EARTH BASED RADAR IMAGERY AND TOPOGRAPHY: INPUT TO LCROSS TARGET SELECTION.

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Introduction: A 10 km maximum level of uncertainty in the targeting of LCROSS at the lunar poles combined with the requirements to impact into a location that is in permanent shadow and visible from Earth, sets a lower size limit of about 25 km for the shadowed area selected for the LCROSS impact site. This eliminates all small areas of permanent shadow from consideration and limits the options to the floors of a few large craters such as Shoemaker and Faustini near the south pole. If the 3km targeting uncertainty can be met then areas of permanent shadow as small as 10 km can be considered. This would allow the floor of the 19 km south pole crater Shackleton to be included in the possible target list as well as a few additional sites at both the north and south poles.

Radar data: Earth based radars are the only current source of detailed information for the shadowed areas at the lunar poles. Despite the poor viewing geometry, they can observe roughly 25% of the shadowed terrain at the lunar south pole and somewhat more at the north pole. Radar interferometric measurements have provided digital elevation models (DEMs) for the polar areas [1] and ray tracing based on these DEMs has outlined most of the large areas in permanent shadow within 5° of the poles [1]. We have recently obtained new multi-polarization radar imaging data for the south pole at 13 cm wavelength with 20 m resolution [2] and at 70 cm wavelength with a resolution of 300-450 m [3]. These data have been used to map the Circular Polarization Ratio (CPR) at resolutions of ~125 m and ~1 km, respectively. While low temperature water ice surfaces on the icy Galilean satellites and, most probably, at the poles of Mercury exhibit high radar CPRs [4, 5], for the lunar south pole high values of the CPR are associated with the walls and ejecta of young impact craters independent of the degree of solar illumination. This is the case at both 13 cm and the more deeply penetrating 70 cm wavelength [2, 3].

From Fig. 1 it is clear that at a 10 km uncertainty level for targeting LCROSS, there are no large Earth-visible north polar shadowed areas within about 6° of the pole that could be reliably impacted. At 3 km uncertainty, there are a small number of possible target sites with sizes between 10 and 20 km. The small size and relative paucity of areas of permanent shadow is consistent with the much lower hydrogen enhancements at the north pole compared with the south pole measured by the Lunar Orbiter neutron spectrometer [6].

For the south pole the shadowed areas within about 6° of the pole on the near side derived from the radar DEM (Fig. 1) are largely confined to crater floors plus a few small areas of inter-crater highlands. Since the shadowed areas were determined by ray tracing using the DEM, there are several near side areas with uncertain shadowing conditions located near (87S, 0), (85S, 45E) and (86S, 40W). The uncertain topography and shadowing conditions make these locations poor choices for LCROSS.

Suggested target location: Within a 10 km targeting constraint, the only viable impact sites appear to be the floors of Shoemaker, Faustine and de Gerlache all of which are within the area of enhanced hydrogen concentration [6]. At 3 km uncertainty the 19 km crater Shackleton is also a possible target site. Of these there is radar imagery and CPR measurements for approximately 50% of the floor of Shoemaker, a small portion of the floor of Faustini and none for the floors of de Gerlache and Shackleton.

As noted above, recent work shows that there is no strong evidence for extensive deposits of relatively clean ice in shadowed craters near the south pole. Such evidence would include (1) high CPR values that cover extended areas of crater floors or walls, and (2) a high degree of correlation between the CPR values and the degree of solar illumination. We observe instead that high CPR values appear to correlate with the proximal ejecta blankets and ray-like deposits of apparently young impact craters, and with debris fans or aprons on the interior walls of craters with relatively steep slopes. We suggest that high CPR areas are actually poor targets for LCROSS given the high local abundance of boulders and the possibility that a relatively young crater may be depleted of even slowly accumulating solar-wind-implanted hydrogen.

Of the two large shadowed crater floors for which we have radar imagery, Shoemaker and Faustine, the floor of Shoemaker (Fig. 2) has significant areas with low CPR values while the small part of the floor of
Faustine that we can observe has closely spaced small craters with high CPRs. Consequently, based on the distribution of hydrogen and our current knowledge of the surface, Shoemaker crater appears to be the best candidate for an impact site. Beyond the broad distribution of hydrogen, little is known about any of the other sites that may be acceptable based on targeting capabilities. An impact into an area visible to Earth based radars may allow pre-impact imagery from Earth – if imagery is not available from another orbiter – that may allow unambiguous identification of the impact site in post-impact imagery.

Figure 1: Top; Permanently shaded areas at the lunar north pole obtained by ray tracing using a radar derived DEM. White indicates shaded areas while grey indicated areas of assumed shadow based on crater symmetry. Bottom; similar data for the lunar south pole. Images from Margot et al [1].

Figure 2: A; Radar image of Shoemaker crater at 20 m resolution. B; The Circular Polarization Ratio superposed on the radar image.