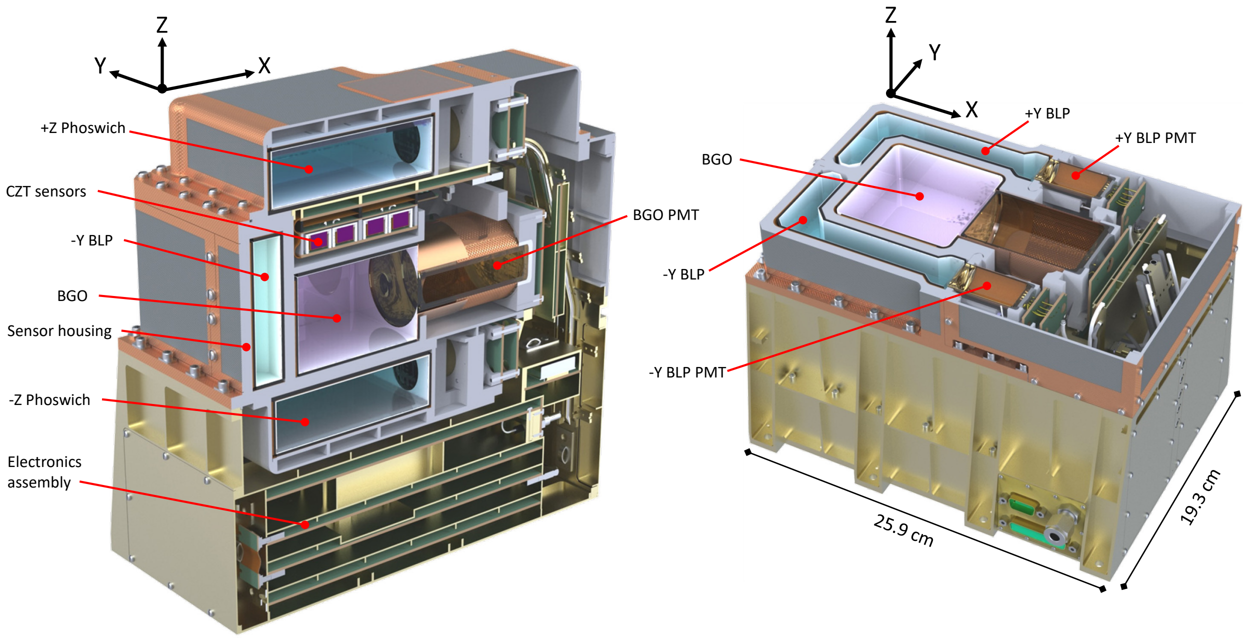
DAWN'S GAMMA RAY AND NEUTRON DETECTOR (GRAND)

RAW DATA DESCRIPTION

The raw collections in the Cruise, Mars, Vesta and Ceres bundles contain time-ordered gamma ray and neutron counting data and histograms acquired by GRaND during all phases of the Dawn mission. Housekeeping data, such as temperature and voltage readings, accompany the science data. All higher-level data products in the GRaND archive were derived from the raw data.



Cutaway view of GRaND showing the coordinate system and location of sensors. Instrument artwork provided by S. Storms of Los Alamos National Laboratory.

Version 2.0 — Based on the PDS3 dataset catalog
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ACRONYMS AND ABBREVIATIONS

BGO	Bismuth Germanate
BLP	Boron-loaded plastic
CAT	Event Category
CZT	Cadmium Zinc Telluride
DSC	Dawn Science Center at the University of California, Los Angeles
DSDb	Dawn Science Database
GRaND	Gamma Ray and Neutron Detector
NAIF/SPICE	Software package for calculating the position and orientation of the spacecraft maintained by the Navigation and Ancillary Information Facility at the NASA Jet Propulsion Laboratory
S/C	Spacecraft
SCLK	Spacecraft clock ticks (s)
TELREADOUT	Length of each science accumulation interval (s)
TELSOH	Sampling interval for the state of health telemetry (s)

MIGRATION NOTES

This archive was migrated from PDS3. While the labels have been updated and improved, none of the data files have been modified. The raw data collection described here have been processed to Level 1A in the PDS3 standard — telemetry data that have been subjected to reversible corrections and packaged with auxiliary data.

INTRODUCTION

The Dawn Mission's Gamma Ray and Neutron Detector (GRaND) was a nuclear spectrometer that collected data used to map the elemental composition of the surfaces of 4 Vesta and 1 Ceres [1]. GRaND measured the spectrum of planetary gamma rays and neutrons, originating from cosmic ray interactions and radioactive decay within the surface, while the spacecraft (S/C) was in orbit around each body (see GRaND_instrument.pdf). The instrument, which was mounted on the +Z deck of the S/C, consisted of 21 sensors designed to separately measure radiation originating from the surface of each asteroid and background sources, including the space energetic particle environment and cosmic ray interactions with the spacecraft. The nuclear spectroscopy data provided by GRaND can be analyzed to determine the abundance of elements that comprise silicate minerals, ice, and the products of aqueous alteration [e.g., 2,3].

The GRaND raw collections contain time-ordered gamma ray and neutron counting data and histograms acquired by GRaND during each phase of the Dawn Mission. The raw data also includes state-of-health data (instrument settings, temperature, and voltage readings) that support scientific analyses of the neutron and gamma ray data. The raw data were derived from the spacecraft telemetry using reversible operations, providing a complete data set from which higher-level data products can be derived. The raw data were produced during the mission by the GRaND team using a data processing pipeline that automatically delivered the data to the Dawn Science Center for archiving.

Within each mission phase, the raw data are organized in folders, which contain time-series data accumulated within coarse time periods roughly aligned with phase boundaries. The data consist primarily of ASCII tables, divided into three functional categories: state of health information (**SOH**); gamma ray spectra and event data (**GAMMA**); and neutron spectra and event data (**NEUTRON**). Gamma ray and neutron event data are recorded in binary files. Some of the data that appear in the human-readable, ASCII files are repeated in the binary files. These serve as breadcrumbs used to verify software to read the binary files.

The telemetry for GRaND consists of science and state-of-health data, accumulated over consecutive time intervals to produce a time-series data set. Each science data record includes scalers, histograms, and event data accumulated over a time interval specified by the commandable parameter TELREADOUT, with units of seconds. The state-of-health data include average temperatures, voltages, and instrument state data sampled at time intervals specified by the commandable parameter TELSOH (also in seconds). Both intervals were adjusted, depending on the measurement conditions and objectives for each mission phase. During mapping, TELREADOUT was set to sub-sample map pixels defined on the surface of Vesta or Ceres. During cruise, TELREADOUT was generally set to large values (e.g., 210s) to minimize data volume. TELSOH was selected to subsample the science accumulation interval, providing information needed to determine, for example, whether and how many times the science scalers rolled over. A detailed description of how rollover corrections are made — with application to the dead time scaler — is provided in [4].

GRaND has 23 scalers, which are described in the **Parameters** section. Scalers are pulse counters. They accumulate counts over time. The scaler registers were read out at the end of each science accumulation interval and then reset to zero to begin the next interval. The same registers were read out at each state-of-health time step. Because the state-of-health data were acquired at a higher cadence than the science data, the accumulation of counts can be monitored during each TELREADOUT interval. The 16-bit scalers roll over (return to zero) when they exceed 65535 counts. Rollover can be detected and counted as a sawtooth pattern in the state-of-health telemetry if TELSOH is set to be smaller than TELREADOUT. For example, if a single reset is observed for a scaler in the state-of-health telemetry, then the counts observed in the science telemetry need to be increased by 65536. Properly accounting for rollover is particularly important for determining dead time from the scaler counting data [4].

During the mission, the telemetry data were downloaded regularly from the spacecraft by the Ground Data System (GDS). The UCLA Dawn Science Center (DSC) captured all the payload instrument telemetry frames as binary files after the data were cleaned up in post-pass processing to produce reconstructed, time-ordered data. The files were inventoried within the Dawn Science Database (DSDb) and retrieved by the GRaND team, which applied reversible processes to unscramble, decompress, decode, and format the raw telemetry data into scientifically useful data files. The decompressed and decoded data, along with their required PDS documentation, form the raw collections.

PARAMETERS

The data are organized into directories corresponding to coarse time periods determined by the mode of spacecraft telemetry (real time vs. playback), the cadence of downlinks of data stored on the S/C, and time intervals queried by the DSC. The directories are in turn organized by mission phase within the Cruse, Vesta, and Ceres bundles. A description of the directory structure follows.

DIRECTORY STRUCTURE

The directory structure for the raw data is given by

GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC	(top level directory)
HK	(directory containing housekeeping data)
GAMMA	(directory containing gamma ray counting data)
NEUTRON	(directory containing neutron counting data)

The top-level directory name contains the SCET UTC dates for the first and last science data records (Y1M1D1 and Y2M2D2, respectively), and the creation date (YCMCDC) for the archive. For example, for GRD-L1A-90217-090218_090517, the first science data record was acquired on 17- Feb-2009. The last science data record was acquired on 18-Feb-2009. The archive was created by the pipeline on 17-May-2009.

HK DIRECTORY

The housekeeping (HK) directory contains the following files derived from the state-of-health and science data included in the spacecraft telemetry:

- GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC-**STA**.TAB — *State file*
  The instrument state file contains the instrument settings, including the mode, power supply states, high voltage settings, the data accumulation interval, and coincidence windows. The state information in the first packet of the state-of-health file is recorded in the state file, stamped with SCET UTC. Thereafter, rows are added only when the instrument settings change.

- GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC-**RDG**.TAB — *Readings file*
  Time-ordered list of temperature and voltage readings averaged over each state-of-health accumulation interval (TELSOH), converted to physical units.

- GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC-**SOH-SCL**.TAB — *State of health scaler data*
  Time-ordered list of the scaler data recorded in the state-of-health telemetry. The accumulation time for the scaler data is TELSOH. Note that the scalers are set to zero the start of each science accumulation interval (TELREADOUT). If the state-of-health accumulation interval is selected to subsample the science interval, then the state-of-health scalers can be used to detect and correct for rollover of the science scalers, such as the dead time counter [4].

- GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC-**SCI-SCL**.TAB — *Science scaler data*
  Time-ordered list of the scaler data recorded in the science telemetry. The accumulation interval for the scalers is TELREADOUT.

SCALER DEFINITIONS

Values for 23 scalers are recorded in the science (-**SCI-SCL**.TAB) and state-of-health (-**SOH-SCL**.TAB) scaler files in the HK directory. The information provided by the scalers is listed in Table 1.

Table 1. Scaler definitions. See instrument description for sensor descriptions.

Index	Description
0	Dead time counts
1	BGO overload events
2	CZT overload events
3	+Z phoswich overload events
4	-Y BLP overload events
5	+Y BLP overload events
6	-Z phoswich overload events
7	+Z phoswich CAT4 events
8	-Y BLP CAT4 events
9	+Y BLP CAT4 events
10	-Z phoswich CAT4 events
11	Early second interaction events
12	Multiple-crystal CZT events
13	Valid CZT events (CAT10)
14	Coincidence BGO and CZT events (CAT7)
15	Coincidence of three or more sensor elements
16	Total events processed by GRaND
17	Number of single CZT events (CAT10) in the gamma ray event buffer
18	Number of BGO-CZT coincidence events (CAT7) in the gamma ray event buffer
19	Number of events (CAT4) in the neutron event buffer
20	Total number of events allowed in the gamma ray event buffer
21	Number of single CZT events (CAT10) allowed in the gamma ray event buffer
22	Number of events allowed in the neutron event buffer

Note that indices 0 through 19 are for 16-bit counters, which are reset at the end of every science accumulation interval specified by TELREADOUT. If the state-of-health accumulation interval is adjusted to subsample the science accumulation interval (for example, TELREADOUT = n $\times$ TELSOH, where n is a whole number), then the scalers will monotonically increase during each acquisition interval, unless overflow occurs. A rollover counter is not provided; however, for situations in which the counting rate is high or the accumulation intervals are large, the number of rollovers for individual scalers can be determined from the SOH scaler data if TELSOH is set to subsample the science accumulation interval [4]. In situations where the counting rate is changing, abrupt changes in the scaler values can also indicate that rollover has occurred.

Indices 20 through 21 are maximum values for the number of events that can be recorded in the event buffers. The number of gamma ray and neutron events is commandable and can be adjusted. The total number of gamma ray and neutron events must be less than 6677.

GAMMA DIRECTORY

The GAMMA directory contains the following science data files:

- GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC-**BGO**.TAB A
  Time-ordered list of pulse height spectra (1024 channels with units of uncorrected counts/channel) acquired by the BGO sensor.

- GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC-**EMG**.DAT
  Gamma ray event data as a time series in a binary file. Each row of this file contains data from a science data record. Each science data record contains a list of 3876 events. Each event [e.g. i=0,...3875] is specified by ID_CZT[i], the index of the CZT sensor struck, CH_CZT[i], the pulse height (0-1023) recorded for ID_CZT[i], and CH_BGO[i], the pulse height (0-511) recorded for the BGO scintillator (see GRD_L1A-GAMMA_EVENTS.FMT). If CH_BGO[i]=0, then the event was CAT7 (coincidence between the BGO and a single CZT sensor). Otherwise, the event was CAT10 (interaction with a single CZT sensor). See [1] and [5] for a detailed description of the event data and examples. In addition, each row of the -EMG.DAT file includes the SCLK, and 23 scalers (SCALER_SCI). These can be compared to values found in the ASCII format -SCI-SCL.TAB (e.g. for debugging programs that read the binary data).

NEUTRON DIRECTORY

The NEUTRON directory contains the following science data files:

- GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC-**PHOS_MZ**.TAB
  GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC-**PHOS_PZ**.TAB
  These files contain time ordered lists of the 256-channel CAT1 pulse height spectra for the +Z and -Z phoswiches. Note that the naming convention for the top, bottom, and side scintillators is determined by the instrument coordinate system.

- GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC-**BGO2_MZ**.TAB
  GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC-**BGO2_PZ**.TAB
  GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC-**BGO2_MY**.TAB
  GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC-**BGO2_PY**.TAB
  These files contain time ordered lists of the 64-channel CAT2 BGO pulse height spectra for coincidences with the BGO and the four sensors.

- GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC-**BLP2_MZ**.TAB
  GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC-**BLP2_PZ**.TAB
  GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC-**BLP2_MY**.TAB
  GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC-**BKP2_PY**.TAB
  These files contain time ordered lists of the 64-channel CAT2 BLP pulse height spectra for coincidences with the BGO and the four BLP sensors.

- GRD-L1A-Y1M1D1-Y2M2D2_YCMCDC-**EMN**.DAT
  This file contains the fast neutron double pulse event data (CAT4) as a binary time series. Each row of this file contains data from a science data record. Each science data record contains a list of 2880 events. Each event [e.g. i=0,...,2879] is specified by ID_FIRST[i], the index of the BLP scintillator that produced the first pulse (0=+Z phoswich; 1=-Y BLP; 2=+Y BLP; 3=-Z phoswich), CH_FIRST[i], the amplitude of the first pulse (0-63), ID_SECOND[i], the index of the BLP scintillator that produced second pulse (0-3), CH_SECOND[i], the amplitude of the second pulse (0-63), and the time to second pulse (0-255), with units of 100 ns per data number. See the instrument catalog and [1] for a detailed description of the event data and examples. In addition, each row of the -EMN.DAT file includes the SCLK, and 23 scalers (SCALER_SCI). These can be compared to values found in the ASCII format -SCI-SCL.TAB (e.g. for debugging programs that read the binary data).

PROCESSING

During the mission, the raw data were automatically processed using a pipeline, which operated on files queried by the DSC over selected time intervals. Each DSC query separated the GRaND data into files containing state-of-health and science data records, in the order in which they were received on the ground and with corrupted packets removed. The state-of-health data were further divided into real time telemetry data and playback data. The science data were stored in a single data file.

The pipeline merged the state-of-health data from the playback and real time files to produce a time-ordered-list of records. Selected data were extracted to produce the raw files included in the archive. Internal temperature readings were converted from data numbers (DN) to engineering units using a linear function determined during ground calibration: T (degrees C) = 0.4354 DN - 0.4354. The high voltage readings for the high voltage power supplies were reported in engineering units using the conversion V (Volts) = 1500 DN/255. The CZT differential bias voltage was converted using V (Volts) = 0.405 DN.

The science data were decompressed, decoded, separated by functionality and written as time-ordered ASCII tables and binary time series. The raw histograms (CAT1, CAT2, and CAT9) were represented as 8 bit numbers in the telemetry and were decompressed and reported as 16 bit, unsigned integers.

The neutron and gamma ray binary event data were recorded in the raw data files in big endian IEEE binary format (MSB order).

All raw data table entries were tagged with a spacecraft clock (SCLK) value. For science data, SCLK gives the end of each accumulation interval to within 1s. The SCLK entry associated with SOH data are accurate to within 1 minute. See [1,4] for further details on time. The raw data include ancillary data in the form of SCET UTC strings reported in each row of the data tables and time series. The UTC strings are determined from the SCLK strings recorded in each state-of-health packet and for the first packet in each science data record using NAIF/SPICE (SCLK and leap seconds kernels).

DATA COVERAGE AND QUALITY

The raw collections include all the available data acquired during flight. Gaps in time occur when the instrument is off during cruise or in STANDBY or ANNEAL mode for which science data are not acquired.

During Initial Checkout (ICO) and Earth-Mars Cruise (EMC), state-of-health data were decimated by a factor of 3 for storage in the virtual recorder on board the spacecraft. Consequently, playback data contained every third state-of-health packet. Full sampling of GRaND housekeeping data was available infrequently during the acquisition of real-time telemetry. The spacecraft flight software was modified to remove the decimation prior to GRaND power on for Mars Gravity Assist (at UTC/ SCET 2009-020/21:19:11), and, thereafter, housekeeping data volume was controlled by the selection of TELSOH. Consequently, fully sampled housekeeping data are available in the EDR following 20-Jan-2009.

GRaND's scalers do not have accompanying roll-over counters. During solar particle events or long accumulation times, it is possible that one or more of the scalers can exceed the maximum number of counts (65535), restarting at 0. In fact, some scalers, such as the dead time counter, can roll over multiple times. The number of times a scaler has rolled over can be determined by watching for abrupt changes in the science scaler data and by analyzing the state-of-health scaler data when the state-of-health readout interval (TELSOH) is set to subsample the science accumulation interval (TELREADOUT) [4].

Successive raw data directories contain short overlapping time periods, such that a few science data records are repeated. Care should be taken to eliminate repeated records when processing raw data from multiple directories. Gaps in the raw data set can occur due to missing packets (e.g. occultations) and for periods of time when the instrument was off following entry of the spacecraft into safe mode.

For completeness, corrupted data (e.g. due to transmission errors) are Included in the dataset; however, instances of corrupt data are rare. Telemetry checksums are discarded in queries of instrument data by the DSC. Consequently, corrupt data can only be identified by anomalies in scaler and spectral data (e.g. incongruous patterns in counts or discontinuous pulse height spectra). Corrupt data are partially excluded from the raw dataset by two mechanisms: 1) packet headers with incorrect SCLK values or other invalid information recognized by the query software are naturally excluded; 2) incomplete science data records (e.g. detected by gaps in the packet sequence counter) are discarded by the raw data pipeline software. A small, but unknown portion of the records may appear to be valid, yet still contain corrupted science data.

Some spectral data products contain artifacts, for example, abrupt increases in counts for the highest channel or a nonphysical change in counts at high channels (e.g. for the CAT1 -Z sensor). The former is likely from events that do not exceed the overload threshold but are not on scale. These wind up in the last channel. In addition, some distortion can occur for large pulses processed by the analog pulse processing circuit. This may account for the roll-off observed for high channels for the -Z sensor (e.g. above channel 230).

LIMITATIONS

The raw data are a low-level data product, which requires significant processing prior to use in scientific analysis.

The raw data directory names include the dates for the first and last science data records in the data files. The date range for the housekeeping data may not match that of the science data. For example, SOH data in the directory GRD_L1A-150817-150818_YCMCDC span 150817 to 150824. The date range for the SOH data can be found quickly by examining the BROWSE report that accompanies each directory.

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