

MODELING THE RESPONSE OF THE LUNAR EXOSPHERE TO THE RELEASE OF SPACECRAFT EXHAUST VOLATILES. P. Prem and D. M. Hurley, Johns Hopkins University Applied Physics Laboratory (parvathy.prem@jhuapl.edu).

Introduction: Understanding how spacecraft alter the environments that they interact with can be critical to planning mission operations and observations. In light of current international interest in returning to the surface of the Moon, it is important to take into account that almost any powered lunar landing will release exhaust gases into the lunar exosphere – presenting both an opportunity to study the interaction of exhaust volatiles with the lunar surface, and a need to develop tools that can predict how these non-indigenous gases are initially dispersed, and how long they persist in the lunar environment.

In this work, we model the propagation of water vapor released by a spacecraft during a nominal descent, in order to characterize (i) how the lunar exosphere responds to the release of exhaust volatiles, and (ii) the sensitivity of the exospheric response to the energetics of desorption of water from the lunar regolith.

Method: We investigate the transport of exhaust volatiles using the Direct Simulation Monte Carlo (DSMC) method [1], which models gas dynamics by tracking the motion of a large number of representative molecules, accounting for the transfer of momentum and energy between molecules through collisions in regions where the gas is sufficiently dense (particularly in the vicinity of the spacecraft). The initial gas density, velocity and temperature at the nozzle exit are derived from Roberts, 1966 [2], based on the combustion characteristics of MMH-NTO propellant [3]. We model a

descent trajectory similar to that of the Chang’e 3 spacecraft [4] and consider a landing at 70° S, at local dawn. Thermal escape, photolysis, and capture at polar cold traps are included, and molecules that collide with the surface are assumed to have a mean surface residence time that depends on the local surface temperature and activation energy.

Results & Discussion: During a typical descent, exhaust gases may temporarily enhance local lunar exospheric density by several orders of magnitude (Figure 1). The exhaust plume may be collisional (though rarefied) out to ~1 km from the nozzle exit. The structure of the water vapor plume, and the manner in which it spreads, depend on the assumed desorption activation energy for water molecules from the lunar regolith – a parameter that remains to be definitively constrained. To characterize the influence of this parameter, we perform two parallel simulations in which the activation energy is set to two different representative values of 0.5 eV and 0.7 eV [5]. In this presentation, we will compare these two cases, and discuss implication for mission operations and observations.

References: Bird, G. A., 1994, *Molecular Gas Dynamics and the Direct Simulation of Gas Flows*. [2] Roberts, L., 1966, *Fluid Dynamics Aspects of Space Flight*. [3] Lee, K. H., 2017, *PLOS One*. [4] Liu, J. J., et al., 2014, *Res. Astron. Astrophys*. [5] Poston, M. J., et al., 2015, *Icarus*.

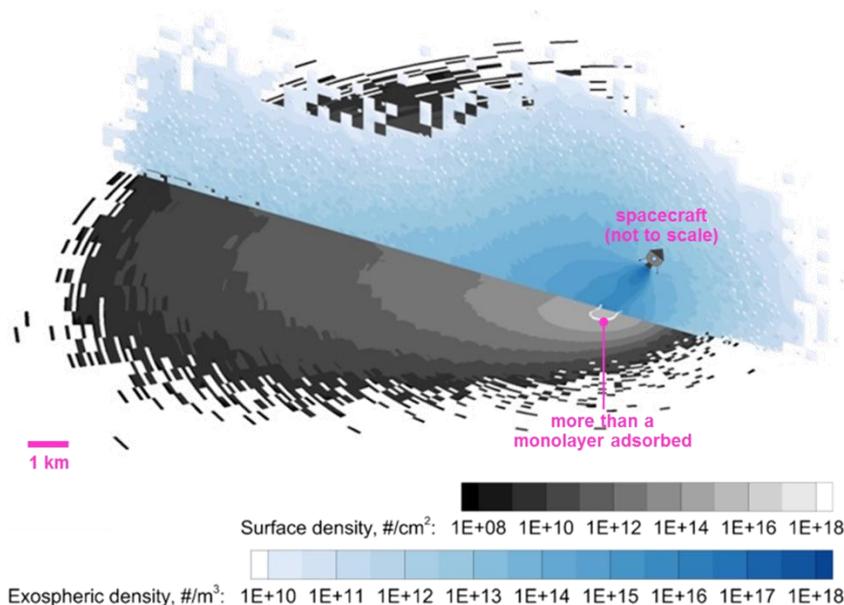


Figure 1: Oblique view of a modeled exhaust plume, 5 s after thruster firing commences. Shades of blue indicate exospheric number density and shades of gray indicate surface density of adsorbed water molecules. The approximate location of the spacecraft in its descent trajectory at this time is also indicated. This simulation assumes a mean desorption activation energy of 0.7 eV.