CHANDRAYAAN-1 MOON IMPACT PROBE: IMPACT LOCATION REFINED. P. J. Stooke[1, 2], S. M. Ahmed[3] and S. Subramanian[4], [1]Department of Geography and Environment, Western University, London, Ontario, Canada N6A5C2; [2]Institute for Earth and Space Exploration, Western University, London, Ontario, Canada N6A3K7; [3]Central Instruments Laboratory, University of Hyderabad, Hyderabad, India; [4]Independent researcher, Chennai, India.

Introduction: India's Chandrayaan-1 mission was launched on 22 October 2008, entered lunar orbit on 8 November and released its Moon Impact Probe (MIP) on 14 November. MIP was released over latitude 13.5° S and struck the lunar surface near the South Pole about 24 minutes later. During the descent it took over 3000 images, measured its altitude with a laser altimeter and measured atmospheric constituents [1], providing the first strong indication of the presence of water on the lunar surface. The exact impact location has been uncertain with several published estimates. Here the final MIP images are located on LROC NAC images to refine the impact location. Impact occurred on the Earth-facing slope of the 'Connecting Ridge' (Spudis Ridge) near 89.55° S, 122.93° W.

Previous MIP location efforts: MIP images taken soon after the probe was released show identifiable features along the 14° E meridian including the Apollo 16 landing site [2]. Images could be located on pre-existing maps, the best of which at the time were the global mosaics from Clementine with resolutions on the order of 120 m/pixel. South of about 80° the MIP images covered too small an area to be unambiguously identified on Clementine maps. Attempts to follow the images down to the surface and locate the impact site relied on extrapolation from the last known image locations, using image times and probe velocity to predict where the image footprints should lie. Published estimates of impact locations include 89.76° S, 39.40° W [3] and 89.54° S, 44.71° W [4]. At the time LROC NAC image mosaics of the polar regions were not available to help locate the final low-altitude images.

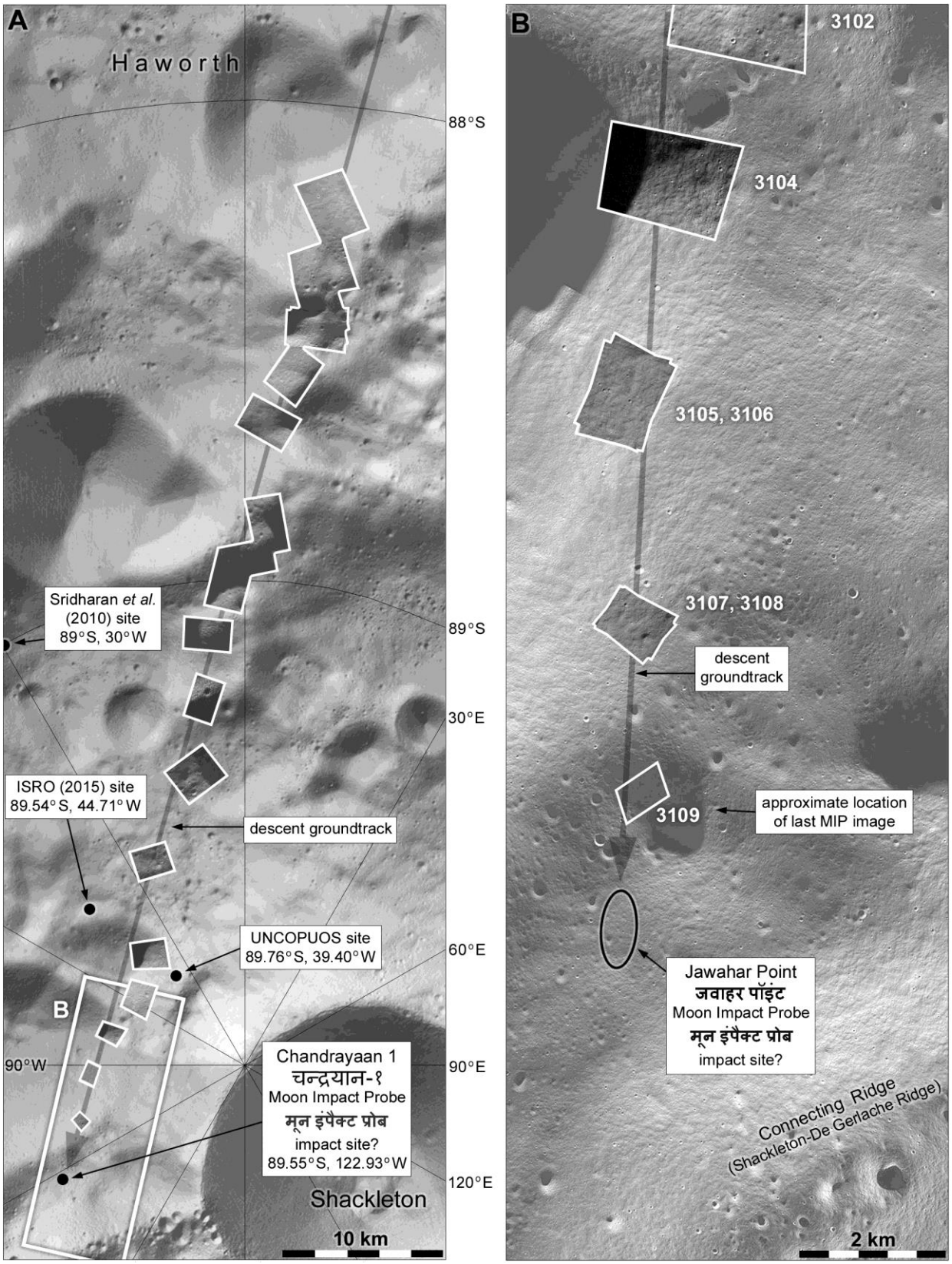
New location analysis: In this study the final MIP images were located unambiguously on LRO images. The effort was conducted publicly on the forum www.unmannedspaceflight.com and is formally reported here. Using images published in [2] and [4] and others provided by S.M. Ahmed the final trajectory of MIP was followed to a point very close to its impact. Figure 1A shows the locations of images from 88° S to the vicinity of the pole and indicates some earlier suggested locations. Figure 1B shows the exact locations of the last few images on the LROC NAC image mosaic from Moon Trek. The results show that MIP passed between the locations suggested in [3] and [4] and continued towards the surface, crossing the mean limb and impacting slightly beyond it on the far side. The last image, numbered 3109 on Figure 2 (though there remains some confusion regarding image numbering) lies in a mostly shaded area on a small shelf or saddle below the so-called Connecting Ridge between Shackleton and De Gerlache craters. This ridge is now sometimes referred to as Spudis Ridge and is a candidate for human landings in the Artemis program.

The impact location must be downrange of the last image. The exact trajectory is not available to us but the elevation of the probe as an image was taken can be estimated from its field of view and image width. The last image was taken from an altitude of 500 m or less and projecting the path onto the topography suggests it should have struck the lower slope of the ridge somewhere near 89.55° S, 122.93° W

Discussion: The MIP impact site is called Jawahar Sthal (Jawahar Point) in India. MIP struck the surface at about 1.6 km/s and will be in fragments spread over the slope of the ridge. There may be some interest in collecting fragments for analysis, for instance to seek traces of remaining bacteria or to examine degradation of engineering materials under lunar conditions, but any part of MIP is still the property of the Government of India and access to it would require negotiation. This is the most accessible anthropogenic impact site near the probable Artemis sites. Examining the effects of a low velocity hollow impactor on the surface may help explain the appearance of other artificial impact sites. The impact crater or ejecta deposit itself has not yet been found in LROC NAC images.

References: [1] Sridharan, R. et al., *PSS 58*, 947-950 (2010), doi:10.1016/j.pss.2010.02.013. **[2]** ISRO, 2011. *Images of the Moon from Chandrayaan-1*. **ISBN:** 978-81-909978-3-6. **[3]** U.N. Committee on Outer Space Affairs (2009). Information furnished in conformity with the Convention on Registration of Objects Launched into Outer Space, 10 November 2009. **[4]** ISRO, 2015. *Chandrayaan-1 Lunar Science Atlas, ed. 2.* ISBN: 978-93-82760-01-6. [5] Author I. J. (2002) *LPS XXXIII*, Abstract #1402.

Figure 1 (next page): MIP images and impact location. A: images from 88° S to the South Pole showing other impact site suggestions. B: the last few MIP images located on the LROC NAC mosaic from Moon Trek. The suggested impact site is indicated with an ellipse.


A
Haworth
88°S
89°S
30°E
60°E
90°E
120°E
90°W
Sridharan et al. (2010) site 89°S, 30°W
ISRO (2015) site 89.54°S, 44.71°W
descent groundtrack
UNCOPUOS site 89.76°S, 39.40°W
B
Chandrayaan 1
चन्द्रयान-१
Moon Impact Probe
मून इंपैक्ट प्रोब
impact site?
89.55°S, 122.93°W
Shackleton
10 km
B
3102
3104
3105, 3106
3107, 3108
descent groundtrack
3109
approximate location of last MIP image
Jawahar Point
जवाहर पॉइंट
Moon Impact Probe
मून इंपैक्ट प्रोब
impact site?
Connecting Ridge
(Shackleton-De Gerlache Ridge)
2 km