Mars Reconnaissance Orbiter

Software Interface Specification
Mars Color Imager (MARCI)
Standard Data Product

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1. Introduction

1.1. Purpose

This document describes the format of the Mars Reconnaissance Orbiter Context Camera (MARCI) Standard Data Product.

1.2. Scope

The format and content specifications in this SIS apply to all phases of the project for which this product is available.

1.3. Applicable Documents

Mars Exploration Program Data Management Plan, R.E. Arvidson, S. Slavney, and S. Nelson, Rev. 3.0, March 20, 2002.

Mars Reconnaissance Orbiter Project Data Archive Generation, Validation, and Transfer Plan, MRO 31-468, JPL D-22246, Version 1.1, January 26, 2006.

Planetary Data System Standards Reference, Version 3.6, JPL D-7669, Part 2, August 1, 2003.

Planetary Science Data Dictionary Document, JPL D-7116, Rev. E, August 28, 2002.

"Mars Color Imager (MARCI) on the Mars Climate Orbiter", Malin, M. C., J. F. Bell III, W. Calvin, R. T. Clancy, R. M. Haberle, P. B. James, S. W. Lee, P. C. Thomas, and M. A. Caplinger, Journal of Geophysical Research, v. 106, no. E8, pp. 17,651-17,672, 2001.

1.4. Functional Description

1.4.1. Data Content Summary

Each MARCI Standard Data Product is a single image contained in either one or two files, in the raw image format as produced by the instrument. The data have been depacketized, decompressed, and reformatted with standard labels, but are otherwise "raw"; that is, as received from the instrument. In that sense these products are most closely analogous to the Experiment Data Record (EDR) products of previous missions. The processing level of this dataset is CODMAC level 2 (NASA level 0).

1.4.2. Source and Transfer Method

MARCI products are produced at the MARCI Mission Operations Facility (MOF) by the *makepds05* program from the format internally used at the MOF. This program reads a raw MARCI image file (in the internal "DDD" format), extracts some information from its headers, formats and attaches the PDS labels, and appends the image data.

MARCI products are validated at the MOF through visual inspection of the images as well as automated verification of various elements of the image header (e.g., SPACECRAFT_CLOCK_START_COUNT, INTERFRAME_DELAY).

It is expected that there will be two ways to receive MARCI products: by electronic file transfer from the Planetary Data System, and on some archival medium such as CD-ROM or DVD.

MARCI is expected to return approximately 1.5 Tb over the course of a 26 Tb primary mission (see the MRO Project Data Archive Generation, Validation, and Transfer Plan).

Volume returned varies as a function of the available data rate; see the Archive Policy and Data Management Plan for more details.

1.4.3. Recipients and Utilization

These products will be available to MARCI team members, the MRO science community, the planetary science community, and other interested parties. Descriptions of data rights and proprietary periods are beyond the scope of this document, and are discussed in the Project Archive Policy and Data Transfer Plan,

and in unique Operational Interface Agreements between the MARCI Science Team and other parties.

These products will be used for engineering support, direct science analysis, or the construction of other science products.

1.5. Assumptions and Constraints

Note that this file contains decompressed image data. Decompression will result in a raw image that is not corrected for instrument signature, effects of spacecraft motion, or the effects of imaging geometry. Although there is enough information in the header to do some processing, for more sophisticated processing ancillary files will be required. These ancillary files are not described in this document. Examples of ancillary files are calibration files, viewing geometry files (e.g., SPICE kernels), image index tables, etc.

2. Environment

2.1. Instrument Overview

MARCI is a framing camera with a 1024x1024 pixel interline transfer CCD (Kodak KAI-1001) with 9x9 micron pixels. MARCI has two all-refractive 180-degree "fisheye" lenses, one optimized for the visible and near-IR and one for the UV bands. The beams from these two lenses are brought to the CCD through a prism. A color filter array with seven different bandpasses (five visible/near-IR and two UV) is directly bonded to the CCD. A typical image consists of seven "framelets", each 1024 pixels wide and 16 pixels high, in each of these bandpasses. The visible bands can be optionally summed; the UV bands are always summed 8x8. The visible resolution from 300 km is about 1 km/pixel at nadir.

The core of the MARCI electronics is a Motorola 56166 DSP, which interfaces to the spacecraft, generates the CCD clocks, and received digitized pixels from an Analog Devices AD1672 analog-to-digital converter. Both lossless and lossy image data compression can be applied by software running in the spacecraft computer.

MARCI was originally designed for the Mars Climate Orbiter mission. For MRO, a separate subsystem, the MARCI Interface Adapter or MIA, was designed and built to translate the MRO command/data protocol into a form that could be interpreted by the heritage MARCI hardware.

2.2. Failure Protection, Detection, and Recovery

Instrument data from the Raw Science Data Server (RSDS) will be safed temporarily by the PDS Imaging Node until the end of the mission. These archives and depacketized compressed image data will be archived at the MARCI MOF.

2.3. End-of-File Conventions

End-of-file labeling shall comply with SFDU standards; specifically, fixed-size records are used, the header explicitly contains the record offset of each subelement of the dataset, and the size of each subelement can be computed from information in the header.

3. Access

3.1. Access Tools

Existing PDS image display programs (e.g. NASAView) can display these files.

3.2. Input/Output Protocols

None identified.

3.3. Timing and Sequencing Characteristics

None.

4. Detailed Interface Specifications

4.1. Labeling and Identification

The dataset ID is MRO-M-MARCI-2-EDR-L0-V1.0.

Each product will have a file name of the form "*id*.IMG", where the ID is not to exceed 27 characters, will start with an alphabetic character, and will consist only of alphanumeric characters. The file name will be unique across all MARCI data product files. For mapping-phase images, the ID will be of the form PPP_NNNNNN_TTTT_"M"X_"00N"BBB"W", where PPP is a mission phase descriptor, NNNNNN is the orbit number, TTTT is the solar longitude at image start (in units of 0.1 degree), X is the filter combination specifier for the image ("U" for ultraviolet and other letters for various combinations of the visible filters, see below), and BBB is the planned sub-spacecraft (west) longitude at ascending or descending equator crossing, whichever is closer to the image center time. Case is not significant; under the Unix operating system, the names will be considered to be in all lower-case.

4.2. Structure and Organization Overview

All MARCI images must be a multiple of 16 pixels in both width and height. Images are broken up into subimages (also called fragments), and each fragment is transmitted separately. Raw and predictively compressed images are reconstructed by concatenating all of their image fragments and then processing; transform compressed images are processed a fragment at a time.

A MARCI data product consists of one or two images (one each for visible and ultraviolet, as acquired) with decompression applied. For each image file, a header identifies various properties of the image and contains a file offset to the data portion of the image. The image data are then appended to the end of the file.

PDS_VERSION_ID	PDS3
FILE_NAME	"filename"
RECORD_TYPE	FIXED_LENGTH
RECORD_BYTES	nnnn
FILE_RECORDS	nn
LABEL_RECORDS	nn
^IMAGE	nn
SPACECRAFT_NAME	MARS_RECONNAISSANCE_ORBITER
INSTRUMENT_NAME	"MARS COLOR IMAGER"
INSTRUMENT_HOST_NAME	"MARS RECONNAISSANCE ORBITER"
MISSION_PHASE_NAME	PSP
TARGET_NAME	MARS
INSTRUMENT_ID	MARCI
PRODUCER_ID	MRO_MARCI_TEAM
DATA_SET_ID	"MRO-M-MARCI-2-EDR-L0-V1.0"
PRODUCT_CREATION_TIME	yyyy-mm-ddThh:mm:ss.fff
SOFTWARE_NAME	"id-string"
UPLOAD_ID	"version-id"
ORIGINAL_PRODUCT_ID	"original-product-id"
PRODUCT_ID	"product-id"
START_TIME	yyyy-mm-ddThh:mm:ss.fff
STOP_TIME	yyyy-mm-ddThh:mm:ss.fff
SPACECRAFT_CLOCK_START_COUNT	"sclk-string"
SPACECRAFT_CLOCK_STOP_COUNT	"N/A"
INTERFRAME_DELAY	ff.fff
FOCAL_PLANE_TEMPERATURE	ff.fff
SAMPLE_BIT_MODE_ID	"mode-id"
LINE_EXPOSURE_DURATION	ff.fff
SAMPLING_FACTOR	ff.f
SAMPLE_FIRST_PIXEL	nn
FILTER_NAME	"filter-list"
RATIONALE_DESC	string
DATA_QUALITY_DESC	"OK" or "ERROR"
ORBIT_NUMBER	nnnnn
OBJECT	IMAGE

LINES	nnn
LINE_SAMPLES	nnn
LINE_PREFIX_BYTES	0
LINE_SUFFIX_BYTES	0
SAMPLE_TYPE	UNSIGNED_INTEGER
SAMPLE_BITS	8
SAMPLE_BIT_MASK	2#11111111#
CHECKSUM	16#xxxx#
END_OBJECT	IMAGE
END	

4.3. Substructure Definition and Format

PDS_VERSION_ID
: The PDS version number for the header format; e.g., PDS3.

FILE_NAME
: The file name for these products; see above.

RECORD_TYPE
: The record type; always FIXED_LENGTH for these products.

RECORD_BYTES
: The number of bytes per record.

FILE_RECORDS
: The total number of records in this file. The last record will be padded with zeros if necessary.

LABEL_RECORDS
: The number of records used for header data. If needed, the last record of the header will be padded with blanks.

^IMAGE
: A pointer to the starting record of the image object in the file.

SPACECRAFT_NAME
: Always MARS_RECONNAISSANCE_ORBITER.

INSTRUMENT_NAME
: Always "MARS COLOR IMAGER".

INSTRUMENT_HOST_NAME
: Always "MARS RECONNAISSANCE ORBITER".

MISSION_PHASE_NAME
: Name of the mission phase; e.g., PSP.

TARGET_NAME
: The name of the target body; typically MARS.

INSTRUMENT_ID
: Always MARCI.

PRODUCER_ID
: Always MRO_MARCI_TEAM.

DATA_SET_ID
: MRO-M-MARCI-2-EDR-L0-V1.0.

PRODUCT_CREATION_TIME
: Time and date of this file's creation. Note that this time is the time of this file's creation in this format, and does not reflect the acquisition time or the time of any other processing that may be associated with this product.

SOFTWARE_NAME
: Identifier of the version of the MARCI Ground Data System software that created this product.

UPLOAD_ID
: Identifier of the command file used to acquire this image.

ORIGINAL_PRODUCT_ID
: Product ID of this image received from the spacecraft. For example, "4A_05_1008803100".

PRODUCT_ID
: This uniquely identifies this MARCI product among all MARCI products. The MARCI product ID format is PPP_NNNNNN_TTTT_"M"X_"00N"BBB"W", where PPP is a string describing the mission subphase, NNNNNN is the orbit number, TTTT is the solar longitude at image start (in units of 0.1 degree), X is the filter combination specifier ("A" for all five visible channels, "B" for blue/green/orange/near-IR, "C" for blue/green/orange, "D" for blue/green/orange/red, "U" for both ultraviolet), and BBB is the planned sub-spacecraft (west) longitude at ascending or descending equator crossing, whichever is closer to the image center time; e.g., "P01_001330_1322_MA_00N237W". For cruise phase (CRU) images, NNNNNN is a sequential image number.

START_TIME
: SCET (UTC) time at start of image acquisition, as commanded. This time will be the start time of the first frame of the MARCI image.

STOP_TIME
: SCET (UTC) time at end of image acquisition, as commanded. This time will be the start time of the last frame of the MARCI image.

SPACECRAFT_CLOCK_START_COUNT
: Value of spacecraft clock at the actual start of image acquisition. There may be small inconsistencies with START_TIME due to varying correlation between UTC and the spacecraft clock. For purposes of data analysis the spacecraft clock value should be used. The format of this field is compatible with the NAIF Toolkit software (e.g., "00610499:32") The corresponding STOP_COUNT is not applicable because the timing of a MARCI image, once started, is independent of the spacecraft clock.

INTERFRAME_DELAY
: The time (in seconds) between acquisitions of adjacent MARCI frames.

The following information can be used, along with calibration files to be included on the volume, to calibrate each image. This information is in some sense redundant with that in the E-kernel.

FOCAL_PLANE_TEMPERATURE
: Temperature of focal plane of optical system associated with this image, in degrees Kelvin, at the start of image acquisition.

SAMPLE_BIT_MODE_ID
: MARCI digitizes pixels to 12 bits and then uses a lookup table to map pixels to 8 bits. This field identifies the table in use. Valid values are SQROOT, LIN1-LIN16, and LIN1CYC-LIN16CYC. The contents of the SQROOT table are given in Appendix A.

LINE_EXPOSURE_DURATION
: Per-frame exposure duration in units of milliseconds.

SAMPLING_FACTOR
: MARCI can do pixel averaging in the instrument before transmission. For MARCI, this value must be 1, 2, 4, 8, or 12. For UV images this field will always be 8.

SAMPLE_FIRST_PIXEL
: This is the first pixel column of the CCD recorded in the image, and thus implicitly specifies the off-nadir look angle. A value of 0 refers to the first pixel in the array.

FILTER_NAME
: A list describing which filter(s) were used to acquire this dataset, from the set "SHORT_UV", "LONG_UV", "BLUE", "GREEN", "ORANGE", "RED", and "NIR".

RATIONALE_DESC
: A text description of the scientific purpose for the acquisition of this image; e.g., "Monthly monitoring of aeolian features on summit of Pavonis Mons". For some specific images, this string will contain a description of the image as actually received; for routine mapping operations, it will more likely be the goal of the image as targeted (which may not be met if the image missed its target significantly, the atmosphere was cloudy, image parameters were set inappropriately, etc.)

DATA_QUALITY_DESC
: This field will be set to "OK" if all fragments of the image are received without detected checksum or sequence errors, and "ERROR" otherwise.

ORBIT_NUMBER
: The orbit number from the start of the mapping phase as defined by the MRO Project.

The following describe keywords found internal to the IMAGE object.

LINES
: Number of lines in the decompressed image.

LINE_SAMPLES
: Number of samples per line in the decompressed image. For UV images this value will always be 128.

LINE_PREFIX_BYTES
: Number of bytes of prefix information per line. This field is always 0 for MARCI products.

LINE_SUFFIX_BYTES
: Number of bytes of suffix information per line. This field is always 0 for MARCI products.

SAMPLE_TYPE
: Type of each sample; for MARCI, always UNSIGNED_INTEGER.

SAMPLE_BITS
: Number of bits for each sample; for MARCI, always 8.

SAMPLE_BIT_MASK
: Bit mask description for each sample; for MARCI, always 2#11111111#.

CHECKSUM
: This is a checksum for the entire data part of this image, to be used for data validation.

4.3.1. Header/Trailer Description Details

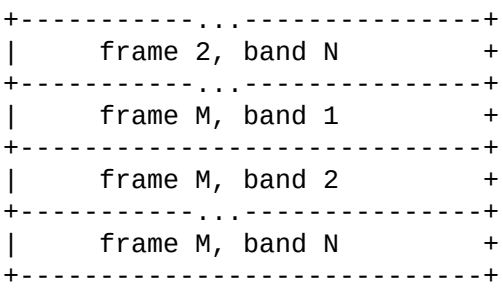
See above. No trailers are present.

4.3.2. Data Description Details

4.3.2.1. Filter order

Each MARCI frame acquired has 16/summing factor lines of image data per selected filter (band) for visible images and 2 lines of image per selected filter for UV images. The image defined by this document has been reordered as follows:

```
+----------------------------+
|     frame 1, band 1        +
+----------------------------+
|     frame 1, band 2        +
+-----------...--------------+
|     frame 1, band N        +
+----------------------------+
|     frame 2, band 1        +
+----------------------------+
|     frame 2, band 2        +
```



To create an image with data from only a single visible (or UV) band, simply extract from each frame in the data product the 16/summing factor (or 2) lines of the desired band.

4.3.2.2. Geometry

Note that MARCI images are acquired and compressed in row-major order by increasing time. The arrangement of the CCD and optics in MARCI somewhat complicates the mapping of pixel to surface feature. Suppose an image acquired while the spacecraft was moving north to south was displayed in left-to-right, top-to-bottom order on a monitor. The MARCI image would then have east at the left.

It is suggested that ancillary products be used to systematically display images in north-up, west-left form. The decompression tool does not perform this transformation.

4.3.3. Data loss considerations

MRO can use a version of the CFDP protocol to retransmit portions of data products that are dropped during initial transmission. This capability may not be employed at all times, however, and so it is possible that some MARCI images will be affected by data loss.

A typical data loss is that of one or two packets, due to uncorrectable bit errors caused by noise in the space-to-Earth communications path (rare), momentary loss of receiver lock caused by a transition between the one-way and two-way tracking modes, or loss in the Earth segment of the Deep Space Network.

For compressed images, a packet loss leads to loss of 'line sync' in the image. We expect the majority of MARCI images to be acquired using the lossless predictive compression mode of MARCI. When a packet is lost from this compressed data stream, the decompression algorithm aligns itself to the next line by searching for the line counter and applying statistical testing to distinguish a valid line counter from a data pattern that coincidentally resembles a line counter. The effect of decompressing the data between the site of packet loss and the next valid line is the loss of one or more partial lines of data, which are zero-filled by the decompression software.

A second type of loss is that of tens or hundreds of packets caused by bad weather, hardware failure, or operator error at the DSN stations, or miscommanding of the telemetry playback on the spacecraft. For these errors in a compressed data stream, many lines of the image are lost, making it impossible to recover even the original downtrack size of the image.

The MARCI ground software that produces the archival data may perform some limited correction of these errors. Correct and complete reconstruction should only be expected if there are no detected checksum errors or sequence gaps in the data; i.e., if the DATA_QUALITY_DESC field is "OK".

5. Appendix -- MARCI square root companding table

8-bit sqroot value	11-bit linear value
0	0
1	1
2	2
3	3

4	3
5	4
6	5
7	5
8	6
9	7
10	8
11	9
12	10
13	11
14	13
15	14
16	15
17	17
18	18
19	20
20	21
21	23
22	25
23	26
24	28
25	30
26	32
27	34
28	36
29	38
30	40
31	43
32	45
33	47
34	50
35	52
36	55
37	57
38	60
39	63
40	65
41	68
42	71
43	74
44	77
45	80
46	83
47	86
48	90
49	93
50	96
51	100
52	103
53	107
54	110
55	114
56	118

57	121
58	125
59	129
60	133
61	137
62	141
63	145
64	150
65	154
66	158
67	163
68	167
69	171
70	176
71	181
72	185
73	190
74	195
75	200
76	205
77	210
78	215
79	220
80	225
81	230
82	235
83	241
84	246
85	251
86	257
87	262
88	268
89	274
90	279
91	285
92	291
93	297
94	303
95	309
96	315
97	321
98	328
99	334
100	340
101	346
102	353
103	359
104	366
105	373
106	379
107	386
108	393
109	400

110	407
111	414
112	421
113	428
114	435
115	442
116	449
117	457
118	464
119	472
120	479
121	487
122	494
123	502
124	510
125	518
126	526
127	534
128	542
129	550
130	558
131	566
132	574
133	582
134	591
135	599
136	608
137	616
138	625
139	633
140	642
141	651
142	660
143	669
144	678
145	687
146	696
147	705
148	714
149	723
150	732
151	742
152	751
153	761
154	770
155	780
156	789
157	799
158	809
159	819
160	829
161	839
162	849

163	859
164	869
165	879
166	889
167	900
168	910
169	920
170	931
171	941
172	952
173	963
174	973
175	984
176	995
177	1006
178	1017
179	1028
180	1039
181	1050
182	1061
183	1073
184	1084
185	1095
186	1107
187	1118
188	1130
189	1142
190	1153
191	1165
192	1177
193	1189
194	1201
195	1212
196	1225
197	1237
198	1249
199	1261
200	1273
201	1286
202	1298
203	1310
204	1323
205	1336
206	1348
207	1361
208	1374
209	1386
210	1399
211	1412
212	1425
213	1438
214	1451
215	1464

216	1478
217	1491
218	1504
219	1518
220	1531
221	1545
222	1558
223	1572
224	1586
225	1599
226	1613
227	1627
228	1641
229	1655
230	1669
231	1683
232	1697
233	1712
234	1726
235	1740
236	1755
237	1769
238	1784
239	1798
240	1813
241	1828
242	1842
243	1857
244	1872
245	1887
246	1902
247	1917
248	1932
249	1947
250	1963
251	1978
252	1993
253	2009
254	2024
255	2040