**Dawn Mission to Vesta and Ceres**

**L-2 Data from Vesta and Ceres**

**Gravity Science Instrument**

**Archive Volume Software Interface Specification**

Dustin Buccino

Jet Propulsion Laboratory, California Institute of Technology

Version 2.1

May 31, 2017

(c) 2017 California Institute of Technology. Government sponsorship acknowledged.

**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 |

**TABLE OF CONTENTS**

[1. INTRODUCTION 4](#_Toc483993632)

[1.1. Purpose and Scope 4](#_Toc483993633)

[1.2. Content Overview 4](#_Toc483993634)

[1.3. References 4](#_Toc483993635)

[2. REDUCED DATA RECORD ARCHIVE OVERVIEW 5](#_Toc483993636)

[2.1. Instrument Overview 5](#_Toc483993637)

[2.2. Data Product Overview 5](#_Toc483993638)

[2.2.1. Detailed Descriptions 5](#_Toc483993639)

[2.3. Data Processing 6](#_Toc483993640)

[2.4. Software 6](#_Toc483993641)

[2.5. File Naming Conventions 7](#_Toc483993642)

[2.6. Data Product Labels 7](#_Toc483993643)

[2.7. Standard Keyword Values 7](#_Toc483993644)

[3. ARCHIVE ORGANIZATION 7](#_Toc483993645)

[3.1. Root Directory 8](#_Toc483993646)

[3.2. CATALOG Directory 8](#_Toc483993647)

[3.3. DOCUMENT Directory 8](#_Toc483993648)

[3.4. INDEX Directory 8](#_Toc483993649)

[3.5. DATA Directory 9](#_Toc483993650)

[4. RELEVANT DATA ARCHIVED AT OTHER SITES 9](#_Toc483993651)

[4.1. NAIF Node 9](#_Toc483993652)

[5. PERSONNEL 9](#_Toc483993653)

[6. ACKNOWLEDGMENTS 9](#_Toc483993654)

**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

# INTRODUCTION

## 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).

## 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

## 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.

# REDUCED DATA RECORD ARCHIVE OVERVIEW

## 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.

## 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 |

### 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*.

## 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.

## 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.

## File Naming Conventions

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

## 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>.

## 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 |

# 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.

## 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

## 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

## 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 |

## 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

## 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 |

# RELEVANT DATA ARCHIVED AT OTHER SITES

## 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/

# PERSONNEL

* Ryan S. Park, Chair of the Dawn Gravity Science Working Group, NASA Jet Propulsion Lab
* Alex S. Konopliv, Dawn Gravity Science Co-Investigator, NASA Jet Propulsion Lab
* Dustin R. Buccino, Dawn Radio Science Analyst, NASA Jet Propulsion Lab

# ACKNOWLEDGMENTS

The work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.