

# New Horizons SDC Pluto 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, 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 Student Dust Counter (SDC) instrument during the PLUTO CRUISE mission phase.

SDC collected science data intermittently during the hibernation years following the Jupiter encounter, designated as the PLUTO CRUISE phase. There were also Annual Checkouts (ACOs), STIM calibrations, Noise calibrations, and an anomaly in November, 2007. SDC's main science data collection periods were during hibernation. During ACOs, science data are taken intermittently but the user must be careful in analyzing these data since there is usually more activity on the spacecraft during hibernation. STIM and Noise refer to scheduled calibrations and are done with a regular cadence of one per year after the Jupiter encounter; they occurred sporadically in the early years of the mission.

Changes since the prior versions include re-running of the ancillary data, updated geometry from newer SPICE kernels, minor editing of documentation, and resolution of liens from December 2014 and May 2016 SDC data reviews.

New observations added with this version include ongoing cruise observations from August, 2014 through January, 2015.

These data were migrated from the previously released PDS3 data set NH-X-SDC-3-PLUTOCRUISE-V2.0.

## Data Set Overview

This data set contains Calibrated data taken by the New Horizons Student Dust Counter (SDC) instrument during the PLUTO CRUISE mission phase. There are a few data files from the JUPITER encounter mission phase included in this data set. They can be identified by the nh:mision\_phase\_name keyword in the data labels.

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<sup>2</sup>, 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.

Note that some SDC data files have the same stop and start time and a zero exposure time. The reason for this is that the start and stop time for SDC data files are the event times for the first and last events in the files, so for files that contain a single event, these two values are the same.

In the years following the Jupiter encounter, designated as the PLUTO CRUISE mission phase, SDC collected science data intermittently during hibernation. There were also Annual Checkouts (ACOs), STIM calibrations, Noise calibrations, and an anomaly in November, 2007. 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 SDC document collection under PDS4 LID `urn:nasa:pds:nh_documents:sdc:seq_sdc_plutocruise`. Please note that some sequences provided may have zero corresponding observations. Refer to the sequence tables to identify and remove calibration data from any science analysis.

SDC's main science data collection periods are during hibernation. During ACOs, science data are taken intermittently but the user must be careful in analyzing this since there is usually more activity on the spacecraft than during hibernation. STIM and Noise refer to scheduled

calibrations and are done with a regular cadence of one per year after the Jupiter encounter; they occurred sporadically in the early years of the mission.

SDC was designed to take advantage of the quiet state of the spacecraft during non-encounter mission phases, especially hibernation. Various active spacecraft operations cause mechanical shocks that are picked up by the polyvinylidene fluoride (PVDF) sensors and registered by SDC as science events. This is particularly true during three-axis pointing and active spin mode when the spacecraft frequently fires short bursts of the attitude thrusters. However, because the thruster-induced events are often frequent enough to violate the SDC autonomy rule B (section 3.4.2 of Horanyi et al. (2008)), during some spacecraft maneuvers many SDC detector channels are switched off, by autonomy processing, for prolonged periods. Level four data reduction (referred to in section 4 of Horanyi et al. (2008)) is used to filter out any events that appear within a second of any thruster firing, thereby allowing science recovery between firings. The science team anticipates that the techniques and results of such Level four processing will be provided in future, higher-level data sets.

Autonomy rules can also affect SDC threshold settings; threshold settings are designed to keep the SDC detection limit above a noise floor. Refer to Horanyi et al. (2008) for descriptions of threshold parameters and how they affect instrument behavior and recorded data.

N.B. The duration of the off, as well as the on, periods must be considered in making any calculation of average dust detection event rates.

During spacecraft checkout activities in the first six months of the Post-LAUNCH Checkout mission phase, spacecraft activity was high and these autonomous off/on transitions occurred quite frequently. There were several periods, some weeks or months long, where SDC was either completely off (or on) for only hours or minutes at a time. Later during the Post-LAUNCH Checkout phase, and much later during the PLUTO CRUISE phase, the autonomy levels for turning off channels were relaxed, and the transition to more frequent hibernation operations meant that autonomous off/on transitions occurred less frequently.

All per-channel off and on transitions, whether initiated by autonomy or by spacecraft on/off commands to the entire instrument, are recorded for the entire mission in a table that can be found in the SDC document collection under PDS4 LID

`urn:nasa:pds:nh_documents:sdc:sdc_on_off_times_alt`. The high frequency of off/on transitions, as described in the previous paragraph, is apparent in this table.

As of early 2014, there have been no events caused by large particles observed in any of these data sets; this has been noted as exceptional by peer reviewers of SDC data sets. The science team agrees and this topic is an active discussion within the science team; the science team anticipates that this will be addressed in some future delivery of SDC data sets.

## 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 \(migration from PDS3 V2.0\)](#)

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 V2.0 data set are:

- The calibration files, documents, and data products were reorganized into separate collections of calibration files, documents, 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 purpose for some data in this phase was changed.
- 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.

### [PDS3 V2.0 \(NH-X-SDC-3-PLUTO CRUISE-2.0\)](#)

This is VERSION 2.0 of this data set. The pipeline (see Processing below) was re-run on these data.

New observations added with this version (V2.0) include ongoing cruise observations from August, 2014 through January, 2015.

The previous delivery (V1.0) went through peer review with many Pluto Cruise data sets in December, 2014. When subsequent versions of the latter were being delivered with additional data (from August, 2014 through January, 2015) before all of those liens were resolved, those data sets were left as is, with those liens folded into the newer data sets. V2.0 is ultimately lien resolved.

The pipeline re-run may have changed ancillary data in the data product and updated geometry from newer SPICE kernels. This version includes minor editing of the documentation, catalogs, etc., and resolution of liens from the December, 2014 review, plus those from the May, 2016 review of the Pluto Encounter data sets. This may affect, for example, the calibration of the data if parameters such as the velocity or orientation of the target relative to the instrument, or the recorded target itself, have changed.

PDS Citation Information: Horányi M., NEW HORIZONS Calibrated SDC PLUTO CRUISE V2.0, NH-X-SDC-3-PLUTO CRUISE-V2.0, NASA Planetary Data System, 2017.

### [PDS3 V1.0 \(NH-X-SDC-3-PLUTO CRUISE-V1.0\)](#)

This is VERSION 1.0 of this data set. This is the first SDC delivery for the Pluto Cruise mission phase.

PDS Citation Information: Horányi M., NEW HORIZONS Calibrated SDC PLUTO CRUISE V1.0, NH-X-SDC-3-PLUTO CRUISE-V1.0, NASA Planetary Data System, 2014.

### 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.

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.:



## 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](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:sdcsdc\\_inst\\_overview](urn:nasa:pds:nh_documents:sdcsdc_inst_overview)
- SDC Space Science Review (SSR) paper: [urn:nasa:pds:nh\\_documents:sdcsdc\\_ssr](urn:nasa:pds:nh_documents:sdcsdc_ssr)
- SOC Instrument ICD: [urn:nasa:pds:nh\\_documents:mission:soc\\_inst\\_icd](urn:nasa:pds:nh_documents:mission:soc_inst_icd)
- SDC SPICE Instrument Kernel: [urn:nasa:pds:nh\\_documents:sdcsdc\\_nh\\_sdc\\_ti](urn:nasa:pds:nh_documents:sdcsdc_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](urn:nasa:pds:nh_documents:mission:nh_mission_trajectory)
- Field of View Illustration: [urn:nasa:pds:nh\\_documents:mission:nh\\_fov](urn:nasa:pds:nh_documents:mission:nh_fov)
- SDC SPICE Instrument Kernel: [urn:nasa:pds:nh\\_documents:sdcsdc\\_nh\\_sdc\\_ti](urn:nasa:pds:nh_documents:sdcsdc_nh_sdc_ti)
- SDC Summary Student Dust Counter (SDC) boresight direction: [urn:nasa:pds:nh\\_documents:sdcsdcram](urn:nasa:pds:nh_documents:sdcsdcram)

### 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 to 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\_plutocruise) 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 a value of zero at "19.January, 2006 18:08:02 UTC" or "JD2453755.256337 TDB."

The leapsecond adjustment ( $\text{DELTA\_ET} = \text{ET} - \text{UTC}$ ) 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:

$$\text{JD TDB} = 2453755.256337 + ( \text{MET} / 86399.9998693 )$$

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 sequences can be found in the SDC document collection under PDS4 LID `urn:nasa:pds:nh_documents:sdc:seq_sdc_plutocruise`. 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.

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.

## 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 SDC Principal Investigator:

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

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## Further Reading

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