Terrain Characterisation of Potential Landing Sites for Chandrayaan-3 Lander using Orbiter High Resolution Camera (OHRC) Images

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Introduction: Chandrayaan-3 mission of ISRO will comprise of a Propulsion module, a Lander Craft containing a Rover and fulfill the goal of soft landing on lunar surface in the south polar area of earth's moon. The prime objective of Chandrayaan-3 mission is to design, realize and deploy a Lunar LanderRover, capable of soft landing on a specified lunar site and deploy a Rover to carry out in-situ analysis. Landing site selection plays a key role in the success of any soft landing mission and it depends on the onboard engineering instruments and landing sensors capabilities (Temperature, accuracies of landing instruments, and shadows due to local and global terrain slope) and operational constraints like earth visibility and sun illumination. Potential landing sites were also identified during Chandrayaan-2 mission [1] and finally a prime landing site covering an area of 500m x 500m was targeted in the south polar area of lunar surface. Unfortunately Chandryaan-2 Lander hard landed on the moon surface near to the identified landing site and hence a lot of debris were spread in and around the chandrayaan-2 landing site. These debris may be danger for a new lander because the safer area for landing has futher reduced due to debris. Additionally, the landing area needs to be increased from 500m x 500m to 4km x 2.4km to cater all the dispersions in along and across track position of lander at hovering point. Due to this, new landing sites are required to be identified and characterized for the Chandrayaan-3 mission.

Landing Site Identification: The basic criteria for landing site selection for chandrayaan-3 includes the local and global slope, sun illumination, radio communication with the earth, crater and boulder sizes. For selecting suitable sites using coarse and medium resolution data: Local Slope should be less than 10 degree, Global slope should tend towards equator, more than 90% of the site area to be in sunlit for 10-11 days, boulder size should not be more than 2m and minimum crater and boulder distribution in the area. The site must be in near side of South Polar Region.

The site selection started with analyzing the 03 shortlisted sites for Chandrayaan-2 Landing in the 70-80 degree latitude range. These sites were again revisited for chandrayaan-3 landing site, but it was found that these sites are not meeting the landing area (4km x 2.4km) requirement. After this, it was decided to study the area between 60 to 70 degree latitude for landing site selection. The study was based on datasets received from Chandrayaan-1, Clementine and Lunar Reconnaissance Orbiter (LRO-NAC, LRO-WAC and LOLA) and Chandrayaan-2 (OHRC) missions.

During the initial study, the landing site identification was based on topography, slope derived from LOLA DEM (30m Grid interval) and shadows detected from selene images on the landing site. Hazard map for entire area within 60 to 70 degree latitude of near side of moon surface was created with a buffer of one degree in minimum and maximum latitudes. A moving window for searching hazard free area of 4 km x 2.4 km was executed over the entire hazard map to select the best sites containing less area of hazard. Twenty sites were selected for terrain analysis by medium resolution datasets (LOLADEM, Selene DEM and Ortho-image and LRO-NAC image). Out of 20 sites, 08 sites (Figure-1) satisfying the conditions particularly maximum percentage of hazard free (safe) area, sun lit area and eastern longitude constraints were selected for further characterization using Orbiter high resolution Camera data.

Characterization of the Hazards using OHRC datasets: Stereo images were acquired for 08 sites by OHRC camera onboard Chandrayaan-2 orbiter. Because of the OHRC on-board Chandrayaaan-2 Orbiter, it was possible to acquired the multi-view (stereo) images of the selected eight sites at better than 32cm pixel resolution. These images have been used for generation of DEM at 0.32m grid interval having a height resolution of 0.05m [2]. The OHRC DEMs and Ortho-images of the 08 sites provided us the freedom to fully characterized the landing site with respect to terrain undulations, slope, aspect and illumination constraints. The following criteria were used to final landing site selection for safe landing.

- Slope less than 10 deg.
- Boulders less than 0.32 meter.
- Crater and boulder distribution.
- Sunlit for at least 11-12 days.
- Visible to Earth for Radio communication
- Local terrain features such that they don't shadow the site for long durations
- Distribution of safe grid of 24m x 24m inside 4km x 2.4km landing area

Results: All the sites were ranked according to terrain parameters, sun illumination and location latitude and finally 03 sites were selected. For all the three sites one additional criteria of distribution of safe grids of 24m x 24m , 36m x 36m and 48m x 48m inside the entire area of 4 km x 2.4 km were considered and it was found that LS-2 contains better safe grid distribution in the entire

area and it provides flexibility for lander to land at any place in 4 km x 2.4 km area within a distance of 100m from the lander hovering point. Figure-2,3 and 4 provides the characteristics of LS-2 while Figure-5 provides the overall ranking of all the 08 sites. LS-2 is considered as prime landing site for Chandrayaan-3. This site lies between Manzius U and Boguslawsky M craters.

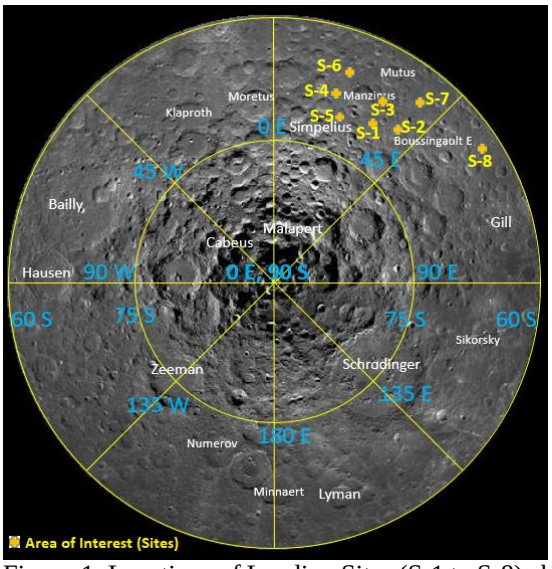

Figure-1: Locations of Landing Sites (S-1 to S-8) characterized using OHRC Images

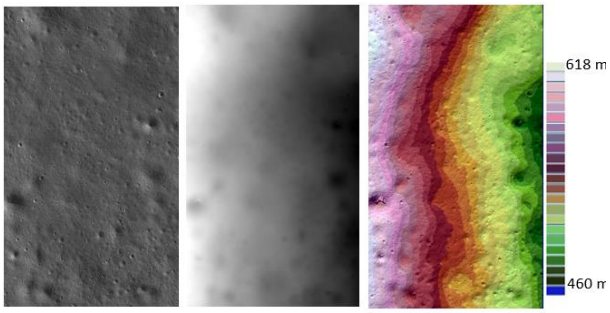

Figure-2: OHRC Ortho-image, DEM and and corresponding painted DEM of LS-2 for 4km x 2.4km area (Prime Landing Site)

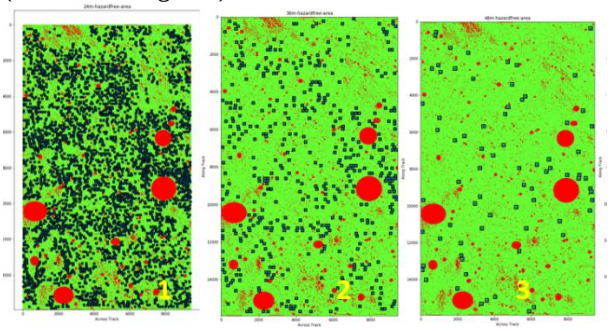

Figure-3: Distribution of safe Grid in the hazard Map of LS-2 (as blue marked, 1- 24m x 24m, 2- 36m x 36m & 3- 48m x 48m)

Dist.(m)	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
100	1	4	0	0	1	0	0	0	0	1	6	0	2	5	4	3	3	6	2	0	0	1	1	5
200	3	6	2	1	0	2	0	0	0	0	5	2	7	5	2	0	4	3	2	0	2	9	6	4
300	7	5	4	0	0	0	0	1	1	0	1	3	5	2	1	1	3	5	0	2	1	2	7	4
400	1	6	7	3	7	3	1	5	3	5	0	1	0	3	3	1	1	6	0	0	2	6	4	4
500	5	3	7	0	2	4	9	7	4	4	1	4	1	4	6	1	0	3	1	0	0	1	1	8
600	0	4	7	6	4	2	4	2	1	2	3	5	4	6	5	2	3	0	1	1	1	3	5	2
700	4	7	8	6	9	5	4	8	6	3	5	7	7	11	8	6	1	0	0	0	0	2	0	3
800	3	3	6	6	6	5	9	8	5	5	6	6	6	3	3	8	2	2	3	2	1	6	6	5
900	3	2	8	3	0	5	0	6	1	4	2	3	3	6	3	5	4	0	2	2	0	4	6	3
1000	3	2	5	4	0	2	4	2	3	4	2	4	6	7	10	4	4	2	0	0	0	2	2	5
1100	5	7	3	4	3	4	8	5	3	3	4	7	7	11	10	6	2	0	3	0	0	0	1	1
1200	6	4	7	2	4	4	2	2	7	4	4	2	8	4	8	6	2	0	1	0	2	1	7	3
1300	4	8	6	3	0	5	8	4	7	5	5	7	11	3	2	2	4	4	5	1	3	0	4	10
1400	3	6	5	3	0	2	6	6	3	4	0	4	5	6	2	5	2	2	8	7	2	9	2	4
1500	5	3	1	5	8	4	6	6	6	4	2	3	4	2	5	7	9	5	5	9	8	3	4	8
1600	4	4	6	6	8	7	3	5	6	4	1	4	2	3	1	4	5	5	3	3	1	4	1	4
1700	7	8	11	3	5	9	8	6	8	6	6	3	3	6	2	3	7	6	3	1	0	3	8	2
1800	7	10	10	9	6	9	3	3	7	3	2	6	1	3	7	5	6	10	5	7	2	6	6	5
1900	1	3	4	0	2	3	3	1	0	8	8	5	6	4	4	3	2	10	7	6	5	5	5	4
2000	4	5	1	2	6	2	3	9	1	7	5	3	5	3	2	2	6	10	8	2	5	3	6	1
2100	3	5	3	0	6	3	5	2	6	5	2	2	4	9	4	2	8	7	7	8	5	8	5	9
2200	3	4	2	1	8	8	4	4	3	10	1	4	2	4	5	6	1	10	7	6	11	8	11	11
2300	3	2	6	5	4	8	11	4	6	4	4	5	2	3	4	1	1	6	6	0	0	0	9	12
2400	5	5	4	4	2	1	7	3	6	5	5	6	4	3	9	8	3	7	2	0	0	0	3	10
2500	8	6	6	0	1	2	5	9	5	4	5	5	3	7	8	8	6	1	6	0	0	0	2	9
2600	6	2	3	2	3	4	4	7	4	3	3	3	7	9	11	10	3	4	5	4	7	3	7	9
2700	0	0	0	3	5	2	8	4	2	2	1	3	2	8	6	4	5	1	3	6	5	0	2	8
2800	0	0	0	5	6	7	3	6	3	6	3	3	4	6	4	5	3	2	5	5	3	1	0	1
2900	0	0	2	4	10	8	4	5	5	6	6	5	5	9	4	7	1	0	3	5	7	10	3	0
3000	5	4	8	7	6	8	9	6	9	4	4	7	7	8	6	10	2	4	2	7	1	6	1	4
3100	6	1	7	9	0	3	0	4	5	5	0	3	6	6	8	2	1	0	7	5	7	5	2	2
3200	3	3	8	2	5	5	4	2	3	2	2	2	3	0	2	0	2	5	5	3	2	2	2	3
3300	9	3	1	0	8	7	7	3	1	5	1	5	3	8	6	5	5	5	2	7	4	4	3	2
3400	3	0	3	1	0	4	6	3	3	3	1	3	7	8	3	1	4	4	4	2	2	3	5	3
3500	8	0	3	2	1	0	9	4	1	2	1	2	1	2	1	1	5	2	4	7	8	6	1	0
3600	7	0	9	3	0	2	7	3	8	9	3	0	0	1	5	4	6	6	5	1	2	4	3	5
3700	8	6	6	1	3	6	4	2	4	5	0	0	1	1	5	3	6	2	5	4	4	6	2	1
3800	8	8	6	2	5	4	4	1	1	4	1	0	2	0	2	2	6	1	2	3	4	2	5	3
3900	6	8	0	0	0	0	0	3	5	0	6	4	0	1	1	2	2	1	0	1	4	3	7	4
4000	6	6	0	1	3	0	0	1	8	9	11	4	2	1	0	0	7	1	0	3	0	2	8	6
4100	2	3	0	4	6	3	3	0	1	5	10	4	1	3	7	9	5	3	3	4	5	6	5	8

Figure-4: No. of 24m x 24m safe Grid available at 100m traversal from any point inside 4km x 2.4 km landing area

LS ID	Lat. (DD)	Long. (DD)	Height (m)	Global Slope (Mean Slope) in Degrees	Safe area (%) 4kmx2.4 km area Using OHRC	Craters (>1.2 m) / Sq km	No. of Free square Grids (24m X 24m)	Rank (As per OHRC Terrain)
1	-62.19	56.73	-435	6.07	81.20	382	571	**7**
2	-69.36	32.34	533	4.27	88.61	280	3901	**1**
3	-68.89	41.32	225	6.10	82.88	306	1247	**5**
4	-66.29	31.82	1210	5.25	81.38	415	1404	**6**
5	-68.59	20.98	615	6.61	82.19	386	108	**8**
6	-70.82	22.81	866	5.57	83.27	362	3585	**2**
7	-65.20	20.26	-701	6.82	74.11	302	3455	**3**
8	-64.08	39.62	-1124	5.27	80.60	295	3447	**4**

Figure-5: Comparison of 08 Probable Landing Sites for Chandrayaan-3

References: (1) Potential Landing Sites for Chandrayaan-2 Lander in Southern Hemisphere of moon, 49th LPSC Conference 2018, 1975.pdf. (2) High Resolution DEM Generation from Chandrayaan-2 Orbiter High Resolution Camera Images, LPSC Conference 2021, 1396.pdf.

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