Synthetic Lunar Atmosphere Experiments and Base Resupply Mission Concept. S.A. Stern[1,3], G.R. Gladstone[2], M. Horanyi[3], B. Kutter[4], D.B. Goldstein[5], and M. Tapley[2]. [1]Southwest Research Institute, 1050 Walnut Street, Boulder, CO 80302 [2]Southwest Research Institute, 6220 Culebra Road, San Antonio, TX 78238. [3]CCLDAS NASA Lunar Science Institute, University of Colorado, Boulder, CO 80309. [4]United Launch Alliance, 7630 S Chester St., Englewood, CO 80112. [5]The University of Texas at Austin, Austin, TX 78712

Introduction: Tenuous, surface boundary exospheres (SBEs) like the Moon's, are the most type common planetary atmospheres in our solar system [1]. The lunar SBE (LSBE) is known to be highly complex [1], consisting of a wide range of neutral and ionized gas species, as well as dust. It is also the transport medium through which most lunar polar water ice [2] reaches the lunar poles.

Active experimentation on the LSBE offers opportunities to probe the physics of SBEs, the gas-surface interaction chemistry of lunar atmospheric transport, to determine the morphology of a cometary-like impact crater and its secondaries, and to measure the transport efficiency of water to the lunar poles [1].

Concept Description: Here we describe a novel technique for active LSBE experiments. The technique is called SLAM, for Synthetic Lunar Atmosphere Mission. SLAM's attractive attributes include lower cost and higher yield than soft-landed active lunar atmospheric releases. SLAM also has applications to the mass-efficient and less expensive delivery of water—a key logistics need—to human lunar outposts.

The SLAM LSBE experiment concept is summarized as follows: A rocket with high lunar mass launch capability and good lunar surface targeting accuracy, launches a simple, thermally insulating container filled with the atmospheric release material onto a low-energy (Hohman transfer) direct impact trajectory with the Moon. Example experimental species of interest include volatiles like Na, K, and H_2O. The SLAM projectile impacts the lunar surface near a pre-determined location approximately 4 days after launch at a speed of ~2.4 km/sec.

An Atlas V 431 launch vehicle is typical of potential SLAM launchers. This vehicle can deliver a 5.4 metric ton SLAM impactor to within 300 km (3-sigma) of its intended lunar surface location [3]. At the 2.4 km/sec impact speed of a Hohman transfer, virtually all of the water ice will come to rest less than 1.5 meters below the surface if properly pre-fractured, with only ~15% vaporized. This is sufficient H_2O mass to create detectable H_2O transport when observed from Earth (see Figure 1). If instead Na is used, 5.4 metric tons represents the ability to temporarily increase the tenuous Na LSBE by a factor of ~50 in order to better study its dynamics.

If the SLAM impact site is located on the lunar dayside, the hot lunar surface (300-400 K) thermally mobilizes the volatiles emplaced by SLAM. Each atom or molecule in the selected experimental species will then undergo random walk diffusive transport until it suffers one of three fates: a chemical interaction that bonds it to the lunar surface grains, loss from the lunar atmosphere (e.g., by photoionization), or surface trapping due to condensation at a cold location such as the poles or the night side. If the impact site is located on the lunar night side, its sublimation into and subsequent transport through the atmosphere will occur after sunrise raises local surface temperatures.

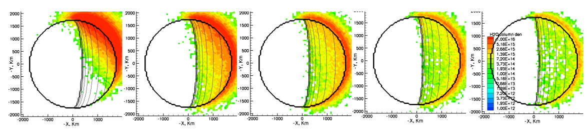

Figure 1. Simulated water vapor column density contours (number/m^2) following twin 1200-kg water ice impacts at 45N and 60N near the noon limb at t=5, 15, 25, 35 and 45 Ksec after impact. The column density drops quickly as molecules spread over the lunar dayside and condense on the night side or dissociate [4].

Other Attributes & Benefits: In addition to its utility for active LSBE experiments, the SLAM mission architecture can also be used to deliver H_2O from Earth to a human outpost. In this application, SLAM is used to impact H_2O-ice in an impact-survivable penetrator near the outpost. Astronauts or robots at the outpost then deploy to the nearby impact site recover the container and its contents to extract the tons of H_2O for use by as H_2O itself, H, or O at the outpost. Using impactor targeting techniques like those pioneered by the recent NASA LCROSS impactor mission, targeting accuracies of order 10 km can be achieved [5], albeit at high mission cost.

In this way, SLAM cuts the Gordian knot that ties valuable lunar polar H_2O to the difficulties of operating an outpost in the dark and extremely cold lunar polar conditions.

Summary. The great benefits of SLAM—its low cost delivery system, simplicity, low technical risk, and high useful mass fraction—all derive from the same two innovations of SLAM: First, no spacecraft is required to transport the desired experimental or logistics material to the Moon, only a material container. This is the direct result of the capability of launchers like Atlas V to accurately target the desired impact site, obviating the need for a spacecraft to perform this function. Second, no soft landing is required, thereby significantly increasing the experimental or logistical mass delivered, again minimizing cost.

References: [1] Stern, S.A., *Reviews of Geophysics*, 37, 453-491, 1999. [2] Clark, R.N., *Science*, 326, 562-564, 2009. [3] Atlas Launch System Mission Planners Guide (CLSB-0409-1109), United Launch Alliance. [4]Goldstein, et al. In: *Rarefied Gas Dynamics*: Proc. of the 25th Int. Symp., ed. M. Ivanov & A. Rebrov, In: *Rarefied Gas Dynamics*: Proc. of the 25th Int. Symp., ed. M. Ivanov & A. Rebrov, Siberian Branch of the Russian Academy of Sciences, Novosibirsk, 2007. [5] Colaprete, A., et al. *Lunar and Planetary Science XXXIX*, Contribution1391,1838, 2008.