Dawn Mission to Vesta and Ceres
L-2 Data from Vesta and Ceres
Gravity Science Instrument
Archive Volume Software Interface Specification

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CHANGE LOG

DATE	CHANGES	REASON	REVISION
12/30/16	Original		0
02/15/17	Improved clarity		1
03/23/17	Combined Vesta and Ceres in same SIS		2
05/31/17	PDS Peer Review		2.1

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ACRONYMS AND ABBREVIATIONS

ASCII	American Standard Code for Information Interchange
CEGR	Ceres Gravity
DOY	Day of Year
DSC	Dawn Science Center
DSN	Deep Space Network
GS	Gravity Science
GSI	Gravity Science Instrument
JPL	Jet Propulsion Laboratory
NAIF	Navigation Ancillary Information Facility
NASA	National Aeronautics and Space Administration
PDS	Planetary Data System
RDA	Raw Data Archive
RDR	Reduced Data Record
RS	Radio Science
RSDMAP	Radio Science Digital Map
RSS	Radio Science Subsystem
RSSG	Radio Science Systems Group
SIS	Software Interface Specification
VEGR	Vesta Gravity

1. INTRODUCTION

1.1. Purpose and Scope

This Software Interface Specification (SIS) describes the format and content of the Dawn Mission to Vesta and Ceres (Dawn) Gravity Science (GS) Reduced Data Record (RDR) Archive for the Vesta and Ceres phase of the mission.

The Dawn Vesta Gravity (VEGR) RDR represents the complete archive of raw data from gravity science investigations conducted using the radio link between the Dawn spacecraft and the Deep Space Network (DSN) tracking stations.

The Dawn Ceres Gravity (CEGR) RDR represents the archive of reduced data from gravity science investigations conducted using the radio link between the Dawn spacecraft and the Deep Space Network (DSN) tracking stations.

The archives are generated by the Dawn Gravity Science Team and the Dawn Science Center (DSC). It is maintained and distributed by the Planetary Data System (PDS).

Gravity Science is a subset of Radio Science, and because of this, the terms Gravity Science (GS) and Radio Science (RS) are used interchangeably in this archive; as are the terms the Gravity Science Instrument (GSI) and Radio Science Subsystem (RSS).

1.2. Content Overview

This archive contains data products derived from raw Dawn Gravity Science tracking data. The radio observations were carried out using the Dawn spacecraft and Earth-based receiving stations of the NASA Deep Space Network.

This SIS describes the format and content of the Dawn GS RDR archive. The data are generated and assembled into archives by the Gravity Science Team and delivered to the Dawn Science Center (DSC). The DSC delivers the completed archive to PDS.

The specific data products included in this archive are:

- **Gravity field model coefficients (SHADR):** The spherical harmonic coefficients of the gravity field derived from the tracking data
- **Gravity field model coefficients and covariance (SHBDR):** The spherical harmonic coefficients of the gravity field and respective covariance derived from the tracking data
- **Gravity field maps (RSDMAP):** Global maps of the gravity

1.3. References

[1] Konopliv, A.S., S.W. Asmar, R.S. Park, B.G. Bills, F. Centinello, A.B. Chamberlin, A. Ermakov, R.W. Gaskell, N. Rambaux, C.A. Raymond, C.T. Russell, D.E. Smith, P. Tricarico, and M.T. Zuber, *The Vesta gravity field, spin pole and rotation period, landmark positions, and ephemeris from the Dawn tracking and optical data*, Icarus 240, 103-117, doi:10.1016/j.icarus.2013.09.005, 2014.

[2] Park R.S., A.S. Konopliv, B.G. Bills, N. Rambaux, J.C. Castillo-Rogez, C.A. Raymond, A.T. Vaughan, A.I. Ermakov, M.T. Zuber, R.R. Fu, M.J. Toplis, C.T. Russell, A. Nathues and F. Preusker, *A partially differentiated interior for (1) Ceres deduced from its gravity field and shape*, Nature 537, 515-517, doi:10.1038/nature18955, 2016.

2. REDUCED DATA RECORD ARCHIVE OVERVIEW

2.1. Instrument Overview

The gravity science instrument utilizes the deep space transponder onboard the Dawn spacecraft and Doppler tracking equipment at the Deep Space Network to perform radio science investigations to determine the gravitational field of celestial bodies.

For the full description of the Gravity Science instrument, please refer to the INST.CAT and DATASET.CAT files in the CATALOG directory.

2.2. Data Product Overview

The derived data are stored in the DATA folder in two subdirectories. The RSDMAP files are binary files with detached PDS labels describing the format. The SHADR files are ASCII files with detached PDS labels describing the format. The table below describes the data products contained in these directories.

File	Abbrev.	File Type	Source of Files
Radio Science Digital Map	RSDMAP	Binary	Dawn Gravity Team
Spherical Harmonics ASCII Data Record	SHADR	ASCII	Dawn Gravity Team
Spherical Harmonics Binary Data Record	SHBDR	Binary	Dawn Gravity Team

2.2.1. Detailed Descriptions

Radio Science Digital Map files

Radio Science Digital Map files are image representations of gravity and other parameters. Free air gravity, geoid, Bouguer anomaly, isostatic anomaly, and topographic values may be displayed using this data type. Data are formatted as PDS image objects.

Radio Science Digital Map products are stored in the DATA/RSDMAP directory with file names of the form *GTsss_ffff_nnnn_cccc.IMG* where '*G*' denotes the generating institution, '*T*' indicates the type of data represented, '*sss*' is a 3-character modifier specified by the data producer, '*ffff*' is a 4- to 6-character modifier specified by the data producer to indicate the degree and order of the solution for the gravity field, '*nnnn*' is a 4- to 8-character modifier indicating the type of data represented, and '*cccc*' is a 4-character modifier specified by the data producer to indicate the degree and order to which the potential solution (gravity, topography or magnetic field) has been evaluated. Each RSDMAP file is accompanied by a detached PDS label; that label is a file in its own right with name *GTsss_ffff_nnnn_cccc.LBL*.

Spherical Harmonics ASCII Data Record files

Spherical harmonic models are tables of coefficients GM, Cmn, and Smn. These can be used to represent gravitational potential of a celestial body, for example. ASCII (data type SHA) formatted spherical harmonics are defined. Because of the low degree field, no binary files (data type SHB) are provided. Each file contains up to three tables: a header table containing general parameters for the model (gravitational constant, its uncertainty, degree and order of the field, normalization state, reference longitude, and reference latitude); a names table, giving the order in which coefficients appear; a coefficients table (degree m, order n, coefficients Cmn and Smn, and their uncertainties).

ASCII spherical harmonic models are stored in the DATA/SHADR directory with file names of the form *GTsss_nnnnvv_SHA.TAB* where '*G*' denotes the generating institution, '*T*' indicates the type of data represented, '*sss*' is a 3-character modifier specified by the data producer, '*nnnnvv*' is a 4- to 6-character modifier specified by the data producer. Each SHADR file is accompanied by a detached PDS label; that label is a file in its own right, having the name *GTsss_nnnnvv_SHA.LBL*.

Spherical Harmonics Binary Data Record files

The Spherical Harmonics Binary Data Record (SHBDR) contains binary coefficients and/or a binary covariance matrix for a spherical harmonic expansion of gravity fields. SHBDR products have variable length, depending on the degree and order of the model and the number of tables included. A model of degree and order N will include approximately N**2 terms and therefore the number of terms in the covariance matrix will be of order N**4. For 8-byte storage and N=50, the total SHBDR volume will be about 30 MB. For N=100, the total SHBDR volume will be approximately 416 MB

ASCII spherical harmonic models are stored in the DATA/SHBDR directory with file names of the form *GTsss_nnnnvv_SHB.DAT* where '*G*' denotes the generating institution, '*T*' indicates the type of data represented, '*sss*' is a 3-character modifier specified by the data producer, '*nnnnvv*' is a 4- to 6-character modifier specified by the data producer. Each SHBDR file is accompanied by a detached PDS label; that label is a file in its own right, having the name *GTsss_nnnnvv_SHB.LBL*.

2.3. Data Processing

Data processing is performed by the Dawn Gravity Science Team at the Jet Propulsion Laboratory in Pasadena, CA. The raw radio tracking data are input into a gravity-specific version of the JPL Orbit Determination Program (ODP) called MIRAGE, which filters the data in a least-squares method to solve for parameters, including spherical harmonic coefficients describing the gravity field. For an overview of the method, see Reference [1] or [2] in Section 1.3.

2.4. Software

No software is included in this archive.

The PDS-provided NASAview software is useful for opening and viewing RSDMAP products. It is available from the Planetary Data System's website at: https://pds.nasa.gov/tools/nasa-view.shtml

The SPICE toolkit provides useful tools and algorithms for ancillary data processing that could help in the use of these products of and is located at the NAIF PDS node naif.jpl.nasa.gov.

2.5. File Naming Conventions

See Section 2.2.1 for file naming conventions in the description of each file type.

2.6. Data Product Labels

Every file in this archive is accompanied by a PDS label. The label is either attached (embedded in the file) or detached (separate file with same name except for extension '.LBL'). Depending on the file type, the detached label may provide the content and structure of the file. Labels are structured in the PDS *KEYWORD=VALUE* fashion. A description of the keywords may be found on the web at http://pds.nasa.gov/tools/ddlookup/data_dictionary_lookup.cfm.

2.7. Standard Keyword Values

The Dawn Gravity Science RDA uses the following standard keywords and values, consistent across the archive:

Keyword	Dawn Standard Values
DATA_SET_ID	DAWN-A-RSS-5-VEGR-V1.0; DAWN-A-RSS-5-CEGR-V1.0
DATA_SET_NAME	DAWN VESTA GRAVITY SCIENCE DERIVED SCIENCE DATA V1.0; DAWN CERES GRAVITY SCIENCE DERIVED SCIENCE DATA V1.0
INSTRUMENT_HOST_ID	DAWN
INSTRUMENT_HOST_NAME	DAWN
INSTRUMENT_ID	RSS
INSTRUMENT_NAME	GRAVITY SCIENCE INSTRUMENT
INSTRUMENT_TYPE	RADIO SCIENCE
MISSION_NAME	DAWN MISSION TO VESTA AND CERES
TARGET_NAME	1 CERES; 4 VESTA
VOLUME_ID	DWNVGRS_2; DWNCGRS_2
VOLUME_SERIES_NAME	DAWN
VOLUME_SET_ID	USA_NASA_PDS_DAWN_GRS_L2
VOLUME_SET_NAME	DAWN GRAVITY SCIENCE INSTRUMENT DERIVED L-2 DATA
VOLUME_VERSION_ID	VERSION 1

3. ARCHIVE ORGANIZATION

The Dawn Gravity Science Raw Data Archive for Ceres has the following directories:

- Root directory
  - CATALOG
  - DOCUMENT
  - DATA
    - RSDMAP

- SHADR
- SHBDR

- INDEX

The contents of the directories are described below.

3.1. Root Directory

This directory is the core directory on which the rest of the archive is built. It contains the following files:

1. AAREADME.TXT: Human readable description of the archive contents
2. ERRATA.TXT: Human readable list of corrections and other comments regarding the archive
3. VOLDESC.CAT: Description of the contents of the volume

3.2. CATALOG Directory

This directory contains descriptions of the dataset, mission, instrument, and spacecraft. They are all ASCII stream files. It contains the following files:

1. CATINFO.TXT: Description of the directory
2. DATASET.CAT: Overview of the RDA
3. INST.CAT: Overview of the Gravity Science Instrument
4. dawninsthost.cat: Overview of the Dawn spacecraft
5. dawnmission.cat: Overview of the Dawn Mission to Vesta and Ceres
6. DSMAP.DAT: Overview of the Radio Science Digital Map files
7. PERSON.CAT: Contributors to the archive and contact information
8. REF.CAT: References for the archive

3.3. DOCUMENT Directory

This directory contains the corresponding documentation to help the end user use and interpret the data included in this archive. The following documents are included:

Filename	Format	Description
DOCINFO.TXT	text	Description of the directory
DAWN_GRAV_RDR_SIS	Word, PDF, html	This document
RSDMAP	html	Description of the contents and format of the Radio Science digital map files
SHADR	html	Description of the contents and format of the Spherical Harmonic ASCII data record files
SHBDR	html	Description of the contents and format of the Spherical Harmonics Binary data record files

3.4. INDEX Directory

This directory contains the following files:

1. INDEXINFO.TXT: Description of the directory
2. INDEX.LBL: Detached label describing INDEX.TAB

3. INDEX.TAB: Table listing all data products in the RDR archive

3.5. DATA Directory

The DATA directory contains the primary data. It contains the following subdirectories and file types:

Directory	File Type	Contents
RSDMAP	Radio Science Digital Map	Contains maps of an evaluated gravity field, such as gravity anomaly
SHADR	Spherical Harmonics ASCII Data Record	Contains the spherical harmonic coefficients of the gravity field of the specified body
SHBDR	Spherical Harmonics Binary Data Record	Contains the spherical harmonic coefficients and covariance of the gravity field of the specified body

4. RELEVANT DATA ARCHIVED AT OTHER SITES

4.1. NAIF Node

The Navigation and Ancillary Information Facility (NAIF) is the navigation node of the PDS. NAIF provides the archives for spacecraft navigation, attitude, events, clock conversion, and planetary ephemerides for most NASA missions. Additionally, NAIF provides the SPICE toolkit, containing useful algorithms to utilize and manipulate data NAIF provide.

Relevant to gravity science are the following types:

- **CK:** Spacecraft and solar array attitude orientation files
- **FK:** Reference frame specification
- **SCLK:** Conversion between spacecraft time and ephemeris time
- **SPK:** Spacecraft and Planetary ephemeris data

The NAIF PDS archive for Dawn is located at:

- naif.jpl.nasa.gov/pub/naif/pds/data/dawn-m_a-spice-6-v1.0/

5. PERSONNEL

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- Alex S. Konopliv, Dawn Gravity Science Co-Investigator, NASA Jet Propulsion Lab
- Dustin R. Buccino, Dawn Radio Science Analyst, NASA Jet Propulsion Lab

6. ACKNOWLEDGMENTS

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