Magellan F-BIDR User's Guide for the PDS4 Dataset

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PDS Geosciences Node

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1 Introduction

This document is a quick start guide to the updated Magellan F-BIDR[1] (Full-Resolution Basic Image Data Record) PDS4 archive. This updated F-BIDR dataset was created by the Planetary Data System's (PDS) Geosciences Node as part of the Node's effort to migrate all its holdings from the PDS3 standard to the PDS4 standard[2]. The F-BIDR dataset consists of full-resolution Magellan Synthetic Aperture Radar (SAR) image data captured in orbit around Venus. This new PDS4 F-BIDR archive contains the same data as the original PDS3 archive, but with a more modern, PDS4-compliant format. This document will help users understand what is in this archive, how it was created, and how it is different from the original F-BIDR dataset. It also discusses caveats and issues discovered during generation of the updated F-BIDR archive.

2 Magellan Mission

The Magellan radar mapping mission produced the first global, high-resolution image dataset of Venus[3]. The spacecraft was launched on May 4, 1989. It arrived at Venus on August 10, 1990, and began systematic mapping of the Venus surface on September 15, 1990. One of the main experiments for geologic mapping was Synthetic Aperture Radar

[1] The archive of F-BIDR products is maintained by the PDS Geosciences Node and can be found at https://pds-geosciences.wustl.edu/missions/magellan/fbidr/index.htm.
[2] Full documentation of the archive standards is available at https://pds.nasa.gov/datastandards/documents/current-version.shtml.
[3] See Saunders et al. (1990) and Saunders et al. (1992). Full citations available in References.

(SAR) imaging. The SAR data for each orbit of Venus were compiled into an F-BIDR product in a dataset originally archived with the PDS during the mission.

Magellan mission operations were divided into several mapping cycles, each being 243 Earth days in duration. This was the time it took Venus to rotate once under Magellan's orbit. The first three mapping cycles concentrated on collecting SAR imaging and altimetry and radiometry data. Ninety-eight percent of the surface was imaged during these three mapping cycles, and many areas were viewed more than once with different imaging geometries and/or directions of illumination. The fourth and fifth cycles were devoted to mapping the planet's gravity field. The final cycle occurred after the spacecraft orbit was lowered to collect better gravity data near the poles. The mission completed on October 13, 1994 after the spacecraft was commanded to drop into the Venusian atmosphere.

3 SAR Image Data

The Magellan spacecraft orbit was elliptical (294 km by 8543 km) and nearly polar with an 85.5° inclination[4]. The orbit period was 3.25 hours. Mapping started when Magellan was located near the North Pole and the High-Gain Antenna (HGA) was pointed toward the Venusian surface. Over four thousand usable SAR imaging orbits were obtained. The area covered by each orbit was typically 20 km wide and 17,000 km long. Because the area of new terrain observed by the sensor in equatorial latitudes was much greater than at the poles, it was possible to map high latitudes on alternating orbits with an acceptable margin of overlap. For example, in the first mapping cycle (Cycle 1), this technique was used to reduce redundancy and maximize areal coverage. Mapping started near the North Pole in each alternate orbit and continued to about 57°S latitude. In the intervening orbits, mapping started at about 70°N and extended to 74°S latitude.

The SAR data acquired on each orbit were formatted into an image product known as an F-BIDR (Full-resolution Basic Image Data Record). F-BIDRs are sampled to a surface pixel size of 75 m in both cross-track and along-track directions. However, the actual spatial resolution of the data in the cross-track direction varies with latitude. F-BIDRs were the input products for generating the F-MIDRs[5] (Full-resolution Mosaicked Image Data Records). A secondary image product, known as a C-BIDR[6] (Compressed Basic Image Data Record), was also created from SAR data. C-BIDRs are similar to F-BIDRs, but they are

[4] See Saunders et al. (1990) and Saunders et al. (1992)
[5] The archive of all MIDR products, including both F-MIDRs and C-MIDRs, is maintained by the PDS Geosciences Node and can be found at https://pds-geosciences.wustl.edu/missions/magellan/midr_pds4/index.htm.
[6] The archive of C-BIDR products is maintained by the PDS Geosciences Node and can be found at https://pds-geosciences.wustl.edu/missions/magellan/cbidr/index.htm.

down-sampled to a pixel size of 225 m. C-BIDRs were used to generate the C1-MIDRs. C2-MIDRs were made by down-sampling C1-MIDRS, and likewise, the C3-MIDRs were made by down-sampling the C2-MIDRs.

The objective of Mapping Cycle 1 was to acquire radar data for 70% of the surface, but data for nearly 83.7% of the surface was obtained. The spacecraft was oriented to acquire left-looking data such that the HGA was pointed to the east of the spacecraft ground track. Mapping Cycle 2 focused on filling gaps in coverage from Mapping Cycle 1 and obtaining coverage of the South Pole region. These polar data were acquired with a right-looking orientation. Mapping Cycle 2 provided only about 54.5% surface coverage because of mapping time lost due to spacecraft issues. Cycle 2 also did a test for acquiring stereo data by observing areas mapped in Cycle 1 with a different (left-looking) incidence angle. The last SAR mapping cycle, Mapping Cycle 3, was focused on acquiring stereo image coverage. About 21.3% of the planet was covered with same-side stereo images.

4 PDS4 Archive Organization

This updated F-BIDR dataset was created using the PDS4 standard. This section describes the organization of the dataset according to PDS4 standards.

The highest level of organization for a PDS4 dataset is called a bundle. A bundle is a set of one or more related collections that can be of different types. A collection is a set of one or more related basic products, which are typically all of the same type (e.g., raw, calibrated, or derived data, documents; etc.). Basic products in PDS4 contain one or more digital objects (table, images, etc.). Bundles and collections are logical structures, not necessarily tied to any physical directory structure, although the physical organization of a PDS4 dataset usually follows the bundle and collection structure.

All items in a PDS4 archive are considered products. A PDS4 product consists of a PDS4 label and the item that the label describes, typically one or more files. For example, an image product comprises both the image and the label that describes that image. The exception is a bundle product, which is a single XML (eXtensible Markup Language) file that lists the collections in the bundle. Bundle products can also reference an optional readme file. PDS4 labels use XML to express the metadata about a product. The PDS4 label is stored in a file separate from the object it describes. Each PDS4 product is uniquely identified by a string in its label called a Logical Identifier (or LID). A LID consists of up to six tokens separated by a colon. The first three are fixed for datasets archived by the PDS. These first three are: "urn:nasa:pds". The fourth token is the bundle identifier. In this case the bundle identifier is: "magellan_fbidr". The fifth token is a collection identifier, whereas

the sixth token is a product identifier. This formation rule generates a unique LID across all of PDS because the bundle identifier has to be unique across the PDS, the collection identifier has to be unique within the bundle, and finally the product identifier has to be unique within its collection. An example of an F-BIDR product LID is:

urn:nasa:pds:magellan_fbidr:data:fbidr_0376_v4_eq

The product identifier token is usually based on the product file name without the extension. The file name formation rule for F-BIDR products is described in Section 6.1.

If there are multiple versions of a PDS4 product, these can be distinguished by version identifier (VID), which has the form M.n, with M indicating the major version (starts with 1) and n noting minor version revisions (starts at 0 for each major version). The VID is listed as an attribute in the PDS4 label. The LID and the VID can be combined to refer to a specific product version by concatenating the LID and VID with two colons. This is known in PDS4 as a LIDVID. For example, the LIDVID of version 1 of the product above would be:

urn:nasa:pds:magellan_fbidr:data:fbidr_0376_v4_eq::1.0

The F-BIDR PDS4 bundle has three collections – data (F-BIDR images and associated observational data), document, and miscellaneous. Each collection is described in more detail in the subsections below.

4.1 Data Collection

The PDS4 F-BIDR products are stored in the data collection. The collection identifier is "data", and all scientific products are stored in a physical directory named "data" under the bundle root directory. The directory "data" contains the collection product, which is a PDS4 label and CSV file with an inventory of all products in the collection. The inventory file has two fields. The first field indicates whether the product is a primary or secondary member of the collection. All F-BIDR products are primary members. The second field lists the LIDVID for a product. For example:

P,urn:nasa:pds:magellan_fbidr:data:fbidr_0376_v4_eq::1.0

There are subdirectories under the "data" directory which group the products into groups of one hundred orbits (e.g., "orbits_0300_to_0399"). Within each orbit group subdirectory are further subdirectories that correspond to individual F-BIDRs (e.g., "fbidr_0376_v4"). Each F-BIDR directory contains the files that make up one or more PDS4 products associated with the given F-BIDR.

See Section 6.1 for more information about the products that correspond to an F-BIDR, and Section 6.2 for information about the files that make up each F-BIDR PDS4 product.

4.2 Document Collection

The document collection contains several types of documentation about the Magellan F-BIDR PDS4 archive. The collection identifier is "document". The document collection includes a series of ASCII text files that were derived from the PDS3 catalog files (see Appendix A). These files describe the Magellan mission, the spacecraft, the radar instrument, and the original F-BIDR dataset. This documentation was largely written in the 1990s by Magellan project personnel and science team members.

The collection also includes a number of SIS (Software Interface Specification) documents produced by the Magellan project. One describes the F-BIDR products as stored on magnetic tape (*fbidr_sis*) and the others describe the parts of the F-BIDR products that originated as parts of the Magellan EDR[7] products. These documents were previously not available online. Paper copies of each were scanned to produce PDF files for inclusion in this archive. The documents preserved in such a way are listed in Table 1.

This user's guide is also located in the document collection as a product, with LID urn:nasa:pds:magellan_fbidr:document:fbidr_userguide.

Table 1: Scanned documents contained in the F-BIDR PDS4 archive. Each LID should be understood as a member of the collection urn:nasa:pds:magellan_fbidr:document. Each product consists of a PDF with filename {LID}.pdf and its label, {LID}.xml.

LID	Number	Name/purpose
edr_sis	TPS-101	SAR and Altimeter EDR/TEDR Tapes SIS
fbidr_sis	SDPS-101	F-BIDR Software Interface Specification (SIS)
mon_105	MON-105	Magellan DSN Monitor Data (Mon 5-12)
mos_rs_ird	603-204	Mission Operation Systems – Radar System – Interface Requirements Document
nav_135	NAV-135	Spacecraft and Planet Ephemerides, NAIF S and P Kernels
res_101	RES-101	Processing Bandwidth (PBW) File
res_104	RES-104	Mapping Quaternions Polynomial Coefficients (MQPC) File
ses_112	SES-112	Magellan SCLK/SCET Coefficients File
ses_115	SES-115	Telemetry Decommutation/Decalibration Data (TMDDAT)
sfoc_5_sys_du_njpl	SFOC-5-SYS-DU-NJPL	NJPL SFDU Global Definitions
sfoc_5_tis_du_sfdu	SFOC-5-TIS-*DU-SFDU	SFDUs Generated/Received by TIS
vrm_2_280	VRM-2-280	VRM Spacecraft System and Subsystem Design Book, Telemetry Measurements and Data Formats

[7] The archive of SAR EDR products is maintained by the PDS Cartography and Imaging Sciences Node and is online at https://pds-imaging.jpl.nasa.gov/volumes/magellan.html#mgnSAR

Another document is an ASCII text file, fbidr_release_notes.txt, that lists issues identified during generation of the new PDS4 archive.

Each document product is accompanied by a PDS4 XML label.

4.3 Miscellaneous Collection

A miscellaneous collection in PDS4 contains supplementary information useful in the interpretation and use of the data in the bundle, but which does not fit in the other collections. The F-BIDR bundle miscellaneous collection has a catalog of F-BIDR PDS4 products containing per-orbit metadata about the F-BIDR images. The file name of the catalog product is orbit_summary_table.csv. This is a CSV file that contains metadata about each F-BIDR product, such as the mapping cycle in which the data acquired, whether the SAR data are left or right looking, and the volume_id of the CD-WO (see Appendix A) that originally contained the F-BIDR. It is intended to help users quickly look through the dataset to find products of interest. This table's PDS4 LID is:

urn:nasa:pds:magellan_fbidr:miscellaneous:orbit_summary_table

The miscellaneous collection also contains orbit_inclusion_table.csv, a catalog of the status of each F-BIDR that existed in the pre-PDS4 archive. It is a CSV file that contains, for each known F-BIDR, whether it was migrated into this PDS4 archive and if not, why not. (There are two main reasons why an F-BIDR would not be migrated: either it was superseded by a reprocessed version which was migrated instead, or its data was corrupted. See Section 7.) This table's PDS4 LID is:

urn:nasa:pds:magellan_fbidr:miscellaneous:orbit_inclusion_table

5 PDS3 F-BIDR Products

In the original PDS3 F-BIDR archive, each F-BIDR corresponds to data gathered during one orbit of Venus and consists of twenty files numbered file_01 to file_20. The formats of the 20 files that make up a PDS3 F-BIDR are described in the F-BIDR SIS[8] and its references. Table 2 contains references to the relevant sections for each file.

[8] The document that we refer to simply as "the F-BIDR SIS" has the following full citation: Leung, K. (SIS Coordinator), *Project Magellan Software Interface Specification: Full-Resolution Basic Image Data Record (SDPS-101), Revision E*. This document is available in this bundle as urn:nasa:pds:magellan_fbidr:document:fbidr_sis; see Section 4.2.

Table 2: Summary of files that make up a PDS3 F-BIDR. This is an adapted version of F-BIDR SIS Table 3.1 (pg. 66 of the PDF) with additional information specific to the PDS4 version. All section references (§) refer to the F-BIDR SIS.

Filename	SIS ref. §	Copied from EDR?	Data in PDS4 F-BIDRs?	Description
file_01	3.2.1	No	No	BIDR Header: Summary BIDR Volume Information
file_02	3.5.2	Yes	No	Orbit Header
file_03	3.5.3	Yes	No	EDR Data Quality Summary
file_04	3.5.4	Yes	No	S/C Ephemeris File (Orbit Description)
file_05	3.5.5	Yes	No	SCLK/SCET Conversion Coefficients
file_06	3.5.6	Yes	No	DSN Monitor Records
file_07	3.5.7	Yes	No	Quaternion Polynomial Coefficients
file_08	3.5.8	Yes	No	Processing Bandwidths
file_09	3.5.9	Yes	No	Decommutation & Decalibration data
file_10	3.5.10	Yes	No	Engineering Data
file_11	3.5.11	Yes	No	Radar Header Records
file_12	3.5.12	No	Yes	Per-Orbit Parameters
file_13	3.5.13	No	Yes	Image Data in Oblique Sinusoidal Projection
file_14	3.5.14	No	Upcoming	Processing Parameters for Oblique Sinusoidal Data
file_15	3.5.15	No	Yes	Image Data in Sinusoidal Projection
file_16	3.5.16	No	Upcoming	Processing Parameters for Sinusoidal Data
file_17	3.5.17	No	Upcoming	Processed Radiometer Data
file_18	3.5.18	No	Upcoming	Cold-Sky Calibration Results
file_19	3.5.19	No	Upcoming	Processing Monitor Results
file_20	3.2.2	No	No	BIDR Trailer: Additional BIDR Volume Information

Of the files included in a PDS3 F-BIDR, Files 1 and 20 contain basic metadata about the original magnetic tape version of the F-BIDR. Files 2-11 were copied from the original SAR Experiment Data Records (EDRs) [9]. Files 12-19 were produced specifically for the F-BIDR products.

This PDS4 version of the F-BIDR dataset contains translations of the contents of file_12 (Per-orbit parameters), file_13 (Image Data in Oblique Sinusoidal Projection), and file_15 (Image Data in Sinusoidal Projection). An upcoming revision of this bundle will include data derived from files 14 and 16 through 19. However, the documentation relating to the formats of all these files, written at the time of the mission, is already included in this bundle (see Section 4.2 above).

5.1 Why Were the Data Products Reformatted?

PDS3 F-BIDR images (found in both file_13 and file_15) were specified across a series of "logical records." Each logical record contains a group of some number of image lines,

[9] The Magellan SAR EDR products are available from the PDS Cartography and Imaging Sciences Node at https://pds-imaging.jpl.nasa.gov/portal/magellan_mission.html.

which are preceded by some metadata that apply to all of the lines. There are typically hundreds to thousands of logical records in an image. The formats for many of the PDS3 F-BIDR non-image files similarly consist of logical records of varying size.

One of the goals of the PDS4 standard is to preserve data over the long term. In support of this goal, observational data products in PDS4 must consist of very straightforward data structures, like tables and arrays, so that no specific specialized software is required to interpret the products. The standard would not support a compact, comprehensible description of the logical records found in PDS3 F-BIDR files. This is the primary reason why new, converted data files were produced to create the PDS4-compliant version of the dataset.

5.2 What Changes Were Made to the Reformatted Data?

5.2.1 Floating-Point Values

Floating-point values are found in many places in PDS3 F-BIDRs, including both the metadata for logical records and the pixel data for some types of images. These floating-point values were stored in now-obsolete VAX single- and double-precision floating point formats. For the convenience of modern users, these values have been converted to the now-standard IEEE single- and double-precision floating point formats. We carried out this conversion with the rms-vax Python package[10], which is a product of the PDS Ring-Moon Systems Node. This conversion has necessarily caused a negligible ($< 10^{-6}$) discrepancy in the least significant bits of these floating-point values.

Additionally, this PDS4 archive includes many of the formerly VAX floating-point values as text, in PDS4 XML labels and in CSV tables. This second layer of conversion, in which the binary mantissas of these values were converted to decimal digits, might have in some cases introduced slight changes to the values. However, since the decimal text representations of these values are never truncated, these differences should also be negligible.

5.2.2 Data Product Structure

To create a PDS4 F-BIDR image, we copied the image data from the image's PDS3 logical records into a single two-dimensional array. The pixel values were not changed in any way (except, if applicable, the floating-point conversions described above).

The PDS3 image logical record metadata values are stored in the PDS4 bundle in a per-line metadata CSV table which, alongside the array of image data, constitutes a PDS4 F-BIDR.

[10] Available at https://github.com/SETI/rms-vax

6 PDS4 F-BIDR Products

6.1 Products

A PDS4 F-BIDR consists of up to two products: one for oblique sinusoidal image data (from file_13, if present and non-empty, containing data from latitudes between 80°S and the South Pole and between 80°N and the North Pole), and one for sinusoidal image data (from file_15, if present and non-empty, containing data from latitudes between 89°S and 89°N). These two products are differentiated by text in their filenames and LIDs representing what we might call their *region*: for oblique sinusoidal data, "polar" (because only data very near one of Venus's poles is included in it), and for sinusoidal data, "eq" (because the data here is comparatively more equatorial).

An F-BIDR product with the four-digit orbit number *oooo* (padded with zeros to four digits if necessary), a product version number *#*, and region *reg*, is called fbidr_{oooo}_v{#}_{reg} (replacing text in curly braces with the values previously described). All such products are contained within the collection urn:nasa:pds:magellan_fbidr:data.

6.2 Anatomy of an F-BIDR Product

A PDS4 F-BIDR product consists of an array of image data, a corresponding CSV table of per-line metadata, and an XML label. An F-BIDR with the name and LID *fbidrname* will have an XML label whose filename is {fbidrname}.xml.

The array of image data is stored in a file with a name of the form {fbidrname}_data.img. Each line of the array consists of the 512 pixel values (each stored as an unsigned byte) of a line from the corresponding PDS3 F-BIDR image. The lines are stored in the same order as they are found in the PDS3 F-BIDR image file.

The CSV table of per-line metadata is stored in a file with a name of the form {fbidrname}_linemeta.csv. The file consists of a header row and one row per image line, meant to be understood in conjunction with the pixel values from the corresponding row of the image array. The columns of this table are as follows:

- burst_counter: Burst counter of the burst associated with the image record that contains this line. This is a numerical index which groups the image lines into their original logical records. See "Burst counter" at F-BIDR SIS §3.4.1.2.1 (pg. 39 of the PDF).
- line_idx: Index of this line within its burst. (The lines are numbered starting from 0.)
- p1: Pointer #1: offset to (number of bytes to but NOT including) the first valid pixel in the line. See "Offset to first valid pixel" at F-BIDR SIS §3.4.2.2.1 (pg. 49 of the PDF).

- p2: Pointer #2: pointer to (number of bytes to AND including) the last valid pixel in the line. See "Pointer to last valid pixel" at F-BIDR SIS §3.4.2.2.1 (pg. 49 of the PDF).
- firstpix_offset_lines: The Coordinate-1 (vertical, "northing") location of this line's first pixel in this F-BIDR's map projection. Given as a count of 75-meter pixels. All subsequent pixels in this line also have this northing. See "Reference Point Offset in Lines" at F-BIDR SIS §3.4.1.2.1 (pg. 39 of the PDF).
- firstpix_offset_pixels: The Coordinate-2 (horizontal, "easting") location of this line's first pixel in this F-BIDR's map projection. Given as a count of 75-meter pixels. Each subsequent pixel in this line has an offset one higher than the previous pixel (i.e., an easting 75 meters greater). See "Reference Point Offset in Pixels" at F-BIDR SIS §3.4.1.2.1 (pg. 39 of the PDF).

6.3 Sources of PDS4 Metadata

The XML label of a PDS4 F-BIDR product contains metadata for that product. Metadata items are derived from the file_12 ("Per-orbit parameters" file) of the PDS3 version of the F-BIDR. They are also included in the orbit_summary_table product found in the miscellaneous collection (see Section 4.3 above).

The metadata items in file_12 that refer to datetimes of events (e.g., the start or end of mapping) are given as Barycentric Dynamical Time (TDB) in seconds since the J2000 epoch. These numeric values are included in the XML labels, but for the purpose of human readability, they are also included as standard UTC timestamps. The UTC timestamp versions were calculated from the TDB values using SpiceyPy, a Python wrapper for the SPICE toolkit[11].

Some, but not all, PDS3 F-BIDRs include PDS3 .lbl labels. Because of the fragmentary nature of their availability, they are not used as the source for any of the PDS4 metadata in this archive. Users should note that the timeframe of an F-BIDR as given in the .lbl labels (the START_TIME and STOP_TIME attributes) may differ by a few milliseconds from the values in this archive's PDS4 labels (given in start_date_time and stop_date_time). This discrepancy is likely due to tweaks to the definition of Barycentric Dynamical Time which have been codified since the time of the Magellan mission. It is not large enough to be relevant to most applications.

[11] Annex et al., (2020). SpiceyPy: a Pythonic Wrapper for the SPICE Toolkit. Journal of Open Source Software, 5(46), 2050, https://doi.org/10.21105/joss.02050

6.4 Map Projections Used in F-BIDRs

In an F-BIDR image, all image lines exist in a map-projected space. Although every image line of a given product is projected with the same map projection and same map projection parameters, not all lines have the same offset from the projection origin. Due to this, the image array's projection cannot be described in the conventional way with the PDS4 CART (cartography) local data dictionary. Instead, four custom attributes in the PDS4 label specify the F-BIDR's projection, and the offsets in the per-line metadata table allow each line to be placed in the projected space relative to the projection origin. The map projection attributes in the label are as described in Table 3.

All Magellan map projections assume a spherical Venus with its radius given as

$$R_v = 6051 \text{ km} \tag{1}$$

Table 3: the PDS4 label attributes needed to interpret F-BIDR map projections, with their meanings. All attributes are children of the element specified by the XPath /Product_Observational/Observation_Area/Mission_Area/mgn:Magellan_Parameters/mgn:BIDR_Parameters.

Attribute	Meaning/notes
mgn:pixel_size	Size of image pixels in the F-BIDR's map projection in meters. For F-BIDRs, this always equals 75 meters.
mgn:projection_name	The name of the map projection used in this product. Either 'sinusoidal' or 'oblique sinusoidal'.
mgn:projection_origin_lat	Latitude of the projection origin, degrees, for products in oblique sinusoidal projection (always 0 for sinusoidal projection).
mgn:projection_origin_lon	Longitude of the projection origin, degrees.

6.4.1 Sinusoidal Projection

The sinusoidal map projection used in Magellan F-BIDRs is defined in F-BIDR SIS App. FG (pg. 160 of the PDF). It is used in this dataset for data between 89°S and 89°N latitude.

The parameter of this projection is the longitude of the projection origin, θ_0. (The latitude of the projection origin, ψ_0, is implicitly 0°.)

In summary, the conversion from sinusoidal projected coordinates of easting and northing in meters (h, v) to latitude and longitude in degrees (ψ, θ) is given by

$$\psi = \frac{180°}{\pi} * \frac{v}{R_v} \tag{2}$$

$$\theta = \theta_0 + \frac{180°}{\pi} * \frac{h}{R_v * \cos\psi} \tag{3}$$

6.4.2 Oblique Sinusoidal Projection

The oblique sinusoidal map projection used in Magellan F-BIDRs is defined in F-BIDR SIS App. FH (pg. 161 of the PDF). It is used in this dataset for data between 80°S and the South Pole and between 80°N and the North Pole.

The parameters of this projection are the latitude and longitude of the projection origin, ψ_0 and θ_0 respectively.

The conversion from oblique sinusoidal projected coordinates of easting and northing in meters (h, v) to latitude and longitude in degrees (ψ, θ) requires the inverse of a series of coordinate transformations which can be derived from the forward transformations (geographic to projected) which were published in the F-BIDR SIS. In summary, as derived from F-BIDR SIS App. FA (pg. 151 of the PDF), the values (ψ, θ) are given by

$$\psi = \text{asin}\,{}^{z_B}/_{r} \tag{4}$$

$$\theta = \text{atan2}(y_B, x_B) \tag{5}$$

where $r = \sqrt{x_B^2 + y_B^2 + z_B^2}$.

The vector $[x_B, y_B, z_B]^T$ is a position vector in the VBF85 ("Venus body-fixed") coordinate system. Per F-BIDR SIS App. FH (pg. 161 of the PDF), it can be derived as

$$\begin{bmatrix} x_B \\ y_B \\ z_B \end{bmatrix} = \begin{bmatrix} \cos\alpha_1 & \sin\alpha_1 & 0 \\ -\sin\alpha_1 & \cos\alpha_1 & 0 \\ 0 & 0 & 1 \end{bmatrix}^{-1} \begin{bmatrix} \cos\alpha_2 & 0 & -\sin\alpha_2 \\ 0 & 1 & 0 \\ \sin\alpha_2 & 0 & \cos\alpha_2 \end{bmatrix}^{-1} \begin{bmatrix} x_A \\ y_A \\ z_A \end{bmatrix} \tag{6}$$

where $\alpha_1 = \theta_0$ and $\alpha_2 = -\psi_0$.

The vector $[x_A, y_A, z_A]^T$ is a position vector in the oblique sinusoidal 3D coordinate system. Per F-BIDR SIS App. FH (pg. 162 of the PDF), it is derived from the oblique sinusoidal easting and northing (h, v) as

$$\begin{bmatrix} x_A \\ y_A \\ z_A \end{bmatrix} = R_v * \begin{bmatrix} \cos\psi' \cos\theta' \\ \cos\psi' \sin\theta' \\ \sin\psi' \end{bmatrix} \tag{7}$$

where $\psi' = \frac{h}{R_v}$ and $\theta' = \frac{v}{R_v \cos\psi'}$ (to be interpreted as angles in radians).

7 Caveats

This section lists known issues and oddities discovered during the F-BIDR migration that produced this bundle.

7.1 Issues that Prevented Products from being Included

Of the 5,948 F-BIDRs that exist in the PDS3 F-BIDR archive, only 4,157 were migrated to this PDS4 bundle. There are two main reasons why a given F-BIDR has not been migrated: either it is superseded by a reprocessed version which we migrated instead, or its data was corrupted.

The orbit_inclusion_table product in the miscellaneous collection (see Section 4.3) lists, for each PDS3 F-BIDR, whether it was migrated and if not, why not. The subsections below explain the conditions that prevent migration.

7.1.1 Superseded Versions

Many Magellan orbits' SAR data were processed into F-BIDRs multiple times, distinguished by an internal F-BIDR version number. We consider the highest-numbered version of an orbit's data to be the best-processed version. Therefore, this bundle contains the highest version of an F-BIDR that we could migrate successfully. 568 F-BIDRs were excluded from the archive on this basis.

7.1.2 Corrupted Files

In 1,133 F-BIDRs, migration could not be completed due to corruption of the PDS3 data files. In some cases, the data files exist but have contents consisting solely of repeated zero bytes; in others, one or more data files do not exist at all. In some instances, notes from the previous transfer of this data from tapes to CD-WO (see Appendix A) indicate errors reading the tape. These errors are unrecoverable.

7.1.3 Non-Conformant Files

There are 90 F-BIDRs not included in the counts above. While each of these F-BIDRs were not fully corrupted, one or more data files did not conform fully to the formats described in the F-BIDR SIS and therefore could not be parsed. This non-conformance might be caused in some cases by tape read errors or other corruption during data transfer.

It is possible that useful partial data could be extracted from these F-BIDRs; if so, they will be included in an upcoming revision of this bundle.

7.2 Issues that Affect Products in this Bundle

7.2.1 Spatial Registration

Features on the Venusian surface are not perfectly registered from one map-projected F-BIDR image to another map-projected F-BIDR image or F-MIDR image. Imprecision, likely introduced by the ways these images were collected (e.g., left-looking vs. right-looking) or by imperfect knowledge of spacecraft pointing during the original F-BIDR creation, means that in some cases a known geographic feature will appear to be hundreds of meters to several kilometers displaced from one F-BIDR image to another. This discrepancy is largest when comparing left-looking orbits to right-looking orbits. It is recommended to coregister to a common base map, like the FMAP mosaic, to be sure of the correspondence between locations.

7.2.2 Individual Flipped Bits

It is possible that some individual bits in the PDS3 F-BIDR product data files might have been flipped at some time preceding migration to PDS4. In fbidr_4186_v2_eq, nearly all logical records list projection_origin_lon value 15.712 (corresponding to VAX bytes 0x659e4**2**7b). However, two of its records, those with burst_counter values 1236 and 1589, list longitude 4022.351 (corresponding to VAX bytes 0x659e4**6**7b, differing from the correct value in only one bit). (In this case, due to the redundancy of the metadata field affected, the incorrect values did not damage the integrity of the product fbidr_4186_v2_eq.)

It is unclear whether these errors originated during the original processing or while at rest on one of the many storage media this archive occupied (see Appendix A). Be warned that this may indicate that bit-level corruption occurred in the dataset, which we cannot in general detect and mitigate against (except in cases of redundant values as seen above).

7.2.3 Incorrect Metadata (Corrected)

In multiple cases, a PDS3 F-BIDR's file_12 (Per-orbit parameters file) indicated a different product version than that implied by the name of the directory that contained the F-BIDR. In these cases, we consider the directory name more trustworthy and have used it in this PDS4 archive. See Table 4 below for the list of all such cases. No action is required from users of this archive.

Table 4: Listing of F-BIDR products in which the names of the PDS3 directory and the internal parameter value BIDR_ID disagree on version number. Asterisks (*) indicate that multiple PDS4 products are associated with the F-BIDR concerned (e.g., both "eq" and "polar" image products). For each F-BIDR, the version number which is considered canonical in the PDS4 archive is shown.

PDS4 LIDs	PDS3 F-BIDR directory name	BIDR_ID value in file_12	Accepted version in PDS4 archive
fbidr_0025_v2_*	F0025_**2**	F00025.**01**	2
fbidr_3495_v2_*	F3495_**2**	F03495.**01**	2

8 References

Saunders, R. S., *et al.*, 1990, The Magellan Venus Radar Mapping Mission, *JGR, 95(B6)*, 8339-8355, doi:10.1029/JB095iB06p08339.

Saunders, R. S., *et al.*, 1992, Magellan Mission Summary, *JGR Planets, 97(E8)*, 13067-13090, doi:10.1029/92JE01397.

Appendix A) History of the F-BIDR Archive

The original version of the Magellan F-BIDR archive was delivered to the PDS Geosciences Node on 9-track tapes. To better preserve the data, and save physical storage space, node personnel copied the data on the tapes to a series of CD-WO (Compact Disc Write Once) discs. During this conversion, they also added ASCII catalog files (with file extension ".cat"), and PDS3 labels (extension ".lbl") that describe the F-BIDR data files in basic terms.

Later, to serve the F-BIDR archive directly to end-users over the World Wide Web, these CD-WOs were read onto hard drives.

At each stage of this process, there were occasional issues with reading physical media that led to the corruption or loss of F-BIDR products. For each PDS3 F-BIDR, information about whether it was successfully converted to a PDS4 F-BIDR, and if not, what was wrong with it, is available in the orbit_inclusion_table product in the miscellaneous collection (see Section 4.3).