Mars Reconnaissance Orbiter

Software Interface Specification
Context Camera (CTX)
Standard Data Product

M. Caplinger
Malin Space Science Systems, Inc.

Approved by:

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M. Malin, President

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L. Gaddis, PDS Imaging Node Manager

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E. Grayzeck, PDS Program Manager

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1. Introduction

1.1. Purpose

This document describes the format of the Mars Reconnaissance Orbiter Context Camera (CTX) 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.

1.4. Functional Description

1.4.1. Data Content Summary

Each CTX Standard Data Product is a single image in the raw image format as produced by the instrument. The data have been depacketized, decompressed, and reformatted with standard labels, but are otherwise unprocessed. 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

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

CTX 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, LINE_EXPOSURE_DURATION).

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

CTX is expected to return approximately 3.5 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 CTX 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 CTX 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. It is 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. Every effort will be made to insure that this ancillary information will be conveniently accessible to users of CTX products (for example, it may be included on the same CDROM volumes as the data products themselves.) Examples of ancillary files are calibration files, viewing geometry files (e.g., SPICE kernels), image index tables, etc.

2. Environment

2.1. Instrument Overview

CTX is a linescan camera with a 5000-element linear CCD (Kodak KLI-5001G) with 7x7 micron pixels. The CTX telescope is a 350 mm f/3.25 catadioptric with two front and two rear correcting elements. Its field of view is about 5.7 degrees, covering a 30-km swath from 300 km altitude at a resolution of 6 meters/pixel. Its mechanical structure is a composite configuration in which the metering structure is graphite/cyanate-ester (GR/CE), the primary mirror is Zerodur, and the elements are mounted in Invar and titanium cells.

The dual CCD outputs are amplified about 4x and then digitized by two Analog Devices AD1672 analog-to-digital converters. All control logic is implemented in a single Actel RT54SX32-SU Field-Programmable Gate Array (FPGA). The instrument uses synchronous DRAMs for image storage. The CTX configuration uses eight devices of 32Mx8 organization, for a total capacity of 256 MB (268,435,456 bytes.) A small SRAM is used to perform 12-to-8 bit companding in the FPGA.

The instrument design has been optimized to take a single image, up to the size of the buffer, and transfer it to the spacecraft solid-state recorder memory via the serial interface. At 10 Mbit/s effective throughput, this process takes about 4 minutes.

The system has an adjustable black level digital-to-analog converter (DAC) and the exposure time per line can vary between 1.27 msec and 132.3 msec in increments of 32.0 usec. Optional 2x2 summing can be commanded. Both lossless and lossy image data compression can be applied by software running in the spacecraft computer.

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 CTX 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-CTX-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 CTX data product files. For mapping-phase images, the ID will be of the form PPP_NNNNNN_TTTT_"X"X_AAHBBB"W", where PPP is a mission phase descriptor, NNNNNN is the orbit number, TTTT is a representation of center latitude (in units of 0.1 degree), X is the command mode ("I" for ITL- or "N" for NIFL-commanded images), AA is the planned center latitude of the image, H is "N" for north or "S" for south, and BBB is the planned center (west) longitude of the image. Case is not significant; under the Unix operating system, the names will be considered to be in all lower-case.

TTTT is measured from the descending equator crossing of orbit NNNNNN: 0 degrees is the descending equator crossing; 90 is the south pole; 180 is ascending equator crossing; and 270 is the north pole.

4.2. Structure and Organization Overview

All CTX 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 CTX data product consists of one image with decompression applied. In the event of data loss caused by packets dropped in the space-to-earth link or in the ground segment of the DSN, a standard first-order correction algorithm has been applied. Selected CTX images may have had additional corrections applied; this archive represents the best available reconstruction at the time of archive production.

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	"CONTEXT CAMERA"
INSTRUMENT_HOST_NAME	"MARS RECONNAISSANCE ORBITER"
MISSION_PHASE_NAME	PSP
TARGET_NAME	MARS
INSTRUMENT_ID	CTX
PRODUCER_ID	MRO_CTX_TEAM
DATA_SET_ID	"MRO-M-CTX-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"
FOCAL_PLANE_TEMPERATURE	ff.fff
SAMPLE_BIT_MODE_ID	"mode-id"
OFFSET_MODE_ID	"offset-id"
LINE_EXPOSURE_DURATION	ff.fffff
SAMPLING_FACTOR	ff.f

SAMPLE_FIRST_PIXEL	nnnn
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. For these products, the same as the LINE_SAMPLES field of the IMAGE object.

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

SPACECRAFT_NAME
: Always MARS_RECONNAISSANCE_ORBITER.

INSTRUMENT_NAME
: Always "CONTEXT CAMERA".

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 CTX.

PRODUCER_ID
: Always MRO_CTX_TEAM.

DATA_SET_ID
: MRO-M-CTX-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 CTX 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_04_1009013100".

PRODUCT_ID
: This uniquely identifies this CTX product among all CTX products. The CTX product ID format is PPP_NNNNNN_TTTT_"X"X_AAHBBB"W", where PPP is a string describing the mission subphase, NNNNNN is the orbit number, TTTT is a representation of center latitude (in units of 0.1 degree), X is the command mode ("I" for ITL or "N" for NIFL), AA is the planned center latitude of the image, H is "N" for north or "S" for south, and BBB is the planned center (west) longitude of the image; e.g., "P01_001330_1221_XN_57S223W". There are two ways to command CTX images: by the Interactive Target List (ITL) mechanism, and by Non-Interactive File Load (NIFL). The image numbers between ITL images and NIFL images may be disjoint, and the mission subphase used for ITLs will be the same as the corresponding mission subphase for NIFLs. For cruise phase (CRU) images, NNNNNN is a sequential image number.

START_TIME
: SCET (UTC) time at start of image acquisition, as commanded.

STOP_TIME
: SCET (UTC) time at end of image acquisition, as commanded.

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 CTX image, once started, is independent of the spacecraft clock.

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
: CTX 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.

OFFSET_MODE_ID
: The CTX offset setting in the form coarse-offset/fine-offset-chan1/fine-offset-chan2 (e.g., "200/58/67")

LINE_EXPOSURE_DURATION
: Per-line exposure duration in units of milliseconds. The time at which a given line was acquired can be determined by multiplying the line exposure time by the number of previous lines and adding it to the image start time. Note that CTX implements downtrack summing by increasing the line time; for example, a 2X2 summed image has an actual line time twice that given by this field.

SAMPLING_FACTOR
: CTX can do pixel averaging in the instrument before transmission. For CTX, this value must be 1

(no summing) or 2 (2x summing).

SAMPLE_FIRST_PIXEL
: This is the first pixel 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.

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 were 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 image.

LINE_SAMPLES
: Number of samples per line in the image. (Each line in the file must have the same number of samples.)

LINE_PREFIX_BYTES
: Number of bytes of prefix information per line. This field is always 0 for CTX products. The number of prefix pixels depends on SAMPLING_FACTOR and SAMPLE_FIRST_PIXEL: 38 prefix pixels when SAMPLING_FACTOR is 1 and SAMPLE_FIRST_PIXEL is 0; 16 when SAMPLING_FACTOR is 1 and SAMPLE_FIRST_PIXEL is not 0; 19 when SAMPLING_FACTOR is 2 and SAMPLE_FIRST_PIXEL is 0; and 8 when SAMPLING_FACTOR is 2 and SAMPLE_FIRST_PIXEL is not 0.

LINE_SUFFIX_BYTES
: Number of bytes of suffix information per line. This field is always 0 for CTX products. The number of suffix pixels depends on SAMPLING_FACTOR and SAMPLE_FIRST_PIXEL: 18 suffix pixels when SAMPLING_FACTOR is 1 and SAMPLE_FIRST_PIXEL is 0; 9 when SAMPLING_FACTOR is 2 and SAMPLE_FIRST_PIXEL is 0; and 0 when SAMPLE_FIRST_PIXEL is not 0.

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

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

SAMPLE_BIT_MASK
: Bit mask description for each sample; for CTX, 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. Geometry

Note that CTX images are acquired and compressed in row-major order by increasing time. The arrangement of the CCD and optics in the CTX 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 CTX 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. These products have not been transformed in this manner.

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 CTX 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 CTX images to be acquired using the lossless predictive compression mode of CTX. 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 CTX 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 -- CTX square root companding table

8-bit sqroot value	11-bit linear value
0	1
1	3
2	5
3	7
4	9
5	11
6	13
7	15
8	17
9	20
10	22
11	24
12	27
13	29
14	32
15	35

16	38
17	41
18	44
19	47
20	50
21	54
22	58
23	61
24	65
25	69
26	73
27	77
28	82
29	86
30	91
31	95
32	100
33	105
34	110
35	115
36	121
37	126
38	131
39	137
40	143
41	149
42	155
43	161
44	167
45	173
46	179
47	186
48	193
49	199
50	206
51	213
52	220
53	228
54	235
55	243
56	250
57	258
58	266
59	274
60	282
61	290
62	298
63	306
64	315
65	324
66	332
67	341
68	350

69	359
70	369
71	378
72	387
73	397
74	407
75	416
76	426
77	436
78	446
79	457
80	467
81	478
82	488
83	499
84	510
85	521
86	532
87	543
88	554
89	566
90	577
91	589
92	601
93	613
94	625
95	637
96	649
97	662
98	674
99	687
100	699
101	712
102	725
103	738
104	751
105	765
106	778
107	792
108	805
109	819
110	833
111	847
112	861
113	875
114	890
115	904
116	919
117	933
118	948
119	963
120	978
121	993

122	1009
123	1024
124	1039
125	1055
126	1071
127	1087
128	1103
129	1119
130	1135
131	1151
132	1168
133	1184
134	1201
135	1218
136	1235
137	1252
138	1269
139	1286
140	1304
141	1321
142	1339
143	1356
144	1374
145	1392
146	1410
147	1429
148	1447
149	1465
150	1484
151	1502
152	1521
153	1540
154	1559
155	1578
156	1598
157	1617
158	1636
159	1656
160	1676
161	1696
162	1715
163	1736
164	1756
165	1776
166	1796
167	1817
168	1838
169	1858
170	1879
171	1900
172	1921
173	1943
174	1964

175	1985
176	2007
177	2029
178	2050
179	2072
180	2094
181	2117
182	2139
183	2161
184	2184
185	2206
186	2229
187	2252
188	2275
189	2298
190	2321
191	2345
192	2368
193	2392
194	2415
195	2439
196	2463
197	2487
198	2511
199	2535
200	2560
201	2584
202	2609
203	2634
204	2658
205	2683
206	2709
207	2734
208	2759
209	2784
210	2810
211	2836
212	2861
213	2887
214	2913
215	2939
216	2966
217	2992
218	3019
219	3045
220	3072
221	3099
222	3126
223	3153
224	3180
225	3207
226	3235
227	3262

228	3290
229	3317
230	3345
231	3373
232	3401
233	3430
234	3458
235	3486
236	3515
237	3544
238	3573
239	3601
240	3630
241	3660
242	3689
243	3718
244	3748
245	3777
246	3807
247	3837
248	3867
249	3897
250	3927
251	3958
252	3988
253	4019
254	4049
255	4080

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