SOFTWARE INTERFACE SPECIFICATION

RADIO SCIENCE DIGITAL MAP (RSDMAP) PRODUCTS

prepared by

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PREFACE

REVISION NUMBER	REVISION DATE	SECTION AFFECTED	REMARKS

DOCUMENT CHANGE LOG

2.0	98/04/20	All	Adapted from V1.0.2 for MGS and Lunar Prospector.
2.0.1	98/12/16	4.2.1	Change MGS DATA_SET_ID to MGS-M-RSS-5-SDP-V1.0
2.0.1	98/12/16	Appendix B	Added examples in B.1 and B.2
2.0.2	99/03/09	Distribution	Update list of PDS recipients
2.0.2	99/03/09	Acr & Abbrev 1.2	Changed "LPX" to "LP" for Lunar Prospector
2.0.2	99/03/09	2.3	Generalized use of "nnnnvv" string in file naming.
2.0.2	99/03/09	Fig. 4-2-3	Generalized value for pointer ^DATA_SET_MAP_PROJECTION
2.0.2	99/03/09	Fig. 4-2-2 B.1	Removed keyword UNIT from IMAGE object definition
2.0.2	99/03/09	1.5.4.1 1.5.4.2	Substituted 7-bit ASCII characters for 8-bit versions
3.0	06/03/15	All	Adapted from V2.0.2 for Messenger and MRO. Streamlined format, omitting obsolete distribution list and table of Items to be
3.1	08/07/28	2.3	Updated file naming convention for MRO
3.2	10/13/10	2.3	Updated file naming convention to include more characters to describe solution of the field
4.0	13/04/17	All	Adapted from V3.2 for GRAIL
4.1	13/06/11	All	Typos and formatting
4.2	13/09/12	Appendices	Revised Appendices A & B for GRAIL
4.3	14/06/06	2.3	Updated file naming convention to include 2 more data types.

Contents

Figures

Acronyms and Abbreviations

ANSI	American National Standards Institute
APL	Applied Physics Laboratory
ARC	Ames Research Center
ARCDR	MGN Altimetry and Radiometry Composite Data Record
ASCII	American Standard Code for Information Interchange
ASU	Arizona State University
CD-WO	compact-disc write-once
CNES	Centre National d'Etudes Spatiales
CR	Carriage return (ASCII character)
dB	Decibel
DEC	Digital Equipment Corporation
DSN	Deep Space Network
DVD	Digital Video Disc or Digital Versatile Disc
EGM96	Earth Gravitational Model 1996
FEA	Front End Assembly
GRAIL	Gravity Recovery and Interior Laboratory
GSFC	Goddard Space Flight Center
IEEE	Institute of Electrical and Electronic Engineers
IAU	International Astronomical Union
JHU	Johns Hopkins University
JPL	Jet Propulsion Laboratory
J2000	IAU Official Time Epoch
K	Degrees Kelvin
kB	kilobytes
km	Kilometers
LAST	Laser Altimeter Science Team (Messenger)
LF	Line feed (ASCII character)
LP	Lunar Prospector (mission or spacecraft)
MESSENGER	MErcury Surface Space ENvironment, GEochemistry, and Ranging (acronym for mission to Mercury)
MGN	Magellan (project or spacecraft)

MGS	Mars Global Surveyor
MIT	Massachusetts Institute of Technology
MLA	MESSENGER Laser Altimeter
MO	Mars Observer
MRO	Mars Reconnaissance Orbiter
NAIF	Navigation and Ancillary Information Facility
NASA	National Aeronautics and Space Administration
NAV	Navigation Subsystem/Team
ODL	Object Definition Language (PDS)
PDS	Planetary Data System
RS	Radio Science
RSDMAP	Radio Science Digital Map Product
RSS	Radio Science Subsystem
RST	Radio Science Team
SCET	Space Craft Event Time
SDS	Science Data System
SHADR	Spherical Harmonic ASCII Data Record
SHBDR	Spherical Harmonic Binary Data Record
SHM	Spherical Harmonic Model
SIS	Software Interface Specification
SOPC	Science Operations Planning Computer
SPARC	Sun Scaleable Processor Architecture
SPK	Spacecraft and Planet Kernel Format, from NAIF
TBD	To Be Determined
TDB	Temps Dynamique Barycentrique - IAU Standard Ephemeris Time
TES	Thermal Emission Spectrometer
UTC	Universal Time Coordinated

1. General Description

1.1. Overview

This Software Interface Specification (SIS) describes Radio Science Digital Map (RSDMAP) files. The RSDMAP product was designed for geoid, isostatic anomaly, Bouguer anomaly, or other digital maps derived primarily from Radio Science data [1]. Use of the RSDMAP format is not limited to Radio Science data, however.

1.2. Scope

The format and content specifications in this SIS apply to all phases of a project for which RSDMAP products are produced.

The RSDMAP product was defined initially for free air gravity maps derived from Magellan (MGN) and Mars Observer (MO) radio tracking data, but the format is more generally useful. It was adapted in 1999 for Mars Global Surveyor (MGS) and Lunar Prospector (LP) radio data with options for MGS Thermal Emission Spectrometer (TES) data. It was later revised for the Mars Reconnaissance Orbiter (MRO) [6,7] and MESSENGER [8,9] missions. In this revision it is adapted for the Gravity Recovery and Interior Laboratory (GRAIL) mission [12].

The Magellan, Mars Observer, Mars Global Surveyor, Mars Reconnaissance Orbiter, and GRAIL missions are or were managed by the Jet Propulsion Laboratory (JPL) for the National Aeronautics and Space Administration (NASA). Lunar Prospector was managed by the Ames Research Center (ARC) for NASA. MESSENGER is managed by the Johns Hopkins University Applied Physics Laboratory (APL), in Laurel Maryland.

1.3. Applicable Documents

[1] Tyler, G.L., G. Balmino, D.P. Hinson, W.L. Sjogren, D.E. Smith, R. Woo, S.W. Asmar, M.J. Connally, C.L. Hamilton, and R.A. Simpson, Radio Science Investigations with Mars Observer, J. Geophys. Res., 97, 7759-7779, 1992.

[2] MGN 630-7, Rev. D, Magellan Planetary Constants and Models, D.T. Lyons, Mission Design, Jet Propulsion Laboratory, 9 January 1991.

[3] MO 642-321, Mars Observer Planetary Constants and Models, JPL D-3444, November 1990.

[4] D-7116, Rev. F, Planetary Science Data Dictionary Document, Jet Propulsion Laboratory, 20 October 2008.

[5] D-7669 Part 2, Planetary Data System Standards Reference, PDS Version 3.8, Jet Propulsion Laboratory, 27 February 2009.

[6] Mars Reconnaissance Orbiter Mission Plan, Revision C: July 2005,

prepared by Robert Lock Document JPL D-22239, MRO-31-201.

[7] MRO-D-22685, Rev B., Planetary Constants and Models, 05-15-2003.

[8] McAdams, J. V. (JHU/APL), MESSENGER mission overview and trajectory design, American Institute of Aeronautics and Astronautics, American Astronautical Society (AIAA/AAS) Astrodynamics Specialist Conference, Paper AAS 03-541, 20 pp., Big Sky, MT, August 3-7, 2003.

[9] McAdams, J. V., D. W. Dunham, R. W. Farquhar (all at JHU/APL), A. H. Taylor, and B. G. Williams (both at KinetX, Inc.), Trajectory design and maneuver strategy for the MESSENGER mission to Mercury, 15th American Astronautical Society (AAS)/American Institute of Aeronautics and Astronautics (AIAA) Space Flight Mechanics Conf., Paper AAS 05-173, 21 pp., Copper Mountain, CO, January 23-27, 2005.

[10] Wessel, P. and W. H. F. Smith, Free software helps map and display data, EOS Trans. AGU, 72, 441, 1991.

[11] Generic Mapping Tools website: http://gmt.soest.hawaii.edu/.

[12] Roncoli, R. B., and K. K. Fujii, Mission Design Overview for the Gravity Recovery and Interior Laboratory (GRAIL) Mission, AIAA/AAS Astrodynamics Specialist Conference, Toronto, Ontario, Canada, 2010. http://arc.aiaa.org/doi/pdf/10.2514/6.2010-8383.

1.4. System Siting

1.4.1. Interface Location and Medium

RSDMAP files are created at the institution conducting the science analysis. RSDMAP files are electronic files.

1.4.2. Data Sources, Transfer Methods, and Destinations

RSDMAP files are created from radio tracking, vertical sounding, in situ, and/or other measurements at the institution conducting the scientific data analysis. They are transferred to and deposited in a data system specified by the managing institution.

RSDMAP files will be delivered to users via electronic networks and/or on physical media such as compact-disc write-once volumes (CD-WO).

1.4.3. Generation Method and Frequency

RSDMAP files are developed separately at each institution conducting scientific analyses on raw data. Each digital map meets criteria specified by the investigators conducting the analysis. Each digital map typically requires data from a large number of latitudes and longitudes, so that RSDMAP files will be issued infrequently and on schedules which cannot be predicted.

1.5. Assumptions and Constraints

1.5.1. Usage Constraints

None.

1.5.2. Priority Phasing Constraints

None.

1.5.3. Explicit and Derived Constraints

None.

1.5.4. Documentation Conventions

1.5.4.1. Data Format Descriptions

The reference data unit is the byte. Data may be stored in fields with various sizes and formats, viz. one-, two-, and four-byte binary integers, four- and eight-byte binary floating-point numbers, and character strings. Data are identified throughout this document as

char	8 bits	character
uchar	8 bits	integer
short	16 bits	integer
long	32 bits	integer
float	32 bits	floating point (sign, exponent, and mantissa)
double	64 bits	floating point (sign, exponent, and mantissa)
u (prefix)		unsigned (as with ulong for unsigned 32-bit integer)
other		special data structures such as time, date, etc. which are described within this document

The detailed formats of the numeric fields are defined in Appendix A.

If a field is described as containing n bytes of ASCII character string data, this implies that the leftmost (lowest numbered) byte contains the first character, the next lowest byte contains the second character, and so forth.

An array of n elements is written as array[n]; the first element is array[0], and the last is array[n-1]. Array[n][m] describes an n by m element array, with first element array[0][0], second element array[0][1], and so forth.

1.5.4.2. Time Standards

RSDMAP files use the January 1.5, 2000 epoch as the standard time. Within the data files, all times are reported in Universal Coordinated Time (UTC) as strings of 23 ASCII characters. The time format is "YYYY-MM-DDThh:mm:ss.fff", where "-", "T", ":", and "." are fixed delimiters; "YYYY" is the year "19nn" or "20nn"; "MM" is a two-digit month of year; "DD" is a two-digit day of month; "T" separates the date and time segments of the string; "hh" is hour of day; "mm" is the minutes of hour (00-59); "ss" is the seconds of hour (00-59); and "fff" is in milliseconds.

The date format is "YYYY-MM-DD", where the components are defined as above.

1.5.4.3. Coordinate Systems

Coordinate systems for RSDMAP products are specified in the IMAGE_MAP_PROJECTION definition in the PDS label (see Section 4.2.3). These may be described more fully in other documents -- e.g. [2,3].

1.5.4.4. Limits of This Document

This document applies only to RSDMAP data files.

1.5.4.5. Typographic Conventions

This document has been formatted for simple electronic file transfer and display. Line lengths are limited to 80 ASCII characters, including line delimiters. No special fonts or structures are included within the file. Constant width characters are assumed for display.

2. Interface Characteristics

2.1. Hardware Characteristics and Limitations

2.1.1. Special Equipment and Device Interfaces

Users of the RSDMAP product must have access to the data system (or to backup media) on which RSDMAP files are stored.

2.1.2. Special Setup Requirements

None.

2.2. Volume and Size

RSDMAP products have variable length depending on the resolution of the map, the number of quantities represented in the image, and the format of the individual data points. A rectangular map of resolution 1 degree in both latitude and longitude with a single parameter given as a double precision floating point number requires about 520 kB total. The same map in one-byte integers would require about 65 kB.

2.3. Labeling and Identification

The length of file names is limited to 27 or fewer characters

before the period delimiter and 3 characters after the period delimiter.

Each file has a name which describes its contents. The name includes the following structure which uniquely identifies it among RSDMAP products. For the GRAIL gravity products the following file naming convention is used:

GTsss_ffff_nnnn_cccc.IMG

where

"G" denotes the generating institution
- "J" for the Jet Propulsion Laboratory
- "G" for Goddard Space Flight Center
- "M" for Massachusetts Institute of Technology

"T" indicates the type of mission data represented
- "G" for gravity field

"sss" is a 3-character modifier specified by the data producer. This modifier is used to indicate the source spacecraft or project, such as MRO for the Mars Reconnaisance Orbiter.

"_" the underscore character is used to delimit information in the file name for clarity.

"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, topography or magnetic field.

"nnnn" is a 4- to 8-character modifier indicating the type of data represented
- "ANOM" for free air gravity anomalies
- "ANOMERR" for free air gravity anomaly errors (1)
- "GEOID" for geoid
- "GEOIDERR" for geoid errors (1)
- "BOUG" for Bouguer anomaly
- "ISOS" for isostatic anomaly
- "TOPO" for topography
- "MAGF" for magnetic field
- "DIST" for gravity disturbances
- "DEGSTR" for degree strength

(1) Geoid and gravity anomaly errors are computed from a mapping of the error covariance matrix of the gravity field solution.

"cccc" is a 2- to 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. In the case of the error maps for the gravity anomalies or geoid, this field indicates to which maximum degree and order the error covariance was used to propagate the spatial errors

".IMG" indicates the data is stored as an image.

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

2.4. Interface Medium Characteristics

RSDMAP products are electronic files.

2.5. Failure Protection, Detection, and Recovery Procedures

None.

2.6. End-of-File Conventions

End of file labeling complies with standards of the data system or medium on which they are stored.

3. Access

3.1. Programs Using the Interface

Data contained in RSDMAP files will be accessed by programs at the home institutions of science investigators. Those programs cannot be identified here.

3.2. Synchronization Considerations

3.2.1. Timing and Sequencing Considerations

N/A

3.2.2. Effective Duration

N/A

3.2.3. Priority Interrupts

None.

3.3. Input/Output Protocols, Calling Sequences

None.

4. Detailed Interface Specifications

4.1. Structure and Organization Overview

The RSDMAP is a file generated by software at the institution conducting scientific data analysis. Each RSDMAP file is accompanied by a detached PDS label.

4.2. Detached PDS Label

The detached PDS label has three parts -- a header, an IMAGE object definition, and an IMAGE_MAP_PROJECTION definition. The header contains information about the origin of the file and its general characteristics such as record type and size. The IMAGE object definition contains information about the image -- lines, pixels, scaling of pixel values, etc. The IMAGE_MAP_PROJECTION definition describes how one should display the image.

Each detached PDS label is constructed of ASCII records; each record contains exactly 80 characters. The last two characters in each record are the carriage-return (ASCII 13) and line-feed (ASCII 10) characters.

An example of a complete label is given in Appendix B.

4.2.1 Label Header

The structure of the label file header is illustrated in Figure 4-2-1. Keyword definitions are given below.

Figure 4-2-1 RSDMAP Label Header

```
PDS_VERSION_ID = PDS3
RECORD_TYPE = FIXED_LENGTH
RECORD_BYTES = nnn
FILE_RECORDS = nnn
^IMAGE = "GTsss_ffff_nnnn_cccc.IMG"
INSTRUMENT_HOST_NAME = "ccccccccccccccccccc"
TARGET_NAME = "cccc"
INSTRUMENT_NAME = "ccccccccccccccccccccccc"
DATA_SET_ID = "ccccccccccccccccccccccc"
ORIGINAL_PRODUCT_ID = "ccccccccccccccc"
PRODUCT_ID = "GTsss_ffff_nnnn_cccc.IMG"
PRODUCT_RELEASE_DATE = YYYY-MM-DD
DESCRIPTION = "ccccccccccccccccc"
START_ORBIT_NUMBER = nnnn
STOP_ORBIT_NUMBER = nnnn
START_TIME = YYYY-MM-DDThh:mm:ss.fff
```

```
|  STOP_TIME = YYYY-MM-DDThh:mm:ss.fff                                |
|  SOFTWARE_NAME = "ccccccc;Vn.m"                                     |
|  PRODUCT_CREATION_TIME = YYYY-MM-DDThh:mm:ss.fff                    |
|  PRODUCER_ID = "ccccccc"                                            |
|                                                                     |
|=====================================================================|
```

PDS_VERSION_ID = The version of the Planetary Data System for which these data have been prepared (set to PDS3 by agreement between the space flight project and PDS).

RECORD_TYPE = The type of record. Set to "FIXED_LENGTH" to indicate that all logical records have the same length.

RECORD_BYTES = The number of bytes per (fixed-length) record.

FILE_RECORDS = The number of records in the RSDMAP file; instance dependent.

^IMAGE = File name of the RSDMAP file in the form "GTsss_ffff_nnnn_cccc.IMG", where the structure is explained in Section 2.3.

INSTRUMENT_HOST_NAME = Name of the spacecraft; acceptable names include "MARS GLOBAL SURVEYOR", "LUNAR PROSPECTOR", "MARS RECONNAISSANCE ORBITER", "MESSENGER", and "GRAVITY RECOVERY AND INTERIOR LABORATORY".

TARGET_NAME = A character string which identifies the target body. For MGS and MRO RSDMAP files, the character string "MARS". For Lunar Prospector and GRAIL RSDMAP files, the character string "MOON". For MESSENGER RSDMAP files, the character string "MERCURY".

INSTRUMENT_NAME = Name of the instrument; set to "RADIO SCIENCE SUBSYSTEM" for products generated from radio science data, or to other instrument names as appropriate. For GRAIL, set to “LUNAR GRAVITY RANGING SYSTEM”.

DATA_SET_ID = Identifier for the data set of which this RSDMAP product is a member. Set to "MGS-M-RSS-5-SDP-Vn.m" for Mars Global Surveyor RSDMAP products, where "Vn.m" indicates the version number of the data set. Set to "MRO-M-RSS-5-SDP-Vn.m" for MRO. Set to "MESS-H-RSS-5-SDP-Vn.m" for MESSENGER. Set to "LP-L-RSS-5-SHGBDR-L2-Vn.m" for Lunar Prospector; Set to "GRAIL-L-LGRS-5-RDR-Vn.m" for GRAIL.

ORIGINAL_PRODUCT_ID = Optional. An identifier for the product provided by the producer. Generally a file name, different from PRODUCT_ID, which would be recognized at the producer's institution.

PRODUCT_ID =	A unique identifier for the product within the collection identified by DATA_SET_ID. Usually the same as the value for ^IMAGE. The naming convention is defined in Section 2.3.
PRODUCT_RELEASE_DATE =	The date on which the product was released to the Planetary Data System; entered in the format "YYYY-MM-DD", where components are defined in Section 1.5.4.2.
DESCRIPTION =	A short description of the RSDMAP product.
START_ORBIT_NUMBER =	Optional. The first orbit represented in the RSDMAP product. An integer.
STOP_ORBIT_NUMBER =	Optional. The last orbit represented in the RSDMAP product. An integer.
START_TIME =	The Earth Receive Time at which the first sample was acquired, expressed in the format "YYYY-MM-DDThh:mm:ss.fff" where the components are defined in Section 1.5.4.2.
STOP_TIME =	The Earth Receive Time at which the last sample was acquired, expressed in the format "YYYY-MM-DDThh:mm:ss.fff" where the components are defined in Section 1.5.4.2.
SOFTWARE_NAME =	The name and version number of the program creating this RSDMAP file; expressed as a character string in the format "PROGRAM_NAME;n.mm" where "PROGRAM_NAME" is the name of the software and "n.mm" is the version number.
PRODUCT_CREATION_TIME =	The time at which this RSDMAP was created; expressed in the format "YYYY-MM-DDThh:mm:ss.fff" where the components are defined in Section 1.5.4.2.
PRODUCER_ID =	The entity responsible for creation of the RSDMAP product; for products generated by the Mars Global Surveyor Radio Science Team, set to "MGS RST"; for products generated by the GRAIL Science Data System, set to "SDS".

4.2.2. Image Object Definition

The Image Object Definition in the label completely describes the accompanying Digital Map. It immediately follows the label header and has the format shown in Figure 4-2-2.

Keywords are defined in [4]. There is no requirement within this document that there be any relationship among RECORD_BYTES, LINE_SAMPLES, and SAMPLE_BITS other than that the number of bytes in an image line be an integral multiple of RECORD_BYTES (Section 4.2.1). It is strongly recommended, however, that producers of RSDMAP files make the line lengths identically equal to RECORD_BYTES to ensure maximum compatibility with existing image processing software. For compatibility, producers are also encouraged to use 8- or 16-bit integer pixels rather than longer formats.

Figure 4-2-2 RSDMAP Image Object Definition

```
OBJECT               = IMAGE
  LINES                     = nnnn
  LINE_SAMPLES              = nnnn
  SAMPLE_TYPE               = nnnn
  SAMPLE_BITS               = nnnn
  OFFSET                    = nnn.ff
  SCALING_FACTOR            = nnn.ff
  DESCRIPTION               = "ccccccccccccc"
END_OBJECT           = IMAGE
```

4.2.3. Image Map Projection Object Definition

The Image Map Projection Object Definition specifies the map projection for an RSDMAP product. It is used for interpretation of the RSDMAP data; it is not required for understanding the structure of the file. It immediately follows the Image Object Definition and has the form shown in Figure 4-2-3.

Figure 4-2-3 RSDMAP Image Map Projection Definition

```
OBJECT               = IMAGE_MAP_PROJECTION
  ^DATA_SET_MAP_PROJECTION     = "cccccccc.CAT"
  COORDINATE_SYSTEM_NAME       = ccccccccccccc
  COORDINATE_SYSTEM_TYPE       = ccccccccccccc
  MAP_PROJECTION_TYPE          = "ccccccccccc"
  A_AXIS_RADIUS                = nnn.ff <unit>
  B_AXIS_RADIUS                = nnn.ff <unit>
  C_AXIS_RADIUS                = nnn.ff <unit>
  FIRST_STANDARD_PARALLEL      = "N/A"
  SECOND_STANDARD_PARALLEL     = "N/A"
  POSITIVE_LONGITUDE_DIRECTION = ccccccccccccc
  CENTER_LATITUDE              = nnn.ff <unit>
  CENTER_LONGITUDE             = nnn.ff <unit>
  REFERENCE_LATITUDE           = "N/A"
  REFERENCE_LONGITUDE          = "N/A"
  LINE_FIRST_PIXEL             = nnn
  LINE_LAST_PIXEL              = nnn
  SAMPLE_FIRST_PIXEL           = nnn
  SAMPLE_LAST_PIXEL            = nnn
  MAP_PROJECTION_ROTATION      = nnn.ff <unit>
  MAP_RESOLUTION               = nnn.ff <unit>
  MAP_SCALE                    = nnn.ff <unit>
  MAXIMUM_LATITUDE             = nnn.ff <unit>
  MINIMUM_LATITUDE             = nnn.ff <unit>
  EASTERNMOST_LONGITUDE        = nnn.ff <unit>
  WESTERNMOST_LONGITUDE        = nnn.ff <unit>
  LINE_PROJECTION_OFFSET       = nnn.ff
  SAMPLE_PROJECTION_OFFSET     = nnn
END_OBJECT           = IMAGE_MAP_PROJECTION
```

| |
|==|

Keywords are defined, and standard values are given, in [4]. For Mars Global Surveyor, Mars Reconnaissance Orbiter, MESSENGER, and GRAIL RSDMAP products, the following are required:

```
COORDINATE_SYSTEM_NAME       = "PLANETOCENTRIC"
COORDINATE_SYSTEM_TYPE       = "BODY-FIXED ROTATING"
POSITIVE_LONGITUDE_DIRECTION = "EAST"
```

DSMP.CAT is a file stored elsewhere (in the CATALOG directory); it specifies the map projection more explicitly.

4.3 Data File

The data file is the Image Object, defined in 4.2.2 and presumed to contain the digital map.

Each map comprises LINES rows of LINE_SAMPLES pixels; each pixel occupies SAMPLE_BITS bits.

Appendix A. Binary Data Format

See PDS 3.8 Standards Reference, Appendix C.7, for the PC binary format.

Appendix B. Example RSDMAP Label and Data Object

B.1 Example Label

```
PDS_VERSION_ID               = PDS3
RECORD_TYPE                  = FIXED_LENGTH
RECORD_BYTES                 = 5760
FILE_RECORDS                 = 721
^IMAGE                       = ("JGGRX_0660B_ANOM_L320.IMG",1)
INSTRUMENT_HOST_NAME         = {"GRAVITY RECOVERY AND INTERIOR LABORATORY A",
                                "GRAVITY RECOVERY AND INTERIOR LABORATORY B"}
TARGET_NAME                  = "MOON"
INSTRUMENT_NAME              = {"LUNAR GRAVITY RANGING SYSTEM A",
                                "LUNAR GRAVITY RANGING SYSTEM B"}
DATA_SET_ID                  = "GRAIL-L-LGRS-5-RDR-V1.0"
ORIGINAL_PRODUCT_ID          = "GL0660B_ANOMALY_TRUNCATE_N=320"
PRODUCT_ID                   = "JGGRX_0660B_ANOM_L320.IMG"
PRODUCT_RELEASE_DATE         = 2013-02-05
DESCRIPTION                  = "
 This file contains a digital map of the gravity anomaly derived from
 the JPL GL0660B model of the Moon's gravity field.  Each point gives the
 Lunar gravity anomaly in milligals, which is the difference of the model
 gravity on the geoid from the gravity on a reference sphere
 with semi-major-axis = 1738.0 km, GM = 4902.8003055554 km**3/s**2,
 and zero rotation rate.

 The JGGRX_0660B_ANOM_320 gravity anomaly is computed from a truncated
 GL0660B solution (from degree 2 up to degree 320).

 The reference for the GL0660B gravity field is KONOPLIVETAL2013,
 published in the Journal of Geophysical Research with the DOI number
 0.1002/jgre.20097."

START_TIME                   = 2012-03-01T16:28:00.000
STOP_TIME                    = 2012-05-29T16:36:00.000
PRODUCT_CREATION_TIME        = 2013-02-05T00:00:00.000
PRODUCER_ID                  = "JPL LEVEL-2 TEAM"

OBJECT               = IMAGE
  LINES                      = 721
  LINE_SAMPLES               = 1440
  SAMPLE_TYPE                = "PC_REAL"
```

```
  SAMPLE_BITS                = 32
  UNIT                       = "MILLIGALS"
  OFFSET                     = 0.0E+00
  SCALING_FACTOR             = 1.0E+00
  DESCRIPTION                = "The Digital Map contains
   values of the gravity anomaly.  The values can be obtained
   by multiplying the sample in the map by SCALING_FACTOR
   and then adding OFFSET.  One milligal equals 0.01 mm/s/s."
END_OBJECT           = IMAGE

OBJECT               = IMAGE_MAP_PROJECTION
  ^DATA_SET_MAP_PROJECTION     = "DSMAP.CAT"
  COORDINATE_SYSTEM_TYPE       = "BODY-FIXED ROTATING"
  COORDINATE_SYSTEM_NAME       = PLANETOCENTRIC
  MAP_PROJECTION_TYPE          = "SIMPLE CYLINDRICAL"
  A_AXIS_RADIUS                = 1738.0 <km>
  B_AXIS_RADIUS                = 1738.0 <km>
  C_AXIS_RADIUS                = 1738.0 <km>
  FIRST_STANDARD_PARALLEL      = "N/A"
  SECOND_STANDARD_PARALLEL     = "N/A"
  POSITIVE_LONGITUDE_DIRECTION = "EAST"
  CENTER_LATITUDE              = 0.0 <DEGREE>
  CENTER_LONGITUDE             = 0.0 <DEGREE>
  REFERENCE_LATITUDE           = 0.0 <DEGREE>
  REFERENCE_LONGITUDE          = 0.0 <DEGREE>
  LINE_FIRST_PIXEL             = 1
  LINE_LAST_PIXEL              = 721
  SAMPLE_FIRST_PIXEL           = 1
  SAMPLE_LAST_PIXEL            = 1440
  MAP_PROJECTION_ROTATION      = 0.0 <DEGREE>
  MAP_RESOLUTION               = 4.0 <PIXEL/DEG>
  MAP_SCALE                    = 7583.4556 <M/PIXEL>
  MAXIMUM_LATITUDE             = 90.0 <DEGREE>
  MINIMUM_LATITUDE             = -90.0 <DEGREE>
  EASTERNMOST_LONGITUDE        = 179.75 <DEGREE>
  WESTERNMOST_LONGITUDE        = -180.0 <DEGREE>
  LINE_PROJECTION_OFFSET       = 360.0
  SAMPLE_PROJECTION_OFFSET     = 719.5
END_OBJECT           = IMAGE_MAP_PROJECTION

END
```

B.2 Example Data Object

The list below contains the ascii dump of the first and last record or the map file cited in A.1. The first record consists of the map data at the northernmost latitude (90 degrees), sequentially from longitude -180 to 179.75 degrees. The last record contains the map data for the southern-most latitude (-90 deg) from longitude -180 to 179.75 degrees.

The image file may be read directly into a GMT (Generic Mapping Tools) [10,11] grd file using the following command: (noting that the command wraps around onto a second line in this document).

```
xyz2grd JGGRX_0660B_ANOM_L320.IMG -ZTLf -Gtest.grd -I0.25/0.25
-R-180.00/179.75/-90/90 -V

xyz2grd: nx = 1440  ny = 721

xyz2grd: Working on file /home/ask/JGGRX_0660B_ANOM_L320.IMG
```

Then, dump the binary grid file to ASCII xyz file as

```
grd2xyz test.grd > test.xyz
```

A GMT script to plot the img file is given below. Settings for grdimage and psscale may be changed to suit the user's needs:

```
=========================================================
#!/bin/csh -f
#
xyz2grd ~ask/JGGRX_0660B_ANOM_L320.IMG -ZTLf -Gtest.grd -I0.25/0.25
-R-180.00/179.75/-90/90 -V
#grd2xyz test.grd > test.xyz
grdinfo -M test.grd

# Create color table
grd2cpt test.grd -Chaxby -L-600/600 -S-600/600/100 -Z -V > test.cpt

# Create color image
grdimage test.grd -Ctest.cpt -JQ0/8.0i -R-180/180/-90/90 -B30g30/30g30
-K > test.ps

# Append colorscale bar
psscale -Ctest.cpt -D11.0/14.0/16.0/0.3h -B:."JGGRX_0660B_ANOM_L320":
-O >> test.ps

# Display Postscript file
display test.ps

# Convert to other graphic file
convert -rotate 90 test.ps test.png


.......
Sample records from JGGRX_0660B_ANOM_L320.IMG
 rec =  1
-180 90   25.948
-179.75    90   25.948
-179.5     90   25.948
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-179.25 90 25.948
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