INTERPRETING THE LCROSS-EDUS IMPACT. P.H. Schultz[1], B., Hermalyn[1], A. Colaprete[2], K. Ennico[2], M. Shirley[2], and the LCROSS Science Team, [1]Brown University, Providence, RI 02912-1846 (peter_schultz@brown.edu), [2]NASA Ames Research Center, Moffet Field, CA 94035

Introduction: Instruments on Apollo [e.g., 1] and Lunar Prospector [2, 3] indicated the presence of mobile volatiles on or around the Moon. Multiple spacecraft recently confirmed these observations by direct measurements of OH and H_2O [4, 5, 6]. The LCROSS mission, however, used a kinetic probe to measure the presence of H-bearing compounds (and water-ice specifically) released from beneath the surface in a permanently shadowed region (PSR) near the south pole region of the Moon.

As the upper stage of the lauch vehicle, or*Earth-Departure-Upper Stage* (the "EDUS"), impacted the surface, the trailing *Sheparding Spacecraft* ("SSc") recorded the evolution and composition of the resulting ejecta with a series of instruments [see 7]. The subsequent collision by the trailing SSc, however, was observable only from the earth-based telescopes and LRO instruments and will not be discussed here. A separate contribution examines in detail spectral measurements of atomic and molecular species observed by LCROSS instruments [8]. Here we focus on observations and implications of the EDUS collision.

Pre-Encounter Predictions: Estimates for the excavated mass and crater diameter were based on extrapolations of crater-scaling relations from much smaller laboratory experiments [e.g., 9, 10] and computational models [10, 11]. Extrapolations from laboratory experiments to the LCROSS impact experiment were based on dimensionless scaling relations [12]. Prior to impact, accurate predictions for the final crater dimensions were limited by targeting uncertainties, unseen landscapes in deep shadow, the low effective density (mass/volume) of the fuel-emptied EDUS (< 0.03 g cm^{-3}), and the orientation of the rotating EDUS at the moment of impact [10]. Results from modeling [10] and laboratory experiments using low-density projectiles [13] and provided first-order estimates of crater properties for such a low effective density.

Laboratory impact experiments at the NASA Ames Vertical Gun Range were used to re-assess the ejecta-velocity distribution for low-density projectiles (hollow aluminum) and a compressible particulate target (i.e., pumice). Rather than focusing on the late-stages of ejecta, the LCROSS impact requires estimates for the earliest stages of excavation, when the classic scaling relations are known to breakdown [14, 15]. Preliminary results focusing on this stage provide insight into processes relevant to the LCROSS impact [16, 17,18]. *First*, the earliest stages of ejection (for both sand and pumice targets) are characterized by much lower low-ejection angles (<30°) than the nominal angle of 45° usually assumed [16]. Such a low-angle component limits the amount (and duration) of high-speed ejecta reaching sunlight. This stage of crater growth constrains the maximum ejected mass and underscores the effect of early-time energy losses [19, 20]. *Second,* low-density projectiles produced a distinctive high-angle plume, starting soon after impact and persisting until near the end of excavation, with ejected material returning to the surface well after crater formation.

Pre-encounter predictions described a sunlit upper ejecta curtain that would increase in diameter with time. The upper portion of the curtain (highest speed ejecta) would thin with ballistic distance, whereas the lower portions of the curtain would increase in diameter as ejecta returned to the surface. This would produce a sunlit ejecta ring, initially increasing in diameter and then fading with time. In this model, the *SSc* would view the ejecta for only a short time as it plunged toward the surface as well.

Observations: The *Near-Infrared Spectrometer* (NSP1) used a dark mask to measure background within a much smaller field of view that did not include sunlit areas. During the time of impact, it operated in a "flash mode" (1ms integration times) during the time of impact, thereby operating as a thermal flash detector. A two-second exposure in the *UV/VIS Spectrometer* (VSP) included the first moments of impact and detected not only a small rise in brightness (in visible light) but also a range of atomic and molecular emission lines. As described elsewhere (8), hydroxyl band strength was observed to increase with time. Absorptions due to water molecules (and other H-species) captured by the near-infrared (NSP) spectrometer lasted over most of the approach. The Mid-Infrared (MIR) cameras recorded "first light" in the first frame after impact and remained visible in multiple frames [e.g., see 19]. The visible (VIS) camera captured the ejecta cloud expanding about over tens of seconds before disappearing. The expected ballistic ejecta annulus, however, never emerged; rather, the ejecta remained as a diffuse (and relatively symmetric) cloud throughout.

EDUS Crater: The final moments before impact, exposure time and gain for the NIR2 camera was

changed in order to image the lunar surface from scattered light off the relief in the distance (a massif of the SPA basin). Even though craters smaller than the identified EDUS crater are resolved during approach, the EDUS crater suddenly emerged within a single frame, only 3 seconds prior to last transmission. Because of the wavelengths covered by the NIR2 camera (0.9µm-1.7µm), images recorded the distribution of slightly warmer ejecta or crater interior.

Interpretations: The combined measurements from the MIR, NIR, VIS, VSP, and NSP instruments provide clues for the evolution of cold-trapped volatiles on the surface and at depth. In the first few seconds, atomic emission lines (e.g., low-energy Na) appear. At the EDUS impact speed (2.5km/s), spectra of laboratory impacts into particulate targets record only short-lived (few microseconds) Na emission lines at the EDUS impact speed [21]. Much higher speeds are needed to generate detectable atomic emission lines. Although the ejecta plume disappeared in the VIS camera, it remained detectable in other instruments. The nominal sequence of crater excavation, however, predicted a ring of ejecta. Its absence requires a high-angle ejecta component filling the inner region. In controlled laboratory experiments, this component first emerges at high speeds (>1km/sec) and persists throughout crater excavation.

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