LUNAR LASER RANGING AND THE LOCATION OF LUNOKHOD 1. P. J. Stooke[1], [1]Department of Geography, University of Western Ontario, London, Ontario, Canada N6A 5C2 (pjstooke@uwo.ca)

Introduction: Five laser retroreflectors were emplaced on the Moon during the 1960s and 1970s. Four are routinely used today for ranging and associated studies of lunar dynamics, geophysics and geodesy. The fifth, deployed on Lunokhod 1, has not been detected since early 1971. Its location, the most northerly of any lunar landing site, would be a useful addition to current ranging options. On the assumption that the reflector is functional but is not being accurately targeted on the lunar surface, a revised location is proposed to assist new efforts to obtain laser returns.

Lunar Laser Retroreflectors: Retroreflectors were placed on the Moon by the astronauts of Apollo 11, 14 and 15 in 1969 and 1971. All Apollo reflectors are still functional. Two more, built in France, were carried on Soviet Lunokhod remotely controlled rovers in 1970 and 1973. Lunokhod 2's reflector is still functional today. Lunokhod 1 also carried a reflector, but returns from it have not been detected since early in its mission [1]. It should be noted that many references to the Soviet missions mistakenly state the opposite, that Lunokhod 2's reflector cannot be used but Lunokhod 1's can be. It is not known why Lunokhod 1 cannot be detected today. Possibilities may include a bad orientation (severe tilt on a crater slope?), excessive contamination by regolith (perhaps thrown up by wheels during efforts to free the rover from a steep crater slope on 13 April 1971, or other similar events), shadowing by a partly closed 'lid' or other rover structure, or uncertainties in location causing erroneous targeting. This study deals only with the latter possibility.

Lunokhod 1 location: The location of Lunokhod 1 is not known precisely. Its position is usually given as 38.28º N, 35.00º W on the basis of contemporary Soviet statements, but this is uncertain by at least 5 km. Whereas all Apollo sites and all Surveyor landing sites except that of Surveyor 5 have been located precisely in high resolution images, all Luna landing sites except Luna 21 (Lunokhod 2) have not been. This is primarily due to the lack of high resolution imaging from orbit in those areas. For Luna 17/Lunokhod 1, the best available images for site location are Apollo 15 Hasselblad frames AS15-93-12714 and 12715. Clementine UVVIS frames of the area are no better that the Apollo images, and Clementine LWIR images are about as good as Apollo images but offer only discontinuous coverage.

The region traversed by Lunokhod 1 was mapped by Soviet cartographers [2], and comparison of this map with orbital images is the only way to locate the rover, since few individual panoramas are readily available at present. Figure 3 is a relief drawing derived from the Soviet map. The map was compiled by 'dead reckoning' (plotting each day's traverse based on telemetry and targeting, not independent localization methods) and may be distorted by wheel slippage and other errors. The most prominent features are two large (400 to 500 m diameter) craters north of centre, 1 km north of the original landing point.

Craters of this size should be visible in the Apollo and Clementine images. Within the landing region there are several craters of this size but very few occur in pairs, and a good match to size and position is only found at one location. Figures 1 to 3 show this location on Apollo 15 and Clementine LWIR images. Evidence in support of this location is limited, but one possible clue is seen in an image of the western horizon taken from the rover while still on its landing stage immediately after landing. The western horizon is marked by a pair of gentle undulations (Figure 4), which are clearly seen as bright ridges if the relief is artificially exaggerated by changing the vertical scale. I interpret these as the rim of a small crater west of the Luna 17 lander. The best estimate of Luna 17's orientation suggest the azimuth of the crater should be roughly 260º from north. A candidate crater is found at the expected place. This is not enough to be certain of the location, but it is better than any other options currently recognized.

Taken together these observations suggest a lander location near 38.26º N, 35.19º W, about 5 km further west than usually stated. The rover was parked 2 km further north at 38.29º N, 35.19º W. If laser returns are still possible this is the best candidate site to target. Laser observations were to be made late in 2004 but results are not yet available. Image pixel coordinates are given in Appendix 1.

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References: [1] Williams, J.G., Turyshev, S.G., Boggs, D.H., Ratcliff, J.T. (2004). 35th COSPAR Sci. Assembly, July 18-24, 2004, Paris, France (http://arxiv.org/PS_cache/gr-qc/pdf/0412/0412049.pdf). [2] Vinogradov, A.P., 1971. Peredvizhnaya laboratoriya na lune Lunokhod-1. Moskva : "Nauka", Vol. 2.

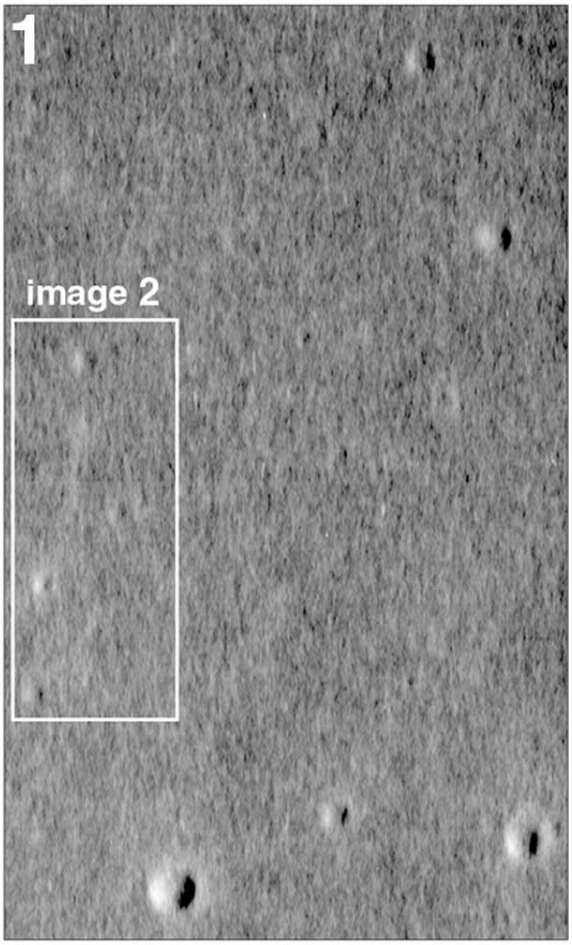

Figure 1: Apollo 15 image AS15-93-12714 (rectified from its original high oblique view) showing the general landing area of Luna 17. The two largest craters at bottom are 10 km apart, for scale.

Figure 2: Mosaic of Clementine LWIR images of the area inside the box in Figure 1. A white outline shows a possible location for Figure 3.

Figure 3: Shaded relief version of the region traversed by Lunokhod 1, based on the route map published by Florensky et al. (1971). For scale, Figure 3 is 4 km top to bottom. The two largest craters, 1 km north of the marked landing area, may be the two craters visible at appropriate locations in Figures 1 and 2.

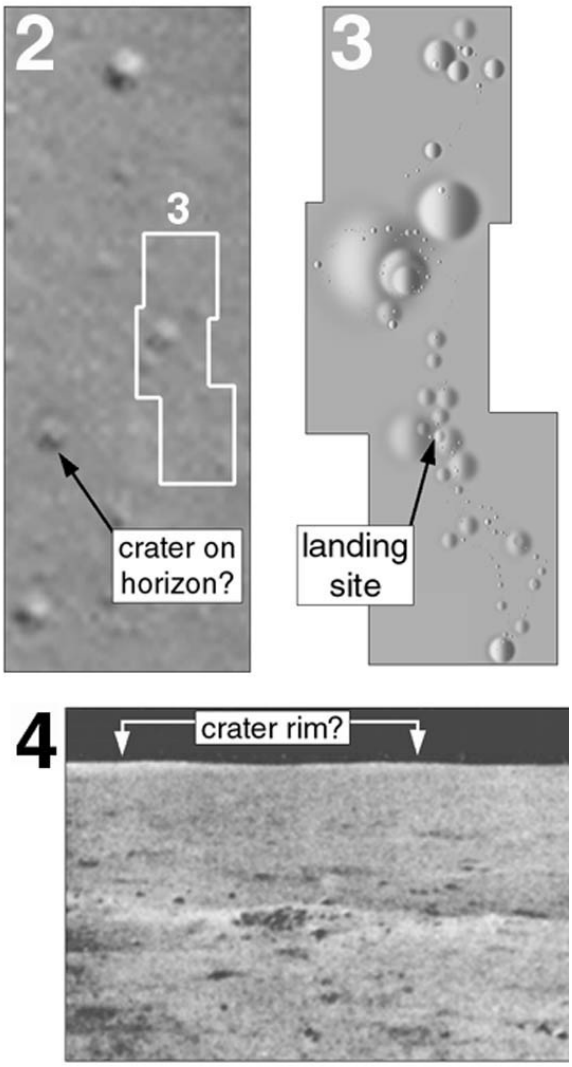

Figure 4: Lunokhod 1 image showing the horizon west of the landing site, taken before the rover left its landing stage. A pair of gentle rises on the horizon (better seen if the relief is exaggerated) may correspond to the rim of the crater indicated in Figure 2.

Appendix 1: Pixel coordinates of the double crater 'saddle':

Clementine LWIR image lla4583m_049, line 13 sample 80.

Clementine UVVIS image lub4713m_313, line 185, sample 310.