delivery with this volume, the packet data associated with each observation were used only if they passed a rigorous verification process including standard checksums.

In addition, raw (CODMAC Level 2) observation data for which adequate contemporary housekeeping and other ancillary data are not available may not be reduced to calibrated (CODMAC Level 3) data. This issue is raised here to explain why some data products in the raw data set may not have corresponding data products in the calibrated data set.

Known Issues

Below is a list of all deficiencies and irregularities that are known to exist at the time of publication.

Missing product label updates

During the data set migration from PDS3 to PDS4, the PDS4 data labels were produced using the PDS3 data labels and/or FITS headers, and so any fixes and/or updates to the PDS3 label pipeline as found in future mission phases may not have been implemented here. For instance, column or field names and descriptions may had been updated or corrected in a data set of a later mission phase, but not here.

Data overlap between mission phases

There is a slight overlap of a few days of data between the end of the Pluto Encounter and the beginning of KEM Cruise 1 PDS3 delivered data sets. No attempt to sort out these data were made during the migration of the PDS3 data sets to the PDS4 standards. Some data files may supersede others. This is due to data being replayed after the Pluto Encounter PDS Deliveries. As a result, the product identifiers (LIDVIDs) may not reflect one product superseding the other. Note that file names (and therefore the original PDS3 product_id) may change between deliveries if the start/stop times are updated when additional data were later downlinked.

Data coverage and quality

Every observation provided in this data set was taken as a part of a particular sequence. For this data set, these sequences can be found in the SWAP document collection under PDS4 LID `urn:nasa:pds:nh_documents:swap:seq_swap_pluto`. Please note that some sequences provided may have zero corresponding observations.

Refer to the Confidence Level Overview section above for a summary of steps taken to assure data quality.

SWAP data product completeness at the end of a mission phase

Downlink data several days beyond the end of the nominal end of mission phase were included in this data set in an attempt to fill the products at the nominal end of mission phase. This was done in an attempt to ensure complete coverage of data up through the nominal end of the mission phase. This also means that for the SWAP last-in-time products in this data set, which

include observations beyond the nominal end of the mission phase, may be incomplete. The following paragraphs provide details about this issue.

SWAP data product completeness - details

SWAP data are taken more or less continuously, but telemetry downlinks are done in batches, so the SWAP data are stored on-board the spacecraft at least until they are downlinked, sometimes hours or days after they are taken. Furthermore, SWAP PDS data are grouped into products, each covering approximately one day's worth of data, starting and ending at a time of day near 18:08 UTC.

This data set comprises data downlinked through a fixed cutoff date. The interaction between the downlink cutoff, the batch nature of downlink, and the grouping of SWAP data will result in the last day's, or few days', data products in this data set containing less than a full day's worth of data. This applies to SWAP science and engineering data as well as housekeeping and thruster data stored in the data products. For example, this has been most noticeable during the Pluto PDS data set deliveries, e.g. the last product in the PDS3 V2.0 delivery with ApID 0x585 had very little science data and neither housekeeping nor thruster data, whereas the same product in the PDS3 V3.0 delivery had the full expected day's worth of data; also, the PDS3 V3.0 delivery has a product with ApID 0x584 that was not present in the PDS3 V2.0 delivery.

The NH project is considering delivering SWAP data sets as a single incrementing data set. Beyond that and other than adding a few days of telemetry beyond the nominal mission phase end, the NH project has no further plans to mitigate this minor issue.

In summary, the choice to deliver New Horizon data sets by mission phase affects SWAP data set product completeness near those mission phase boundaries.

Caveat about target name in PDS labels and observational

The downlink team on New Horizons has created an automated system to take various uplink products, decode things like Chebyshev polynomials in command sequences representing celestial body ephemerides for use on the spacecraft to control pointing, and infer from those data what the most likely intended target was at any time during the mission. This works well during flyby encounters and less so during cruise phases and hibernation.

The user of these PDS data needs to be cautious when using the target name and other target-related parameters stored in this data set. This is less an issue for the plasma and particle instruments, more so for pointed instruments. To this end, the heliocentric ephemeris of the spacecraft, the spacecraft-relative ephemeris of the inferred target, and the inertial attitude of the instrument reference frame are provided with all data, in the J2000 inertial reference frame, so the user can check where that target is in the Field Of View (FOV) of the instrument.

Finally, note that, within the FITS headers of the data products, the sequence tables, and other NH Project-internal documents used in this data set, informal names are often used for targets instead of the canonical names used within the PDS labels. For example, during the Pluto

mission phase, instead of the target name '15810 ARAWN (1994 JR1)' there might be found any of the following: 1994JR1; 1994 JR1; JR1. However, within the context of this data set, these project abbreviations are not ambiguous (e.g. there is only one NH target with 'JR1' in its name), so there has been, and will be, no attempt to expand such abbreviations where they occur outside formal PDS keyword values.

Contact Information

For any questions regarding the data format of the archive, contact the New Horizons SWAP Principal Investigator:

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Further Reading

Steffl, A.J., J. Peterson, B. Carcich, L. Nguyen, and S.A. Stern, NEW HORIZONS SPICE KERNELS, V1.0, NH-J/P/SS-SPICE-6-V1.0, NASA Planetary Data System, 2007.
https://doi.org/10.17189/1520109