CHALLENGES IN THE DESIGN OF SPACE GRADE STATE OF THE ART NAVIGATION CAMERAS FOR LUNAR ENVIRONMENT. Jayanta laha[1] ,B.Dinesh[2], P Selvaraj[3] and Subhalakshmi Krishnamoorthy[4] Scientist[1-4], Laboratory For Electro Optics Systems, Indian Space Research Organization, 1Stage ,1 Phase, Peenya Industrial Estate,Bangalore-560058,India. Email: jslakshmi@leos.gov.in

Introduction: The Lunar Rover in Chandrayaan-2 will have the basic mobility to do scientific operations on the lunar terrain [1] , and it is designed to have semi autonomous mobility. It will have a pair of navigation cameras to provide imaging of the terrain ahead which is used in ground to construct 3–dimensional Digital Elevation Model (DEM) of the lunar surface features. This paper gives the details regarding the design of state of the art Navigation Cameras and the challenging methodologies adopted to make it withstand the lunar planetary environment.

Mission Requirements:

- Resolve 20 mm @ 5 meter.
- Overlap between 2 cameras > 60%.
- Scene illumination: 0.3 lux to 1, 50,000 lux.
- Operating temp: - 55^0 C to + 80^0 C.
- Storage temp : - 150^0 C to + 80^0 C.
- Rad hardness : To with stand 10 k rads.

Table 1. Camera Specification:

PARAMETERS	VALUE
Detector	STAR 1000 APS
FOV	37°(H) x 37°(V)
Spectrum	Visible (400 to 900nm)
Power	< 1.5 W
Frame Rate	3 FPS
Data rate	24 Mega bits per sec
Interface	Serial digital
Supply Voltage	5V ± 150mv
Pixel dimension	15 µm x 15 µm
Focal length	21 mm.
Size of camera	55 x 55 x 75 mm,
Weight	150 gm including optics

Lunar Environment: The entire Lunar Rover system/design is oriented towards the survival of the lunar environment. Since the landing site is tentatively fixed as the south pole of the Moon, the published environment parameters of Lunar South Pole [2] is taken as the input for Camera design. Among the various environmental factors, the long freezing cold during lunar nights and the high energy particle radiation are the most challenging parameters to be survived. The design of image sensor, lens, electronics and the structure holding all the above elements have been configured accordingly. The stringent mass requirement is met by adopting suitable packaging technology and mechanical design.

Design of the Navigation camera:

Electronics design. Fig 1 depicts the block diagram of camera electronics. It consists of APS, FPGA, Digital circuits and LVDS transceivers. The image sensor is a monochromatic radiation hardened Active Pixel Sensor (APS) having 15µmX15µm pixels arranged in 1024 x 1024 patterns [3]. It also survives thermal extremes with a BK7 window. They are populated in a Flex rigid PCB made of Polyimide and surface finish of ENIG with minimum deformation coefficient over the extreme temperature range. The solder material, wire material, conformal coating and potting materials are selected to withstand the Cryo temperatures.

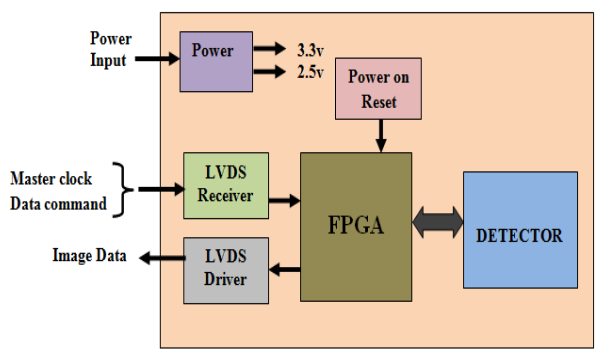

Fig1. Block diagram of the Nav Camera.

Optics design. The optics is a combination of BK7 and quartz optical elements with precise geometry. Survival of residual thermal loads due to expansion and contraction are suitably handled by providing a special space grade epoxy in between glass and the titanium mounts. Care is taken to avoid thermal load reaching the optical elements through an optimum design of epoxy thickness. Though the lens is held by an aluminum structure, the variation in focal length due to temperature variations is almost nullified by providing titanium spacers between the lens and the image sensor.

Mechanical design. A simple space qualified aluminum alloy structure made of a single block holds the electronics and the lens in their positions. Also it is designed to survive the launch and landing loads. By adopting compact rigid flex electronics and a miniature lens, and CFRP cover, the camera mass is brought down to 150gm.The focal length is 21mm and the F number is 1/7 to get optimum image [4]. The mass achieved for the lens is 30gmFig2 shows the flex rigid PCB.Fig3 shows the 3D model. Fig4 gives the exploded view of the camera.

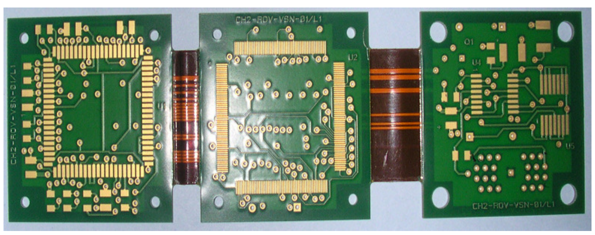

Fig2. Flex rigid PCB

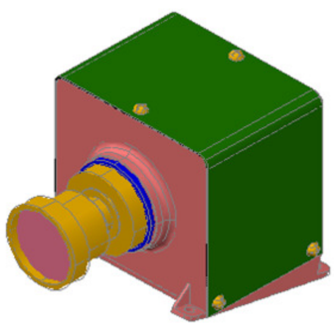

Fig3. 3D Model of the Camera

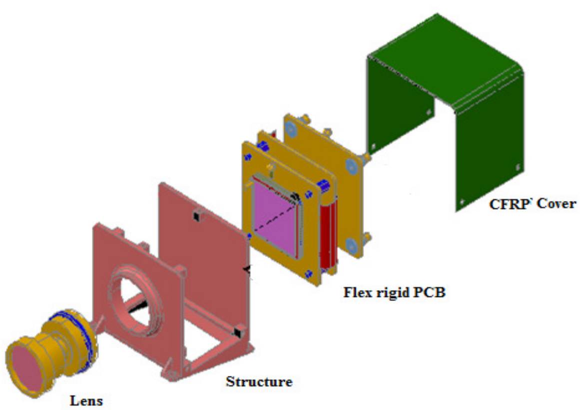

Fig 4. 3D Exploded view of the Camera.

Additional features:

- Telecommand provision to control electronics exposure and gain.
- Without Onboard memory, pixel average based image compression is incorporated in FPGA.
- Custom Digital Serial Interface.

Test plan: A test system is developed with PC and high speed digital I/O card to acquire the stereo images from the pair of cameras and display. Using DEM software the depth and height of the object is obtained. The following tests will be performed on the camera.

1. Thermovaccuum test.
2. Vibration Tests.
3. Camera photometric calibration test in Integrating sphere facility to estimate the SNR for different illumination conditions and to obtain Dynamic range.
4. Qualitative analysis of the images like MTF, Histogram.
5. Alignment of the cameras to obtain stereo images for generating DEM.
6. Estimation of DEM accuracies.

Conclusion: Proto model cameras, two numbers were developed and integrated with the Rover. Images from cameras were read out through Rover onboard telemetry, acquired and displayed. This test was carried out on lunar soil simulant with simulated lunar illumination conditions.

References:

[1]J. N. Goswami[1] and M. Annadurai[2].(2011) LPS 47 ,Abstract# 2042 [2] James Fincannon (2007), 5th IECEC. [3] Ram K. Tripathi, John E. Nealy (2007) IEEEAC paper #1291, Version 4. [4] J.F. Bell III[1], S.W. Squyres[1], K.E. Herkenhoff[2], J. Maki[3], M. Schwochert[3], A. Dingizian[3], D. Brown3, R.V. Morris[4], H.M. Arneson[1], M.J. Johnson[1], J. Joseph[1], J.N. Sohl-Dickstein[1], and the Athena Science Team. (2003) LPSXXXIV, Abstract# 1980.