

New Horizons SWAP KEM1 Encounter Raw Data Overview

During the migration to the Planetary Data System's (PDS) PDS4 data standards, this current description was adapted from the PDS3 SWAP dataset catalog file, 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 Raw data taken by the New Horizons Solar Wind Around Pluto (SWAP) instrument during the KEM1 ENCOUNTER mission phase.

This version includes data acquired by the spacecraft between 08/14/2018 and 04/30/2022. It only includes data downlinked before 05/01/2022. Future datasets may include more data acquired by the spacecraft after 08/13/2018 but downlinked after 04/30/2022.

The data includes SWAP observations and plasma rolls in the approach and departure of Arrokoth. A gain test was also performed.

These data were migrated from the previously released PDS3 data set NH-A-SWAP-2-KEM1-V6.0.

Data Set Overview

This data set contains Raw data taken by the New Horizons Solar Wind Around Pluto (SWAP) instrument during the KEM1 ENCOUNTER mission phase. The closest approach to asteroid (486958) Arrokoth was on January 1, 2019, at approximately 05:33 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](#)).

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 \(migration from PDS3 V6.0\)](#)

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 V6.0 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.

[PDS3 V6.0 \(NH-A-SWAP-2-KEM1-V6.0\)](#)

This version includes data acquired by the spacecraft between 08/14/2018 and 04/30/2022. It only includes data downlinked before 05/01/2022. Future datasets may include more data acquired by the spacecraft after 08/13/2018 but downlinked after 04/30/2022.

This version includes SWAP observations and plasma rolls in the approach and departure of ASTEROID 486958 Arrokoth (2014 MU69).

Histogram data collected on the spacecraft after MET 476063588 for Application ID (ApID) 0x586 utilizes a new playback format. The FITS file structure for this data has changed accordingly. Consult the Science Operations Center Instrument Interface Control Document (see PDS4 LID: [urn:nasa:pds:nh_documents:mission:soc_inst_icd](#)) for details.

PDS Citation Information: McComas, D., NEW HORIZONS RAW SWAP KEM1 V6.0, NH-A-SWAP-2-KEM1-V6.0, NASA Planetary Data System, 2023.

[PDS3 V5.0 \(NH-A-SWAP-2-KEM1-V5.0\)](#)

Version 5.0 includes data acquired by the spacecraft between 08/14/2018 and 03/01/2021. It only includes data downlinked before 03/01/2021. Future datasets may include more data acquired by the spacecraft after 08/13/2018 but downlinked after 02/28/2021.

This version includes SWAP observations and plasma rolls in the approach and departure of ASTEROID 486958 Arrokoth (2014 MU69). A gain test was also performed.

The New Horizons team removed one partial file from this dataset (swa_0476496000_0x584_*.fit) because some data for this file was downlinked on or after 03/01/2021. The complete file will be included in the next delivery.

The New Horizons team also removed the following seven files from this dataset because the files utilize a new, undocumented FITS file format. These files will be included in the next delivery, along with the appropriate documentation changes:

```
swa_0476064032_0x586_*.fit
swa_0476068192_0x586_*.fit
swa_0476150432_0x586_*.fit
swa_0476236832_0x586_*.fit
swa_0476323232_0x586_*.fit
swa_0476409632_0x586_*.fit
swa_0476496032_0x586_*.fit
```

PDS Citation Information: McComas, D., NEW HORIZONS RAW SWAP KEM1 V5.0, NH-A-SWAP-2-KEM1-V5.0, NASA Planetary Data System, 2022.

[PDS3 V4.0 \(NH-A-SWAP-2-KEM1-V4.0\)](#)

Version 4.0 of this data set included data acquired by the spacecraft between 08/14/2018 and 04/30/2020. It only included data downlinked before 05/01/2020.

The data included SWAP observations and plasma rolls in the approach and departure of Arrokoth. A gain test was also performed.

PDS Citation Information: McComas, D., NEW HORIZONS RAW SWAP KEM1 V4.0, NH-A-SWAP-2-KEM1-V4.0, NASA Planetary Data System, 2021.

[PDS3 V3.0 \(NH-A-SWAP-2-KEM1-V3.0\)](#)

Version 3.0 of this dataset included data acquired by the spacecraft between 08/14/2018 and 07/31/2019. It only included data downlinked before 08/01/2019.

PDS Citation Information: McComas, D., NEW HORIZONS RAW SWAP KEM1 V3.0, NH-A-SWAP-2-KEM1-V3.0, NASA Planetary Data System, 2020.

[PDS3 V2.0 \(NH-A-SWAP-2-KEM1-V2.0\)](#)

Version 2.0 included data acquired by the spacecraft between 08/14/2018 and 01/31/2019. It only included data downlinked before 02/01/2019.

Two digits of precision have also been added to the EXPOSURE_DURATION value in all data labels after V1.0.

PDS Citation Information: McComas, D., NEW HORIZONS RAW SWAP KEM1 V2.0, NH-A-SWAP-2-KEM1-V2.0, NASA Planetary Data System, 2020.

[PDS3 V1.0 \(NH-A-SWAP-2-KEM1-V1.0\)](#)

This version includes data acquired by the spacecraft between 08/14/2018 and 12/31/2018. It only includes data downlinked before 01/01/2019. Future datasets may include more data acquired by the spacecraft after 08/13/2018 but downlinked after 12/31/2018.

PDS Citation Information: McComas, D., NEW HORIZONS RAW SWAP KEM1 V1.0, NH-A-SWAP-2-KEM1-V1.0, NASA Planetary Data System, 2019.

[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.

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:

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:kem1_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_kem1`) 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 (LID: `urn:nasa:pds:nh_document: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.

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 KEM1 sequences can be found in the SWAP document collection under LID

urn:nasa:pds:nh_documents:swap:seq_swap_kem1. 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 V2.0 delivery with ApID 0x585 had very little science data and neither housekeeping nor thruster data, whereas the same product in the V3.0 delivery had the full expected day's worth of data; also, the V3.0 delivery has a product with ApID 0x584 that was not present in the 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.

[Observation descriptions in this overview file](#)

Some users will expect to find descriptions of the observations in this data set here. This data set follows the more common convention of placing those descriptions under the Data Set Overview section of this overview file.

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>