| REV. | BY | DESCRIPTION | DATE |
|---|---|---|---|
| – | DD | First Release | Nov. 19, 2002 |
| | DD | Revisions based on the updated launch date (and resulting trajectory) are incorporated. The addition of the AGVDP as an appendix (B) is based on a recommendation from the DAWG. Changes in text and tables are highlighted in blue. Changes in figures and/or figure captions show highlighted figure captions (in blue). The added Appendix B (the AVGDP) is NOT highlighted in its entirety, only those sections that have been changed due to updates since its initial draft. | Jan. 29,2004 |
| | RLM | Labeled as rev "A" only one version has ever been released – changes highlighted in pink and blue from changes above; entire Appendix B is updated. | Sep. 4, 2006 |
| A | RLM | Still rev A; incorporates RS and further changes in yellow – [all here per DCN E25228]. | Sep. 26, 2006 |
| B (Draft) | AAM/SLE/MRR/PDB | Updated for new CDR delivery requirements and schedule. Simplified based on PDS examples. Changed the name of the document from "Data Management and Science Analysis Plan" to "Data Management and Archiving Plan". | Jul. 13, 2011 |
| B (Draft) | SLE/MRR/PDB | Updated for extended mission. | Feb. 15, 2012 |
| B | SLE | Release at Rev B in PLM | May 7, 2013 |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

Revision: B

Date: May 7, 2013

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| PART NUMBER | SIZE | NEXT ASSEMBLY | QTY./NA | USED ON | EFFECTIVITY – END ITEM SER. NO. | WEIGHT |

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
11100 JOHNS HOPKINS ROAD, LAUREL, MARYLAND 20723-6099

# MESSENGER Data Management and Archiving Plan

| | FSCM NO. | SIZE | DRAWING NO. | REV. |
|---|---|---|---|---|
| | 88898 | A | 7384-9019 | B |
| | SCALE NONE | DO NOT SCALE PRINT | SHEET 1 OF 27 | |

## Technical Content Approvals

**Prepared/Approved by:**

Susan L. Ensor,
MESSENGER SOC Lead Engineer [1]

**Approved by:**

Sean C. Solomon,
Principal Investigator [2]

Peter D. Bedini,
MESSENGER Project Manager [1]

Edwin J. Grayzeck,
Program Scientist, PDS Program Manager [2]

Thomas H. Morgan,
PDS Deputy Program Manager [2]

Ralph L. McNutt, Jr.,
MESSENGER Project Scientist [1]

Steven P. Joy,
PDS Point of Contact [2]

Michael J. Freeze,
MESSENGER System Assurance Manager [1]

[1] A Release stamp electronically affixed at bottom of the pages of this document certifies that the above personnel or designated alternates have approved this revision. Please refer to the APL Product Lifecycle Management System (PLM) for record of these approvals.

[2] The following personnel have reviewed and approved by display of e-mail response for this release as cited below.

Sean C. Solomon,
Principal Investigator

From: SeanSolomon <solomon@ldeo.columbia.edu>
Date: Monday, May 6, 2013 4:26 PM
To: "Susan L. Ensor" <Susan.Ensor@jhuapl.edu>
Cc: SeanSolomon <solomon@ldeo.columbia.edu>
Subject: Re: Your reply needed - approval of MESSENGER DMAP Rev B

I approve document 7384-9019, Revision B, MESSENGER Data Management and Archiving Plan, signed by Sean C. Solomon, Principal Investigator.

Thomas H. Morgan
PDS Deputy Program Manager

From: "<EXT Morgan>", Thomas <thomas.h.morgan@nasa.gov>
Date: Monday, May 6, 2013 1:25 PM
To: "Susan L. Ensor" <Susan.Ensor@jhuapl.edu>
Subject: Re: Your reply needed - approval of MESSENGER DMAP Rev B

I approve document 7384-9019, Revision B, MESSENGER Data Management and Archiving Plan, signed by Thomas H. Morgan, PDS Deputy Program Manager.

Edwin J. Grayzeck,
Program Scientist, PDS Program Manager

From: <Grayzeck>, "Edwin J. (GSFC-6901)" <edwin.j.grayzeck@nasa.gov>
Date: Monday, May 6, 2013 1:31 PM
To: "Susan L. Ensor" <Susan.Ensor@jhuapl.edu>
Cc: "Grayzeck, Edwin J. (GSFC-6901)" <edwin.j.grayzeck@nasa.gov>
Subject: RE: Your reply needed - approval of MESSENGER DMAP Rev B

I approve document 7384-9019, Revision B, MESSENGER Data Management and Archiving Plan, signed by Edwin J. Grayzeck, Program Scientist, PDS Program Manager.

Steven P. Joy,
PDS Point of Contact

From: SteveJoy <sjoy@igpp.ucla.edu>
Date: Monday, May 6, 2013 6:30 PM
To: "Susan L. Ensor" <Susan.Ensor@jhuapl.edu>
Subject: Re: Your reply needed - approval of MESSENGER DMAP Rev B

I approve document 7384-9019, Revision B, MESSENGER Data Management and Archiving Plan, signed by Steven P. Joy, PDS Point of Contact.

**Table of Contents**

**Tables**

# 1 Introduction

## 1.1 Purpose

The MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) mission's Data Management and Archiving Plan (DMAP) presents a high-level strategy for the generation, validation, and delivery of mission data and data products from the MESSENGER project's Science Operations Center (SOC) to the Planetary Data System (PDS) in complete, well-documented, and permanent archives. The plan also specifies policies for distributing data and data products within the MESSENGER project and to the science community and general public.

## 1.2 Scope

The plan covers the archiving of raw and reduced data sets and related information to be acquired or derived during the MESSENGER mission. Specific aspects addressed in this plan are as follows:

1. Reduction of science packet data to experiment data records (EDRs) and reduced data records (RDRs), including generation of data sets expressed in physical units, with associated documentation that describes when and where the data were acquired and for what purpose
2. Generation of high-level mission, spacecraft, and instrument documentation, instrument calibration reports, and documentation of software or algorithms used to produce RDRs
3. Generation of SPICE (Spacecraft ephemeris, Planet/satellite ephemeris, Instrument information, Camera orientation, Event information) archives for use with software from the Jet Propulsion Laboratory's Navigation and Ancillary Information Facility (NAIF)
4. Generation and validation of PDS-compliant archives containing MESSENGER EDRs and RDRs, documentation, and ancillary information
5. Delivery to the community of validated MESSENGER archives through the PDS
6. Generation of deep archive volumes for permanent storage at the National Space Science Data Center (NSSDC)

## 1.3 Contents

The plan starts with an overview of the MESSENGER mission, including the spacecraft's payload and the Ground Data System (GDS). An overview of the archiving functions is then presented, including generation, validation, and delivery of data, and the roles and responsibilities for the major archiving functions and organizations are discussed. Policies for the release of data and other public information are described, and schedules for public release of the data are given. Additional information includes applicable documents referenced in the plan, definitions of processing levels, a synopsis of the data sets to be delivered, and a glossary of selected terms, acronyms, and abbreviations.

## 1.4 Applicable Documents


1. Arvidson, R., E. Guinness, and S. L. Dueck (1994). The Planetary Data System, *Remote Sensing Rev.*, **9**, 255–269.
2. Gold, R. E., *et al*. (2001). The MESSENGER mission to Mercury: Scientific payload, *Planet. Space Sci.*, **49**, 1467–1469.
3. McMahon, S. K. (1996). Overview of the Planetary Data System, *Planet. Space Sci.*, **44**, 3–12.

4. Santo, A. G., *et al*. (2001). The MESSENGER mission to Mercury: Spacecraft and mission design, *Planet. Space Sci.*, **49**, 1481–1500.

5. Solomon, S. C., *et al*. (2001). The MESSENGER mission to Mercury: Scientific objectives and implementation, *Planet. Space Sci.*, **49**, 1445–1465.

6. Solomon, S. C., *et al*. (2007). MESSENGER mission overview, *Space Sci. Rev.*, **131**, 3 – 39.

# 2 Overview of the MESSENGER Mission

MESSENGER is a Discovery Program mission whose goal is to perform a global characterization of the planet Mercury. The mission's science goals are to provide the first images of the entire planet and collect detailed information on the composition and structure of Mercury's crust, its topography and geologic history, the nature of its thin atmosphere and active magnetosphere, and the makeup of its core and polar materials.

MESSENGER's Principal Investigator (PI) is Sean C. Solomon of the Lamont-Doherty Earth Observatory of Columbia University, and the mission is managed by The Johns Hopkins University Applied Physics Laboratory (JHU/APL), which operates the spacecraft through its Mission Operations Center (MOC). The SOC resides at JHU/APL, and its responsibilities are shared among JHU/APL personnel, MESSENGER Science Team representatives, and the Applied Coherent Technology Corporation, which acts under subcontract to JHU/APL. Launched in August 2004 from the Cape Canaveral Air Force Station in Florida, the MESSENGER spacecraft completed six planetary flybys during its 6.6-year cruise phase: one of Earth (August 2005), two of Venus (October 2006 and June 2007), and three of Mercury itself (January and October 2008 and September 2009). In March 2011, the spacecraft entered orbit about Mercury, becoming the first craft ever to do so and initiating a yearlong primary mission campaign of focused observations. One year of data analysis and archiving will follow the end of the operational phase of the mission.

In November 2011, NASA approved a plan to continue operations from orbit about Mercury for a second year. The previously planned year of data analysis and archiving will now follow the second year of orbital operations. The MESSENGER mission is currently planned to end on 17 March 2014 at the conclusion of the year of data analysis and distribution.

## *2.1 Payload and Primary Mission*

The MESSENGER primary mission was designed to answer the following set of focused science questions about the nature and history of the planet Mercury:

- What planetary formational processes led to the high metal/silicate ratio in Mercury?
- What is the geological history of Mercury?
- What are the nature and origin of Mercury's magnetic field?
- What are the structure and state of Mercury's core?
- What are the radar-reflective materials at Mercury's poles?
- What are the important volatile species and their sources and sinks on and near Mercury?

To answer these questions, the MESSENGER spacecraft carries an optimized scientific payload of seven miniaturized instruments that, along with the radio science experiment, provide the data needed to conduct its mission. Descriptions of the investigations follow.

- *Mercury Dual Imaging System (MDIS)*

  The MDIS consists of a narrow-angle imager and wide-angle, multispectral imager. Pointing is assisted with a pivot platform. This instrument maps landforms, surface spectral variations, and topographic relief from stereo imaging.

- *Gamma-Ray and Neutron Spectrometer (GRNS)*

  The GRNS consists of a Gamma-Ray Spectrometer (GRS) and a Neutron Spectrometer (NS). The GRS measures the emissions from radioactive elements and gamma-ray fluorescence stimulated by cosmic rays. It is used to determine elemental abundances in regions of the crust. The NS determines sensitivity to hydrogen in ices at the poles and to elements having substantial thermal-neutron absorption in surface regions and provides an average sub-spacecraft atomic weight of crustal material.

- *X-Ray Spectrometer (XRS)*

  The XRS measures Mercury surface fluorescence in low-energy X-rays that are stimulated by solar X-rays. It is used to map elemental abundances of crustal materials.

- *Mercury Laser Altimeter (MLA)*

  The MLA is an infrared laser transmitter coupled with a receiver that measures the round-trip time of a burst of laser light reflected off of Mercury's surface, yielding a distance measurement. It produces highly accurate measurements of topography and measures Mercury's physical libration.

- *Mercury Atmospheric and Surface Composition Spectrometer (MASCS)*

  The MASCS consists of the Ultraviolet and Visible Spectrometer (UVVS) and the Visible and Infrared Spectrograph (VIRS). The UVVS measures composition and spatial and temporal variations of exospheric species. The VIRS maps surface reflection to determine mineral composition.

- *Energetic Particle and Plasma Spectrometer (EPPS)*

  The EPPS measures the composition, spatial distribution, energy, and time-variability of charged particles within and surrounding Mercury's magnetosphere. It consists of the Fast Imaging Plasma Spectrometer (FIPS) and the Energetic Particle Spectrometer (EPS). Plasma is measured by the FIPS, and higher-energy particles are measured by the EPS.

- *Magnetometer (MAG)*

  The MAG maps the detailed structure and dynamics of Mercury's magnetic field and searches for regions of magnetized crustal rocks.

- *Radio Science (RS)*

  RS uses the Doppler effect (the shift in the frequency of the spacecraft's radio signal with changes in the spacecraft's velocity relative to Earth) to measure Mercury's gravitational field and to infer its corresponding mass distribution, including spatial variations in crustal thickness.

## 2.2 Extended Mission

Given the performance of the spacecraft during the first half of the primary mission orbital operations as well as the availability of the necessary resources to continue operations, NASA agreed to extend the period of orbital observations by one additional Earth year.

During the extended mission, the spacecraft is spending more time close to the planet than during the primary mission, and there are a broader range of scientific objectives and the opportunity to make many more targeted observations with the imaging system and other instruments. MESSENGER is also able to view the innermost planet as solar activity continues to increase toward the next maximum in the solar cycle. Mercury's responses to the changes in its environment over that period continue to yield new surprises.

The extended mission has been designed to answer six scientific questions, each of which has arisen as a direct result of discoveries made from orbit:

- What are the sources of surface volatiles on Mercury?
- How late into Mercury's history did volcanism persist?
- How did Mercury's long-wavelength topography change with time?
- What is the origin of localized regions of enhanced exospheric density near Mercury?
- How does the solar cycle affect Mercury's exosphere and volatile transport?
- What is the origin of Mercury's energetic electrons?

Data archive delivery to the PDS in the second year of orbital operations continues at the same cadence as that of the first year, and all deliveries scheduled for the primary mission will be completed as planned. In addition, some high-level products being developed and delivered as part of the primary mission will be expanded for the extended mission. The details associated with these products can be found in sections 6 and 7.

## 2.3 Ground Data System

The MESSENGER GDS will convert the raw spacecraft data stream to science data products. The MOC will receive telemetry packets from the Deep Space Network (DSN) and process them through Committee on Data Management and Computation (CODMAC) Level 1, providing the CODMAC Level 1 data to the SOC. (See section 8 for CODMAC data-level definitions.) Navigation data, including spacecraft and planetary ephemerides and spacecraft pointing data, will be transmitted from the MOC to the SOC in SPICE format. The SOC will also acquire and process RS data, which are obtained from the DSN.

The SOC supports the MESSENGER Science Team in the processing and analysis of the science data. It provides easy access to all data required by the Science Team and the MOC. The SOC will accept and process telemetry and navigation data through CODMAC Level 1, creating CODMAC Level 2 EDRs, calibration files, and a telemetry archive. The SOC will archive the Level 2 through Level 6 data in the PDS.

The Science Team, with assistance from the SOC, is responsible for science data processing through CODMAC Levels 3 through 5 and for delivering these products to the SOC in PDS-compliant formats, including associated documentation. The SOC is responsible for negotiating with the PDS all product formats and for delivery of all data products to the PDS.

# 3 Overview of Archiving Functions

Standard products form the core of the archives produced by the MESSENGER SOC and released to the PDS for distribution to the science community and others. Standard products are well-defined, systematically generated data products, including EDRs and RDRs. These products and associated supporting information (e.g., documentation and index tables) are validated and delivered to the PDS at regular intervals. Additional special data products whose creation may require more subjective judgment are incorporated in the final MESSENGER PDS release, in some cases by reference to scientific publications reporting these results. The schedule for releases is provided in section 6. Standard and special products are listed by instrument in Tables 7-1 and 7-2, respectively, and the processing levels defined for science data are given in Table 8-1.

The following sections discuss the processes for generation and validation of products and archives, delivery to the PDS, and distribution to the science community and the general public.

## *3.1 Generation*

Responsibility for generating archive components is specified in section 4. Science data products are generated in PDS-compliant formats. Each data file (data table or image file) is in a format approved by the PDS and is accompanied by a PDS "*label*," which describes the content and structure of the accompanying data file. Navigation, geometry, and engineering data necessary to interpret the science data are provided as ancillary archive components. In addition, files documenting the archive components are prepared by the parties generating the data. In general, all information necessary to interpret and use the data is included in the archive.

The PDS "*catalog objects*" are files that document the mission, spacecraft, instruments, and data products. The catalog objects take the form of templates that must be filled out with prescribed information. The required catalog objects are the "*mission template*," describing the MESSENGER mission as a whole; the "*instrument host template*," describing the spacecraft; one "*instrument template*" for each instrument; and one "*data-set template*" for each data set. These templates contain the information needed to document the archive and enable future scientists to make correct use of the data when mission personnel are no longer available to support them.

## *3.2 Validation and Delivery of Archives to the Planetary Data System*

There are two types of data validation: validation of the science data and validation of the compliance of the archive with PDS archiving and distribution requirements. The first type of validation is carried out by the Science Team, and the second is overseen by the PDS, in coordination with the Science Team.

When volumes are approved for release by the project, the SOC transfers the archives to the PDS. Validation and transfer takes place in advance of the release dates specified in Table 6-3, allowing adequate time for the PDS review.

The formal validation of data content, adequacy of documentation, and adherence to PDS archiving and distribution requirements is scheduled and coordinated by the PDS. This review may include peer reviewers from the science community, at the PDS's discretion. The review process may result in "*liens*," which are actions that are recommended by the reviewers or by PDS personnel to correct the archive. All liens must be resolved by the data-set provider. Once the liens are cleared, the PDS completes a final validation before release.

## *3.3 Distribution of Data Products*

The MESSENGER project is responsible for making data products available to its own personnel. The PDS is responsible for making data products available to the rest of the science community and to the public.

Archives associated with specific instruments or types of data are transmitted to the PDS discipline node designated by the PDS for archiving and distribution of those data. Archives are transmitted electronically

via the Internet or on physical media according to the preference of the receiving node. For electronic transmissions, unless otherwise requested by the receiving node, the MESSENGER SOC initiates and completes the transmission. That is, the data are “pushed” by the SOC rather than “pulled” by the node. Transmission is accomplished by commonly available protocols (e.g., FTP) and uses a commonly available archiving and compression format (e.g., tar or gzip) acceptable to the receiving node.

## 3.4 Permanent Storage and Backups

The PDS is responsible for maintaining at least three copies of its science archives and for delivering one copy of the data to the NSSDC for deep archive. As archives are released, the PDS discipline nodes or their data nodes generate at least three copies on appropriate physical media for long-term storage by PDS and NSSDC.

During the period after data capture from the spacecraft, through delivery, and while the PDS is writing delivered archives to physical media, the data are backed up periodically by the SOC or copies are otherwise maintained until they are permanently stored with the PDS.

# 4 Roles and Responsibilities

The primary roles and responsibilities associated with MESSENGER data management and archiving are summarized in the following sections.

## 4.1 The MESSENGER Team

The MESSENGER team is responsible for operating the MESSENGER spacecraft, making observations, collecting the Level 1 data from the spacecraft, and providing the technical and scientific expertise to process, validate, and analyze the data in order to create the data products to be archived by the PDS. The MESSENGER team will:

- plan and generate the data archives and associated documentation in accordance with PDS standards and requirements;
- participate in the formal peer reviews conducted by the PDS and correct or resolve any issues raised; and,
- transmit the data archives to the designated PDS nodes and support the review, correction, and retransmission of the data in order to ensure timely release to the scientific community and the general public.

## 4.2 The Planetary Data System

The PDS Planetary Plasma Interactions (PPI) node is the designated point of contact for MESSENGER on archive-related issues. The PDS will:

- consult on archive generation and advise the project Science Team on PDS standards, requirements, and documentation needs;
- conduct formal peer reviews, track issues raised in the reviews, and coordinate their resolution;
- maintain the MESSENGER science data collection online for access by the general public and the planetary science community;
- replicate archive volumes for distribution to the NASA-supported science community whenever physical media, as opposed to online access, are deemed appropriate; and,
- provide a copy of the archive volume set to the NSSDC for long-term preservation.

## 4.3 The National Space Science Data Center

The NSSDC will maintain a "*deep archive*" of the data for long-term preservation and for filling large delivery orders to the science community. The PDS will serve as the interface between the MESSENGER team and the NSSDC.

# 5 Policies for Release of Data and Public Information

Because of the expected widespread interest in new results from Mercury and the strong commitment of the MESSENGER project to release data on a timely basis, the following policies will guide the release of scientific data and measurements to the general public and to the scientific community:

- The principal means of releasing scientific data to the scientific community and the general public is through NASA's PDS. To ensure the quality and integrity of the data, a sufficient amount of time is required by the MESSENGER team to process and validate it before release. The release of data generally follows major mission events and milestones (flybys of planetary bodies, orbit insertion at Mercury, etc.) by six months according to the schedule defined in Table 6-3.

  Before release by the PDS, any scientific use and analysis of the data, use of results from unpublished papers derived from such analysis, or any other public release of such information for public outreach and education purposes requires the explicit agreement of the PI.

- For the purposes of public outreach and education, selected information and data of interest to the general public or of particular scientific importance are made available through press conferences, press releases, posting on the World Wide Web, and through other media, in coordination with NASA headquarters and relevant members of the Science Team, and with the concurrence of the MESSENGER PI. The MESSENGER Project Office is informed of any such release in a timely manner in order to ensure that the relevant offices and departments are properly informed.

- To facilitate the processing and validation of the data, the MESSENGER SOC provides electronic access to the data as they are downlinked from the spacecraft to the instrument and scientific discipline teams and other scientists affiliated with the project. The PI, the instrument scientists, and the science discipline group leaders are responsible for coordinating this access.

Information regarding the general status and progress of mission operations is made available to the public on a continuing basis. However, information concerning spacecraft and instrument anomalies may be released only by the MESSENGER Project Office, in coordination with NASA headquarters and the PI.

# 6 Archive Generation, Validation, and Release Schedules

The MESSENGER mission is divided into a series of mission phases divided by major events such as flybys of planetary bodies and orbital operations at Mercury. Distinct cruise phases are included between mission events before Mercury orbit insertion. Table 6-1 lists the major MESSENGER mission events. Table 6-2 defines the mission phases derived from these events.

The generation, validation, and release of archives to the PDS are also keyed to major mission events. Table 6-3 defines the release dates and data products associated with each mission phase. Generally, archives are delivered to the PDS at least 2 weeks before the release date. When possible, archives are delivered sooner, to give the PDS flexibility in validating and processing the archives in order to have the data available to the public by the release date. Further details on the individual science data products are provided in section 7 of this document.

Table 6-4 shows the actual uncompressed data volumes by PDS node for each delivery completed at the time of publication (i.e., through delivery 8). Note that these delivery volumes reflect some reprocessed products also included in earlier deliveries. The NAIF node delivery volumes reflect the requirement by that node that all previous kernels be redelivered with each successive delivery. Also, the MASCS data are delivered to both the Atmospheres and the Geosciences PDS nodes. The MESSENGER team is compiling data-volume estimates for the remaining deliveries (i.e., deliveries 9 through 11) and will provide those estimates to the PDS when they are available.

Additional deliveries above and beyond those defined may be made by mutual agreement between the MESSENGER Project Office and the PDS.

**Table 6-1. MESSENGER Mission Events**

| Event | Event Date UTC (DOY) | Event Time UTC |
|---|---|---|
| Launch | 03 Aug 2004 (216) | 06:15:56.537 |
| Phase E start | 13 Sep 2004 (257) | 00:00:00.0 |
| Earth flyby | 02 Aug 2005 (214) | 19:13:08.4 |
| Venus flyby 1 | 24 Oct 2006 (297) | 08:31:26.3 |
| Venus flyby 2 | 06 Jun 2007 (157) | 00:12:36.9 |
| Mercury flyby 1 | 14 Jan 2008 (014) | 20:14:22.5 |
| Mercury flyby 2 | 06 Oct 2008 (280) | 13:39:08.2 |
| Mercury flyby 3 | 30 Sep 2009 (273) | 01:33:50.9 |
| Mercury orbit insertion | 18 Mar 2011 (077) | 00:45:15.5 |
| Orbit transition | 20 Apr 2012 (111) | 23:05:34.9 |

## Table 6-2. MESSENGER Mission Phase Definitions

| Phase Name | Phase Start[1,2] UTC (DOY) | Phase End[1,3] UTC (DOY) |
|---|---|---|
| Launch | 03 Aug 2004 (216) | 12 Sep 2004 (256) |
| Earth Cruise | 13 Sep 2004 (257) | 18 Jul 2005 (199) |
| Earth Flyby | 19 Jul 2005 (200) | 16 Aug 2005 (228) |
| Venus 1 Cruise | 17 Aug 2005 (229) | 09 Oct 2006 (282) |
| Venus 1 Flyby | 10 Oct 2006 (283) | 07 Nov 2006 (311) |
| Venus 2 Cruise | 08 Nov 2006 (312) | 22 May 2007 (142) |
| Venus 2 Flyby | 23 May 2007 (143) | 20 Jun 2007 (171) |
| Mercury 1 Cruise | 21 Jun 2007 (172) | 30 Dec 2007 (364) |
| Mercury 1 Flyby | 31 Dec 2007 (365) | 28 Jan 2008 (028) |
| Mercury 2 Cruise | 29 Jan 2008 (029) | 21 Sep 2008 (265) |
| Mercury 2 Flyby | 22 Sep 2008 (266) | 20 Oct 2008 (294) |
| Mercury 3 Cruise | 21 Oct 2008 (295) | 15 Sep 2009 (258) |
| Mercury 3 Flyby | 16 Sep 2009 (259) | 14 Oct 2009 (287) |
| Mercury 4 Cruise | 15 Oct 2009 (288) | 03 Mar 2011 (062) |
| Mercury Orbit | 04 Mar 2011 (063) | 17 Mar 2012 (077) |
| Mercury Orbit Year 2 | 18 Mar 2012 (078) | 17 Mar 2013 (076) |

[1]Data are associated with mission phases by their time of acquisition on the spacecraft.

[2]Mission phases start at the beginning of the specified UTC day.

[3]Mission phases end at the end of the specified UTC day.

## Table 6-3. Schedule of Data Product Deliveries

| Release | Includes Data Acquired Through | Date Released to Public* | Products |
|---|---|---|---|
| Release 1 | Pre-launch | 05/18/05 | ***On-ground calibration data*** |
| Release 2 | 06/20/07 | 12/20/07 | ***EDRs for all instruments through VF2 (including EF)***<br>SPICE files used in processing data |
| Release 3 | 01/28/08 | 07/15/08 | ***EDRs for all instruments through MF1***<br>***CDRs for MAG, MDIS, and MASCS through MF1 (including EF and VF2)***<br>Calibration files from MAG, MDIS, and MASCS<br>Reprocessed EDRs (as needed)<br>SPICE files used in processing data |
| Release 4 | 10/20/08 | 04/15/09 | ***EDRs from all instruments through MF2***<br>***CDRs for MAG, MDIS, and MASCS through MF2***<br>Reprocessed EDRs and CDRs (as needed)<br>Calibration files from MAG, MDIS, and MASCS<br>SPICE files used in processing data |
| Release 5 | 10/14/09 | 03/15/10 | ***EDRs from all instruments through MF3***<br>***CDRs from all instruments through MF3 (first delivery of CDRs from MLA, XRS, GRNS, and EPPS)***<br>Reprocessed EDRs and CDRs (as needed)<br>Calibration files from all instruments<br>SPICE files used in processing data |
| Release 6 | 05/17/11 | 09/08/11** | ***EDRs and CDRs from all instruments through first 2 months of orbital operations***<br>Calibration files from all instruments<br>Reprocessed EDRs and CDRs (as needed)<br>SPICE files used in processing data |
| Release 7 | 09/17/11 | 03/08/12 | ***EDRs and CDRs from all instruments through first 6 months of orbital operations***<br>Calibration files from all instruments<br>Reprocessed EDRs and CDRs (as needed)<br>SPICE files used in processing data |
| Release 8 | 03/25/12 | 09/07/12 | ***EDRs and CDRs from all instruments through first 12 months of orbital operations***<br>Reprocessed EDRs and CDRs (as needed)<br>Calibration files from all instruments<br>SPICE files used in processing data |
| Release 9 | 09/17/12 | 03/08/13 | ***EDRs and CDRs from all instruments through first 18 months of orbital operations***<br>***Primary mission DDPs and DAPs for all instruments through first 12 months of orbital operations***<br>Reprocessed EDRs and CDRs (as needed)<br>Calibration files from all instruments<br>SPICE files used in processing data |
| Release 10 | 03/17/13 | 09/06/13 | ***EDRs and CDRs from all instruments through 24 months of orbital operations***<br>Reprocessed EDRs, CDRs, DDPs, and DAPs (as needed)<br>Calibration files from all instruments<br>SPICE files used in processing data |
| Release 11 | 03/17/13 | 03/07/14 | ***Primary and extended mission DDPs and DAPs for all instruments through 24 months of orbital operations***<br>Reprocessed EDRs, CDRs, DDPs, and DAPs (as needed)<br>Final calibration files from all instruments<br>SPICE files used in processing data<br>Engineering data |

CDR, Calibrated Data Record; DAP, Derived Analysis Product; DDP, Derived Data Product; EF, Earth flyby; MF, Mercury flyby; VF, Venus flyby

*Release dates are dates that the PDS releases MESSENGER archives to the public. MESSENGER delivers archives to the PDS at least two weeks before the date of release to the public.

**Released to the public one week in advance of the scheduled 09/15/11 release date.

## Table 6-4. Delivery Sizes

| PDS Node | Delivery 2<br>EF/VF2 EDR | Cumulative |
|---|---|---|
| IMAGING | 4.4 GB | 4.4 GB |
| ATMOSPHERES | 1.3 GB | 1.3 GB |
| PPI | 7.8 GB | 7.8 GB |
| GEOSCIENCES | 3.7 GB | 3.7 GB |
| NAIF | 3.9 GB | 3.9 GB |
| **TOTAL** | **21.1 GB** | **21.1 GB** |
| **PDS Node** | **Delivery 3<br>MF1 EDR, CDR** | **Cumulative** |
| IMAGING | 44.9 GB | 49.3 GB |
| ATMOSPHERES | 1.6 GB | 2.9 GB |
| PPI | 40.3 GB | 48.1 GB |
| GEOSCIENCES | 6.6 GB | 10.3 GB |
| NAIF | 7.9 GB | 11.8 GB |
| **TOTAL** | **101.3 GB** | **122.4 GB** |
| **PDS Node** | **Delivery 4<br>MF2 EDR, CDR** | **Cumulative** |
| IMAGING | 46.3 GB | 95.6 GB |
| ATMOSPHERES | 22.4 GB | 25.3 GB |
| PPI | 49.3 GB | 97.4 GB |
| GEOSCIENCES | 59.3 GB | 69.6 GB |
| NAIF | 12.1 GB | 23.8 GB |
| **TOTAL** | **188.4 GB** | **311.8 GB** |
| **PDS Node** | **Delivery 5<br>MF3 EDR, CDR** | **Cumulative** |
| IMAGING | 21.0 GB | 116.6 GB |
| ATMOSPHERES | 70.5 GB | 95.8 GB |
| PPI | 165.6 GB | 263.0 GB |
| GEOSCIENCES | 100.0 GB | 169.6 GB |
| NAIF | 12.5 GB | 36.4 GB |
| **TOTAL** | **369.6 GB** | **681.4 GB** |
| **PDS Node** | **Delivery 6<br>Orbital EDR, CDR** | **Cumulative** |
| IMAGING | 73.0 GB | 189.6 GB |
| ATMOSPHERES | 130.2 GB | 226.0 GB |
| PPI | 238.2 GB | 501.2 GB |
| GEOSCIENCES | 163.4 GB | 333.0 GB |
| NAIF | 14.2 GB | 50.6 GB |
| **TOTAL** | **619.0 GB** | **1.3 TB** |

| PDS Node | Delivery 7 Orbital EDR, CDR | Cumulative |
|---|---|---|
| IMAGING | 188.8 GB | 378.4 GB |
| ATMOSPHERES | 168.2 GB | 394.2 GB |
| PPI | 191.5 GB | 692.7 GB |
| GEOSCIENCES | 186.2 GB | 519.2 GB |
| NAIF | 15.2 GB | 65.8 GB |
| **TOTAL** | **749.9 GB** | **2.0 TB** |
| **PDS Node** | **Delivery 8 Orbital EDR, CDR** | **Cumulative** |
| IMAGING | 166.3 GB | 544.7 GB |
| ATMOSPHERES | 188.9 GB | 583.1 GB |
| PPI | 483.3 GB | 1176.0 GB |
| GEOSCIENCES | 219.4 GB | 738.6 GB |
| NAIF | 17.8 GB | 83.6 GB |
| **TOTAL** | **1.0 TB** | **3.0 TB** |

EF, Earth flyby; MF, Mercury flyby; VF, Venus flyby

# 7 Science Data Products

Table 7-1 provides a summary of the current and anticipated standard science data products at time of preparation of this document. Details on EDRs and CDRs are found in the Software Interface Specification (SIS) documents for each instrument that are available through the PDS. Derived Data Products (DDPs) and Derived Analysis Products (DAPs) will be documented in RDR SIS documents and/or other PDS documentation, as appropriate. All standard DDP and DAP products will be included in PDS deliveries 9 and 11 and constitute the "Primary mission DDPs and DAPs" referenced in Table 6-3. Data quality indicators or figures of merit, referred to as data quality indices (DQIs), are noted for instruments for which they are, at time of preparation of this document, computed as part of product generation.

**Table 7-1. Standard Science Data Products Summary**

| Instrument(s) | EDR | CDR | DDP | DAP |
|---|---|---|---|---|
| **MDIS** | Single, raw, uncompressed WAC and NAC images; associated parameters and multi-bit DQI | Single, calibrated images; units: radiance or I/F; associated parameters and multi-bit DQI | | Map-projected monochrome base map (BDR) and map-projected multispectral map (MDR) [corrected to i = 30°, e = 0°] |
| **GRNS/GRS** | HPGe raw, anti-coincident, and shield spectra; microphonics time series; software rate counters; status, diagnostics, and command echo data; multi-bit DQI | HPGe raw, anti-coincident, and shield spectra and associated timing, spatial, and engineering data; multi-bit DQI | Corrected and calibrated gamma-ray spectra summed over the orbital mission to date | |
| **GRNS/NS** | Full science, galactic cosmic ray, and neutron burst spectra; gamma burst time series; sensor counters; event time series; command echo and diagnostics; no DQI | Time-normalized spectra and sensor counters, with associated timing, spatial, spacecraft attitude, and engineering data | Neutron flux (net neutron count rates) | |
| **XRS** | Science spectra and associated parameters, command echo, multi-bit DQI (only single-bit used) | Calibrated science spectra (engineering information converted to engineering units, spectral energy scales and spatial information included); multi-bit DQI (only single-bit used) | | |
| **MAG** | 3-axis field samples, AC, burst, status, housekeeping in engineering units; no DQIs | Calibrated 3-axis field data in physical units and coordinate systems, tagged with MET, UTC, and spacecraft location; 3-digit DQI included for each CDR in label release notes | Calibrated 3-axis field data averages in physical units and coordinate systems, tagged with MET, UTC, and spacecraft location; 3-digit DQI included for each RDR in label release notes | |

| Instrument(s) | EDR | CDR | DDP | DAP |
|---|---|---|---|---|
| **MLA** | Raw ranging data, status, and diagnostics; no explicit DQIs | Ranging data converted into physical and engineering units; no explicit DQIs | Altimeter profiles with geolocation and DQIs (Science RDR), radiometry (RADR) | Northern hemisphere digital elevation maps, resampled and interpolated (TOPO GDR) |
| **MLA with RS** | | | | Derived planetary constants (libration amplitude, RA and DEC of rotational pole) provided as references to publications; coefficients for the spherical harmonic representation of the planet shape |
| **MASCS/UVVS** | Raw atmospheric and surface scan data (counts), observation geometry, housekeeping; no DQIs | Corrected/calibrated atmospheric and surface scan data in physical units (radiance) and coordinate systems with reference geometry and time; multi-bit DQIs set during CDR generation | Limb tangent height spectra | |
| **MASCS/VIRS** | Surface spectra, observation geometry, housekeeping; no DQIs | Corrected/calibrated surface data in physical units (radiance) and coordinate systems with reference geometry and time; multi-bit DQIs set during CDR generation | Surface reflectance spectra | |
| **EPPS/EPS** | PHA data, ion and electron energy spectra, rate counters, engineering and status data | PHA data, ion and electron energy spectra in physical units (differential flux), rate counters; 2-state DQI covers 1 day's data (nominal science configuration or not set based on scientist-provided periods) | Pitch angle distributions over selected ranges of energies for selected time periods | |
| **EPPS/FIPS** | PHA and scan data, proton velocity distributions, rate counters, engineering and status data | PHA data and differential intensity spectra in physical units; 2-state DQI covers 1 record's data (nominal science configuration or not set based on scientist-provided periods) | Spatial and temporal distribution of measured flux for major ion species; for selected time periods, energy spectra and pitch angle distributions for major ion species | |
| **RS** | TNF data (raw DSN TRK-2-34), ODF data (DSN TRK-2-18), RSR files, and ancillary information to support analysis | N/A | Occultation times and radii | Coefficients for the spherical harmonic representation of the gravity field |

AC, Alternating Current; BDR, Map Projected Basemap Reduced Data Record; DEC, Declination; HPGe, High-Purity Germanium; MDR, Map Projected Multispectral Reduced Data Record; MET, Mission Elapsed Time; NAC, Narrow-Angle Camera; ODF; Orbit Data Files; PHA, Pulse-Height Analysis; RA, Right Ascension; RADR, Radiometric Active Data Record; RDR, Reduced Data Record; RSR, Radio Science Receiver; TNF, Tracking and Navigation Files; TOPO GDR, Topographic Gridded Data Record; WAC, Wide-Angle Camera

Table 7-2 provides a summary of the anticipated special science data products at time of preparation of this document. Special products will be included in PDS delivery 11. These special DDP and DAP products constitute the "Extended mission DDPs and DAPs" referenced in Table 6-3.

## Table 7-2. Special Science Data Products Summary

| Instrument(s) | DDP | DAP |
|---|---|---|
| **MDIS** | Image backplanes including latitude/longitude and incidence, emission, and phase angles | High-resolution, 3-color map with photometric correction |
| **MDIS with MLA** | | Digital Elevation Model (DEM) |
| **GRNS/GRS** | | Element concentrations; accumulations by latitude–longitude, feature, and time; regional compositions |
| **GRNS/NS** | | Neutron composition information |
| **XRS** | | Maps of element abundances and abundance ratios |
| **MAG** | | Planetary magnetic field and stationary magnetosphere models; stationary magnetosphere model to be provided as a reference to a publication |
| **MLA** | Radiometry based on flight calibration algorithms with DQIs | |
| **MASCS/UVVS** | Reflectance spectra of targeted areas | |
| **MASCS/UVVS with EPPS/FIPS, GRNS, XRS** | | Identification of volatile species and sources |
| **MASCS/VIRS** | | Map-projected base map with backplanes describing parameters of interest for the observation points |
| **EPPS/FIPS** | For selected time periods, arrival direction distributions for selected ion species | For selected time periods within the magnetosphere, density, temperature, and pressure for selected ion species |

# 8 Processing Levels of Science Data Sets

Table 8-1 provides descriptions of the CODMAC/NASA processing levels for science data sets, and Table 8-2 provides a quick reference for the common terminology of these processing levels.

### Table 8-1. CODMAC/NASA Processing Levels for Science Data Sets

| NASA | CODMAC | Description |
|---|---|---|
| Packet data | Raw – Level 1 | Telemetry data stream as received at the ground station, with science and engineering data embedded. Referred to as Packetized Data Records (**PDRs**). |
| Level 0 | Edited raw – Level 2 | Instrument science data (e.g., raw voltages, counts) at full resolution, time ordered, with duplicates and transmission errors removed. Referred to as Experiment Data Records (**EDRs**). |
| Level 1A | Calibrated – Level 3 | NASA Level 0 data that have been located in space and may have been transformed (e.g., calibrated, rearranged) in a reversible manner and packaged with needed ancillary and auxiliary data (e.g., radiances with the calibration equations applied). Referred to as Calibrated Data Records (**CDRs**). In some cases, these also qualify as Derived Data Products (**DDPs**) or Derived Data Records (**DDRs**). |
| Level 1B | Resampled – Level 4 | Irreversibly transformed (e.g., resampled, remapped, calibrated) values of the instrument measurements (e.g., radiances, magnetic field strength). Referred to as either Derived Data Products (**DDPs**) or Derived Analysis Products (**DAPs**), also termed Derived Data Records (**DDRs**) or Derived Analysis Records (**DARs**). |
| Level 1C | Derived – Level 5 | NASA Level 1A or 1B data that have been resampled and mapped onto uniform space-time grids. The data are calibrated (i.e., radiometrically corrected) and may have additional corrections applied (e.g., terrain correction). Referred as Derived Analysis Products (**DAPs**) or Derived Analysis Records (**DARs**). |
| Level 2 | Derived – Level 5 | Geophysical parameters, generally derived from Level 1 data, and located in space and time commensurate with instrument location, pointing, and sampling. Referred to as Derived Analysis Products (**DAPs**) or Derived Analysis Records (**DARs**). |
| Level 3 | Derived – Level 5 | Geophysical parameters mapped onto uniform space-time grids. Referred to as Derived Analysis Products (**DAPs**) or Derived Analysis Records (**DARs**). |
| | Ancillary Data – Level 6 | Non-science data needed to generate calibrated or resampled data sets and consisting of such information as instrument gains and offsets, spacecraft positions, target information, and pointing information for scan platforms. |

The above is based on the National Research Council CODMAC data levels.

### Table 8-2. Common Terminology

| Abbreviation | Description | NASA | CODMAC |
|---|---|---|---|
| PDR | Packetized Data Record | Packet data | Raw – Level 1 |
| EDR | Experiment Data Record | Level 0 | Edited raw – Level 2 |
| CDR | Calibrated Data Record | Level 1A | Calibrated – Level 3 |
| DDR/DDP | Derived Data Record/Product | Level 1B | Resampled – Level 4 |
| DAR/DAP | Derived Analysis Record/Product | Levels 1C, 2, 3 | Derived – Level 5 |
| RDR | Reduced Data Record | Levels 1–3 | Levels 3–5 |

# 9 Glossary of Selected Terms, Acronyms, and Abbreviations

**Ancillary Data** – Non-science data needed to generate calibrated or resampled data. Any information needed to create any of the data products, such as CDRs, DDPs, and DAPs.

**Archive** – An archive consists of one or more data sets along with all of the documentation and ancillary information needed to understand and use the data. An archive is a logical construct independent of the medium on which it is stored.

**Archive Volume, Archive Volume Set** – A *volume* is a unit of medium on which data products are stored (e.g., one CD-ROM). An *archive volume* is a volume containing all or part of an archive (i.e., data products plus documentation and ancillary files). When an archive spans multiple volumes, they are called an *archive volume set*. Usually the documentation and some ancillary files are repeated on each volume of the set so that a single volume can be used alone.

**Calibrated Data Records** – CODMAC Level 2 data that have been located in space and may have been transformed (e.g., calibrated, decompressed, and rearranged) in a reversible manner and packaged with needed ancillary and auxiliary data (e.g., radiances with the calibration equations applied).

**CODMAC** – National Research Council Committee on Data Management and Computation. CODMAC defined processing levels for science data sets, described in Table 8-1.

**Data Product** – A labeled grouping of data resulting from a scientific observation, usually stored in one file. A product label identifies, describes, and defines the structure of the data. An example of a data product is a planetary image, a spectrum table, or a time series table.

**Data Set** – An accumulation of data products. A data set together with supporting documentation and ancillary files is an archive.

**Derived Analysis Products/Records** – CODMAC Level 3 through 5 data products for which the values of the instrument measurements (e.g., radiances, magnetic field strength) have been irreversibly transformed (e.g., resampled, remapped, and calibrated). Data that have been resampled and mapped onto uniform space-time grids. The data are calibrated and may have additional corrections applied.

**Derived Data Products/Records** – CODMAC Level 3 or 4 data products for which the values of the instrument measurements (e.g., radiances, magnetic field strength) have been irreversibly transformed (e.g., resampled, remapped, and calibrated).

**Engineering Products** – A subset of Ancillary Data, often in the form of instrument settings (such as voltages, current, and temperature), and spacecraft health status.

**Experiment Data Records** – NASA Level 0/CODMAC Level 2 data for a given instrument; raw data.

**Navigation Data** – A subset of Ancillary Data, often in the form of SPICE files, that aid in the interpretation and processing of data products and are needed for producing the higher-level data products, such as the DDPs and DAPs.

**Packetized Data Records** – Telemetry data stream as received at the ground station, with science and engineering data embedded (CODMAC Level 1).

**Processed Data** – CODMAC Level 3 or higher data products.

**Project Data** – Any data products produced by the MESSENGER project for archiving to the PDS.

**Raw Data** – Same as Packetized Data Records.

**Raw Science Data** – Same as Raw Data and Packetized Data Records.

**Reduced Data Records** – Science data that have been processed from raw data to NASA Level 1 or higher (CODMAC Level 3 or higher). See Table 8-1 for definitions of processing levels.

**Science Data** – PDRs, EDRs, and RDRs that have scientific value.

**Special Product** – A data product of special interest that may require subjective judgment to produce and may not be produced in a pipeline fashion. Special products are produced as resources permit.

**SPICE Data** – A suite of elemental ancillary data sets, often called kernels. They include spacecraft ephemeris, planet/satellite ephemerides, instrument information, camera orientation, and event information.

**Standard Product** – A data product that has been defined during the proposal and selection process and that is contractually promised by the PI as part of the investigation. Standard data products are generated in a predefined way, using well-understood procedures, and processed in "pipeline" fashion.

## Table 9-1. Definitions of Acronyms and Abbreviations

| Acronym | Definition |
|---|---|
| AC | Alternating current |
| BDR | Map-projected base map Reduced Data Record |
| CDR | Calibrated Data Record |
| CODMAC | Committee on Data Management and Computation |
| DAP | Derived Analysis Product |
| DAR | Derived Analysis Record |
| DDP | Derived Data Product |
| DDR | Derived Data Record |
| DEC | Declination |
| DEM | Digital Elevation Model |
| DMAP | Data Management and Archiving Plan |
| DOY | Day of Year |
| DQI | Data Quality Index |
| DSN | Deep Space Network |
| e | Emission angle |
| EDR | Experiment Data Record |
| EF | Earth flyby |
| EPPS | Energetic Particle and Plasma Spectrometer |
| EPS | Energetic Particle Spectrometer |
| FIPS | Fast Imaging Plasma Spectrometer |
| GDS | Ground Data System |
| GDR | Gridded Data Record |
| GRNS | Gamma-Ray and Neutron Spectrometer |
| GRS | Gamma-Ray Spectrometer |
| HPGe | High-purity germanium |
| i | Incidence angle |
| I/F | Intensity divided by flux, or the ratio of radiance to incident solar irradiance |
| JHU/APL | The Johns Hopkins University Applied Physics Laboratory |
| MAG | Magnetometer |
| MASCS | Mercury Atmospheric and Surface Composition Spectrometer |
| MDIS | Mercury Dual Imaging System |
| MDR | Map-projected multispectral Reduced Data Record |
| MESSENGER | MErcury Surface, Space ENvironment, GEochemistry, and Ranging |
| MET | Mission elapsed time |
| MF1/MF2/MF3 | Mercury flyby 1, 2, 3 |
| MLA | Mercury Laser Altimeter |
| MOC | Mission Operations Center |
| NAC | Narrow-angle camera |
| NAIF | Navigation and Ancillary Information Facility |
| NASA | National Aeronautics and Space Administration |
| NS | Neutron Spectrometer |

| Acronym | Definition |
|---|---|
| NSSDC | National Space Science Data Center |
| ODF | Orbit Data File (edited raw RS Doppler data or TRK-2-18 data) |
| PDR | Packetized Data Record |
| PDS | Planetary Data System |
| PHA | Pulse-height analysis |
| PI | Principal Investigator |
| PPI | Planetary Plasma Interactions |
| RA | Right ascension |
| RADR | Radiometric active data record |
| RDR | Reduced Data Record |
| RS | Radio Science |
| RSR | Radio Science Receiver |
| SIS | Software Interface Specification |
| SOC | Science Operations Center |
| SPICE | Spacecraft ephemeris, Planet/satellite ephemeris, Instrument information, Camera orientation, Event information |
| TNF | Tracking and Navigation File (raw RS Doppler data from closed-loop receiver, TRK-2-34 data) |
| TOPO GDR | Topographic Gridded Data Record |
| UTC | Coordinated Universal Time |
| UVVS | Ultraviolet and Visible Spectrometer |
| VF1/VF2 | Venus flyby 1, 2 |
| VIRS | Visible and Infrared Spectrograph |
| WAC | Wide-angle camera |
| XRS | X-Ray Spectrometer |