New Horizons SDC KEM2 Cruise 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, 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 Student Dust Counter (SDC) instrument during the KEM2 CRUISE mission phase.

This version includes data acquired by the spacecraft between 10/01/2022 and 04/30/2024. It only includes data downlinked before 05/01/2024. Future datasets may include more data acquired by the spacecraft after 10/01/2022 but downlinked after 04/30/2024.

This version includes Dust Counts.

This dataset corresponds to New Horizons NAIF SPICE distribution v0008.

Data Set Overview

This data set contains Calibrated data taken by the New Horizons Student Dust Counter (SDC) instrument during the KEM2 CRUISE mission phase.

The mission of the SDC is to analyze the size and distribution of Interplanetary Dust Particles (IDPs) along the New Horizons trajectory to the Kuiper Belt. SDC comprises twelve thin, permanently polarized polyvinylidene fluoride (PVDF) plastic film sensors, with a combined area of about 0.1 m**2, mounted on the top surface of a support panel and normal to the spacecraft ram direction (flight velocity). In addition, there are two reference sensors, identical to the top surface sensors, mounted on the back side of the detector support panel and protected from any dust impacts, used to monitor background noise levels.

An impacting IDP causes a depolarization charge when it penetrates the PVDF film on one of the sensors. That charge is then measured by that sensor's electronics (channel); if the measurement is above a preset level, the instrument records and stores the event for later downlink. The level preset is adjusted based on in-flight Noise Floor Calibrations, and there are extensive autonomy rules adjusting SDC behavior, even turning channels off for up to thirty days at a time, to avoid overloading the storage system with noise.

SDC was designed to detect events for particles down to about one picogram at Pluto (see Bagenal et al. (2016)); that detection limit is lower than earlier in the mission where the spacecraft velocity was higher. The SDC instrument has a temperature- and velocity-dependent calibration, first converting the raw measurement to charge, then converting charge to particle mass.

The common data product is a binary table of downlinked event data: time; sensor channel; magnitude; threshold magnitude. Associated data products are housekeeping data such as instrument temperatures for calibration and near-in-time spacecraft thruster events, which may induce false positives i.e. SDC events not caused by IDPs. The channels in the binary table for raw data are numbered from 0 to 13; the channel in the binary table for calibrated data are numbered from 1 to 14.

Some time between instrument delivery to the spacecraft and launch, the detector on one channel began exhibiting symptoms of degraded electrical contacts to the PVDF; data from that channel (channel number 10 in raw data; channel number 11 in calibrated data) are still processed but should be ignored.

The Student Dust Counter (SDC), aboard the New Horizons spacecraft, is the first dedicated and calibrated dust instrument to measure the density and size distributions of interplanetary dust particles (IDPs) between 18 and 35 AU, and during KEM (Kuiper belt Extended Mission) will extend these measurements to 50 AU near the edge of the KB. SDC provides a near continuous mapping of the dust density distribution along the trajectory of New Horizons with this data set spanning from roughly 36.8AU to 40.2AU. These measurements will aid in the interpretation of the complementary Voyager observations of the putative dust densities derived from the Plasma Wave System (PWS) out to ~100 AU.

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

This version includes data acquired by the spacecraft between 10/01/2022 and 04/30/2024. It only includes data downlinked before 05/01/2024. Future datasets may include more data acquired by the spacecraft after 10/01/2022 but downlinked after 04/30/2024.

This version includes Dust Counts from the KEM2 CRUISE mission phase.

General statement about data set versions

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.

SDC data calibration is a two-step process: raw data numbers from a particle impact are converted to a charge, and the charge is converted to a particle mass via the ground calibrations obtained at a dust acceleration facility. Refer to the provided documentation for more information. The latest calibration procedure is described in James et al. (2010).

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.:

```
sdc_0123456789_0x700_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
SDC	SDC

See the 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

Also note that a dust hit may be recorded in more than one data product. The product name reflects the MET when data was transferred from instrument memory. More than one transfer may have been requested for any given interval from start_date_time to stop_date_time. When processing the data, check these intervals carefully. Obvious cases of duplicate dust hit data spanning long time intervals have already been removed from this dataset.

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)
0x700	SDC Science Data/SDC

There are other ApIDs that contain housekeeping values and other values. See the 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 SDC instrument overview: `urn:nasa:pds:nh_documents:sdc:sdc_inst_overview`
- SDC Space Science Review (SSR) paper: `urn:nasa:pds:nh_documents:sdc:sdc_ssr`
- SOC Instrument ICD: `urn:nasa:pds:nh_documents:mission:soc_inst_icd`
- SDC SPICE Instrument Kernel: `urn:nasa:pds:nh_documents:sdc:nh_sdc_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`
- Field of View Illustration: `urn:nasa:pds:nh_documents:mission:nh_fov`
- SDC SPICE Instrument Kernel: `urn:nasa:pds:nh_documents:sdc:nh_sdc_ti`
- SDC Summary Student Dust Counter (SDC) boresight direction: `urn:nasa:pds:nh_documents:sdc:sdcram`

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 (PDS4 LID `urn:nasa:pds:nh_documents:sdc:seq_sdc_kem2` or, previously, `urn:nasa:pds:nh_documents:sdc:seq_sdc_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.

For SDC the target name is always Dust.

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 SDC document collection (PDS4 LID `urn:nasa:pds:nh_documents:sdc`) 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 KEM2 sequences can be found in the SDC document collection under PDS4 LID `urn:nasa:pds:nh_documents:sdc:seq_sdc_kem2`. If the sequence file for this mission phase does not exist, the active sequence continues from the prior mission phase (`urn:nasa:pds:nh_documents:sdc:seq_sdc_kem1`). Please note that some sequences provided may have zero corresponding observations (but not for SDC).

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

For SDC, the stimulus calibration activity is known to generate false positive events in the science data. This data set includes a table, found within the SDC document collection under PDS4 LID `urn:nasa:pds:nh_documents:sdc:sdc_stim`, that lists time periods when stimulus calibrations were active (several times during Launch and Jupiter mission phases, and about half an hour per year during Annual CheckOuts (ACO) in the Pluto Cruise mission phase. Eventually, the Science Operations Center (SOC) operational pipeline may be enhanced to filter individual events that occur near stimulus events.

Since launch, the SDC team has observed systematically higher count rates in channel A than in channel B. This phenomena is discussed more thoroughly in Piquette et al., (2019) [PIQUETTEETAL2019A].

During hibernation intervals, spacecraft noise is reduced, resulting in fewer coincident events. This reduces the raw counts. Calibrated counts remain consistent when coincidents are removed.

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.

Caveat about temperature oscillations during hibernation periods

During hibernations the temperature of the instrument typically follows a stable oscillation. During periods of normal operation, the temperature can be more variable due to other instrument activity. As long as temperatures remain in the nominal range, the instrument will operate without issue.

Contact Information

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

Mihály Horányi
Laboratory for Atmospheric and Space Physics
University of Colorado
Boulder, CO 80302-3092
USA

Reference List

Bagenal, F., M. Horányi D.J. McComas, R.L. McNutt Jr, H.A. Elliott, M.E. Hill, L.E. Brown, P.A. Delamere, P. Kollmann, S.M. Krimigis, M. Kusterer, C.M. Lisse, D.G. Mitchell, M. Piquette, A.R. Poppe, D.F. Strobel, J.R. Szalay, P. Valek, J. Vandegriff, S. Weidner, E.J. Zirnstein, S.A. Stern, K. Ennico, C.B. Olkin, H.A. Weaver, L.A. Young, and New Horizons Science Team, Pluto's interaction with its space environment: Solar wind, energetic particles & dust, Science, Volume 351, Issue 6279, 18 Mar 2016. https://doi.org/10.1126/science.aad9045

Further Reading

James, D., V. Hoxie, and M. Horanyi, Polyvinylidene fluoride dust detector response to particle impacts, Review of Scientific Instruments, Volume 81, Issue 3, id. 034501-034501-8, 2010. https://doi.org/10.1063/1.3340880

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