Chandrayaan-1 captures Halo around Apollo-15 landing site using stereoscopic views from Terrain Mapping Camera

High resolution data from Chandrayaan-1 Terrain Mapping Camera (TMC) has found evidence of surface reflectance anomalies in and around the vicinity of the Apollo-15 landing site. The TMC camera has a spatial resolution of 5 m and a multiviewing stereo capability from an altitude of 100 km over the Lunar surface[1]. The Lunar module of Apollo-15, called the Falcon, touched down at the Hadley–Apennine region near the Apennine Mountains on 31 July 1971 on the eastern margin of the Imbrium Basin in the region known as Palus Putredinis[2]. Falcon was the first of the piloted landers to carry enlarged fuel tanks, as well as tote along a Moon rover. There were two main objectives in selecting this landing site. First, the rim of the Imbrium Basin could be sampled along the Apennine Mountains. It was expected that this would provide material from deeper in the Lunar crust than was sampled by Apollo-14 mission. Second, this site provided an opportunity to explore Hadley Rille, a photogenic channel in the mare surface that is probably formed by volcanic processes. The Apollo-15 was the ninth manned mission, and fourth Lunar landing mission of the Apollo programme. The Apollo-15 was launched on 26 July 1971 and landed on the Moon on 31 July 1971, and then landed back on Earth on 8 August 1971. This mission was the first 'J mission' which was primarily concerned with scientific research and longer stay period on the Moon than previous Apollo missions[3].

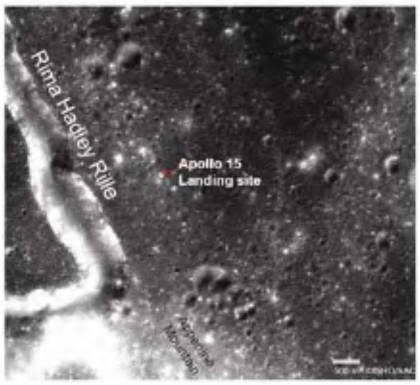

Figure 1. Chandrayaan-1 Terrain Mapping Camera (TMC) nadir view context image around the Apollo-15 landing site.

Chandrayaan-1 TMC has taken spectacular images over the Apollo-15 landing site on 9 January 2009, covering parts of Rima Hadley Rille and surrounding regions of Apennine Mountains. Figure 1 shows a sub-sampled nadir viewing image of Chandrayaan-1 TMC around the Apollo-15 landing site shown here as a context image for the study area. Parts of Rima Hadley Rille and southern-west portion of Apennine Mountain front are clearly visible in this compressed image of TMC sensor. In this communication we report the detection of reflectance anomaly or 'Halo' around the vicinity of the Apollo-15 landing site using 5 m TMC data having three different views: from nadir, aft and fore cameras. Anomalous signatures around Apollo-15 landing site have also been reported in the past by Japanese Aerospace Agency (JAXA) using SELENE Terrain Camera (TC)[4], however our finding brings out surface disturbance caused by Apollo-15 landing on a much improved resolution using three different view angles and

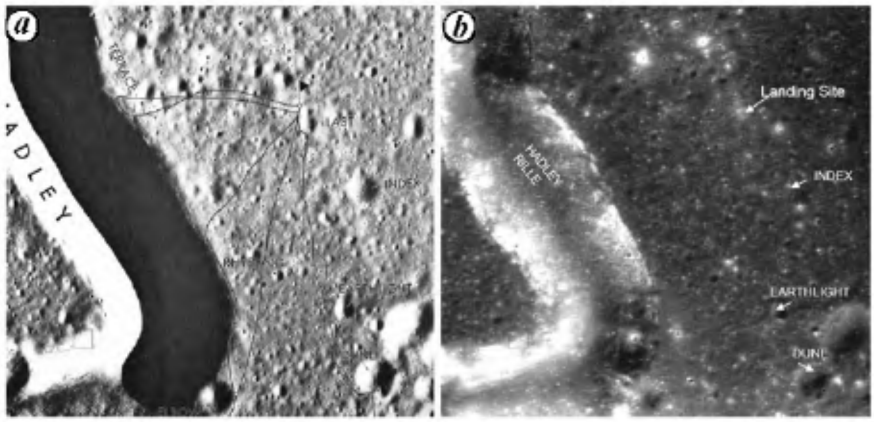

Figure 2. ***a***, Apollo-15 traverses as mapped by NASA on to a high-resolution images acquired during descend of Apollo-15 landing module; ***b***, Corresponding image of Chandrayaan-1 TMC sensor.

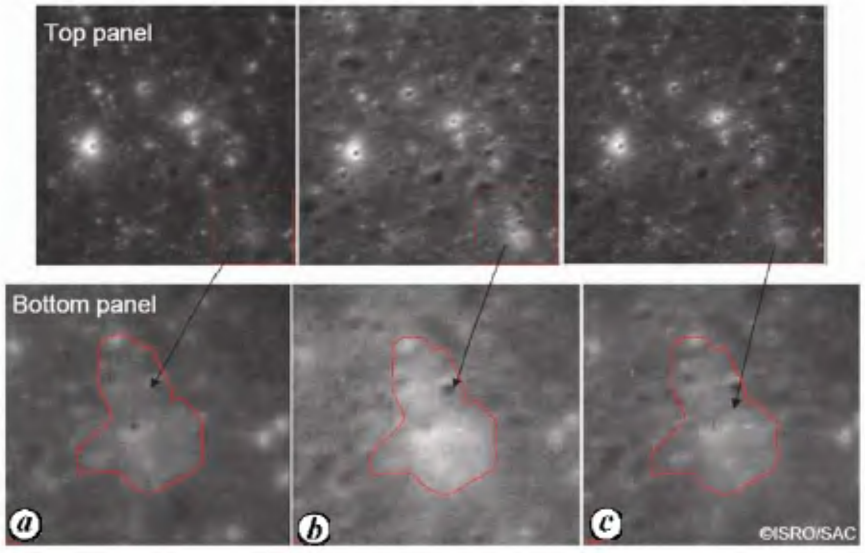

Figure 3. Closer view of Apollo-15 landing site using (***a***) aft camera, (***b***) nadir view and (***c***) fore view of the Apollo-15 landing site, top panel shows landing site marked in red box, bottom panel shows 5 m resolution image. A brighter 'halo' is clearly seen around the landing site in all the three views.

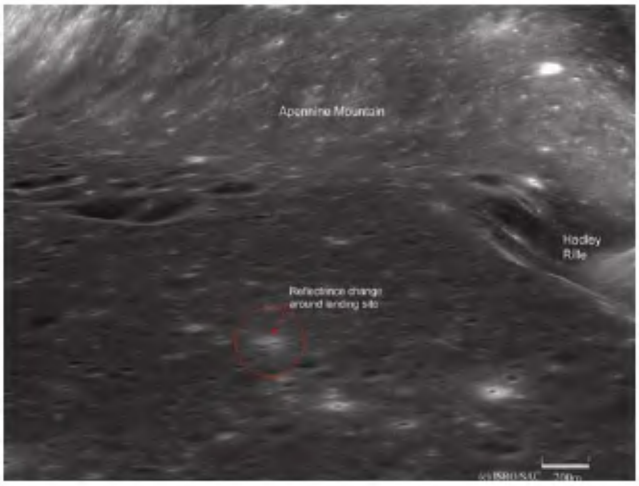

Figure 4. Three-dimensional view of Apollo-15 landing site showing front of Apennine Mountain, parts of Rima Hadley Rille and 'halo' around the landing site of the Apollo-15 Lunar module.

digital elevation data derived using TMC stereoscopic observations. As a matter of fact, for the first time after the end of the Apollo programme, surface disturbance caused by humans have been brought out on such a large scale.

Figure 2 *a* shows the Apollo-15 traverses as mapped by National Aeronautics and Space Administration (NASA) on a high-resolution image acquired during the descend of Apollo-15 landing module and Figure 2 *b* shows the TMC image of Apollo-15 landing site. Both these images have been co-registered and many of the common features on both the images can be clearly observed. Some of the common features are marked on both the images. The enlarged portion around the landing site from the three different views (i.e. nadir, fore and aft) obtained by TMC around the Apollo-15 landing site are shown in Figure 3. The TMC acquired these three views separated by ~26°. The top panel shows landing site area marked by red-coloured boxes for three different view angles and the bottom panel shows the full resolution images for the landing site. The 'halo' or a brighter patch of reflected light is clearly seen in all the three views of the TMC data. It is also clear from the images that this spot is not associated with any fresh crater and exactly coincides with Apollo-15 landing site. It is important to mention here that in general the brighter spots on the Lunar surface are associated with impact craters and represents relatively fresh surface excavated by the impact cratering process[5]. This change of reflectivity around the landing site is supposed to be caused by the exhaust plume of the Lunar Module engine and apparently created a reflectance anomaly. The anomalous reflected region is approximately of the order of 150 m in length and all the three views, i.e. aft, nadir and fore, confirm this size of the so called 'halo' around the Apollo-15 landing site. A careful examination of the bottom panel of Figure 3 shows the presence of a rectangular-shaped object which corresponds to the descent landing module 'Falcon' left behind by the astronauts of the Apollo-15 mission.

Chandrayaan-1 TMC also provides digital terrain model (DTM) of the Lunar surface. DTM for the Apollo-15 landing site was generated using stereoscopic pairs of the TMC data using a methodology developed at the Space Applications Centre, Ahmedabad[6]. Figure 4 shows a 3D view of the Apollo-15 landing site using image draping technique on to corresponding DTM data. The 3D view from TMC data shows front of Apennine Mountain, depressions of Rima Hadley Rille and different impact craters around the Apollo-15 landing site. The 'Falcon' Lunar module of the Apollo-15 landed on the Moon near the Hadley Rille, at the foot of the Apennine Mountains encircling the Mare Imbrium. The Hadley Rille is a sinuous Rille with a length of 80 km and depth of 300 m, what can be seen in Figure 4 is only a portion of Hadley Rille. One of the missions of the Apollo-15 was to study the origin of this Rille. The exact position of landing site is marked by red circle on Figure 4. This figure further confirms reflectance anomaly around the landing site and clearly shows that the brightness around the landing site is not associated with any impact crater.

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