New Horizons SDC Instrument Overview

This document is an overview of the New Horizons' Student Dust Counter (SDC) instrument. The SDC description was originally adapted from the http://lasp.colorado.edu/sdc/ website, Horányi et al. (2008), and Weaver et al. (2008). During migration to PDS4, this current copy was adapted from the PDS3 SDC instrument catalog file, providing light edits to the text, format, and flow.

Instrument Overview

Introduction

As the name implies, a dust counter is an instrument that counts particles of dust. There are various ways of making one work, but in the end, the instrument usually collects information on mass, velocity, density, size, or some combination of those four.

The Student Dust Counter has 3 main goals. The first is to map the dust density distribution in the solar system. Dust is not spread evenly throughout space; instead, it varies in density throughout the Solar System. The first goal would be to get an accurate map of how this dust density varies.

The second goal of the Student Dust Counter is to understand the dust particle size distribution and how it varies throughout the Solar System.

The third main goal is to determine how fast the Kuiper Belt produces dust. The small, icy bodies in the Kuiper Belt are constantly colliding and causing little bits of each other to chip off. These little bits in turn hit each other and slowly grind into dust, in a somewhat similar fashion to how sand on a beach is created. The SDC team hopes to be able to find out how fast this is happening.

Specifications

NAME:	SDC (Student Dust Counter)
DESCRIPTION:	Dust Counter
PRINCIPAL INVESTIGATOR:	Mihaly Horányi, University of Colorado
MASS RANGE:	~4 picogram - 4 nanogram (Note 1)
FIELD OF VIEW:	~ 180 deg
ANGULAR RESOLUTION:	N/A
MASS RESOLUTION:	approx factor of 2 in mass

Note 1: actual mass range dependent on time (spacecraft and particle velocities) during mission

Final Name

After 6 months of successful operations in space the SDC instrument was renamed, and the dedication reads:

> *New Horizons, the first mission to Pluto and the Kuiper Belt, is proud to announce that the student instrument (SDC) aboard our spacecraft is hereby named 'The Venetia Burney Student Dust Counter' in honor of Ms. Venetia Burney Phair, who at age of eleven nominated the name Pluto for our solar system's ninth planet. May 'Venetia' inspire a new generation of students to explore our solar system, to make discoveries which challenge the imagination, and to pursue learning all through their lives.*

In this archive, the name Student Dust Counter and the acronym SDC will continue to be used.

Scientific Objectives

The Student Dust Counter (SDC) will count and measure the sizes of dust particles along New Horizons' entire trajectory, which covers regions of interplanetary space never before sampled. Such dust particles are created by comets shedding material and Kuiper Belt Objects colliding with one another. The SDC is managed and was built primarily by students at the University of Colorado in Boulder Laboratory of Atmospheric and Space Physics (LASP), with supervision from a professional space scientist and mentoring from a number of professional engineers at LASP.

Calibration

See Horányi et al. (2008), especially sections 3.4.3 and 3.5.

Operational Considerations

1) Autonomy and on/off events

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. These shocks are particularly evident during three-axis pointing and active spin mode when the spacecraft frequently fires short bursts of the attitude thrusters. Level four data reduction (section 4 of Horányi et al. (2008)) is used to filter out any hits that appear within a second of any thruster firing, thereby allowing science recovery between firings. However because the thruster induced-events are often frequent enough to violate the autonomy rule B (section 3.4.2 of Horányi et al. (2008)), during spacecraft maneuvers many SDC detector channels are switched off, by autonomy processing, for prolonged periods. In addition, in order to minimize autonomy related switching off of the channels, the channels are commanded off and on around DSN (Deep Space Network) tracks when the spacecraft transitions from Passive Spin to Active Spin, called a tweakup. The channels are turned off for normally around 90 minutes each tweakup.

> **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 mission phase, spacecraft activity was high and these autonomous off/on events 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 on, the autonomy levels for turning off channels were relaxed, plus the transition to more frequent hibernation operations meant that autonomous off/on events occurred less frequently.

All per-channel off and on events, whether initiated by autonomy or by spacecraft on/off commands to the entire instrument, are recorded for the entire mission to-date in a PDS TABLE sequence file that is provided within the SDC document collection; updated versions will be provided as the mission progresses.

Note that event threshold instrument settings are used to trade off maximizing instrument sensitivity against minimizing the number of spurious, non-particle events (noise) detected; see the Threshold section under Measured Parameters below for more detail.

2) Stimulus calibrations generate false positives

The stimulus calibration activity is known to generate false positive events in the science data; data taken during such activities exhibits cross-talk and should be excluded from science analysis. Please refer to the SDC Stimulus Calibration Table found, within the PDS, that lists time periods when stimulus calibrations were active (sporadically 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.

3) Channel 11 failed

Channel 11 failed before launch; all data from channel 11 should be ignored.

4) No particle events over 2.8E-10 g, as of 2016.

As of late 2016, events from particles larger than 2.8E-10 grams (approximately 3 microns radius*) have not been observed in these data sets; this has been noted as exceptional by peer reviewers of SDC data sets. The reason for this is an active discussion within the science team and will eventually be addressed in a future delivery of SDC data sets.

The SDC instrument team is currently working on new calibrations of the PVDF sensors in response to both oblique impacts and particles with densities lower than what was used in previous calibrations (i.e. iron).

* Assumes a 2500 kg m^{-3} density for particles, which is what is generally used by the SDC instrument team.

Detector

The SDC's sensors are thin, permanently polarized PVDF plastic films that generate an electrical signal when dust particles penetrate their surface. The SDC has a total sensitive surface area of ~0.1 m^2, comprising 12 separate film patches, each 14.2 cm x 6.5 cm, mounted onto the top surface of a support panel. In addition, there are two reference sensor patches mounted on the backside of the detector support panel, protected from any dust impacts. These reference sensors, identical to the top surface sensors, are used to monitor the various background noise levels, from mechanical vibrations or cosmic ray hits.

See note about channel 11 in the Operational Considerations section above.

Electronics & Construction

The Student Dust Counter comprises three major pieces:

> The Detector Assembly is 18 inches x 12 inches (46 cm x 30 cm). This is the piece of equipment that is mounted on the outside of the spacecraft and is exposed to the dust particles. The detector is thermally isolated from the New Horizons Spacecraft and lies outside its Thermal Blanket.
>
> The Electronics Box is approximately 5.4 inches x 8.25 inches x 1.825 inches (13.7 cm x 20.96 cm x 4.64 cm). This is the brains of the Dust Counter; when a hit occurs on the detector the electronics box will decipher the data and determine the mass and speed of the dust particle. The electronics box is actually located within the spacecraft and is thermally and electronically bonded to the New Horizons Spacecraft.
>
> The Intra-Harness is the 'bridge' between the detector assembly and the electronics box. It serves a similar purpose as the cable which allows your home computer to communicate with your printer.

The space environment through which the New Horizons Mission will be traveling contains a large variety of conditions which can negatively affect spacecraft materials. The dust collector must be made of a substance which is not affected by changes in the temperature, radiation environment, or quantity of high-energy particles surrounding it.

To meet these challenges, a simple, reliable substance called PolyVinyliDene Fluoride (PVDF) has been chosen. When PVDF is manufactured, it is polarized. This means all of the molecules in the material are aligned so that they are pointing in the same direction.

When a dust particle impacts on the detector, it randomly re-aligns some of these previously organized molecules, resulting in the destruction of dipoles. This depolarization generates an electric signal; signals beyond a preset noise threshold (see Measured Parameters below) are recorded.

Operating Modes

Data taking and Autonomy. See Horányi et al. (2008) for details.

Measured Parameters

Along with various instrument configuration settings, the SDC records four main parameters for each detected Interplanetary Dust Particle (IDP) impact event: measured charge (generated by each event); timestamp; count; channel (sensor number).

The measured charge of an event in its raw form is a 16-bit unsigned integer value in the range 65535-0; note that this SDC raw integer value decreases with increasing event charge in physical units (equivalent electrons).

Calibration

Based on ground and in-flight calibrations, the actual charge, in equivalent electrons, of an event can be inferred from its raw integer value measurement.

Assuming a stable keplerian orbit at the location of the spacecraft at the time of the event for an assumed impact particle defines a spacecraft-relative velocity for the particle.

The mass of an assumed impact particle may be estimated from the combination of its spacecraft-relative velocity and the inferred charge of the event.

See Horányi et al. (2008) and James et al. (2010) for more details about SDC calibration.

Thresholds

The SDC channels have threshold integer values set by uplinked commands and/or by autonomy rules; thresholds limit the effective sensitivity of the instrument. Threshold values are recorded along with each detected event. Note that the scale of the threshold integer values are reversed with respect to charge, like the raw integer measurements described above, so the threshold integer values are maxima.

Setting the threshold levels is a tradeoff between

1. the desire for maximum instrument sensitivity, and
2. the desire to exclude non-particle events (noise) such as other spacecraft events.

Events that do not extend below the threshold integer value (smaller charges) will not be detected or recorded. When the minimum integer value (charge peak) of an event goes below the threshold integer value it will be detected, which triggers the measuring and recording of the event. There is a delay between this detection trigger of an event and the time when its recorded value measured; because of that delay, the event charge will decay and it is possible that the measured integer value will be slightly above the threshold value (the event will have slightly less measured charge in equivalent electrons than the equivalent threshold charge).

See Horányi et al. (2008) for more details about SDC thresholds.

References

Horányi, M., V. Hoxie, D. James, A. Poppe, C. Bryant, B. Grogan, B. Lamprecht, J. Mack, F. Bagenal, S. Batiste, N. Bunch, T. Chanthawanich, F. Christensen, M. Colgan, T. Dunn, G. Drake, A. Fernandez, T. Finley, G. Holland, A. Jenkins, C. Krauss, E. Krauss, O. Krauss, M. Lankton, C. Mitchell, M. Neeland, T. Reese, K. Rash, G. Tate, C. Vaudrin, and J. Westfall, The Student Dust Counter on the New Horizons Mission, Space Science Reviews, Volume 140, Issue 1-4, pp. 387-402, 2008. https://doi.org/10.1007/s11214-007-9250-y (A preprint is available in the PDS at urn:nasa:pds:nh_documents:sdc:sdc_ssr)

Weaver, H.A., W.C. Gibson, M.B. Tapley, L.A. Young, and S.A. Stern, Overview of the New Horizons Science Payload, Space Sci. Rev., Vol. 140, 75-91, 2008. https://doi.org/10.1007/s11214-008-9376-6 (A preprint is available in the PDS at urn:nasa:pds:nh_documents:mission:payload_ssr)

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

SDC Stimulus Calibration Table, urn:nasa:pds:nh_documents:sdc:sdc_stim, NASA Planetary Data System

SDC Document collection, urn:nasa:pds:nh_documents:sdc, NASA Planetary Data System