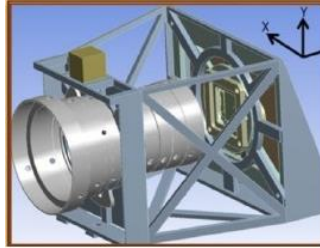


MARS ORBITER MISSION



Mars Colour Camera (MCC)



Experimenter to Archive Interface Control Document [EAICD]

ISRO Science Data Archive

	Name	Date	Signature
Prepared by:	Ajay Kumar Prashar S. Manthira Moorthi Sampa Roy		
Reviewed by:	A.S. Arya (PI)		



**MARS ORBITER
MISSION (MOM)**
MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 2

Document Change History

*A: Addition; M: Modification; D: Deletion

Version No.	Date	Section No.	A/M/D*	Description of Change
V1.0	June 15,2013	All	A	Initial version
	Aug,2015	ALL	A	Updated version
	Mar,2016	ALL	A	Updated version



Contents

GLOSSARY.....	8
1 Introduction.....	9
1.1 Purpose and Scope.....	9
1.2 Contents.....	9
1.3 Intended Readership.....	9
1.4 Applicable Documents	9
1.5 Acronyms and abbreviations	10
1.6 Contact names and addresses.....	11
2 Overview of Instrument Design, Data Handling Process and Product Generation.....	12
2.1 Instrument Overview.....	12
2.2 Data Handling Process	16
2.3 Overview of Process and Data Product Generation	20
2.3.1 Pre-Flight Data Products.....	20
2.3.2 Instrument Calibrations.....	20
2.3.3 Calibration.....	20
2.3.4 In Cruise Data Product.....	26
2.3.5 In Orbit Data Product	26
2.3.6 Level 2 Data Products.....	26
2.3.7 Level 3 Data Products.....	27
2.3.8 Data Processing Software.....	27
2.4 Documentation.....	28
2.4.1 Derived & Other Data Products	28
2.4.2 Ancillary Data Usage.....	28
3 Archive Format and Content	29
3.1 Format and Conventions	29
3.1.1 Deliveries and Archive Volume Format.....	29



3.1.2 Data Set ID Formation	29
3.1.3 Data Directory Naming Convention	31
3.1.4 File Naming Convention	31
4 Standards Used in Data Product Generation.....	34
4.1 PDS Standards	34
4.2 Time Standards	34
4.3 Reference Systems	34
4.4 Imaging Model.....	34
4.5 Coordinate Systems	34
4.5.1 Inertial coordinate system.....	35
4.5.2 Areographic coordinates	35
4.5.3 Mars Centered Inertial coordinate system.....	35
4.5.4 Mars Body-Fixed Reference System	36
4.5.5 Mars Topo centric Coordinate Frame	36
4.5.6 Orbital Coordinate system:	37
4.5.7 Body Coordinate system:	38
4.5.8 Payload Coordinate System (PCS):	38
4.5.9 Image Plane coordinate system (image space):	38
4.5.10 Estimation of ground coordinates from image coordinates	38
4.5.11 Mars Rotation Computation	39
4.6 Geometric foot print	39
4.7 Other Applicable Standards	40
4.8 Data Validation approach	40
5 PDS content for Long Term Archive.....	41
5.1 Volume Set:	41
5.2 Data Set	41
5.2.1 Data Coverages in multiple Imaging seasons	41
5.2.2 Directories	42
5.2.3 Root Directory Contents.....	42



**MARS ORBITER
MISSION (MOM)**
MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 5

5.2.3.1 Catalog Directory Contents	43
5.2.3.2 Index Directory Contents	44
5.2.3.3 Browse Directory Contents	44
5.2.3.4 Geometry Directory Contents	44
5.2.3.5 Software Directory Contents	44
5.2.3.6 Document Directory Contents	45
5.2.3.7 Extras Directory Contents	45
5.2.3.8 Data Directory Contents	45
5.3 Structure and Organization Overview	46
5.4 Data Product and Label Design.....	46
APPENDIX I: SAMPLE PDS LABEL FOR EDR IMAGE DATA PRODUCT.....	54
APPENDIX II: SAMPLE PDS LABEL FOR RDR IMAGE DATA PRODUCT.....	59
APPENDIX III: SAMPLE PDS LABEL FOR RDR BROWSE DATA PRODUCT.....	64
Table 14 Sample PDS Label for Grid data.....	68
APPENDIX IV: SAMPLE PDS LABEL FOR RDR GRID DATA PRODUCT	68



List of Tables & Figures

Table 1 MCC Specifications	13
Table 2 Data Processing Level definitions of MOM	17
Table 3 Comparison of levels between CODMAC, NASA and ISRO.....	18
Table 4 Mapping between ISRO Level and CODMAC Level	19
Table 5 Volume ID's, Names and Data Set ID's	29
Table 6 DataSetID Formation	30
Table 7 Data Set ID and Data Set Name	31
Table 8 File Naming Convention	32
Table 9 MCC Standard PDS Data Products	33
Table 10 Data Product Design	47
Table 11 Sample PDS Label for EDR Image Data	54
Table 12 Sample PDS Label for RDR Image Data	59
Table 13 Sample PDS Label for Browse data.....	64
Table 14 Sample PDS Label for Grid data.....	68



Figure 1 : Mars Colour Camera: design and realized Camera system	12
Figure 2: Schematic of MCC Imaging Chain.....	13
Figure 3: RGB Bayer Pattern.....	14
Figure 4: Data Processing Schema operational at ISSDC	17
Figure 5: MCC mean count versus radiance plots.....	21
Figure 6: Pixel count versus mean count plot for 0.133 ms integration time	22
Figure 7: Percentage Non linearity profile for RED Channel counts	22
Figure 8: Normalized Spectral Response In Band for Green	23
Figure 9: Spectral response for green band log normalised	24
Figure 10: Relative spectral responses for red , green and blue bands.....	24
Figure 11: Data Product Generation Software	27
Figure 12: EME2000 Inertial Reference Frame.....	35
Figure 13: Mars Body-Fixed Reference System	36
Figure 14: Mars Local Level Coordinate Frame	37
Figure 15: Mars Coverages obtained by MCC in moderate resolutions.....	41
Figure 16: Mars Coverages obtained by MCC in full disc snaps	41
Figure 17: Mars polar Coverages obtained by MCC full disk coverages.....	Error! Bookmark not defined.
Figure 18: PDS Directory Structure.....	42
Figure 19: EDR Data Product Structure.....	46
Figure 20: RDR Data Product Structure	47



GLOSSARY

Archive – An archive consists of one or more data sets along with all 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 media on which data products are stored; for example, one CD-ROM or DVD-ROM. An archive volume is a volume containing all or part of an archive; that is, 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.

Catalog Information – Descriptive information about a data set (e.g. mission description, spacecraft description, instrument description), expressed in Object Description Language (ODL) which is suitable for loading into a PDS catalog.

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.



1 Introduction

1.1 Purpose and Scope

The purpose of this EAICD (Experimenter to Archive Interface Control Document) is manifold. First it provides users of the MCC (Mars Colour Camera) instrument data obtained from Mars Orbiter mission with a detailed description of the products and a description of how it is generated, including data sources and destinations. As such, it is also a requirements document to the Ground Support Software, which has to generate the data files in the format described herein.

Indian Space Science Data Center (ISSDC) will be the custodian of all the science data obtained from Mars Orbiter Mission. Different correction levels of instrument data will be archived at ISSDC. Secondly, this document is the official interface the MCC instrument team and the ISRO science data archive (ISDA) hosted by ISSDC.

1.2 Contents

This document describes the data flow of the MCC instrument on Mars Orbiter Mission from the S/C until insertion into the ISDA. It includes information on how data were processed, formatted, labelled and uniquely identified. The document discusses general naming schemes for data volumes, data sets, data and label files. Standards used to generate the product are explained. The design of the data set structure and the data product is given following the planetary data standards initiated by NASA known as Planetary Data System (PDS), generally adopted standard worldwide.

1.3 Intended Readership

The staff of archiving authority (ISDA), the s/w design team and any science user of the MCC data.

1.4 Applicable Documents

	Name	Reference
AD1	Planetary Data System Preparation Workbook Part 1	JPL-D-7669/3.1, 01 Feb 1995
AD2	Planetary Data System Standards Reference	JPL D-7669, Part 2 February 27, 2009 Version 3.8
AD3	MOM Archive Plan	MOM-DAP-SAC-01



AD4	MOM Archive Conventions	MOM-SAC-PDS-02
-----	-------------------------	----------------

Reference documents

NIL

1.5 Acronyms and abbreviations

AD	Applicable Document
MOM	Mars Orbiter Mission
ISDA	ISRO Science Data Archive
MCC	Mars Colour Camera
TIS	Thermal-Infrared Imaging Spectrometer
MSM	Methane Sensor for Mars
LAP	Lyman Alpha Photometer
MENCA	Methane Exosphere Neutral Composition Analyzer
EBP	Earth Bound Phase
CEM	Cruise Enroute Mars
MOI	Mars Orbit Insertion
MOP	Mars Orbital Phase
EAICD	Experimenter to Archive Interface Control Document
EDR	Experimental Data Record
IDSN	Indian Deep Space Network
ISAC	ISRO Satellite Centre
ISRO	Indian Space Research Organisation
ISSDC	Indian Space Science Data Centre
JPEG	Joint Photographic Experts Groups



**MARS ORBITER
MISSION (MOM)**
MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 11

JPL	Jet Propulsion Laboratory
LTC	Light Transfer Characteristics
N/A	Not Applicable
PDS	Planetary Data System (a standard to archive data)
POC	Payload Operations Centre
PSA	Planetary Science data Archive
PVT	PDS Verifier Tool
QLD	Quick Look Display
RDR	Reduced Data Record
SAC	Space Applications Centre
SCC	Space Control configuration
SIPA	Signal and Image Processing Area
SPICE	Space craft Planet Instrument Camera Events
TBC	To be Confirmed
TBD	To Be Decided
UNK	Unknown
UTC	Universal Coordinated Time

1.6 Contact names and email addresses

1	Dr. A.S. Arya	-Principal Investigator for MCC	arya_as@sac.isro.gov.in
2	Shri. S.S.Sarkar	-Instrument Scientist MCC	sssarkar@sac.isro.gov.in
3	Shri. S. Manthira Moorthi Shri Ajay Kumar Prashar Shri Indranil Misra	Data Products - PDS Long Term Archive	smmoorthi@sac.isro.gov.in ajay_prashar@sac.isro.gov.in indranil@sac.isro.gov.in

2 Overview of Instrument Design, Data Handling Process and Product Generation

2.1 Instrument Overview

Mars Colour Camera (MCC) is one of the payloads flown on the Mars Orbiter Mission. It is a medium resolution RGB frame camera which captures image of the topography of Martian surface. It is also expected to give high quality visual images of mars, its moons, and other celestial bodies.

MCC acquires images in the snap-shot mode with an IGFOV of 20m at 500 km altitude, having a frame size of ~ 40km x 40km from periareion and covers the full Martian disc from apoareion using an area array detector having 2048 x 2048 elements on a pixel pitch of 5.5 μ with RGB Bayer pattern. In order to cater to the above requirements MCC requires a f/4 optical system with a focal length of 105mm and a circular field of view of $\pm 4.4^\circ$, operating in the visible spectral range from 0.4 to 0.7 μ m.

The highly elliptical orbit chosen for the mars mission allows imaging of localized scenes at high spatial resolution as well as provides a synoptic view of the full globe. The MCC instrument shown in the below figure

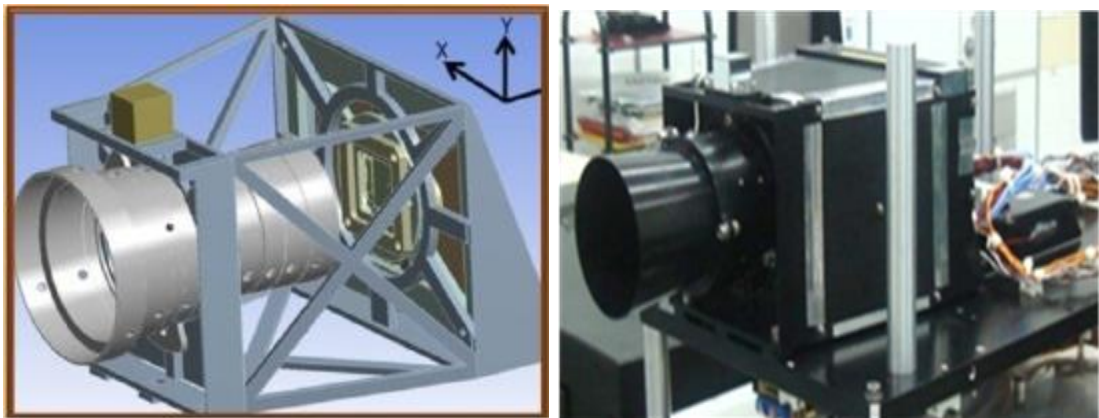


Figure 1 : Mars Colour Camera: design and realized Camera system

MCC has following Scientific Objectives:-

- To image the topography of Martian surface
- To provide context information for observations from other instruments
- To map Martian polar ice caps and its seasonal variations
- To observe and study events like dust storms, dust devils etc.
- To image moons of Mars, asteroids and other celestial bodies from close quarters

MCC uses a multi-element lens assembly and a 2K×2K area array detector with RGB Bayer pattern to take images. The f/4 lens has a focal length of 105mm with a circularly symmetric field of view of $\pm 4.4^\circ$. The detector has 2048 x 2048 elements on a pixel pitch of 5.5 μ . The sensor is driven by a custom-built electronics designed around the proposed detector. The schematic of MCC imaging chain is shown in figure 1.

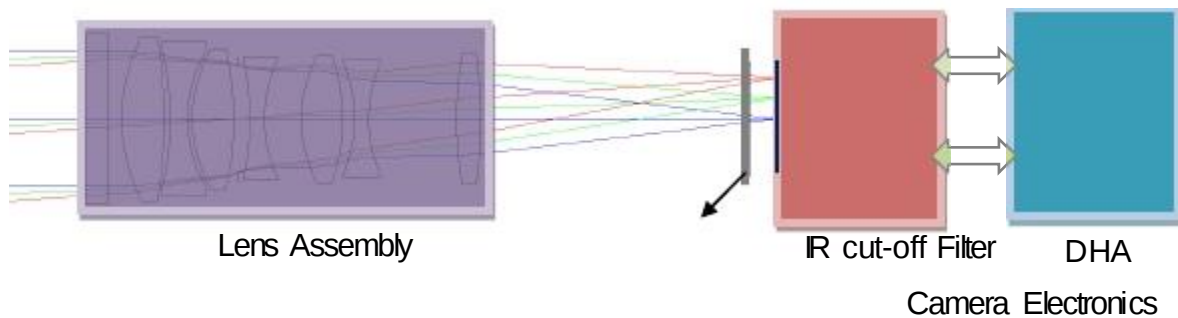


Figure 2: Schematic of MCC Imaging Chain

Camera electronics generates bias for detector, clock generation, data reprocessing and generation of biases from raw bus.

The raw data volume is 40Mb/Frame (2048 x 2048 x 10 bits) from which colour image will be generated at ground using standard demosaicing. The final demosaicked image size is 8 MB (2048 x 2048 x 2 bytes). MCC hardware is realized with light-weight miniaturized components.

The MCC instrument specifications are given in Table 1.

Table 1 MCC Specifications

MCC Specifications	
S/C Altitude planned	372km x 80,000km
IGFOV	19 m (Alt : 372 Km @ Periareion) 4 Km (Alt : 80000 Km)
Frame Size (km)	40 x 40 @ Periareion (Alt : 372 Km @ Periareion)
Full Disc	Alt : 70000 Km
Integration time (ms)	0.133 to 0.4 ms for Mars imaging at 100% albedo
Imaging Unit	2K×2K area array detector (RGB Bayer pattern)
Quantization (Bits)	10
SNR @ 3.5mW/cm ² -st- μ m	> 50
Data volume per frame (Mb)	40
Data Rate	52.5 Mbps
Operating Temperature	20±10 °C

The Mars Colour Camera has a simple and compact design which aids in keeping the camera weight low while meeting the functional requirements. Generation of colour image from a remote sensing camera typically involves obtaining separate monochrome images in the three primary colours blue (B), green (G) and red (R) and then combining them to get the colour image. This calls for either three separate imaging chains or common optics with either filter wheel for colour selection or spectral splitting/selection mechanism. These methods, however add to the overall size and weight of the camera. MCC makes use of a RGB Bayer pattern (Figure below)

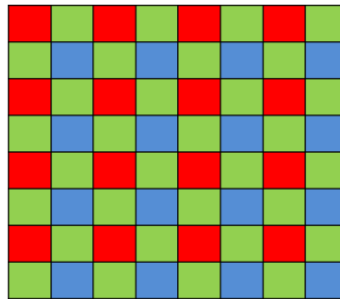


Figure 3: RGB Bayer Pattern

In the focal plane with organic R, G or B filter deposited on each pixel to generate colour images. Thus a single imaging chain comprising a multi-element lens assembly with a 2K x 2K area array in its focal plane serves the purpose.

In MCC development, a commercial NIKOR lens with suitable optical parameters has been selected as collecting optics. This lens was customized through in-house development to bring down its weight and size to suit the payload physical parameters and performance requirements of MCC flight model. An IR cut-off filter is also placed in front of the detector to achieve good colour separation.

The detector used in MCC is CMV4000 – a high resolution, high speed snapshot colour CMOS image sensor. As mentioned earlier, each of the 2K x 2K pixels in the area array has an R, G or B organic filter deposited on top of it. The incoming light is filtered out at pixel level to acquire information in one band (either R or G or B). Data in other two bands is estimated by interpolating information from surrounding pixels. This approach lends simplicity to the overall system design.

Sensor has multiple operating modes of operation and these modes can be activated by programming appropriate registers of the sensor through SPI interface. Various modes of sensor operations are listed below:-

- Exposure mode: Desired exposure can be programmed by writing appropriate values in internal registers of the sensor via SPI interface or by commanding T_EXP1 and Frame_Req control input pins of the sensor. Required mode of operation is selectable



through SPI. Frame Req decides starting of exposure in internal exposure mode (via SPI) whereas T_Exp1 decides start of exposure when integration time is driven by control inputs of the sensor.

- Interleaved Readout: In this mode odd and even rows can have different integration time
- Multi-linear response: Pixel response to the light through piece wise linear response
- Multi-frame readout: Different frames are readout with increasing exposure

Subsequently, photo generated electrons are converted to voltage using pixel level charge to voltage amplifiers. These signals are digitized at column level Analog to Digital Converters (ADCs) using row and column level multiplexers and decoders . Like the optics, the detector underwent the entire process of ruggedization and qualification for development of flight model. Detector head assembly incorporated necessary electrical, mechanical and thermal interfaces. Figure-6 shows a photograph of the actual realized FM detector head assembly.

The design and development of Camera Electronics (CE) was based on the system and detector requirements of sixteen programmable exposure controls, high speed detector operation (52.5 MHz) and low noise detector bias generation ($<1\text{mV}$) while taking into account the requirements of miniaturization (low weight ($\sim 0.4\text{kg}$) and raw power ($\sim 3\text{W}$)) and usage of available space grade components to meet the realization schedule in the shortest possible time. The miniaturization and performance requirements of Camera electronics was met by selecting state of the art space grade components, Field Programmable Gate Array (FPGA) for logic implementation, Low Drop Out (LDO) voltage regulators, compact hybrid DC-DC modules, integrating electronics functions near to focal plane, usage of Micro-D connectors, Multi-Layer PCBs etc. The CE consisted of three major functional blocks - the Detector Proximity Electronics (DPE) which generates the necessary low noise bias voltages and clock signals for the detector, the Logic and Control Electronics (LCE) which generates the required clocks for detector operation, interfaces with the Base-band Data Handling (BDH) and Tele-command (TC) of space-craft (S/C) bus etc. and the Power Supply Electronics (PSE) which takes the raw power from the S/C and provides low noise ($<5\text{mV}$ PARD) regulated power lines to the payload. The CE incorporated exposure control logic to facilitate matching detector dynamic range with intended scene dynamic range.

The Electro Optic Module (EOM) structure was designed and analyzed with the objective of keeping the packages and the overall payload light weight and compact while ensuring adequate structural stiffness, electrical shielding and thermal stability to withstand the specified environmental loads and meet the performance requirements. The EOM structure is designed to take the environmental loads like dynamic vibration, shock and temperature excursions during the orbiting period. The structure has been optimized for thermo-structural stability (20g RMS for structural and -400C to 600C for thermal) for minimum deformation (change of distance between lens mounting plane and DHA mounting plane) of the order of $20\text{ }\mu\text{m}$. The structure is machined



from Al.Alloy 6061-T6 solid block into a ultra light weight structure (mass less than 200 grams) with alignment accuracy better than 10 microns (parallelism between lens and detector mounting planes and perpendicularity of these planes with respect to structure base).

2.2 Data Handling Process

The ground segment for MOM comprises four major elements, namely Deep Space Network (DSN), Spacecraft Control Center (SCC), Indian Space Science Data Center (ISSDC) and Payload Operations Centre (POC). The ground segment is responsible for making the data available for the scientists along with auxiliary information, in addition to storage of payload, spacecraft data and product to identified users. Science and housekeeping telemetry arrives at the ISSDC in form of telemetry packets. Within the ISSDC the raw science data is transformed into Level-0 data product that is uncalibrated in Planetary Data Standards (PDS) compatible files. Spacecraft transmits data both primary (instrument data) and auxiliary (house keeping data) in a manner through onboard hardware and received using identified specialized ground systems known as Payload Data Acquisition System (PACQ) as shown in Fig-4. If the primary data or science data is compressed onboard for reducing data rates, will be decompressed in ground processing. Both primary and ancillary data is placed to the storage identified at data archive centre ISSDC.

Data processing system processes instrument data for edited and calibrated, derives meta data about mission events, spacecraft operations, instrument operations, processing parameters, orbit and housekeeping details from ancillary data to generate data products following PDS standards. Data Processing system also produces “Active Archive” for raw and calibrated data for instruments mentioned above, is minimum PDS compliant which will be accessed by instrument specific Principal Investigator (PI) community; this archive will reside at ISSDC as well as payload operations centres. The onboard data handling system handles all five payload data and auxiliary data. Quick Look Display (QLD) uses packet data to provide a quick display of data as a first quality check (Fig.4). First processing step for MARS mission captures all packet processing requirements of payload data and auxiliary data and transfers decompressed, formatted, time tagged payload data with OAT and HK information to next level processing steps involving radiometric processing, geometry tagging and PDS conversion.

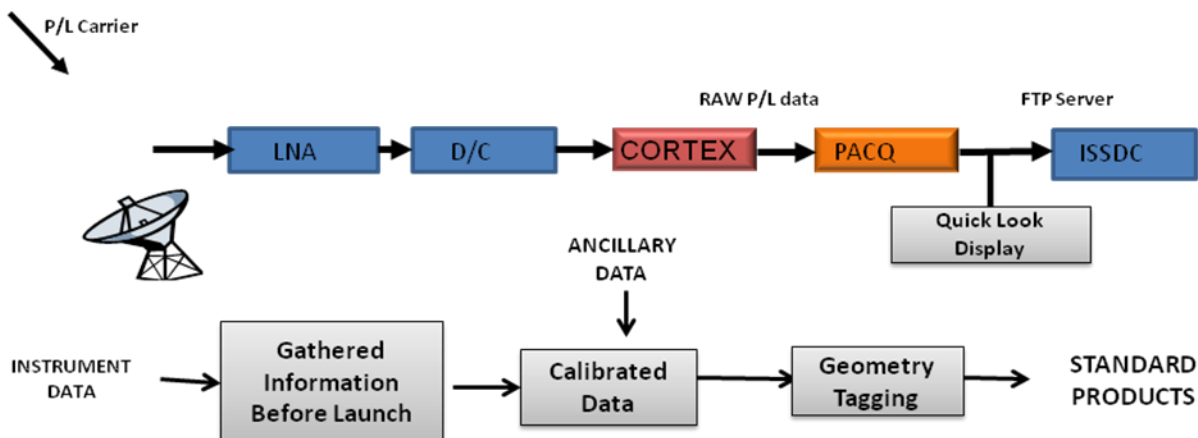


Figure 4: Data Processing Schema operational at ISSDC

The following Table 2 gives the data Processing Level definitions of MOM.

Table 2 Data Processing Level definitions of MOM

Description	Definition
Level-0	Raw payload data along with the ancillary information, which includes ephemeris and attitude. This level of processing includes data qualification, (byte alignment, data decompression, band separated, if required) and time tagging. Also the data is given along with the calibration information.
Level-1	Calibrated/ corrected and geometrically mapped. (For imaging sensor like MCC or TIS, the processing includes detector response normalization; framing, line/pixel loss correction and tagging the aerographic coordinate to each pixel.



For the description corresponding to the different type of data and the corresponding data processing CODMAC (Committee on Data Management and Computation) levels see Appendix C: Processing Levels (PDS Processing Levels) and AD1. The comparison of levels between CODMAC, NASA and ISRO is given in table below

Table 3 Comparison of levels between CODMAC, NASA and ISRO

Type	Description	ISRO Level	CODMAC Level	Data set type ID
Raw Data	Telemetry data with data embedded.	----	1	UDR
Edited Data	Corrected for telemetry errors and split or decommutated into a data set for a given instrument. Sometimes called Experimental Data Record. Data are also tagged with time and location of acquisition.	0	2	EDR
Calibrated Data	Edited data that Are still in units produced by instrument, but that have been corrected so that values are expressed in or are proportional to some physical unit such as radiance. No resampling,	1/1b	3	RDR

The above descriptions in table 3 can be mapped to CODMAC standard levels practiced in “Planetary Data System”.



The table 4 shows the mapping between ISRO levels and CODMAC levels.

Table 4 Mapping between ISRO Level and CODMAC Level

Type	Description	Teams	CODMAC Level	Data set type ID
Raw Data	Telemetry data with data embedded.		1	UDR
Edited Data (Level-0)	Corrected for telemetry errors and split or decommutated into a data set for a given instrument. Sometimes called Experimental Data Record. Data are also tagged with time and location of acquisition.	ISAC processor + SAC DP Elements	2	EDR
Calibrated Data (Level-1)	Edited data that are still in units produced by instrument, but that have been corrected so that values are expressed in or are proportional to some physical unit such as radiance. No resampling, so edited data can be reconstructed.	SAC DP Elements	3	RDR



2.3 Overview of Process and Data Product Generation

2.3.1 Pre-Flight Data Products

No pre-Flight data products are planned at present.

2.3.2 Instrument Calibrations

MCC calibration details are given in the following sections.

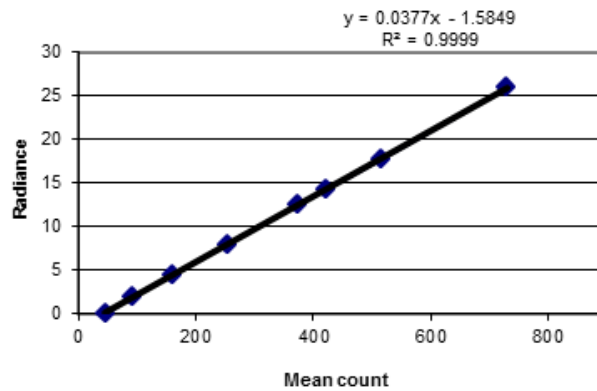
2.3.3 Calibration

Light Transfer Characteristics (LTC) of MCC-FM is carried out using an integrating sphere. The main objective of radiometric calibration is to determine transfer function to convert payload output into absolute physical quantity (radiance) of each pixel. Using it appropriate exposure setting for imaging of Mars planet can be determined. The procedure involved measurement of MCC output for Red, Green and Blue pixels at various illumination levels using the integrating sphere. From the measured data, saturation radiances for various integration times were computed.

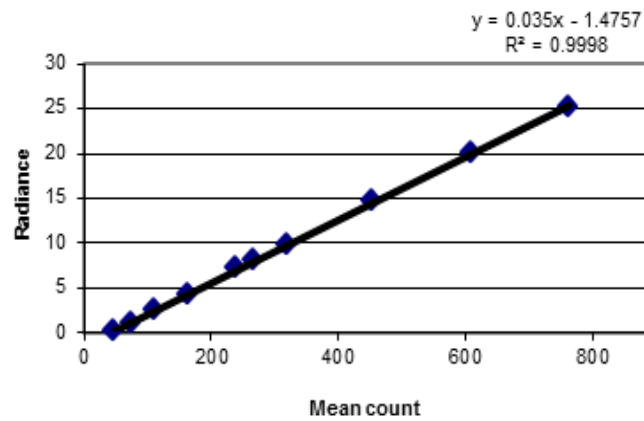
Details on MCC calibration exercises

MCC has 6 spherical lens elements and a thermal filter at its front end with a sharp cut off beyond 730nm. LTC were measured and modeled with 6 different integration times (34 μ s, 66 μ s, 133 μ s, 200 μ s and 400 μ s) and ten different radiance levels to cover entire dynamic range of the sensor. Dark currents were measured to offset the LTC measurements and a linear response trend is maintained from 0 to 800 counts in a 10 bit radiometric quantization for the multispectral data. Spectral calibration was carried out for 300 nm to 1100 nm range. Also thermovac tests were carried to measure sensitivity related to temperature variations. Spectral response measurements were characterized separately for red, green and blue bands. The out of band response was kept less than 0.5 %. Predominantly MCC data acquisitions over Mars are obtained using the integration time 400 μ s for 100% albedo of Mars against the minimum exposure setting of 133 μ s derived using frame over head time in which the photon generated charges from photo diodes are transferred and stored in pixel level registers.

MCC FM mode 13(0.133ms) red pixel



MCC FM mode 13(0.133ms) green pixel



MCC FM mode 13(0.133ms) blue pixel

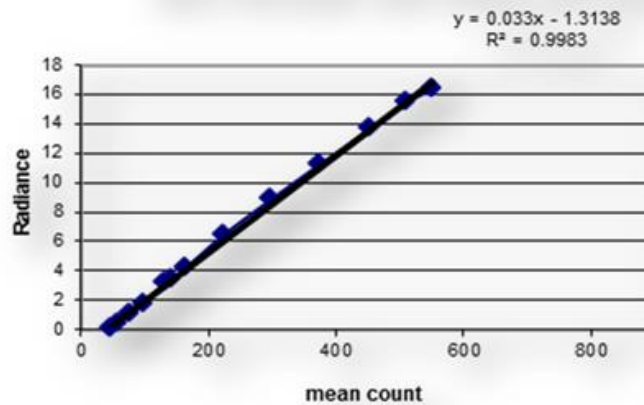


Figure 5: MCC mean count versus radiance plots

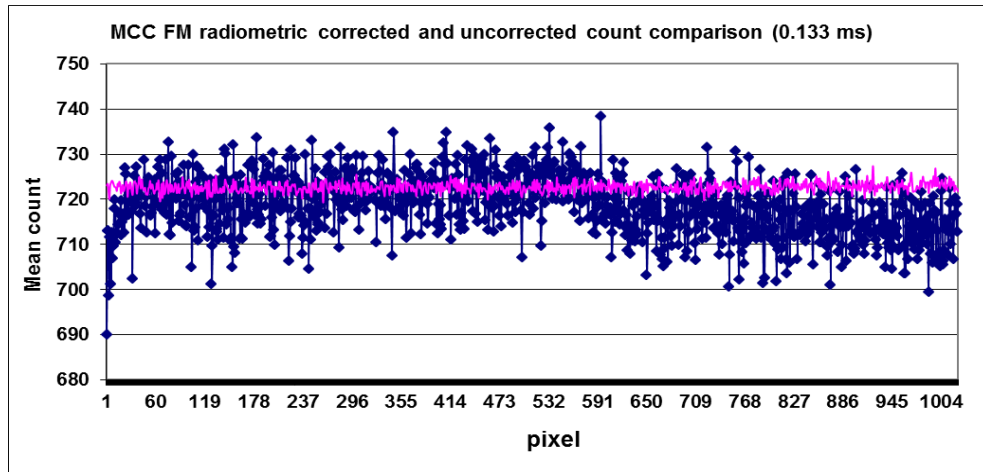


Figure 6: Pixel count versus mean count plot for 0.133 ms integration time

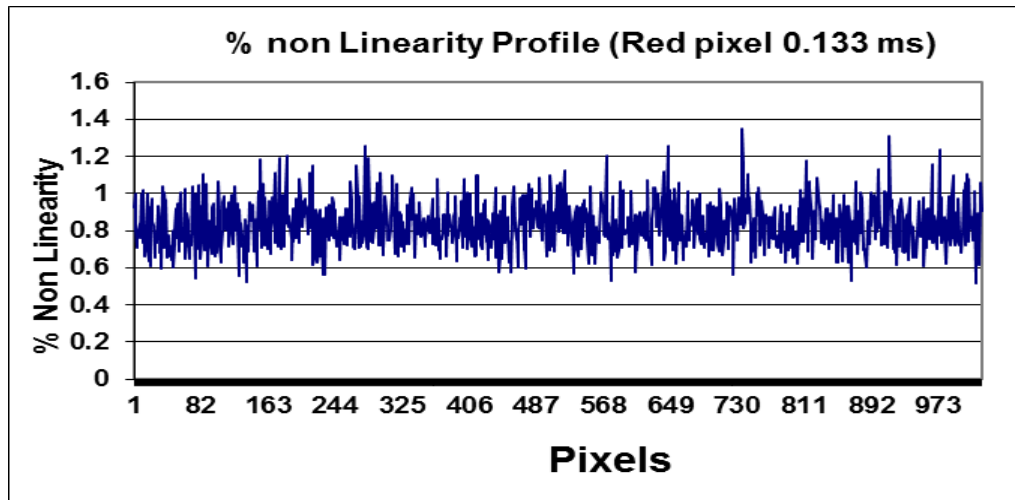


Figure 7: Percentage Non linearity profile for RED Channel counts

Table- 3: saturation radiance for MCC

Integration time (ms)	Saturation Radiance (mw/cm ² -sr-um)		
	Red	Green	Blue
0.4 (mode 3)	8.9	9.5	10.2
0.2 (mode 5)	19.3	18.2	18.8
0.133 (mode 13)	30.4	28.3	26.7
0.074 (mode 12)	53.3	50.6	48.9
0.066 (mode 15)	56.1	56.4	60.0
0.034 (mode 14)	110.7	110.2	116.2

Fig-5,6,7,8,&9 are meant to portray the performance parameters of MCC instrument. Table-5 gives all saturation radiance levels for MCC instrument. Radiance versus count plot shows a linear trend. The mean count trend shows stability. Fig-8 & 9 are spectral responses from MCC in the green band. Fig-10 show the relative spectral response for red, green and blue bands.

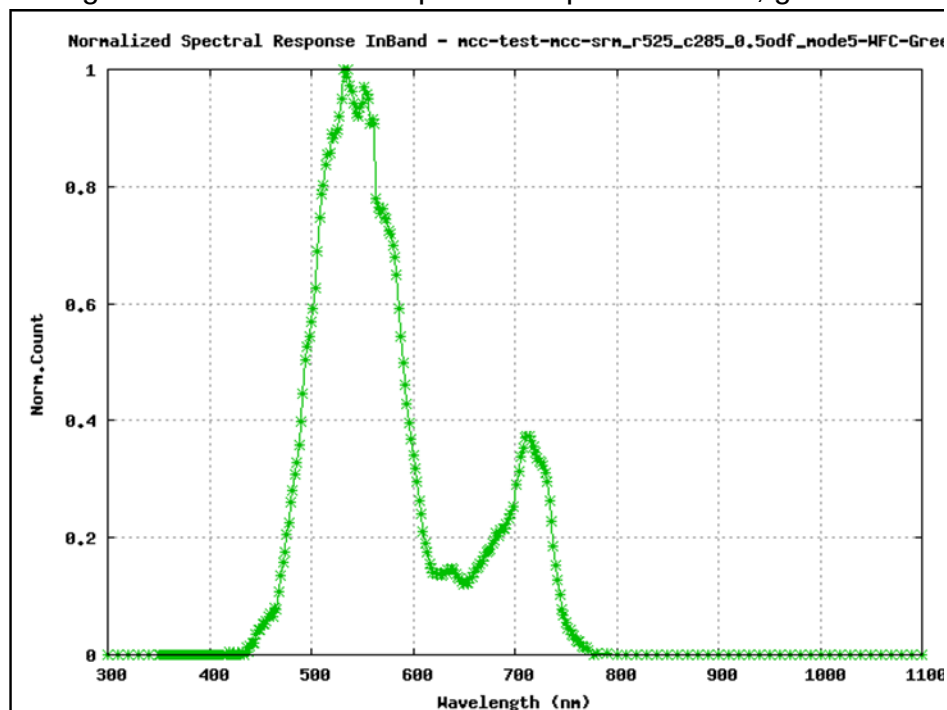


Figure 8: Normalized Spectral Response In Band for Green

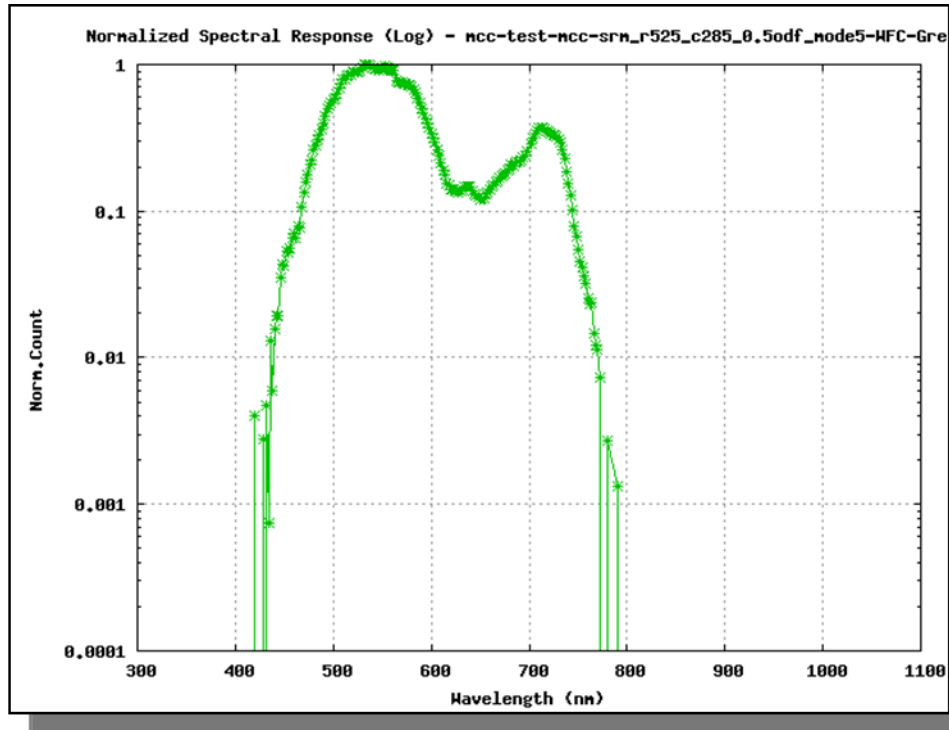


Figure 9: Spectral response for green band log normalised

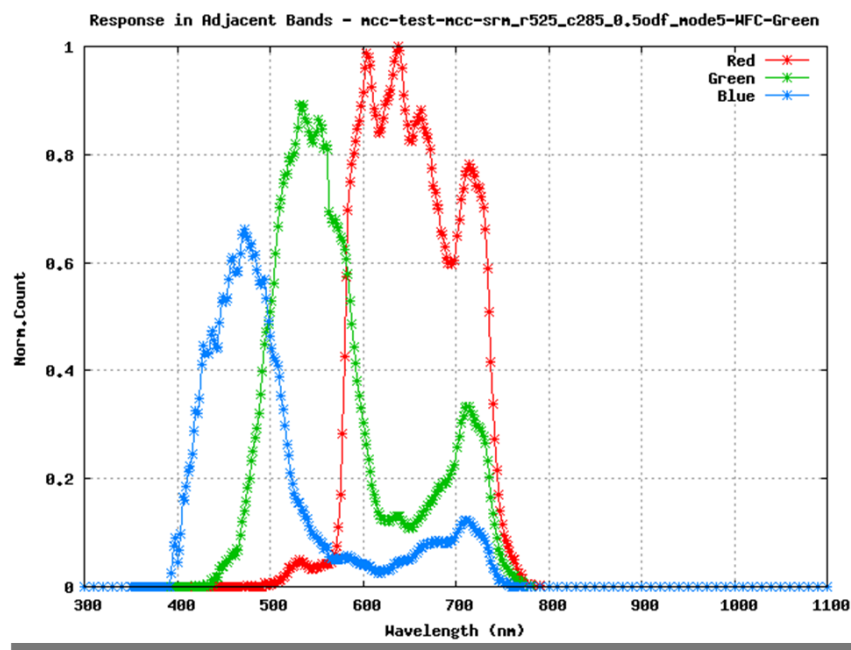


Figure 10: Relative spectral responses for red , green and blue bands



Calibration Summary

- Lens Assembly – with six spherical lens elements and a thermal filter at its front-end
- IR cut-off filter - with a sharp cut-off beyond 730nm in front of the area array detector
- Detector cover window – made of D263 glass with T>92% (300-1100nm), having thickness of 0.55mm and at a distance of 1.6mm from detector array
- LTC measurements carried out for six different integration times (34, 66,74,133,200 and 400 microseconds)
- More than 10 GTR levels generated for each configuration to cover payload full dynamic range.
- Dark data recorded for each configuration during LTC
- Spectral calibration carried out for full spectral range(300 to 1100 nm)
- During Thermovac test dark and fixed illumination data acquired at different temperatures (5 deg to 35 deg) to characterize payload performance dependency on temperature
- Radiometric calibration of MCC-FM had been done in 6 different configurations and SR is computed separately for red, green and blue pixels.
- For 100% albedo illumination at Mars, mode13(0.133ms) is optimum and for earth mode 12 (0.072 ms) is optimum
- Spectral Response Measurement (SRM) of MCC had been done at five locations (4 corner +centre) and observed central wavelength is similar in all five locations.
- Relative Spectral Response is computed for red, green and blue pixels separately.
- Out of Band response is <0.5% (when in-band is considered up to 1% response point)



2.3.4 In Cruise Data Product

During the cruise period (Heliocentric Phase) , MCC was stitched on many a times to monitor the sensor performance and taking dark sky object images to assess the dark current estimates and compare the performance to the lab. calibration results.

2.3.5 In Orbit Data Product

The data products provided includes observations made during the “Mars Orbital Phase” (MOP) phase of the mission.

The data products are of two types (referred collectively as the MCC-EDR and MCC-RDR data products) that includes raw and calibrated images as IMAGES in visible region. Both the types of data products which is PDS formatted are explained in detail below sub-section. MCC images are regularly obtained from the day of insertion into mars orbit, 24th Sep, 2014. During the initial phase operation, MOM was imaging mars mainly from apogee orbital locations due to the favourable illumination conditions and hence you will many full mars disc images from this duration compared to the low altitude images. Comet siding spring encounter with mars was around mid of October, 2014, and MOM had to be manoeuvred to reduce its orbital sweep to come safe orbital geometry mainly due to the apprehension that, comet dust could endanger the spacecraft. During the period 18th October,2014 to 21st, October,2014 many data sets were obtained to take pictures of comet siding spring. And MOM again started a phase of taking snaps over mars surface.

Solar illumination conditions were favourable now along the perigee orbital locations, more low altitude pictures were obtained compared to September, October, November coverages which were mainly global snap shots. Moderate to better scale images were continuously obtained till April, 2015 before the blackout period approached. The imaging restarted on 14th July, 2015, and it was confirmed that, MCC pictures were as thrilling as obtained before black out period. The MCC Mars coverages are shown in section 5.2.1.

2.3.6 Level 2 Data Products

The Level 2 data products are raw data that have been unpacked from the telemetry packets, time tagged, converted to engineering units and output in an easily readable form together with the necessary labels and auxiliary information.

RGB data is generated using bilinear interpolation in ground data processing chain. This procedure is known as demosaicking. There are many such demosaicking schemes, which can be experimented on the RAW data. Bilinear demosaicking scheme is chosen for data product and archival purposes due to its simplicity and consistency.

2.3.7 Level 3 Data Products

The Level 3 data products are calibrated, radio metrically corrected, geometrically and time tagged processed data converted to engineering units and output in an easily readable form together with the necessary labels and auxiliary information. Geometrically corrected products are generated while there are no cold space data in the frame.

2.3.8 Data Processing Software

MOM Data Product Generation System (MOM-DPGS) is developed by Data Processing Team at SAC, ISRO, Ahmedabad (fig-1). The MOM-DPGS contains collection of software packages includes following software packages:

- Scheduler
- Level-0 Data Product (DP) Chain for MCC, TIS and MSM instruments.
- Level-1 Data Product (DP) Chain for MCC, TIS and MSM instruments.
- PDS Archive Pipeline

MOMDPGS will take the instrument wise Level-0 tar files (output from ISAC Level0 chain) as input, generate Level-0 & Level-1 data. The PDS Archive pipeline will create final PDS data sets. MOMDPGS is operational and maintained at ISSDC, Bangalore.

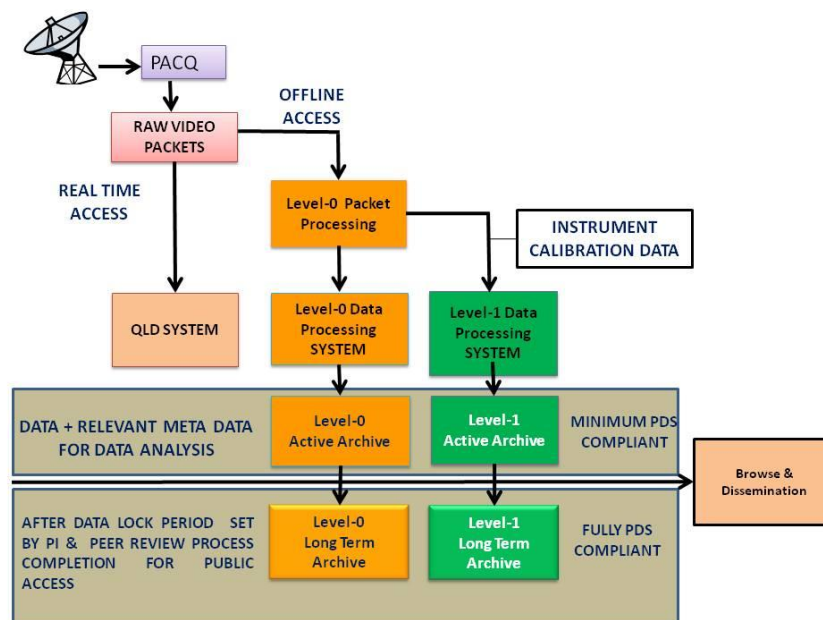


Figure 11:Data Product Generation Software



2.4 Documentation

All the documents including the EAICD and the related MCC documents are kept in a directory namely DOCUMENT in the archive volumes.

2.4.1 Derived & Other Data Products

Using the geometric foot print computations, the MCC Level-1 data can be warped to Mars areographic map at a particular scale, of course with only system level accuracy which can vary from 3-50 km accuracy. Using reference data sets available from other international missions to Mars, for e.g MDIM-2.1 (Mars Digital Image Mosaic version 2.1) the location accuracy of the MCC product can be improved. This can be achieved by automatic means by collecting reference features from both MDIM and MCC, matching for correspondences and registering them together.

2.4.2 Ancillary Data Usage

The ancillary information is important for the studies using the science data of MCC experiment as it gives information on where in space and time the spacecraft is located. The ancillary information includes Sun parameter (SPM), Orbit & Attitude (OAT), browse and geometry.



3 Archive Format and Content

3.1 Format and Conventions

3.1.1 Deliveries and Archive Volume Format

The initial delivery shall consist of PDS level2 and level3 data. During the “Mars Orbital Phase” mission phase, the PDS level2/3 data sets for MCC to be delivered to ISDA.

One archive volume is produced for each level of PDS data set and contains single data set covering MOP phase observations. Each data set consist mainly science observations.

The archive volumes have the following naming convention:

MR1MCC_<sequence identifier YYXX> where <sequence identifier YYXX> = the first digits (YY) represent volume set, the remaining digits (XX) represent the volume number in the set.

Table 5 Volume ID's, Names and Data Set ID's

Volume Name	Volume ID	Data Set ID
VOLUME 1 MARS ORBITER MISSION MCC MOP EDR DATA	MR1MCC_1001	MR1ORB-M-MCC-2-MOP-EDR- RAW-V1.0
VOLUME 2 MARS ORBITER MISSION MCC MOP RDR DATA	MR1MCC_1002	MR1ORB-M-MCC-3-MOP-RDR- RAD-V1.0

3.1.2 Data Set ID Formation

As explained in the previous section, two data sets will be made available to the ISDA archive at ISSDC. The first data set will contain MCC level 2 data from the Mars orbital phase (MOP). The second dataset will contain MCC level 3 data Mars orbital phase (MOP). Each PDS data set must have a unique identifier. PDS data set identifiers and names conform to the following format:

DATA_SET_ID = “<INSTRUMENT_HOST_ID>-<TARGET_ID>-<INSTRUMENT_ID>-<data processing level number>-<mission phase abbreviation>-<data set type>-<description>-<version>”



Table 6 DataSetID Formation

<INSTRUMENT_HOST_ID>	MR1ORB this is fixed, and is the instrument host ID for Mars Orbiter Mission
<TARGET_ID>	It can have any one of the following values: = M (refers to the target Mars) = E (refers to the target Earth) = D (refers to the target DEIMOS) = P (refers to the target PHOBOS) = X (refers to the target Dark Sky) = A (refers to the target Asteroids)
<INSTRUMENT_ID>	MCC this is fixed and identifies the instrument as MCC (Mars Colour Camera)
<data processing level number>	It can have any one of the following values (refers column CODMAC Level in table 4): = 2 (refers to standard CODMAC Level2) = 3 (refers to standard CODMAC Level3)
<mission phase abbreviation>	It can have any one of the following values (refers to the MISSION_PHASE_NAME under MOM Archive Conventions) = EBP (refers to the Earth Bound Phase) = CEM (refer to the CRUISE ENROUTE MARS) = MOP (refer to the MARS ORBITAL PHASE)
<data set type>	It can have any one of the following values (refers to the data set type ID column in table 4) = EDR (refers to the Experiment Data Record) = RDR (refers to the Reduced Data Record)
<description>	It is optional. But it can have any one of the following values = RAW (refers to the raw data) = RAD (refers to the calibrated data)
<version>	V1.0 this is fixed and identifies the version number.



When all the things put together Data Set ID value is shown in below table.

Table 7 Data Set ID and Data Set Name

Data Set ID	Data Set Name
MR1ORB-M-MCC-2-MOP-EDR-RAW-V1.0	MR1 ORBITER MARS MCC 2 MOP EDR RAW V1.0
MR1ORB-M-MCC-3-MOP-RDR-RAD-V1.0	MR1 ORBITER MARS MCC 3 MOP RDR RAD V1.0

3.1.3 Data Directory Naming Convention

Inside the DATA directory, the data products are organized into year month wise subdirectories. The following data directory structure will be used to archive the science data from the instrument.

DATA
|
|--YYYYMM

Where,

DATA is the data directory

YYYY denotes year

MM denotes the month

3.1.4 File Naming Convention

PDS data product files conform to the following convention:

MCC_MTC_TTTTTTTTTTTTTTTTTT_P_STN.FFF



Table 8 File Naming Convention

MCC	It denotes the instrument name refers to “Mars Colour Camera”)
M	It denotes the mission phase name, it can have following value = E (refers to the EBP - EARTH BOUND PHASE) = C (refers to the CEM - CRUISE ENROUTE MARS) = M (refers to the MOP - MARS ORBITAL PHASE)
T	It denotes the data type, it can have following values: = E (it denotes an Experiment Data Record (EDR) as defined in the PDS standard (AD2). It will be used for raw data coming from the instrument) = R (It denotes the Reduced Data Record (RDR) as defined in the PDS standard (AD2))
C	It denotes the imaging mode/camera_id. It can be one of the following: = B (It denotes the Bayer Pattern Raw Digital Data) = D (It denotes the Demosaicked Radiance Data) = C (it denotes the Demosaicked Count Data) = R (it denotes Reformatted Data)
TTTTTT TTTTTT TTTT	It denotes the observation/imaging start time in format [YYYYMMDDHHMMSSsss] TTTT = stand for year in YYYY format TT = stand for month in MM format TT = stand for day in DD format TT = stand for hour in HH format TT = stand for minute in MM format TT = stand for seconds in SS format TTT = stand for millisecond in sss format
P	It denotes the PDS Data Products categories. It value can be any of the following: = D (It denotes data products under DATA directory)



	= B (it denotes browse data products under BROWSE directory) = G (it denotes gridded data products under GEOMETRY directory)
STN	It denotes the station id from which data was acquired. It value can be any of the following: = D32 (ISSDC Bangalore) = D18 (ISSDC Bangalore) = GDS (Gold Stone USA) = CNB (Canberra, Australia)
FFF	It denotes the standard file type extension. It can have any one of the following values: = IMG (PDS Image Data File) = LBL (PDS Detached Label File) = PNG (PDS Browse Data File) = DAT (PDS Geometry Data File)

All underscore characters '_' are mandatory and separate the different fields.

For example sample standard MCC PDS Data Products derived from file naming conventions are given in the table below

Table 9 MCC Standard PDS Data Products

Level-2 EDR Image Data Product (Image Data + Detached PDS Label)	MCC_MEB_20141113T165305278_D_D32.IMG MCC_MEB_20141113T165305278_D_D32.LBL
Level-3 RDR Image Data Product (Image Data including radiance and count data + Detached PDS Label Products)	MCC_MRD_20141113T165305278_D_D32.IMG MCC_MRD_20141113T165305278_D_D32.LBL MCC_MRC_20141113T165305278_D_D32.IMG MCC_MRC_20141113T165305278_D_D32.LBL
Level-3 RDR Browse Image Data Product (Browse image data + Detached PDS Label File)	MCC_MRD_20141113T165305278_B_D32.JPG MCC_MRD_20141113T165305278_B_D32.LBL
Level-3 RDR Geometry Data Product (grid data + Detached PDS Label File)	MCC_MRD_20141113T165305278_G_D32.TAB MCC_MRD_20141113T165305278_G_D32.LBL



4 Standards Used in Data Product Generation

4.1 PDS Standards

MCC-EDR and MCC-RDR data products comply with Planetary Data System standards for file formats and labels, as specified in the PDS Standards Reference [AD2].

4.2 Time Standards

The CCSDS time standards as described in the PDS standards are used. All time values in the PDS labels shall be given in Coordinated Universal Time (UTC). The time in UTC shall be represented in ISO calendar format standard: yyyy-mm ddThh: mm: ss.ss e.g. "2006-08-14T15:02:10.12".

4.3 Reference Systems

The geometric foot prints provided along for every detector response are given in Mars planetographic coordinate system, practised world over.

4.4 Imaging Model

A major task in correction of imagery is to establish a relation between images and object space (mars surface). A series of coordinate transformations are established to derive view direction and look point set in a simple pin hole geometry in push broom, frame view or just a detector foot print calculation.

4.5 Coordinate Systems

In order to establish a precise relation between any two coordinate systems, it is first necessary to consider and list all the coordinate systems in use.

4.5.1 Inertial coordinate system

The J2000 Inertial Reference Frame is a right-handed Cartesian set of 3 orthogonal axes chosen as follows: (Fig-12)

+Z_{J2000} is normal to the Earth's mean equator of epoch 2000

+X_{J2000} is parallel to the vernal equinox of Earth's mean orbit of epoch 2000

+Y_{J2000} completes the right-handed system

The epoch J2000 is the Julian Ephemeris Date (JED) 2451545.0. These axes are depicted in Figure 5-1. These vectors are used as the basis for expressing the positions and velocities of objects in space, such as stars, planets, satellites, asteroids, comets, and spacecraft.

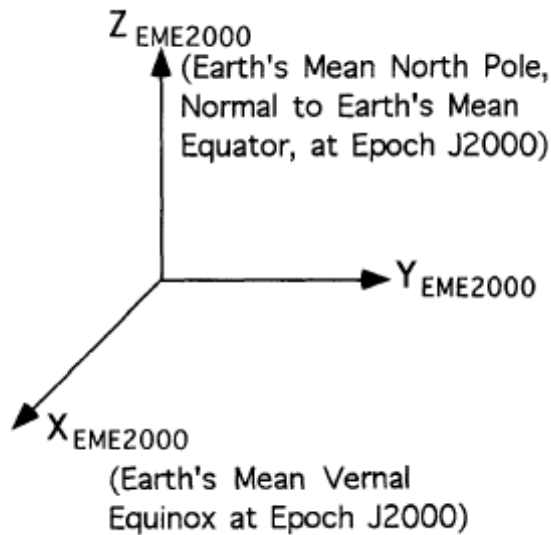


Figure 12: EME2000 Inertial Reference Frame

4.5.2 Areographic coordinates

Once the spacecraft nears the vicinity of Mars, it makes the most sense to utilize Mars centered coordinate systems. These are systems that are centered at the center of the planet itself, neither at the Mars system barycenter nor at a point on its surface.

4.5.3 Mars Centered Inertial coordinate system

One inertial coordinate system is defined by simply attaching the origin of the EME2000 frame defined in section 5.3.3 to the center of Mars. This system is called Mars-centered Earth Mean Equator and Equinox of epoch J2000.

4.5.4 Mars Body-Fixed Reference System

This system is designed by the International Astronomical Union/International Association of Geodesy (IAU/IAG) Working Group. The Mars body fixed reference axes have their origin at the Mars center-of-mass and are aligned with the spin axis and prime meridian. This frame can be described as the following:

+X_{MBF} = Vector lies in the Mars equatorial plane and intersects the prime meridian.

+Y_{MBF} = Vector lies in the Mars equatorial plane and completes a right handed Coordinate system.

+Z_{MBF} = Mars spin axis, pointing toward Martian North Pole.

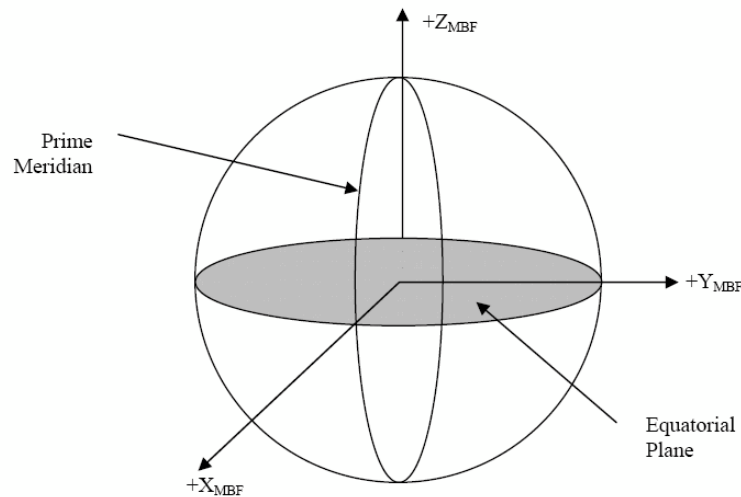


Figure 13: Mars Body-Fixed Reference System

The Mars body-fixed reference system is mainly used for mapping ground features observed from orbiting spacecraft.

4.5.5 Mars Topo centric Coordinate Frame

This coordinate frame is right handed, orthogonal, and defined by axes X_M, Y_M, and Z_M.

+X_M axis is along the local north direction (north)

+Y_M axis completes the right hand frame (east)

+Z_M axis is along the downward normal at the landing site (nadir)

Any position on the Mars surface in the Mars Local Level Coordinate Frame can be calculated by using the following formula provided that the latitude and longitude values of the point are known.

$$X_M = r \cdot \cos(\varphi) \cos(\lambda)$$

$$Y_M = r \cdot \cos(\varphi) \sin(\lambda)$$

$$Z_M = r \cdot \sin(\varphi)$$

Where;

r = planet radius

$-90 < \text{latitude}(\varphi) < 90$ deg (positive in northern hemisphere)

λ = Longitude $0 < \lambda < 360$ deg (positive east)

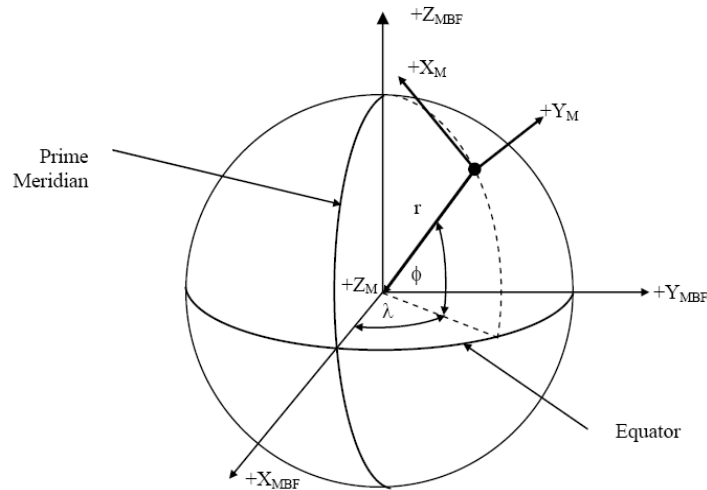


Figure 14: Mars Local Level Coordinate Frame

4.5.6 Orbital Coordinate system:

This is defined as follows. At any instant of time, spacecraft x-axis towards mars center(yaw), z is along -ve orbit normal perpendicular to x-axis in the orbital plane and the third one,y-axis is perpendicular to both x and z.

Yaw Axis = $-\vec{R}$ Along the radius vector of the spacecraft around the planet

Pitch Axis = $(-\vec{R} \times \vec{V})$ Along the detector array Length

Roll Axis = $(\vec{R} \times \vec{V}) \times \vec{R}$ Along the motion the spacecraft



4.5.7 Body Coordinate system:

Body coordinate system is nothing but orientation of orbital coordinate system for a given pitch, roll and yaw angles. This coincides with orbital coordinate system in the absence of roll, pitch and yaw angles (i.e. all of them are zero).

4.5.8 Payload Coordinate System (PCS):

This is the focal plane coordinate system where f (focal length) is in the direction of positive yaw x-direction, z is along the detector array and y is perpendicular to the array.

4.5.9 Image Plane coordinate system (image space):

This is a simple (sample, line) coordinate to locate a sample in the image.

4.5.10 Estimation of ground coordinates from image coordinates

For every (sample, line) image coordinate, the target planet (Mars in our case) imaged point planetographic coordinate can be computed using a series of coordinate transformations.

$$X_{MCF} = [T] X_{PCS}$$

Where,

X_{MCF} MARS ground point 3D Cartesian coordinate in Mars Centered fixed System

X_{PCS} Pixel onboard 3D Cartesian coordinate in PCS

T Transformation that takes any point in PCS to MCF through operations of many 3x3 matrices corresponding to the conversions listed below.

Following are the sequence of transformations, which are considered for computing the ground coordinates using image coordinates as the input

- a) Image coordinates to focal plane coordinates
- b) Focal Plane coordinates to Payload coordinate system
- c) Payload coordinates to Spacecraft coordinates using payload-MRC alignment angles
- d) Spacecraft coordinates to Orbital coordinates using s/c position and velocity vectors in J2000 frame (EME 2000)
- e) Orbital coordinates to Mars Centered Inertial coordinate system
- f) Mars Centered inertial to Mars Centered Mars Fixed coordinate system
- g) Mars Centered Mars Fixed coordinate system to Arieographic latitude and longitude coordinates.



4.5.11 Mars Rotation Computation

The difference between the Mars inertial reference system and the body fixed reference system is the “rotation,” or orientation, of Mars. According to the IAU/IAG Working Group, it is defined by specifying that the north pole of the rotation axis of the Mars body-fixed reference system points to right ascension (α) and declination (δ):

$$\alpha = 317.68143^\circ - 0.1061^\circ T \text{ and}$$

$$\delta = 52.88650^\circ - 0.0609^\circ T, \text{ of the ICRF,}$$

Where T is the interval in Julian centuries (of 36525 days)

from the standard epoch, i.e. J2000.0 = 2000 January 1.5 TDB.

The orientation of Mars on its axis is defined by:

$$W = W_0 + 350.89198226^\circ d, \text{ (with } W_0 \text{ is } 176.630^\circ)$$

Where W is the angle measured along the equator from the equator's intersection with the celestial equator to the Prime Meridian and d is the interval in days from the standard epoch.

The fixed term W_0 is 176.630° and was recently redetermined by comparing MOLA-derived coordinates and digital image models with Viking and Mars Orbiter Camera (MOC) images of the Airy-0 crater. This work was undertaken by the NASA Mars Geodesy and Cartography Working Group and is reported in . This new value was derived with an absolute accuracy of about ± 250 m and has been adopted by the IAU/IAG working group along with a new determination for Mars's spin rate, leading to the resulting equation for W. From radio tracking of the Viking and Mars Pathfinder landers, Mars is actually known to have slight variations in its orientation from these values. However, they have not yet been measured (or at least modeled) at a level accurate enough to allow for their prediction.

4.6 Geometric foot print

This establishes the mappings from locations on object space (mars surface or also called as output space) to locations in a satellite image (input image space) covering that area fully/partially and records these mappings in a grid file. This grid file is provided along with the data file for use at analyst's side. This grid file can also be used for transforming the image (resampling) to generate geometrically corrected data after employing a map projection transformation. It should be noted that corrected data space is defined in a specified map projection. It should be further noted that the mapping is done only at locations separated by pre-established horizontal/vertical grid interval.



The major inputs to geometric correction are scene/strip start time, CCD number, number of lines, mars shape and size parameters, s/c state vectors along with quaternions, payload & mission parameters. For Level-1 product, the

4.7 Other Applicable Standards

NONE

4.8 Data Validation approach

For the data validation, the PDS verification tool (PVV: NASA source) is used. Both the active archive content and long term archive PDS contents are validated against this document. However the active archive contents are validated only for image and associated label not for complete PDS compliance. Higher level data products are validated first by POC, SAC team and subsequently by ISSDC review process. The data pipeline explained here is also validated by the review process. The peer review shall be conducted by scientists knowledgeable in the area along with POC staff and PDS archive team.

Data Quality Evaluation (DQE) exercises helped in determining the geometric accuracy of the data products of different levels generated both from viewpoint of spacecraft platform and imaging payload sensor performances. DQE is carried out in two phases: Initial and Normal Phases. In the Initial phase, the DQE results provided quantitative results for the Mission to take necessary steps for orbit manoeuvring and Data Processing Software (DPS) to fine tune the algorithm parameters in order to meet the Mission and Data Products Specifications. In the Normal phase, the DQE operations are carried out throughout the mission life in order to verify if both the payload and platform performances are within the specifications and provide inputs if there are deviations or anomalies to the concerned design teams for improvement.

5 PDS content for Long Term Archive

5.1 Volume Set:

One data volume is planned to be one data set.

5.2 Data Set

The following sections bring out details on the data sets and their identification using keywords.

5.2.1 Data Coverages in multiple Imaging seasons

Data obtained from different orbits on different days are grouped under year-month folders in the archive. MCC images obtained in moderate resolutions and global snap shots are portrayed in the following figures 15 & 16.

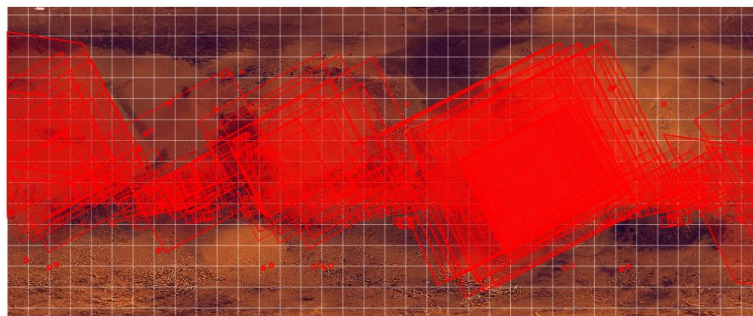


Figure 15: Mars Coverages obtained by MCC in moderate resolutions

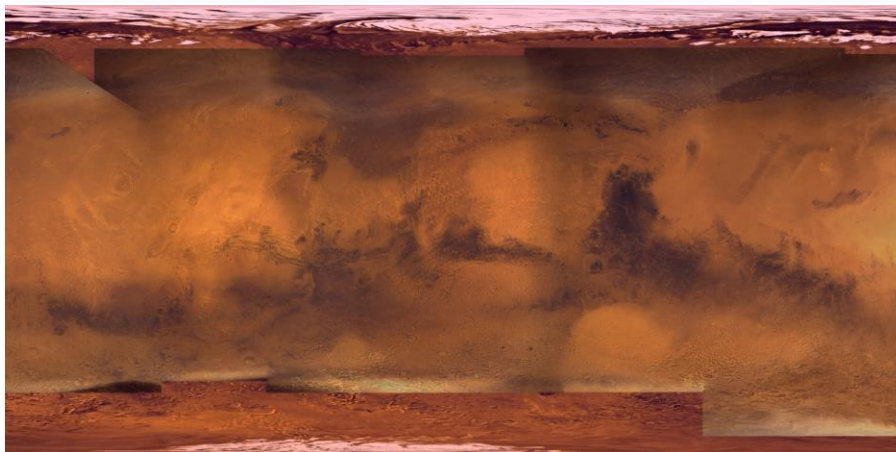


Figure 16: Mars Coverages obtained by MCC in full disc snaps

As the orbit has an inclination of ~ 150 deg, the entire planetosphere can't be covered by regular orbits and hence there will be gaps in the poles which may be covered by later acquisitions.

5.2.2 Directories

The following describe the contents of the sub-directories in the PDS volume according to the “MOM Archive conventions” [AD4].

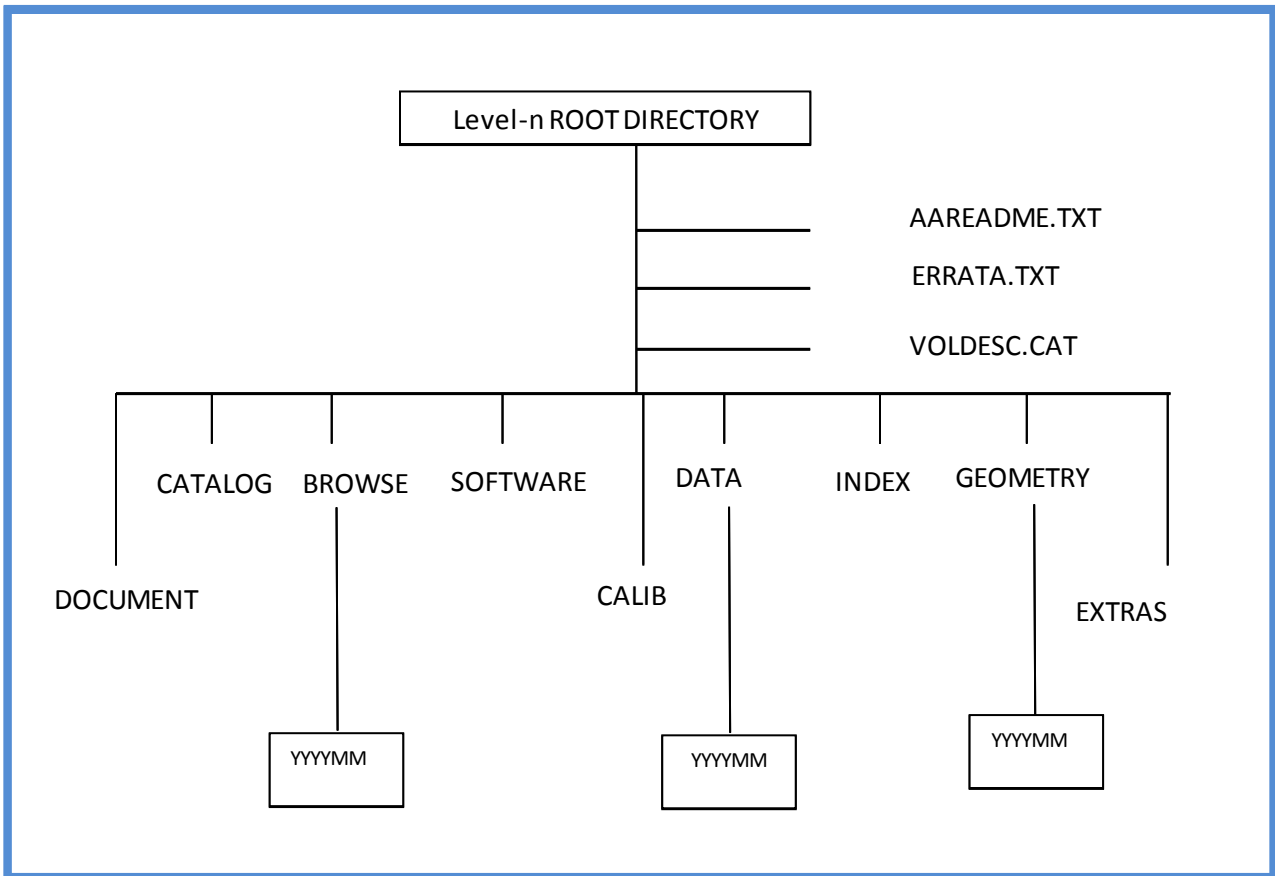


Figure 17:PDS Directory Structure

5.2.3 Root Directory Contents

Files in the Root Directory include an overview of the archive, a description of the volume for the PDS Catalog, and a list of errata or comments about the archive. The following files are contained in the Root Directory.

File Name	File Contents	File Provided By
AAREADME.TXT	Volume content and format information	Archive Team
ERRATA.TXT	A cumulative listing of comments and updates concerning all archive volumes published to date	Archive Team
VOLDESC.CAT	A description of the contents of this volume in a PDS format readable by both humans and computers	Archive Team



5.2.3.1 Catalog Directory Contents

The files in the Catalog Directory provide a top-level understanding of the mission, spacecraft, instruments, and data sets. The files in this directory are coordinated with the PDS data engineer, who is responsible for loading them into the PDS catalog. The following files are found in the Catalog Directory.

File Name	File Contents	File Provided By
CATINFO.TXT	A description of the contents of this directory	Archive Team
DS.CAT	Data set information for the PDS catalog	Archive Team
INSTHOST.CAT	Instrument host (i.e., spacecraft) information for the PDS catalog	Archive Team
INST.CAT	Instrument information for the PDS catalog	Instrument Team
MISSION.CAT	Mission information for the PDS catalog	Mission Team
PERSON.CAT	Personnel information for the PDS catalog (Team and PDS personnel responsible for generating the archive)	Archive Team
REF.CAT	References mentioned in other *.CAT files	Archive Team
SOFT.CAT	List and description of the software distributed with the data set	Archive Team



5.2.3.2 Index Directory Contents

Files in the Index Directory are provided to help the user locate products on this archive volume and on previously released volumes in the archive. The following files are contained in the Index Directory.

File Name	File Contents	File Provided By
INDXINFO.TXT	A description of the contents of this directory	Archive Team
INDEX.TAB	A table listing all data products on this volume	Archive Team
INDEX.LBL	A PDS detached label that describes INDEX.TAB	Archive Team
GEOMETRY_IND EX.TAB	A table listing all geometry data products on this volume	Archive Team
GEOMETRY_IND EX.LBL	A PDS detached label that describes INDEX.TAB	Archive Team
BROWSE_INDEX .TAB	A table listing all browse data products on this volume	Archive Team
BROWSE_INDEX .LBL	A PDS detached label that describes BROWSEINDEX.TAB	Archive Team

5.2.3.3 Browse Directory Contents

Under the Browse directory there is a separate subdirectory which is year and month wise for each type of product. The year and month wise subdirectory contains browse image for each image, which is a down sampled version of the full resolution image, with the size of m pixels x n lines and 8 bits per pixel, is defined as an object and contained in the data file.

JPEG images derived from the browse image are stored in this directory, as well as the label files pointing to these images. All the browse JPEG images are named as per file naming convention.

5.2.3.4 Geometry Directory Contents

Under the Geometry directory there is a separate subdirectory which is year and month wise for each type of product. The year and month wise subdirectory contains table files including the areographic coordinates of the image. SPICE files are separately provided to the users in ISDA portal for this mission. The GEOMETRY directory contains a table objects in multiple files corresponding to number of data products which lists areographic coordinates for gridded image locations. Also it contains Label files for each of the data product files archived. All the geometry data products named as per standard file naming convention.

5.2.3.5 Software Directory Contents

The Software Directory contains utilities or application programs to aid the user in viewing or extracting data from the data product files. The following files are contained in the Software Directory.



File Name	File Contents	File Provided By
SOFTINFO.TXT	A description of the contents of this directory	
MCCViewer.zip	A MS windows tool to display RGB images	MCC DP Team
MCCViewer.LBL	Description of MCCViewer tool	MCC DP Team

5.2.3.6 Document Directory Contents

The Document Directory contains documentation to help the user understand and use the archive data. The following files are contained in the Document Directory.

File Name	File Contents	File Provided By
DOCINFO.TXT	A description of the contents of this directory	Archive Team
EAICD.PDF	The EAICD file as a PDF file	Archive Team
DPSIS.LBL	A PDS detached label that describes both EAICD.PDF	Archive Team

5.2.3.7 Extras Directory Contents

The EXTRAS directory is the designated area for housing additional “value added” elements provided by data preparers beyond the scope of the PDS archive requirements. The following files are contained in the EXTRAS directory.

File name	Description	File provided by
Payload APID Flag File	APID loss information	ISAC Level-0 processor
Angles Grid File (in case of RDR Data Set Id)	Computed angle parameters	MCC DP Team
Orbit and Attitude Header File	Header information for orbit and attitude data	ISAC Level-0 processor
Orbit and Attitude File	Orbit and attitude data	ISAC Level-0 processor

5.2.3.8 Data Directory Contents

Under the Data directory there is a separate subdirectory which is year and month wise for each type of product. The year and month wise subdirectory contains image data product.

There are two types of data sets (Level-2 and Level-3) provided. Same structure of data directory is used. Level-2 data set contains raw RGB bayer pattern image data. Level-3 data set contains calibrated, radio metrically corrected and geometrically tagged data.

5.3 Structure and Organization Overview

In section 5.2.2, it is possible to see the /data directory structure organization.

5.4 Data Product and Label Design

In this section and subsequent sections, we give the details of the PDS data product. MCC data product consists of a detached PDS label and the image data object that it describes.

There are basically two types of data products one is EDR Level-2 and another is RDR Level-3 data products.

The Level-2 EDR data product contains raw image data RGB Bayer pattern along with some ancillary information.

The Level-3 RDR data products contains calibrated, radio-metrically corrected, demosaicked, geometrically tagged colour data along with ancillary information includes browse & geometrically data product.

The structure of Level-2 EDR and Level-3 RDR are given in the below figures.

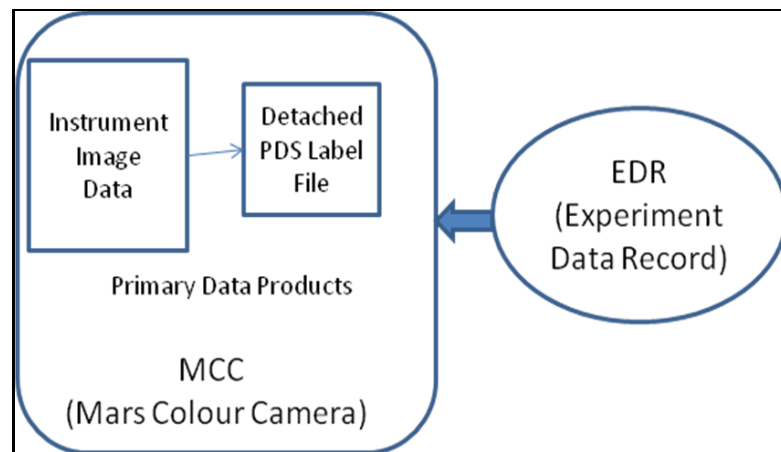


Figure 18:EDR Data Product Structure

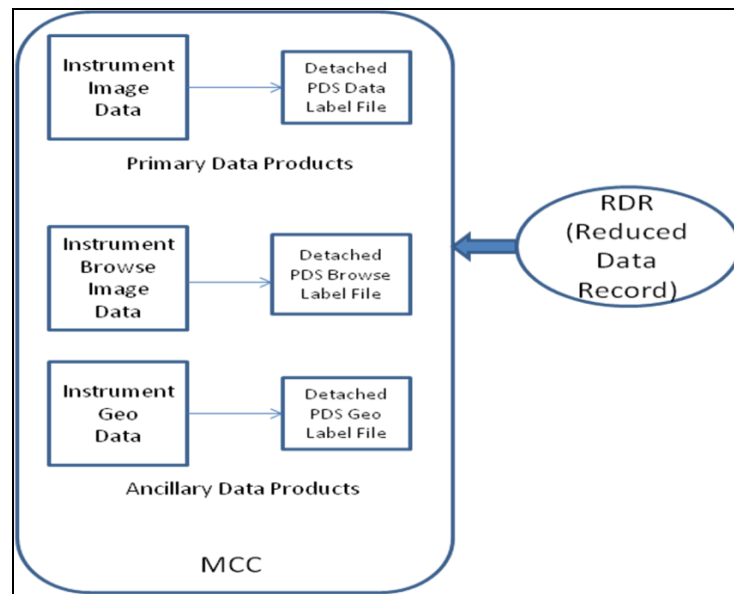


Figure 19:RDR Data Product Structure

The Level-2 EDR data products & Level-3 RDR data products are designed in PDS data objects. Below table shows the different types of data objects used in data product designing.

Data Set Type	Instrument Data/Ancillary Data	PDS Object
Level-2 EDR	Raw Image data Bayer RGB pattern	IMAGE
Level-3 RDR	Radio-metrically corrected, demoasicked and geometrically time tagged data	IMAGE
	Browse Image Data from image data	BROWSE_IMAGE
	Grid data	TABLE

Table 10 Data Product Design

After designing the data product its associated PDS Label needs to be designed.

For each of the data product, corresponding PDS Labels are designed based on the PDS objects mentioned in the table 10.

**MARS ORBITER
MISSION (MOM)**
MCC EAICD

PDS Keywords	Definitions
PDS_VERSION_ID	PDS version number for the label format
LABEL_REVISION_NOTE	Label Revision Note
/* File Characteristics */	
FILE_NAME	This element defines the Data Product File Name ["MCC_MEB_TTTTTTTTTTTTTTTTTT_P_STN.IM G" for EDR "MCC_MRD_TTTTTTTTTTTTTTTTTT_P_STN.IM G" for RDR]
RECORD_TYPE	This describes the type of records used in the file. A 'record' is a single line in a data product, and records can therefore be fixed in length throughout the product, variable in length within a product, or can be a stream. For MCC products, every record inside the file has a fixed length
RECORD_BYTES	This element defines the length for every record [2048*2 for EDR and 2048*4 for RDR]
FILE_RECORDS	Number of records in the data product. Value 2048 is fixed for EDR/RDR
/* POINTERS TO DATA OBJECTS */	
^IMAGE	For MCC, only one pointer is present, identifying the binary image within which the data are stored. for RDR value will be ["MCC_MEB_TTTTTTTTTTTTTTTTTT_P_STN.IM G" for EDR "MCC_MRD_TTTTTTTTTTTTTTTTTT_P_STN.IM G" for RDR]
/* IDENTIFICATION DATA ELEMENTS */	
RELEASE_ID	Release id
DATA_SET_ID	Data set ID that uniquely identifies the MCC dataset for EDR value will be ["MR1ORB-M-MCC-2-MOP-EDR-RAW-V1.0"] for RDR ["MR1ORB-M-MCC-3-MOP-RDR-RAD-V1.0"]
DATA_SET_NAME	Dataset Name describing in long hand the identification elements of the DATA_SET_ID for EDR value will be "MR1 ORBITER MARS MCC 2 MOP EDR RAW V1.0" for RDR value will be "MR1 ORBITER MARS MCC 3 MOP RDR RAD V1.0"
PRODUCT_ID	This element uniquely identifies the product within the data set. ["MCC_MEB_TTTTTTTTTTTTTTTTTT_P_STN.IM G" for EDR "MCC_MRD_TTTTTTTTTTTTTTTTTT_P_STN.IM G" for RDR]



**MARS ORBITER
MISSION (MOM)**
MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 49

PRODUCT_TYPE	The product type keyword describes the type of data present. For the MCC datasets, this will be for Level-2 Data Sets [EDR] and for Level-3 Data Sets [RDR]
PRODUCER_ID	Data producer id ["MR1-ISRO-SAC-DP-TEAM"]
PRODUCT_CREATION_TIME	Time of creation of Product on the ground (in UTC). [yyyy-mm-ddThh:mm:ss]
PRODUCER_FULL_NAME	The producer_full_name element provides the full_name of the individual mainly responsible for the production of a data ["MARS ORBITER MISSION ISRO SAC DATA PROCESSING TEAM"]
PRODUCER_INSTITUTION_NAME	The producer_institution_name element identifies institution associated with the production of a data set. ["SPACE APPLICATIONS CENTRE, (ISRO) AHMEDABAD"]
PROCESSING_LEVEL_ID	The processing_level_id element identifies the processing level of a set of data according to the eight_level CODMAC standard. For EDR [2] and for RDR [3]
PROCESSING_LEVEL_DESC	The processing_level_desc element provides the CODMAC standard definition corresponding to a particular processing_level_id value ["2 Experiment Data Record, 3 Reduced Data Record"]
MISSION_ID	The mission_id element provides a synonym or mnemonic for the mission_name element. ["MOM"]
MISSION_NAME	The mission_name element identifies a major planetary mission or project. ["MARS ORBITER MISSION"]
MISSION_PHASE_NAME	This identifies the phase of the mission in which the data were produced.{ ["EARTH BOUND PHASE"], ["CRUISE ENROUTE MARS"], ["MARS ORBIT INSERTION"] ["MARS ORBITAL PHASE"]}
SPACECRAFT_ORIENTATION_DESC	Description of rotation axis corresponding to values of SPACECRAFT_ORIENTATION keyword. [(PITCH,ROLL,YAW)]
SPACECRAFT_ORIENTATION	MOM orientation during which this image was collected; described as a angle (in degrees) of rotation away from nadir around the three axes spacecraft frame of reference; see given in SPACECRAFT_POINTING_MODE_DESC value for more information. [(0,0,0)]
SPACECRAFT_POINTING_MODE	Description of the MOM pointing mode during which this image was collected; see text given in SPACECRAFT_POINTING_MODE_DESC value for definitions of valid modes.



**MARS ORBITER
MISSION (MOM)**
MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 50

^SPACECRAFT_POINTING_MODE_DESC	Pointer to text file describing valid MOM orientation values and pointing modes; text file is in the DOCUMENT directory. ["MOM_ORIENT_POINT.TXT"]
INSTRUMENT_HOST_ID	The instrument_host_id element provides a unique identifier for the host where an instrument is located. This host can be either a spacecraft or an earth base (e.g., and observatory or laboratory on the earth). ["MOMORB"]
INSTRUMENT_HOST_NAME	The instrument_host_name element provides the full name of the host on which an instrument is based. This host can be either a spacecraft or an earth base. ["MOM ORBITER"]
TARGET_NAME	Target Name for the observation: ["MARS" , ["PHOBOS"], ["INTERNAL SOURCE" , ["DEEP SPACE"], ["ASTEROID"], ["EARTH"]
TARGET_TYPE	Type of target observed: ["SATELLITE"], ["CALIBRATION"] or ["PLANET"]
START_TIME	The start time of observation in UTC Format: [YYYY-MM-DDThh:mm:ss[.fff]]
STOP_TIME	The stop time of observation in UTC Format: [YYYY-MM-DDThh:mm:ss[.fff]]
ORBIT_NUMBER	imaging orbit number
IMAGE_OBSERVATION_TYPE	image observation type ["REGULAR"]
/* DESCRIPTIVE DATA ELEMENTS */	
INSTRUMENT_ID	instrument id ["MCC"]
INSTRUMENT_NAME	instrument name ["MARS COLOUR CAMERA"]
INSTRUMENT_TYPE	instrument type ["IMAGING CAMERA"]
INST_CMPRS_NAME	instrument compression name ["ISRO PROPRIETARY"]
FRAMES	The frames element provides the number of frames within a particular cycle, which is identified by the cycle_id element. Depends upon the s/c altitude. [1600<km>]
FILTER_NAME	The filter_name element provides the commonly-used name of the instrument filter through which an image or measurement was acquired or which is associated with a given instrument mode. ["BAYER FILTER"]
FILTER_NUMBER	The filter_number element provides the number of an instrument filter through which an image or measurement was acquired or which is associated with a given instrument mode [3]
FILTER_TEMPERATURE	The filter_temperature element provides the temperature, in degrees celsius (unless otherwise specified), of the instrument filter. ["N/A"]



FILTER_TYPE	The filter_type element identifies the type of a given instrument filter. [ORGANIC]
CENTER_FILTER_WAVELENGTH	The center_filter_wavelength element provides the mid_point wavelength value between the minimum and maximum instrument filter wavelength values. ["N/A"]
BANDWIDTH	The bandwidth element provides a measure of the spectral width of a filter or channel. ["N/A"]
LINE_EXPOSURE_DURATION	The line_exposure_duration data element indicates the time elapsed during the aquisition of one image line of data. [6.3 <ms>]
FOCAL_PLANE_TEMPERATURE	The focal_plane_temperature element provides the temperature of the focal plane array in degrees kelvin at the time the observation was made. ["N/A"]
DETECTOR_ID	The detector_id element identifies a particular instrument detector. ["CMV4000"]
DETECTOR_DESC	The detector_desc element describes a detector utilized by an instrument. ["CMV4000 –a high resolution, high speed snapshot colour CMOS image sensor"]
DETECTOR_TYPE	The detector_type element identifies the type of an instrument's detector.
DETECTORS	The detectors element provides the number of detectors of a specified type contained in the subject instrument. 2048x2048 that can be mentioned under NOTE keyword [4194304]
DETECTOR_PIXEL_WIDTH	The detector_pixel_width element provides the width of a pixel in the Charge-Coupled Device (CCD) sensor measured in microns. [5.5]
DETECTOR_PIXEL_HEIGHT	The detector_pixel_height element provides the height of a pixel in the CCD sensor measured in microns. [5.5]
DETECTOR_TEMPERATURE	The DETECTOR_TEMPERATURE is the temperature that the instrument (detector) operated at while a measurement was made. ["N/A"]
SOFTWARE_NAME	The software_name element identifies data processing software such as a program or a program library. ["MOMDPGS"]
SOFTWARE_VERSION_ID	The software_version_id element indicates the version (development level) of a program or a program library. [V1.0]
/* GEOMETRY DATA ELEMENTS */	
SPACECRAFT_ALTITUDE	The spacecraft_altitude element provides the distance from the spacecraft to a reference surface of the target body measured normal to that surface. It is value is variable



NOTE	The note element is a text field which provides miscellaneous notes or comments (for example, concerning a given data set or a given data processing program).
GROUP	
RETICLE_POINT_NUMBER	The reticle_point_number element provides the number of an image reticle point, as follows: 1 upper left, 3 - upper right, 5 - middle, 7 - lower left, 9 - lower right.
RETICLE_POINT_LATITUDE	The reticle_point_latitude element provides the latitude of the surface intercept points of the principle points of the camera.
RETICLE_POINT_LONGITUDE	The reticle_point_longitude element provides the longitude of the surface intercept points of the principle points of the camera.
END_GROUP	
GROUP	
RETICLE_POINT_NUMBER	
RETICLE_POINT_LATITUDE	
RETICLE_POINT_LONGITUDE	
END_GROUP	
GROUP	
RETICLE_POINT_NUMBER	
RETICLE_POINT_LATITUDE	
RETICLE_POINT_LONGITUDE	
END_GROUP	
GROUP	
RETICLE_POINT_NUMBER	
RETICLE_POINT_LATITUDE	
RETICLE_POINT_LONGITUDE	
END_GROUP	
/* DATA OBJECT DEFINITIONS */	
OBJECT	
LINES	The lines element indicates the total number of data instances along the vertical axis of an image. Note: In PDS label convention, the number of lines is stored in a 32-bit integer field. The minimum value of 0 indicates no data received. [2048]
LINE_SAMPLES	The line_samples element indicates the total number of data instances along the horizontal axis of an image. [2048]
SAMPLE_TYPE	The sample_type element indicates the data storage representation of sample value. For EDR value will be [LSB_UNSIGNED_INTEGER] & RDR value will be [PC_REAL]



SAMPLE_BITS	The sample_bits element indicates the stored number of bits, or units of binary information, contained in a line_sample value. For EDR value will be [16] and for RDR value will be [32]
SAMPLE_BIT_MASK	The sample_bit_mask element identifies the active bits in a sample. Note: In the PDS, the domain of sample_bit_mask is dependent upon the currently-described value in the sample_bits element and only applies to integer values. For an 8-bit sample where all bits are active the sample_bit_mask would be [2#11111111#]
MAXIMUM	The maximum element indicates the largest value occurring in a given instance of the data object.
MINIMUM	The minimum element indicates the smallest value occurring in a given instance of the data object.
MEAN	The mean element provides the average of the DN values in the image array.
STANDARD_DEVIATION	The standard_deviation element provides the standard deviation of the DN values in the image array.
LINE_DISPLAY_DIRECTION	The line_display_direction element is the preferred orientation of lines within an image for viewing on a display device. The default value is down, meaning lines are viewed top to bottom on the display. Note that if this keyword is present in a label, the SAMPLE_DISPLAY_DIRECTION keyword must also be present and must contain a value orthogonal to the value selected for this keyword. [DOWN LEFT RIGHT UP]
SAMPLE_DISPLAY_DIRECTION	The SAMPLE_DISPLAY_DIRECTION element is the preferred orientation of samples within a line for viewing on a display device. The default is right, meaning samples are viewed from left to right on the display. Note that if this keyword is present in a label, the LINE_DISPLAY_DIRECTION keyword must also be present and must contain a value orthogonal to the value selected for this keyword. [DOWN LEFT RIGHT UP]
HORIZONTAL_PIXEL_SCALE	depends upon s/c altitude
VERTICAL_PIXEL_SCALE	depends upon integration time and s/c ground trace velocity



BAND_SEQUENCE	This keyword will be used for RDR products. The band_sequence element identifies the order in which spectral bands are stored in an image or other object. Note: In the PDS, this data element is used to identify the primary colors composing a true color image. The standard values that appear in sets of three support color image display. They are not appropriate for describing multi-spectral bands. For these, it is advisable to use the sampling_parameter keywords defined elsewhere in the PSDD. [(BLUE, GREEN, RED) (BLUE, RED, GREEN) (GREEN, BLUE, RED) (GREEN, RED, BLUE) (RED, BLUE, GREEN) (RED, GREEN, BLUE)]
BAND_STORAGE_TYPE	This keyword will be used for the RDR products. The band_storage_type element indicates the storage sequence of lines, samples and bands in an image. The values describe, for example, how different samples are interleaved in image lines, or how samples from different bands are arranged sequentially. Example values: BAND SEQUENTIAL, SAMPLE INTERLEAVED, LINE INTERLEAVED.
BANDS	This keyword will be used for RDR product. The BANDS element indicates the number of bands in an image or other object.
CHECKSUM	
END_OBJECT	
END	

The sample PDS Labels for EDR & RDR data sets are shown in the APPENDIX (I-IV) section.

Table 11 Sample PDS Label for EDR Image Data

APPENDIX I: SAMPLE PDS LABEL FOR EDR IMAGE DATA PRODUCT

```
PDS_VERSION_ID          = PDS3
LABEL_REVISION_NOTE      = "2013-04-22, MR1-ISRO-SAC-DP-TEAM"
/* FILE CHARACTERISTICS */
FILE_NAME                = "MCC_MEB_20150509T160721620_D_D32.IMG"
RECORD_TYPE              = FIXED_LENGTH
RECORD_BYTES             = 4096
FILE_RECORDS             = 2048
/* POINTERS TO DATA OBJECTS */
^IMAGE                   = "MCC_MEB_20150509T160721620_D_D32.IMG"
/* IDENTIFICATION DATA ELEMENTS */
RELEASE_ID               = 1
```



MARS ORBITER MISSION (MOM)

MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 55

DATA_SET_ID = "MR1ORB-M-MCC-2-MOP-EDR-RAW-V1.0"
DATA_SET_NAME = "MR1 ORBITER MARS MCC 2 MOP EDR RAW V1.0"
PRODUCT_ID = MCC_MEB_20150509T160721620_D_D32
PRODUCT_TYPE = "EDR"
PRODUCER_ID = "MR1-ISRO-SAC-DP-TEAM"
PRODUCT_CREATION_TIME = 2015-05-12T11:41:42.042
PRODUCER_FULL_NAME = "MARS 1 ISRO SAC DATA PROCESSING TEAM"
PRODUCER_INSTITUTION_NAME = "
SPACE APPLICATIONS CENTRE ISRO, AHMEDABAD INDIA
"

PROCESSING_LEVEL_ID = "2"
PROCESSING_LEVEL_DESC = "2 Experiment Data Record,
3 Reduced Data Record"

MISSION_ID = "MR1"
MISSION_NAME = "MARS 1"
MISSION_PHASE_NAME = "MARS ORBITAL PHASE"
SPACECRAFT_ORIENTATION = 1
SPACECRAFT_ORIENTATION_DESC = "0 means descending,
1 means ascending"

SPACECRAFT_POINTING_MODE = NULL
SPACECRAFT_POINTING_MODE_DESC = NULL
QUATERNION = (0.261849,-0.255591,0.673985,0.641758)
QUATERNION_DESC = "Inertial-to-Body Quaternions"
SOLAR_AZIMUTH = 84.7816594834
SOLAR_ELEVATION = 57.120567
PHASE_ANGLE = 34.1969012761
EMISSION_ANGLE = 1.4966202893
INCIDENCE_ANGLE = 32.8581896428
SOLAR_DISTANCE = 1.5063998427
SOLAR_LONGITUDE = 339.4344765474

INSTRUMENT_HOST_ID = "MR1ORB"
INSTRUMENT_HOST_NAME = "MR1 ORBITER"
TARGET_NAME = "MARS"
TARGET_TYPE = "PLANET"
DSN_STATION_NUMBER = D32
START_TIME = 2015-05-09T16:07:21.620
STOP_TIME = 2015-05-09T16:07:21.620

START_ORBIT_NUMBER = 000105
STOP_ORBIT_NUMBER = 000105
IMAGE_OBSERVATION_TYPE = "REGULAR"

/* DESCRIPTIVE DATA ELEMENTS */

INSTRUMENT_ID = "MCC"
INSTRUMENT_NAME = "MARS COLOUR CAMERA"
INSTRUMENT_TYPE = "IMAGING CAMERA"
INSTRUMENT_PARAMETER_NAME = "RADIANCE"
INSTRUMENT_PARAMETER_UNIT = "
MILLIWATT_CENTIMETER**-2_STERADIAN**-1_MICROMETER**-1
"



MARS ORBITER MISSION(MOM)

MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 56

INST_CMPRS_NAME = "ISRO PROPRIETRY"
FILTER_NAME = "BAYER FILTER"
FILTER_NUMBER = "3"
FILTER_TEMPERATURE = "N/A"
FILTER_TYPE = "ORGANIC"
CENTER_FILTER_WAVELENGTH = "N/A"
MR1:EXPOSURE_ID = 4
LINE_EXPOSURE_DURATION = "0.8 <ms>"
FOCAL_PLANE_TEMPERATURE = "N/A"
DETECTOR_ID = "CMV4000"
DETECTOR_DESC = "
CMV4000 - a high resolution, high speed snapshot colour CMOS image sensor
"

DETECTOR_TYPE = "CMOS IMAGE SENSOR"
DETECTORS = 4194304
DETECTOR_PIXEL_WIDTH = 5.5
DETECTOR_PIXEL_HEIGHT = 5.5
DETECTOR_TEMPERATURE = "8.571375 <deg C>"
SOFTWARE_NAME = "MOM-MCC-DPGS"
SOFTWARE_VERSION_ID = "V1.0"
MR1:JOB_ID = "
MCC01D32MR10010600NNNN15131025410426_00_V1_0
"

MR1:L0_TAR_FILE_NAME = "
MCC01D32MR10010600NNNN15131025410426.tar_V1.0
"

/* GEOMETRY DATA ELEMENTS */

SPACECRAFT_ALTITUDE = 732.0839245650
NOTE = "Mars Colour Camera (MCC) is a
Bayer Array RGB camera operating
in the visible range (0.4-0.7)
is a medium resolution camera
flown on the Mars Orbiter Mission.
It captures images of topography
of Martian surface.
It observes and helps in
furthering our understanding of events
like dust storms, dust devils etc.
Moving in an elliptical orbit of
372km x 80000km around mars,
the camera produces
visible images of Mars and its
environs. The highly elliptical orbit
chosen for the Mars mission allow
imaging of localized scenes at high
spatial resolution as well as providing
a synoptic view of the full globe.
from apogee position of the orbit.



MARS ORBITER MISSION (MOM)

MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 57

This instrument is from Space Applications
Centre, Ahmedabad, India

Scientific Objective :-

1. To map various morphological features on Mars with varying resolution and scales using the unique elliptical orbit.
2. To map the geological setting around sites of Methane emission source.
3. To provide context information for other science payloads.

Sensor Configuration :-

MCC uses a multi-element lens assembly and a 2Kx2K area array detector with RGB Bayer pattern to take images. The f/4 lens has a focal length of 105mm with a circularly symmetric field of view of plusminus4.4deg.

The detector has 2048 x 2048 elements on a pixel pitch of 5.5 microns

Salient Features:-

1. Spacecraft Altitude (km) - 372x80000
2. Resolution (m) - 19.5@Periareion
3. Frame Size (km) - 40x40@Periareion (Full Mars disc from 63000km Apoareion)
4. Spectral region (micrometer) - 0.4-0.7
5. Frame rate - 1s (frame selection at 1s, 8s or 15s period by BDH through ground commanding)
6. Exposure time (ms) - Total 16 ground programmable exposures ranging from 34 ms to 490 ms
7. Data volume/frame (Mb)- 40
8. System MTF@46 LP/mm ()-greater than 15
- SNR @9. Near Saturation - greater than 50 values 999.999 for latitude and longitude keywords indicate that the location maps to cold space."

/* RETICLE POINT LAT-LON INFORMATION */

```
GROUP                = UPPER_LEFT_RETICLE_POINT
RETICLE_POINT_NUMBER  = "1"
RETICLE_POINT_LATITUDE    = -13.8846493449
RETICLE_POINT_LONGITUDE   = 310.0719370306
END_GROUP              = UPPER_LEFT_RETICLE_POINT
GROUP                = UPPER_MID_RETICLE_POINT
RETICLE_POINT_NUMBER    = "2"
RETICLE_POINT_LATITUDE   = -14.1828836074
RETICLE_POINT_LONGITUDE  = 309.4556889554
END_GROUP              = UPPER_MID_RETICLE_POINT
```



MARS ORBITER MISSION (MOM)

MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 58

GROUP = UPPER_RIGHT_RETICLE_POINT
RETICLE_POINT_NUMBER = "3"
RETICLE_POINT_LATITUDE = -14.4987353369
RETICLE_POINT_LONGITUDE = 308.7989951945
END_GROUP = UPPER_RIGHT_RETICLE_POINT
GROUP = MID_LEFT_RETICLE_POINT
RETICLE_POINT_NUMBER = "4"
RETICLE_POINT_LATITUDE = -13.2811885941
RETICLE_POINT_LONGITUDE = 309.7672715660
END_GROUP = MID_LEFT_RETICLE_POINT
GROUP = MIDDLE_MID_RETICLE_POINT
RETICLE_POINT_NUMBER = "5"
RETICLE_POINT_LATITUDE = -13.5784997102
RETICLE_POINT_LONGITUDE = 309.1526618740
END_GROUP = MIDDLE_MID_RETICLE_POINT
GROUP = MID_RIGHT_RETICLE_POINT
RETICLE_POINT_NUMBER = "6"
RETICLE_POINT_LATITUDE = -13.8929479710
RETICLE_POINT_LONGITUDE = 308.4975475621
END_GROUP = MID_RIGHT_RETICLE_POINT
GROUP = LOWER_LEFT_RETICLE_POINT
RETICLE_POINT_NUMBER = "7"
RETICLE_POINT_LATITUDE = -12.6398747460
RETICLE_POINT_LONGITUDE = 309.4459280549
END_GROUP = LOWER_LEFT_RETICLE_POINT
GROUP = LOWER_MID_RETICLE_POINT
RETICLE_POINT_NUMBER = "8"
RETICLE_POINT_LATITUDE = -12.9364465913
RETICLE_POINT_LONGITUDE = 308.8325811596
END_GROUP = LOWER_MID_RETICLE_POINT
GROUP = LOWER_RIGHT_RETICLE_POINT
RETICLE_POINT_NUMBER = "9"
RETICLE_POINT_LATITUDE = -13.2496589287
RETICLE_POINT_LONGITUDE = 308.1786354067
END_GROUP = LOWER_RIGHT_RETICLE_POINT
/* IMAGE DATA OBJECT DESCRIPTION */
OBJECT = IMAGE
LINES = 2048
LINE_SAMPLES = 2048
SAMPLE_TYPE = LSB_UNSIGNED_INTEGER
SAMPLE_BITS = 16
SAMPLE_BIT_MASK = "<2#0000001111111111>"
MAXIMUM = "558,401,278"
MINIMUM = "266,0,9"
MEAN = "468.000000,324.000000,175.000000"
STANDARD_DEVIATION = "18.698366,11.879083,6.824882"
LINE_DISPLAY_DIRECTION = "UP"
SAMPLE_DISPLAY_DIRECTION = "LEFT"



**MARS ORBITER
MISSION (MOM)**
MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 59

HORIZONTAL_PIXEL_SCALE = "38.0752868568 <m/pixel>"
VERTICAL_PIXEL_SCALE = "38.0752868568 <m/pixel>"
CHECKSUM = 2055888179
MR1:MCC_RED_RADIANCE_MAX = 5.182173
MR1:MCC_RED_RADIANCE_MIN = -0.087068
MR1:MCC_GREEN_RADIANCE_MAX = 4.798032
MR1:MCC_GREEN_RADIANCE_MIN = -0.103176
MR1:MCC_BLUE_RADIANCE_MAX = 4.372246
MR1:MCC_BLUE_RADIANCE_MIN = -0.084304
END_OBJECT = IMAGE
END

Table 12 Sample PDS Label for RDR Image Data

APPENDIX II: SAMPLE PDS LABEL FOR RDR IMAGE DATA PRODUCT

PDS_VERSION_ID = PDS3
LABEL_REVISION_NOTE = "2013-04-22, MR1-ISRO-SAC-DP-TEAM"
/* FILE CHARACTERISTICS */
FILE_NAME = "MCC_MRC_20150509T160319661_D_D32.IMG"
RECORD_TYPE = FIXED_LENGTH
RECORD_BYTES = 8192
FILE_RECORDS = 2048
/* POINTERS TO DATA OBJECTS */
^IMAGE = "MCC_MRC_20150509T160319661_D_D32.IMG"
/* IDENTIFICATION DATA ELEMENTS */
RELEASE_ID = 1
DATA_SET_ID = "MR1ORB-M-MCC-3-MOP-RDR-RAD-V1.0"
DATA_SET_NAME = "MR1 ORBITER MARS MCC 3 MOP RDR RAD V1.0"
PRODUCT_ID = MCC_MRC_20150509T160319661_D_D32
PRODUCT_TYPE = "RDR"
PRODUCER_ID = "MR1-ISRO-SAC-DP-TEAM"
PRODUCT_CREATION_TIME = 2015-05-11T16:39:28.028
PRODUCER_FULL_NAME = "MARS 1 ISRO SAC DATA PROCESSING TEAM"
PRODUCER_INSTITUTION_NAME = "
SPACE APPLICATIONS CENTRE ISRO, AHMEDABAD INDIA
"
PROCESSING_LEVEL_ID = "3"
PROCESSING_LEVEL_DESC = "2 Experiment Data Record,
3 Reduced Data Record"
MISSION_ID = "MR1"
MISSION_NAME = "MARS 1"
MISSION_PHASE_NAME = "MARS ORBITAL PHASE"
SPACECRAFT_ORIENTATION = 1
SPACECRAFT_ORIENTATION_DESC = "0 means descending,
1 means ascending"



MARS ORBITER MISSION(MOM)

MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 60

```
SPACECRAFT_POINTING_MODE      = NULL
SPACECRAFT_POINTING_MODE_DESC = NULL
QUATERNION                     = (0.230158,-0.284468,0.744352,0.558610)
QUATERNION_DESC                = "Inertial-to-Body Quaternions"
SOLAR_AZIMUTH                  = 94.8690097983
SOLAR_ELEVATION                = 45.15681
PHASE_ANGLE                    = 45.9209212570
EMISSION_ANGLE                 = 1.1448486199
INCIDENCE_ANGLE                = 44.8240132309
SOLAR_DISTANCE                 = 1.5063961801
SOLAR_LONGITUDE                = 339.4329814706
INSTRUMENT_HOST_ID             = "MR1ORB"
INSTRUMENT_HOST_NAME           = "MR1 ORBITER"
TARGET_NAME                    = "MARS"
TARGET_TYPE                    = "PLANET"
DSN_STATION_NUMBER             = D32
START_TIME                     = 2015-05-09T16:03:19.661
STOP_TIME                      = 2015-05-09T16:03:19.661
START_ORBIT_NUMBER             = 000105
STOP_ORBIT_NUMBER              = 000105
IMAGE_OBSERVATION_TYPE         = "REGULAR"
/* DESCRIPTIVE DATA ELEMENTS */
INSTRUMENT_ID                  = "MCC"
INSTRUMENT_NAME                 = "MARS COLOUR CAMERA"
INSTRUMENT_TYPE                 = "IMAGING CAMERA"
INSTRUMENT_PARAMETER_NAME      = "RADIANCE"
INSTRUMENT_PARAMETER_UNIT      = "
MILLIWATT_CENTIMETER**-2_STERADIAN**-1_MICROMETER**-1
"
INST_CMPRS_NAME                = "ISRO PROPRIETRY"
FILTER_NAME                    = "BAYER FILTER"
FILTER_NUMBER                   = "3"
FILTER_TEMPERATURE              = "N/A"
FILTER_TYPE                     = "ORGANIC"
CENTER_FILTER_WAVELENGTH       = "N/A"
MR1:EXPOSURE_ID                = 4
LINE_EXPOSURE_DURATION         = "0.8 <ms>"
FOCAL_PLANE_TEMPERATURE        = "N/A"
DETECTOR_ID                    = "CMV4000"
DETECTOR_DESC                  = "
CMV4000 - a high resolution, high speed snapshot colour CMOS image sensor
"
DETECTOR_TYPE                  = "CMOS IMAGE SENSOR"
DETECTORS                      = 4194304
DETECTOR_PIXEL_WIDTH           = 5.5
DETECTOR_PIXEL_HEIGHT          = 5.5
DETECTOR_TEMPERATURE           = "8.571375 <deg C>"
SOFTWARE_NAME                   = "MOM-MCC-DPGS"
```



MARS ORBITER MISSION (MOM)

MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 61

SOFTWARE_VERSION_ID = "V1.0"
MR1:JOB_ID = "
MCC01D32MR10010600NNNN15130025510978_00_V1_0
"

MR1:L0_TAR_FILE_NAME = "
MCC01D32MR10010600NNNN15130025510978.tar_V1.0
"

/* GEOMETRY DATA ELEMENTS */

SPACECRAFT_ALTITUDE = 1044.6315129395

NOTE = "Mars Colour Camera (MCC) is a
Bayer Array RGB camera operating
in the visible range (0.4-0.7)
is a medium resolution camera
flown on the Mars Orbiter Mission.
It captures images of topography
of Martian surface.
It observes and helps in
furthering our understanding of events
like dust storms, dust devils etc.
Moving in an elliptical orbit of
372km x 80000km around mars,
the camera produces
visible images of Mars and its
environs. The highly elliptical orbit
chosen for the Mars mission allow
imaging of localized scenes at high
spatial resolution as well as providing
a synoptic view of the full globe.
from apogee position of the orbit.
This instrument is from Space Applications
Centre, Ahmedabad, India
Scientific Objective :-

1. To map various morphological features on Mars with varying resolution and scales using the unique elliptical orbit.
2. To map the geological setting around sites of Methane emission source.
3. To provide context information for other science payloads.

Sensor Configuration :-

MCC uses a multi-element lens assembly and a 2Kx2K area array detector with RGB Bayer pattern to take images. The f/4 lens has a focal length of 105mm with a circularly symmetric field of view of plusminus4.4deg.

The detector has 2048 x 2048 elements on a pixel pitch of 5.5 microns



MARS ORBITER MISSION(MOM)

MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 62

Salient Features:-

1. Spacecraft Altitude (km) - 372x80000
2. Resolution (m) - 19.5@Periareion
3. Frame Size (km) - 40x40@Periareion
(Full Mars disc from 63000km Apoareion)
4. Spectral region (micrometer) - 0.4-0.7
5. Frame rate - 1s (frame selection at 1s, 8s or 15s period by BDH through ground commanding)
6. Exposure time (ms) - Total 16 ground programmable exposures ranging from 34 ms to 490 ms
7. Data volume/frame (Mb)- 40
8. System MTF@46 LP/mm ()-greater than 15
SNR @9. Near Saturation - greater than 50
values 999.999 for latitude and longitude keywords indicate that the location maps to cold space."

/* RETICLE POINT LAT-LON INFORMATION */

```
GROUP                = UPPER_LEFT_RETICLE_POINT
RETICLE_POINT_NUMBER  = "1"
RETICLE_POINT_LATITUDE    = -7.6712591897
RETICLE_POINT_LONGITUDE   = 323.5888738475
END_GROUP              = UPPER_LEFT_RETICLE_POINT
GROUP                = UPPER_MID_RETICLE_POINT
RETICLE_POINT_NUMBER    = "2"
RETICLE_POINT_LATITUDE    = -8.1279526884
RETICLE_POINT_LONGITUDE   = 322.7461749837
END_GROUP              = UPPER_MID_RETICLE_POINT
GROUP                = UPPER_RIGHT_RETICLE_POINT
RETICLE_POINT_NUMBER    = "3"
RETICLE_POINT_LATITUDE    = -8.6127204290
RETICLE_POINT_LONGITUDE   = 321.8486540404
END_GROUP              = UPPER_RIGHT_RETICLE_POINT
GROUP                = MID_LEFT_RETICLE_POINT
RETICLE_POINT_NUMBER    = "4"
RETICLE_POINT_LATITUDE    = -6.8284798087
RETICLE_POINT_LONGITUDE   = 323.1319585948
END_GROUP              = MID_LEFT_RETICLE_POINT
GROUP                = MIDDLE_MID_RETICLE_POINT
RETICLE_POINT_NUMBER    = "5"
RETICLE_POINT_LATITUDE    = -7.2840547157
RETICLE_POINT_LONGITUDE   = 322.2911960242
END_GROUP              = MIDDLE_MID_RETICLE_POINT
GROUP                = MID_RIGHT_RETICLE_POINT
RETICLE_POINT_NUMBER    = "6"
RETICLE_POINT_LATITUDE    = -7.7667665812
RETICLE_POINT_LONGITUDE   = 321.3953874839
```



MARS ORBITER MISSION (MOM)

MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 63

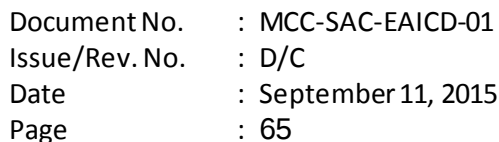
```
END_GROUP          = MID_RIGHT_RETICLE_POINT
GROUP              = LOWER_LEFT_RETICLE_POINT
RETICLE_POINT_NUMBER      = "7"
RETICLE_POINT_LATITUDE    = -5.9327436831
RETICLE_POINT_LONGITUDE   = 322.6496352172
END_GROUP          = LOWER_LEFT_RETICLE_POINT
GROUP              = LOWER_MID_RETICLE_POINT
RETICLE_POINT_NUMBER      = "8"
RETICLE_POINT_LATITUDE    = -6.3876805574
RETICLE_POINT_LONGITUDE   = 321.8099752194
END_GROUP          = LOWER_MID_RETICLE_POINT
GROUP              = LOWER_RIGHT_RETICLE_POINT
RETICLE_POINT_NUMBER      = "9"
RETICLE_POINT_LATITUDE    = -6.8687919319
RETICLE_POINT_LONGITUDE   = 320.9149681143
END_GROUP          = LOWER_RIGHT_RETICLE_POINT
/* IMAGE DATA OBJECT DESCRIPTION */
OBJECT              = IMAGE
LINES               = 2048
LINE_SAMPLES        = 2048
SAMPLE_TYPE         = LSB_UNSIGNED_INTEGER
SAMPLE_BITS         = 16
SAMPLE_BIT_MASK     = "<2#0000001111111111>"
MAXIMUM             = "557,458,343"
MINIMUM             = "220,249,90"
MEAN                = "464.679047,323.926880,172.482925"
STANDARD_DEVIATION  = "15.545102,8.153424,5.201393"
LINE_DISPLAY_DIRECTION = "UP"
SAMPLE_DISPLAY_DIRECTION = "LEFT"
HORIZONTAL_PIXEL_SCALE = "54.3307169850 <m/pixel>"
VERTICAL_PIXEL_SCALE  = "54.3307169850 <m/pixel>"
CHECKSUM            = 3345865541
BANDS               = 3
BAND_SEQUENCE       = "RED, GREEN, BLUE"
BAND_STORAGE_TYPE    = "BAND_SEQUENTIAL"
MR1:MCC_RED_RADIANCE_MAX    = 5.182173
MR1:MCC_RED_RADIANCE_MIN    = -0.087068
MR1:MCC_GREEN_RADIANCE_MAX  = 4.798032
MR1:MCC_GREEN_RADIANCE_MIN  = -0.103176
MR1:MCC_BLUE_RADIANCE_MAX   = 4.372246
MR1:MCC_BLUE_RADIANCE_MIN   = -0.084304
END_OBJECT           = IMAGE
END
```



Table 13 Sample PDS Label for Browse data

APPENDIX III: SAMPLE PDS LABEL FOR RDR BROWSE DATA PRODUCT

PDS_VERSION_ID = PDS3
LABEL_REVISION_NOTE = "2013-04-22, MR1-ISRO-SAC-DP-TEAM"
/* FILE CHARACTERISTICS */
FILE_NAME = "MCC_MRD_20150501T114952183_B_GDS.PNG"
RECORD_TYPE = FIXED_LENGTH
RECORD_BYTES = 1024
FILE_RECORDS = 512
/* POINTERS TO DATA OBJECTS */
^BROWSE_IMAGE = "MCC_MRD_20150501T114952183_B_GDS.PNG"
/* IDENTIFICATION DATA ELEMENTS */
RELEASE_ID = 1
DATA_SET_ID = "MR1ORB-M-MCC-3-MOP-RDR-RAD-V1.0"
DATA_SET_NAME = "MR1 ORBITER MARS MCC 3 MOP RDR RAD V1.0"
PRODUCT_ID = MCC_MRD_20150501T114952183_B_GDS
PRODUCT_TYPE = "RDR"
PRODUCER_ID = "MR1-ISRO-SAC-DP-TEAM"
PRODUCT_CREATION_TIME = 2015-07-25T15:49:29.029
PRODUCER_FULL_NAME = "MARS 1 ISRO SAC DATA PROCESSING TEAM"
PRODUCER_INSTITUTION_NAME = "
SPACE APPLICATIONS CENTRE ISRO, AHMEDABAD INDIA
"
PROCESSING_LEVEL_ID = "3"
PROCESSING_LEVEL_DESC = "2 Experiment Data Record,
3 Reduced Data Record"
MISSION_ID = "MR1"
MISSION_NAME = "MARS 1"
MISSION_PHASE_NAME = "MARS ORBITAL PHASE"
SPACECRAFT_ORIENTATION = 1
SPACECRAFT_ORIENTATION_DESC = "0 means descending,
1 means ascending"
SPACECRAFT_POINTING_MODE = NULL
SPACECRAFT_POINTING_MODE_DESC = NULL
QUATERNION = (0.285832,-0.224591,0.598311,0.714061)
QUATERNION_DESC = "Inertial-to-Body Quaternions"
SOLAR_AZIMUTH = 74.7152066030
SOLAR_ELEVATION = 64.178314
INSTRUMENT_HOST_ID = "MR1ORB"
INSTRUMENT_HOST_NAME = "MR1 ORBITER"
TARGET_NAME = "MARS"
TARGET_TYPE = "PLANET"
DSN_STATION_NUMBER = GDS



```

START_TIME = 2015-05-01T11:49:52.183
STOP_TIME = 2015-05-01T11:49:52.183
START_ORBIT_NUMBER = 000102
STOP_ORBIT_NUMBER = 000102
IMAGE_OBSERVATION_TYPE = "REGULAR"
/* DESCRIPTIVE DATA ELEMENTS */
INSTRUMENT_ID = "MCC"
INSTRUMENT_NAME = "MARS COLOUR CAMERA"
INSTRUMENT_TYPE = "IMAGING CAMERA"
INST_CMPRS_NAME = "ISRO PROPRIETRY"
FILTER_NAME = "BAYER FILTER"
FILTER_NUMBER = "3"
FILTER_TEMPERATURE = "N/A"
FILTER_TYPE = "ORGANIC"
CENTER_FILTER_WAVELENGTH = "N/A"
MR1:EXPOSURE_ID = 4
LINE_EXPOSURE_DURATION = "0.8 <ms>"
FOCAL_PLANE_TEMPERATURE = "N/A"
DETECTOR_ID = "CMV4000"
DETECTOR_DESC = "
CMV4000 - a high resolution, high speed snapshot colour CMOS image sensor
"
DETECTOR_TYPE = "CMOS IMAGE SENSOR"
DETECTORS = 4194304
DETECTOR_PIXEL_WIDTH = 5.5
DETECTOR_PIXEL_HEIGHT = 5.5
DETECTOR_TEMPERATURE = "8.571375 <deg C>"
SOFTWARE_NAME = "MOM-MCC-DPGS"
SOFTWARE_VERSION_ID = "V1.0"
MR1:JOB_ID = "
MCC01GD5MR10010300NNNN15122154232721_01_V1_0
"
MR1:L0_TAR_FILE_NAME = "
MCC01GD5MR10010300NNNN15122154232721.tar_V1.0
"
/* GEOMETRY DATA ELEMENTS */
SPACECRAFT_ALTITUDE = 553.4763796245
NOTE = "Mars Colour Camera (MCC) is a
Bayer Array RGB camera operating
in the visible range (0.4-0.7)
is a medium resolution camera
flown on the Mars Orbiter Mission.
It captures images of topography
of Martian surface.
It observes and helps in
furthering our understanding of events
like dust storms, dust devils etc.
Moving in an elliptical orbit of

```



MARS ORBITER MISSION (MOM)

MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 66

372km x 80000km around mars,
the camera produces
visible images of Mars and its
environs. The highly elliptical orbit
chosen for the Mars mission allow
imaging of localized scenes at high
spatial resolution as well as providing
a synoptic view of the full globe.
from apogee position of the orbit.
This instrument is from Space Applications
Centre, Ahmedabad, India
Scientific Objective :-

1. To map various morphological features
on Mars with varying resolution and
scales using the unique elliptical orbit.
2. To map the geological setting around
sites of Methane emission source.
3. To provide context information
for other science payloads.

Sensor Configuration :-

MCC uses a multi-element lens assembly
and a 2Kx2K area array detector with RGB
Bayer pattern to take images. The f/4 lens
has a focal length of 105mm with a
circularly symmetric field of view of
plusminus 4.4deg.

The detector has 2048 x 2048
elements on a pixel pitch of 5.5 microns
Salient Features:-

1. Spacecraft Altitude (km) - 372x80000
2. Resolution (m) - 19.5@Periareion
3. Frame Size (km) - 40x40@Periareion
(Full Mars disc from 63000km Apoareion)
4. Spectral region (micrometer) - 0.4-0.7
5. Frame rate - 1s (frame selection at 1s,
8s or 15s period by BDH through ground
commanding)
6. Exposure time (ms) - Total 16 ground
programmable exposures
ranging from 34 ms to 490 ms
7. Data volume/frame (Mb)- 40
8. System MTF@46 LP/mm ()-greater than 15
SNR @9. Near Saturation - greater than 50
values 999.999 for latitude and
longitude keywords indicate
that the location maps to cold space."

/* RETICLE POINT LAT-LON INFORMATION */
GROUP = UPPER_LEFT_RETICLE_POINT



MARS ORBITER MISSION(MOM)

MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 67

```
RETICLE_POINT_NUMBER      = "1"
RETICLE_POINT_LATITUDE    = -18.9279961955
RETICLE_POINT_LONGITUDE   = 287.7715533365
END_GROUP                  = UPPER_LEFT_RETICLE_POINT
GROUP                      = UPPER_MID_RETICLE_POINT
RETICLE_POINT_NUMBER      = "2"
RETICLE_POINT_LATITUDE    = -19.1286234924
RETICLE_POINT_LONGITUDE   = 287.2812024914
END_GROUP                  = UPPER_MID_RETICLE_POINT
GROUP                      = UPPER_RIGHT_RETICLE_POINT
RETICLE_POINT_NUMBER      = "3"
RETICLE_POINT_LATITUDE    = -19.3406345794
RETICLE_POINT_LONGITUDE   = 286.7590667128
END_GROUP                  = UPPER_RIGHT_RETICLE_POINT
GROUP                      = MID_LEFT_RETICLE_POINT
RETICLE_POINT_NUMBER      = "4"
RETICLE_POINT_LATITUDE    = -18.4603570245
RETICLE_POINT_LONGITUDE   = 287.5608868821
END_GROUP                  = MID_LEFT_RETICLE_POINT
GROUP                      = MIDDLE_MID_RETICLE_POINT
RETICLE_POINT_NUMBER      = "5"
RETICLE_POINT_LATITUDE    = -18.6604536587
RETICLE_POINT_LONGITUDE   = 287.0719934848
END_GROUP                  = MIDDLE_MID_RETICLE_POINT
GROUP                      = MID_RIGHT_RETICLE_POINT
RETICLE_POINT_NUMBER      = "6"
RETICLE_POINT_LATITUDE    = -18.8716597068
RETICLE_POINT_LONGITUDE   = 286.5513216372
END_GROUP                  = MID_RIGHT_RETICLE_POINT
GROUP                      = LOWER_LEFT_RETICLE_POINT
RETICLE_POINT_NUMBER      = "7"
RETICLE_POINT_LATITUDE    = -17.9634694601
RETICLE_POINT_LONGITUDE   = 287.3387537744
END_GROUP                  = LOWER_LEFT_RETICLE_POINT
GROUP                      = LOWER_MID_RETICLE_POINT
RETICLE_POINT_NUMBER      = "8"
RETICLE_POINT_LATITUDE    = -18.1631225818
RETICLE_POINT_LONGITUDE   = 286.8511221550
END_GROUP                  = LOWER_MID_RETICLE_POINT
GROUP                      = LOWER_RIGHT_RETICLE_POINT
RETICLE_POINT_NUMBER      = "9"
RETICLE_POINT_LATITUDE    = -18.3735998329
RETICLE_POINT_LONGITUDE   = 286.3317007174
END_GROUP                  = LOWER_RIGHT_RETICLE_POINT
/* BROWSE IMAGE DATA OBJECT DESCRIPTION */
OBJECT                     = BROWSE_IMAGE
ENCODING_TYPE              = PNG
LINES                      = 512
```



LINE_SAMPLES = 512
SAMPLE_TYPE = LSB_UNSIGNED_INTEGER
SAMPLE_BITS = 8
END_OBJECT = BROWSE_IMAGE
END

Table 14 Sample PDS Label for Grid data

APPENDIX IV: SAMPLE PDS LABEL FOR RDR GRID DATA PRODUCT

PDS_VERSION_ID = PDS3
LABEL_REVISION_NOTE = "2013-04-22, MR1-ISRO-SAC-DP-TEAM"
/* FILE CHARACTERISTICS */
FILE_NAME = "MCC_MRD_20150501T114750181_G_GDS.DAT"
RECORD_TYPE = FIXED_LENGTH
RECORD_BYTES = 80
FILE_RECORDS = 1156
/* POINTERS TO DATA OBJECTS */
^TABLE = "MCC_MRD_20150501T114750181_G_GDS.DAT"
/* IDENTIFICATION DATA ELEMENTS */
RELEASE_ID = 1
DATA_SET_ID = "MR1ORB-M-MCC-3-MOP-RDR-RAD-V1.0"
DATA_SET_NAME = "MR1 ORBITER MARS MCC 3 MOP RDR RAD V1.0"
PRODUCT_ID = MCC_MRD_20150501T114750181_G_GDS
PRODUCT_TYPE = "RDR"
PRODUCER_ID = "MR1-ISRO-SAC-DP-TEAM"
PRODUCT_CREATION_TIME = 2015-07-25T15:49:30.030
PRODUCER_FULL_NAME = "MARS 1 ISRO SAC DATA PROCESSING TEAM"
PRODUCER_INSTITUTION_NAME = "
SPACE APPLICATIONS CENTRE ISRO, AHMEDABAD INDIA
"
PROCESSING_LEVEL_ID = "3"
PROCESSING_LEVEL_DESC = "2 Experiment Data Record,
3 Reduced Data Record"
MISSION_ID = "MR1"
MISSION_NAME = "MARS 1"
MISSION_PHASE_NAME = "MARS ORBITAL PHASE"
SPACECRAFT_ORIENTATION = 1
SPACECRAFT_ORIENTATION_DESC = "0 means descending,
1 means ascending"
SPACECRAFT_POINTING_MODE = NULL
SPACECRAFT_POINTING_MODE_DESC = NULL
QUATERNION = (0.269893,-0.243480,0.645359,0.671853)



MARS ORBITER MISSION (MOM)

MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 69

```
QUATERNION_DESC          = "Inertial-to-Body Quaternions"
SOLAR_AZIMUTH            = 84.9204737573
SOLAR_ELEVATION          = 57.756935
PHASE_ANGLE              = 33.2932450951
EMISSION_ANGLE           = 1.1755920825
INCIDENCE_ANGLE          = 32.2259376225
SOLAR_DISTANCE           = 1.4957245887
SOLAR_LONGITUDE          = 335.0368611425
INSTRUMENT_HOST_ID       = "MR1ORB"
INSTRUMENT_HOST_NAME     = "MR1 ORBITER"
TARGET_NAME              = "MARS"
TARGET_TYPE              = "PLANET"
START_TIME                = 2015-05-01T11:47:50.181
STOP_TIME                 = 2015-05-01T11:47:50.181
START_ORBIT_NUMBER       = 000102
STOP_ORBIT_NUMBER        = 000102
IMAGE_OBSERVATION_TYPE   = "REGULAR"
/* DESCRIPTIVE DATA ELEMENTS */
INSTRUMENT_ID             = "MCC"
INSTRUMENT_NAME           = "MARS COLOUR CAMERA"
INSTRUMENT_TYPE           = "IMAGING CAMERA"
INST_CMPRS_NAME           = "ISRO PROPRIETRY"
FILTER_NAME               = "BAYER FILTER"
FILTER_NUMBER             = "3"
FILTER_TEMPERATURE        = "N/A"
FILTER_TYPE               = "ORGANIC"
CENTER_FILTER_WAVELENGTH  = "N/A"
MR1:EXPOSURE_ID           = 4
LINE_EXPOSURE_DURATION    = "0.8 <ms>"
FOCAL_PLANE_TEMPERATURE   = "N/A"
DETECTOR_ID               = "CMV4000"
DETECTOR_DESC             = "
    CMV4000 - a high resolution, high speed snapshot colour CMOS image sensor
"
DETECTOR_TYPE             = "CMOS IMAGE SENSOR"
DETECTORS                 = 4194304
DETECTOR_PIXEL_WIDTH      = 5.5
DETECTOR_PIXEL_HEIGHT     = 5.5
DETECTOR_TEMPERATURE      = "10.857075 <deg C>"
SOFTWARE_NAME              = "MOM-MCC-DPGS"
SOFTWARE_VERSION_ID       = "V1.0"
MR1:JOB_ID                = "
    MCC01GDSMR10010300NNNN15122154232721_00_V1_0
"
MR1:L0_TAR_FILE_NAME      = "
    MCC01GDSMR10010300NNNN15122154232721.tar_V1.0
"
/* GEOMETRY DATA ELEMENTS */
```



MARS ORBITER MISSION (MOM)

MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 70

SPACECRAFT_ALTITUDE = 646.2591038735
NOTE = "Mars Colour Camera (MCC) is a Bayer Array RGB camera operating in the visible range (0.4-0.7) is a medium resolution camera flown on the Mars Orbiter Mission. It captures images of topography of Martian surface. It observes and helps in furthering our understanding of events like dust storms, dust devils etc. Moving in an elliptical orbit of 372km x 80000km around mars, the camera produces visible images of Mars and its environs. The highly elliptical orbit chosen for the Mars mission allow imaging of localized scenes at high spatial resolution as well as providing a synoptic view of the full globe. from apogee position of the orbit. This instrument is from Space Applications Centre, Ahmedabad, India

Scientific Objective :-

1. To map various morphological features on Mars with varying resolution and scales using the unique elliptical orbit.
2. To map the geological setting around sites of Methane emission source.
3. To provide context information for other science payloads.

Sensor Configuration :-

MCC uses a multi-element lens assembly and a 2Kx2K area array detector with RGB Bayer pattern to take images. The f/4 lens has a focal length of 105mm with a circularly symmetric field of view of plusminus4.4deg.

The detector has 2048 x 2048 elements on a pixel pitch of 5.5 microns

Salient Features:-

1. Spacecraft Altitude (km) - 372x80000
2. Resolution (m) - 19.5@Periareion
3. Frame Size (km) - 40x40@Periareion (Full Mars disc from 63000km Apoareion)
4. Spectral region (micrometer) - 0.4-0.7
5. Frame rate - 1s (frame selection at 1s, 8s or 15s period by BDH through ground



MARS ORBITER MISSION (MOM)

MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 71

commanding)

6. Exposure time (ms) - Total 16 ground
programmable exposures

ranging from 34 ms to 490 ms

7. Data volume/frame (Mb)- 40

8. System MTF@46 LP/mm ()-greater than 15

SNR @9. Near Saturation - greater than 50

values 999.999 for latitude and

longitude keywords indicate

that the location maps to cold space."

/* RETICLE POINT LAT-LON INFORMATION */

GROUP = UPPER_LEFT_RETICLE_POINT

RETICLE_POINT_NUMBER = "1"

RETICLE_POINT_LATITUDE = -15.6978525342

RETICLE_POINT_LONGITUDE = 295.7994855954

END_GROUP = UPPER_LEFT_RETICLE_POINT

GROUP = UPPER_MID_RETICLE_POINT

RETICLE_POINT_NUMBER = "2"

RETICLE_POINT_LATITUDE = -15.9526495477

RETICLE_POINT_LONGITUDE = 295.2462250541

END_GROUP = UPPER_MID_RETICLE_POINT

GROUP = UPPER_RIGHT_RETICLE_POINT

RETICLE_POINT_NUMBER = "3"

RETICLE_POINT_LATITUDE = -16.2222095626

RETICLE_POINT_LONGITUDE = 294.6570472001

END_GROUP = UPPER_RIGHT_RETICLE_POINT

GROUP = MID_LEFT_RETICLE_POINT

RETICLE_POINT_NUMBER = "4"

RETICLE_POINT_LATITUDE = -15.1607275700

RETICLE_POINT_LONGITUDE = 295.5367820791

END_GROUP = MID_LEFT_RETICLE_POINT

GROUP = MIDDLE_MID_RETICLE_POINT

RETICLE_POINT_NUMBER = "5"

RETICLE_POINT_LATITUDE = -15.4148696284

RETICLE_POINT_LONGITUDE = 294.9850751099

END_GROUP = MIDDLE_MID_RETICLE_POINT

GROUP = MID_RIGHT_RETICLE_POINT

RETICLE_POINT_NUMBER = "6"

RETICLE_POINT_LATITUDE = -15.6834057019

RETICLE_POINT_LONGITUDE = 294.3974229891

END_GROUP = MID_RIGHT_RETICLE_POINT

GROUP = LOWER_LEFT_RETICLE_POINT

RETICLE_POINT_NUMBER = "7"

RETICLE_POINT_LATITUDE = -14.5899459324

RETICLE_POINT_LONGITUDE = 295.2597156779

END_GROUP = LOWER_LEFT_RETICLE_POINT

GROUP = LOWER_MID_RETICLE_POINT



MARS ORBITER MISSION(MOM)

MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 72

```
RETICLE_POINT_NUMBER      = "8"
RETICLE_POINT_LATITUDE    = -14.8435723126
RETICLE_POINT_LONGITUDE   = 294.7092817325
END_GROUP                  = LOWER_MID_RETICLE_POINT
GROUP                      = LOWER_RIGHT_RETICLE_POINT
RETICLE_POINT_NUMBER      = "9"
RETICLE_POINT_LATITUDE    = -15.1112103916
RETICLE_POINT_LONGITUDE   = 294.1228489674
END_GROUP                  = LOWER_RIGHT_RETICLE_POINT
/* TABLE DATA OBJECT DESCRIPTION */
OBJECT                     = TABLE
INTERCHANGE_FORMAT        = ASCII
ROWS                      = 1156
ROW_BYTES                 = 80
COLUMNS                  = 4
NAME                      = "MCC GRID"
DESCRIPTION                = "This table contain martian
                           coordinates for the image points."
OBJECT                     = COLUMN
COLUMN_NUMBER             = 1
NAME                      = "PIXEL"
DATA_TYPE                 = LSB_UNSIGNED_INTEGER
START_BYTE                = 6
BYTES                     = 6
DESCRIPTION                = "pixel of an image"
END_OBJECT                = COLUMN
OBJECT                     = COLUMN
COLUMN_NUMBER             = 2
NAME                      = "SCAN"
DATA_TYPE                 = LSB_UNSIGNED_INTEGER
START_BYTE                = 1
BYTES                     = 4
DESCRIPTION                = "scan of an image"
END_OBJECT                = COLUMN
OBJECT                     = COLUMN
COLUMN_NUMBER             = 3
NAME                      = "LATITUDE"
DATA_TYPE                 = ASCII_REAL
START_BYTE                = 13
BYTES                     = 12
FORMAT                    = "F12.8"
UNIT                      = DEGREE
DESCRIPTION                = "LATITUDE"
END_OBJECT                = COLUMN
OBJECT                     = COLUMN
COLUMN_NUMBER             = 4
NAME                      = "LONGITUDE"
DATA_TYPE                 = ASCII_REAL
```



MARS ORBITER MISSION (MOM)

MCC EAICD

Document No. : MCC-SAC-EAICD-01
Issue/Rev. No. : D/C
Date : September 11, 2015
Page : 73

START_BYTE = 26
BYTES = 12
FORMAT = "F12.8"
UNIT = DEGREE
DESCRIPTION = "LONGITUDE"
END_OBJECT = COLUMN
END_OBJECT = TABLE
END