Mars Colour Camera (MCC)

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Abstract

Mars Colour Camera (MCC), on-board Mars Orbiter Mission (MOM), is a `true colour' (offering a natural colour rendition) medium resolution camera based on Bayer pattern detector and operating in the visible range (0.4μ to 0.7μ).The camera returns high quality visible images of Mars and its environs. The highly elliptical orbit chosen for the Mars mission allows imaging of localized scenes at high spatial resolution as well as providing a synoptic view of the full globe. MCC has taken a large number of images showing interesting morphological features on the Martian surface and has also captured the two moons of Mars – Phobos and Deimos during its current Martian orbit phase of the mission.

1. Introduction

Mars, one of the terrestrial planets in our solar system, has been an object of general curiosity as well as specific scientific inquiries since time immemorial due to its similarities with Earth in terms of seasonal cycles and thermal environment which is considered to be conducive to the evolution and development of life forms. Even though there have been concerted efforts to gather information about Mars over the years, still much needs to be known about it. ISRO has sent its first orbiter mission to Mars carrying instruments with well-defined scientific objectives. The orbit for the Mars mission is nearly 400km x 72,000km around Mars. Choice of such a highly elliptical orbit facilitates both localized observations with higher spatial resolution as well as observations with large coverage and high radiometric and temporal resolutions.

Mars Colour Camera (MCC) is a medium resolution camera with a RGB Bayer pattern detector. It is a `true colour' (offering a natural colour rendition, i.e., the colours in the image appearing the same way as in the object) and has been designed to return images of Mars, its Moons (Phobos & Deimos) and other celestial objects in natural colour. MCC is designed to meet the following scientific objectives: -

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, if any.
3. To provide context information for other science payloads.

MCC is capable of taking images with a spatial resolution of nearly 20m from an altitude of 400km and can acquire complete Martian disc from an altitude of 63000km and beyond. Fig. 1 gives the Instantaneous Geometric Field Of View (IGFOV) and coverage of the camera from orbital heights of 372km (Periareion), 43000km, 63000km and 80000km (Apoareion).

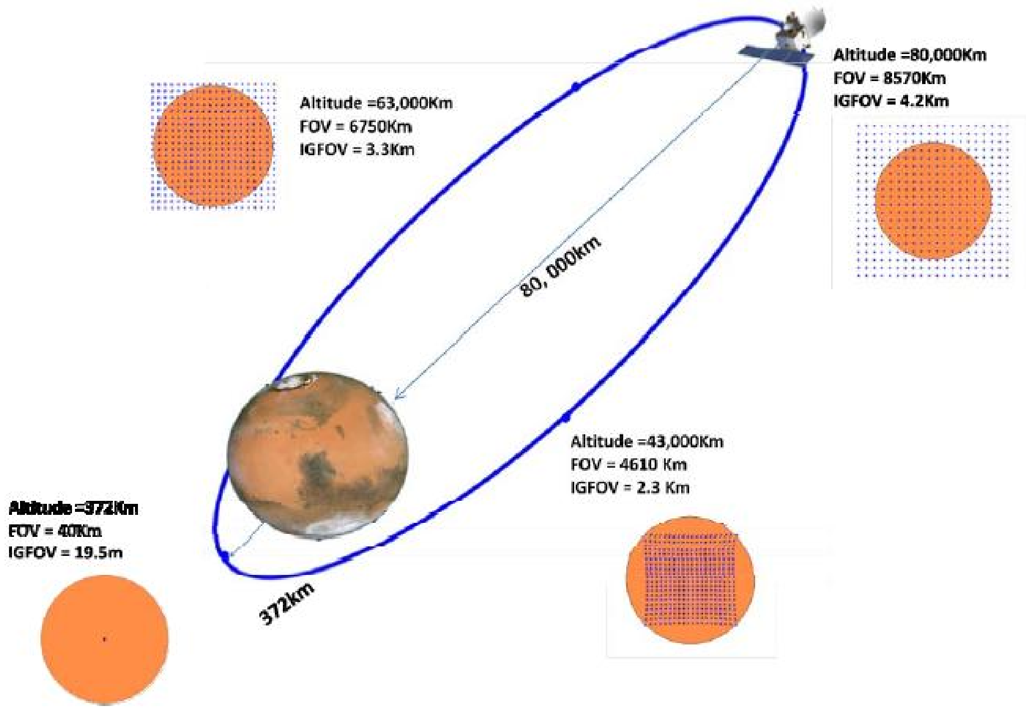

Fig.1: Coverage with MCC from different orbital heights

2. Working Principle

MCC uses a multi-element lens assembly and an area array detector with RGB Bayer pattern to take images just like a typical colour digital camera. The incident light or signal is collected by the lens assembly and focused on to an area array detector (having 2048 x 2048 pixels). As mentioned earlier MCC makes use of a RGB Bayer pattern (Fig.2) in the focal plane with organic R, G or B filter deposited on each pixel to generate colour images.

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. The signal from the detector is then further processed by the associated camera electronics. The Camera electronics generates bias for detector and carries out

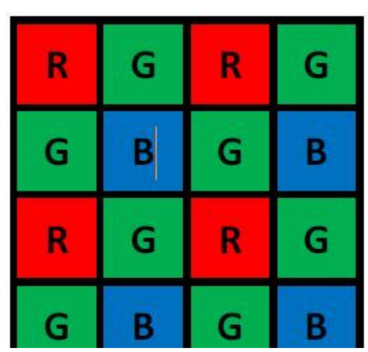

Fig.2: A typical RGB Bayer Pattern

clock generation, data preprocessing and generation of biases from raw bus. The raw data volume is 40Mb/Frame from which colour image is generated at ground using standard demosaicing. MCC hardware is realized with light-weight miniaturized components.

3. MCC Configuration

Table 1 lists the salient features and performance specifications of MCC. Fig.3 gives the schematic of the camera. MCC uses a multi-element lens assembly for collecting the incident radiation from Mars and focusing on the detector. A Commercial Off-The-Shelf (COTS) lens assembly having a focal length of 105mm with an f-number of 4.0, diagonal field of view (±4.4˚) and spectral range (400nm to 700nm) was selected for MCC based on the performance parameters and mission requirements of smaller, size and weight.

Table. 1 Salient Features and Performance Specifications of MCC

Parameter	Value
S/C Altitude (km)	372 x 80000 (Elliptical orbit)
Resolution (m)	19.5 @ Periareion
Frame Size (km)	40 x 40 @ Periareion Full Mars disc from 63000 km to Apoareion
Spectral region (µm)	0.4 – 0.7
Frame time	1s (frame selection at 1s, 8s or 15s period by ground commanding)
Exposure time	Total 16 ground programmable exposures ranging from 34µs to 490ms
Data volume/frame (Mb)	40
System MTF @ 46 LP/mm (%)	>21 (Spec. > 15%)
SNR @ Near Saturation	>95 (Spec. > 50)
Size (mm^3)	346 x 128 x 113 (EOM + LCE) 122 X 105 X 26 (PSE)
Mass (kg)	1.27 (Goal < 1.5kg)
Raw Power (W)	3.0 (Goal < 4W)

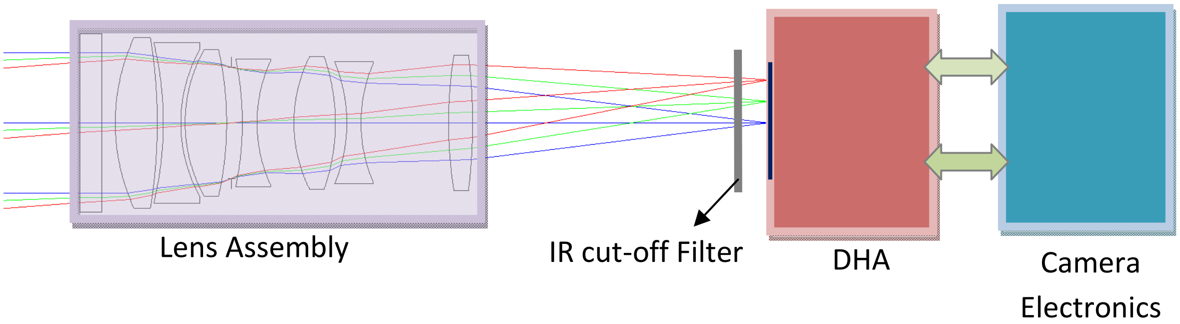

Fig.3: Schematic of MCC payload

An IR cut-off filter (with an average transmission of 95% from 400nm to 700nm with a sharp cut-off at 735nm) mounted on a precisely designed and machined, stress free mounting using flexures was placed in front of the detector to limit the out-of-band response beyond the red region (>700nm) for obtaining colour images with high fidelity.Fig.4 below shows theopto-mechanical lens assembly for MCC payload.

Fig.4: MCC lens assembly

Detector head assembly (DHA) consists of a commercial high speed silicon based snapshot colour CMOS detector and proximity electronics interfaced in a mechanical housing. It is an area array having organic filters. Incoming light is filtered out through Red (R), Green (G) and Blue (B) organic filters deposited on top of each pixel in the form of a RGGB Bayer pattern. Colour imagery is generated by using the property of depth of penetration of light in a silicon wafer.

With this approach, each pixel gets to detect information in one band (either R or G or B). Information on other two bands is estimated by interpolating information from the surrounding pixels. The detector incorporates most of front electronics including analog to digital converter in it. Fig.5 shows the populated fight model detector head assembly.

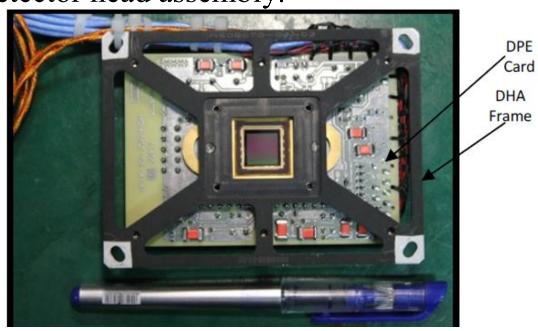

Fig.5: Populated Flight Model DHA

The Camera Electronics (CE) design and development 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 (<1mV) while taking into account the requirements of miniaturization. The miniaturization and performance requirements of Camera electronics are met by selecting state of the art space grade components like Field Programmable Gate Arrays (FPGA) for logic implementation, Low Drop Out (LDO) voltage regulators, compact hybrid DC-DC modules, integrating electronics functions near to the focal plane, usage of Micro-D connectors, Multi-Layer PCBs etc.

The CE consists 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 (<5mV PARD) regulated power lines to the payload.Fig.6shows the block diagram of camera electronics.

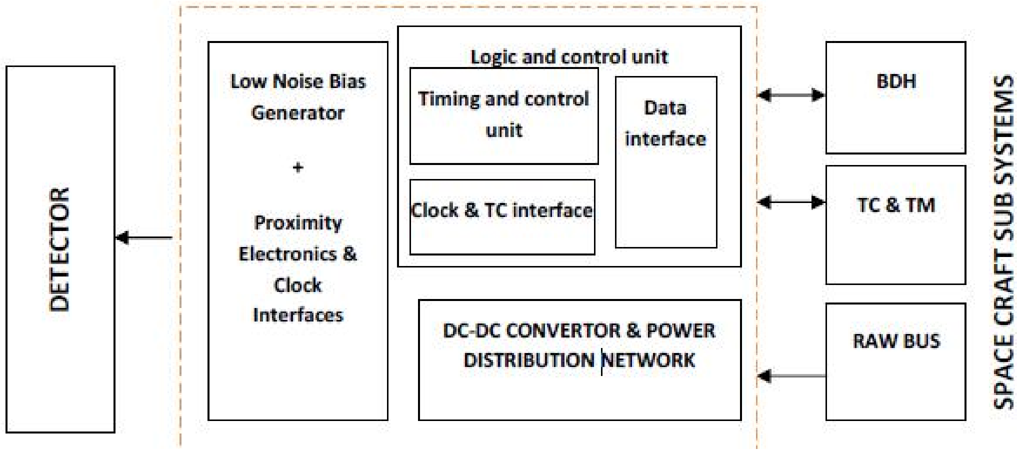

Fig.6: Block Diagram of Camera Electronics

The Electro Optic Module (EOM) structure is 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.

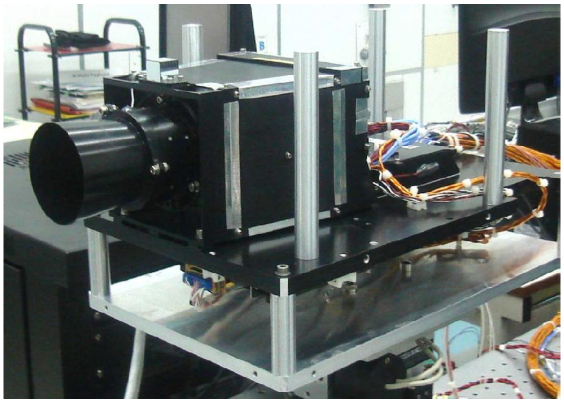

Fig.7:Flight Model of MCC payload

Integrated payload evaluation and characterization: Fig.7 shows the flight model of MCC payload. Performance of the payload has been evaluated at the integrated payload level as per the test & evaluation (T&E) guidelines. Payload performance were verified during Initial Bench Test (IBT), Post Vibration Test, Thermovac tests and Final Bench Test (FBT) phases of T&E. MCC system is optimized to produce best optical and electrical performance for all three bands. MCC payload has been characterized in terms of various performance parameters like Modulation Transfer Function (MTF), payload alignment and its stability, effective focal length (EFL) and distortion, ghost/background analysis, dark noise, Signal to Noise Ratio (SNR) at near saturation etc. Radiometric, spectral and geometric performance meets the requirements with comfortable margins. Performance of MCC payload is found consistent and satisfactory during the development in lab, payload integration, T&E, S/C integration & testing, operation during geocentric, heliocentric and in Martian orbit till the date

4. Post-Launch Performance

Mars Orbiter spacecraft was launched on 5^{th} Nov, 2013. During the long cruise of MOM towards Mars, health parameters were monitored and the performance of the camera was tested. MCC started imaging from 19^{th} Nov 2013. Earth Imaging Experiments (EIE) and Mars imaging experiments (MIE) were conducted during the Earth & Mars Orbit Phase (EOP / MOP) in order to assess the functional and performance aspects of MCC and to assess its application potential vis-à-vis the objectives envisaged. Three imaging sessions on two different dates viz. two sessions on 19th November and one session on 23rd November 2013, were conducted during EOP. This included imaging from varying – altitudes (spatial resolution), -illumination conditions , taking multiple snap-shots of a given area of interest (AOI) etc. in order to view physiographic, morphological and other geological details of our planet so as to ascertain the expected results from highly elliptical Mars Orbit.

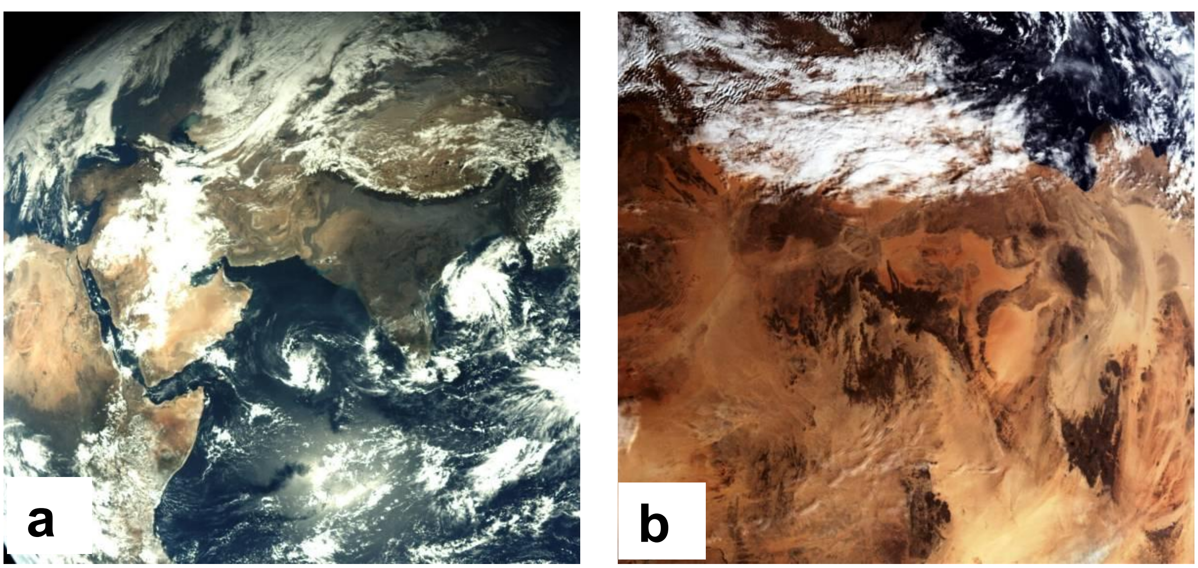

Fig.8: a) First image acquired by MCC on 19 Nov 2013 (left) and b) image on 23^{rd} Nov 2013 over Sahara desert (right)

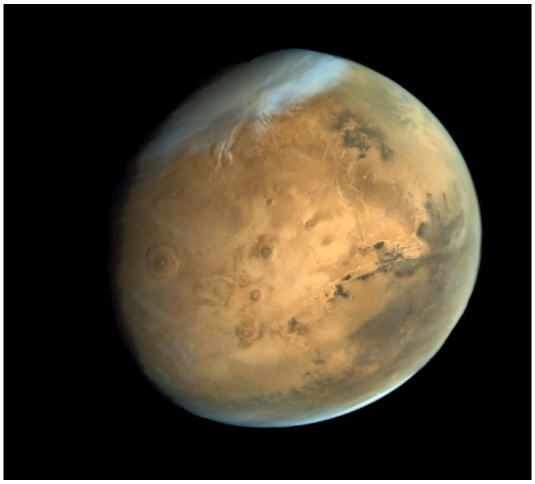

Fig.9: HDR product of the global view of Mars imaged by MCC

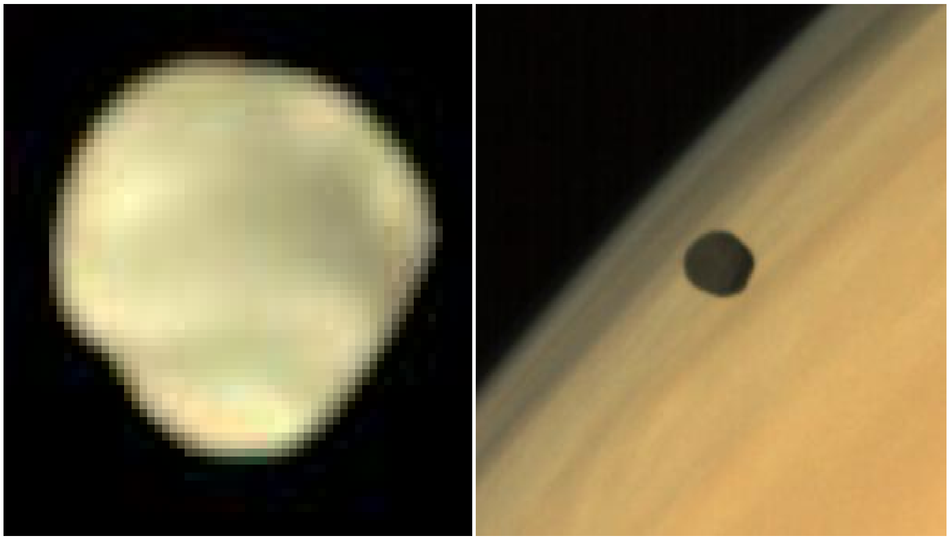

Fig. 10: Deimos (left) and Phobos (right), the two natural satellites of Mars as imaged by MCC. Bright Mars can be seen in the background of darker & smaller Phobos occupying the centre of the frame

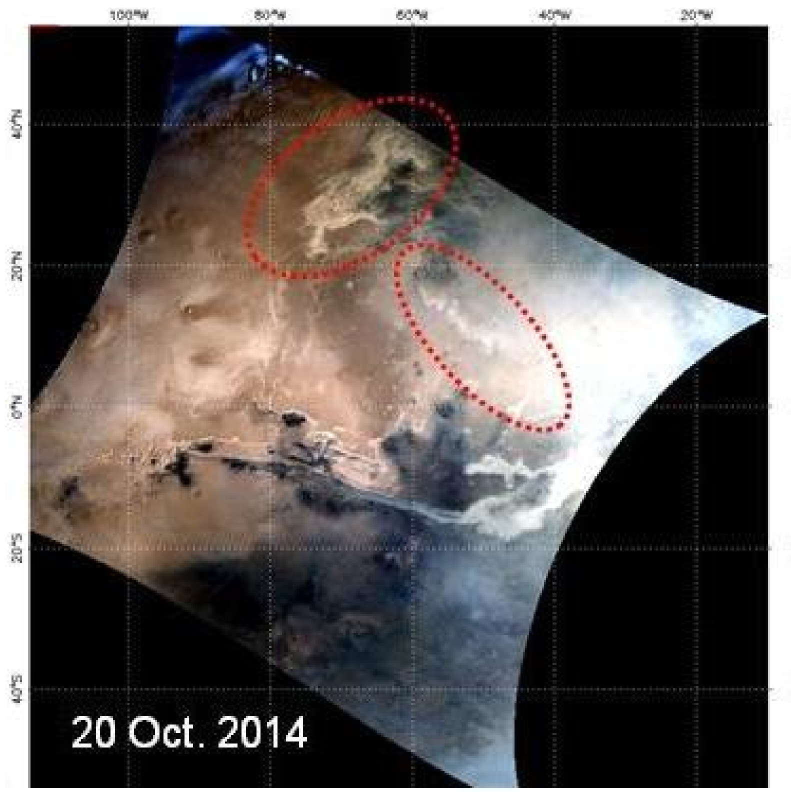

Fig.11: Dust storm (within red dotted circles), north of Vallies Marineries, appears bright.

5. Conclusions

Mars Colour Camera on-board Mars Orbiter Mission is the first camera to acquire a global 2-dimensional image of the surface of Mars. Post launch performance of the payload has been very good. The images generated from MCC are expected to help the scientific community to further understand the static (morphological) Martian features and dynamic processes (Ice-cap changes, Dust devils etc.) during the useful life of the mission.

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