SCOURING THE SURFACE: EJECTA DYNAMICS AND THE LCROSS IMPACT EVENT B. Hermalyn[1], P. H. Schultz[1], M. Shirley[2], K. Ennico[2], and A. Colaprete[2] [1]Brown University, Providence, RI 02912-1846 (Brendan_Hermalyn@brown.edu), [2]NASA Ames Research Center, Moffett Field, CA 94035

Introduction and Background: The Lunar CRater Observation and Sensing Satellite mission (LCROSS) utilized the spent upper stage of a rocket as a kinetic impactor to launch material from a permanently shadowed region (PSR) within Cabeus crater above the sunlight horizon [1]. A suite of nine instruments onboard the LCROSS shepherding spacecraft (SSc) made measurements of the sunlit ejecta and released volatiles[1, 2]. By integrating the observations from multiple instruments (including those onboard LRO [3, 4]), a time-resolved evolution of the cratering event can be constructed. While the combined observations establish the presence of volatiles, interpretation of the source region and conditions in the PSR from these data is highly dependent on the specific mechanics of the impact (e.g., the high weight percent of species reported in [3]). Here we present the results of a series of impact experiments designed to explore the LCROSS event using both high-speed cameras and LCROSS engineering units.

LCROSS Impact: The impact was a unique cratering event due to the low density and geometry of the hollow Centaur and the relatively low impact speed (2.5km/s). In addition, the ejecta needed to reach the 833m sunlight horizon from the permanently-shadowed floor of Cabeus, placing a high velocity requirement for any material reaching sunlight. In contrast to the standard "inverted lampshade" ejecta curtain, the visible camera (VIS) revealed a relatively symmetric cloud (Fig. 1a). A continued presence of volatiles (and integrated intensity over pre-impact background) in the spectrometer measurements persisted for almost 4 minutes after impact[1].

Experimental Studies and Analysis: Prior to impact, several independent studies predicted the ejecta dynamics of the impact event (e.g., [5, 6, 7]. In this study, a series of impact experiments was performed at NASA Ames Vertical Gun Range to explore the unique characteristics relevant to the LCROSS event. Both high-speed equipment and LCROSS engineering instruments (identical to flight hardware) were used to record the experiments, allowing direct comparison to the mission data. These studies revealed: 1) an early-time, low-angle departure from dimensionally-predicted ejecta models 2) shallower coupling and excavation depths in regolith-like target materials 3) the emergence of a high-angle, high-speed plume that remains aloft well past the end of crater growth (Fig. 1b) and 4) the non-homogenous distribution of heated projectile/target material emplaced by impact. A ballistics analysis of the two-component ejecta curtain scaled from experiments matches the spectrometer and VIS camera measurements of the impact event when convolved with the instruments' fields of view. The LCROSS thermal measurements are more consistent with frictionally-heated target and projectile material dispersed in clumps around the newly-formed crater than a homogeneous layer of heated material.

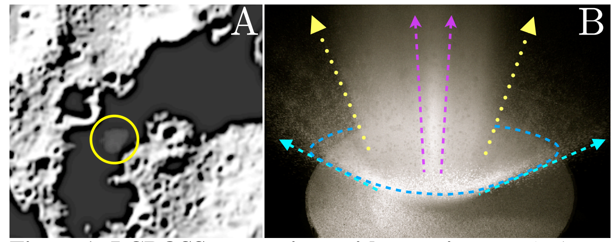

Figure 1: LCROSS comparison with experiments. A shows ejecta (circled in yellow) in LCROSS image reaching sunlight a few seconds after the impact into Cabeus. B is an oblique view of an experiment demonstrating low-angle (blue dashed) and high-angle (dotted yellow) ejecta components. A near-vertical portion of the plume is prominant (magenta).

Conclusions: The unique conditions of the LCROSS impact created a two-component ejecta plume (e.g., Fig. 1) which sampled to different depths in the subsurface: the usual inverted lampshade "low-angle" component and a high speed, high-angle plume. Extrapolations from experimental studies match the VIS data and the light curves in the spectrometers. The impact caused only small amounts of vaporization or shock heating. Warm material is emplaced at early times by sparse ejecta launched at high speeds and heterogeneously around the crater at late times, rather than a simple homogenous "warm" blanket. The crater itself was probably cooled quite rapidly, leaving only localized areas surrounding frictionally-heated portions of the crushed Centaur impactors thermally emitting. Additionally, the ballistic return of sunlight-warmed ejecta surrounding the crater may lead to a significant increase in the surficial source region for volatiles measured in by the LCROSS spectrometers. These results have implications for the spatial distribution of volatiles in the shadows of Cabeus.

References:

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