Prototype Low-Pressure Advanced Thermal Mining System with Vapor Extraction, Ionization and Electrostatic Transportation, and Deposition of Ice in an Engineered Cold Trap

N. I. Jurado[1], H. Mahadi[1], P. Mendoza[1], Z. Oropeza[1], D. Austen[1], A. Shirin[2], J. Hernandez[3], L. Vera[3], M. M. Rahman[4], A. Greig[4], E. Shafirovich[5], A. Choudhuri[5*]
[1]Research Assistant, [2]Postdoctoral Associate, [3]Engineer, [4]Asssistant Professor, [5]Professor
*Corresponding Author: ahsan@utep.edu
Aerospace Center (cSETR), University of Texas at El Paso (UTEP), El Paso, TX 79902, USA

Introduction: The ongoing "Advanced Thermal Mining Approach for Extraction, Transportation, and Condensation of Lunar Ice" project at UTEP cSETR funded under NASA LuSTR [1] is focused on the design, development and demonstration of a lab-scale advanced thermal mining prototype of 1 kg ice collection capacity that integrates engineered extraction, transportation, and desposition of water vapor from lunar regolith (Fig. 1). There are significant uncertainties in estimating the thermophysical properties of icy lunar regolith such as effective specific heat and thermal diffusivity. It is known that lunar regolith has a rather low thermal conductivity, about 0.01 W/(m·K) [1]. In contrast, the thermal conductivity of ice is over 2 W/(m·K). This indicates that the thermal conductivity of icy regolith can change over a wide range depending on the regolith/ice mass ratio. This dependence cannot be reliably predicted. Moreover, the vapor sublimates in an ultra low-pressure environment that makes it difficult to transport the rarefied vapor to the cold trap to re-capture the ice. Furthermore, the limitation of power in lunar south pole and poor thermal conductivity of deposited ice in the cold trap makes the ice re-capture system less efficient.

Therefore, this work experimentally measures the thermophysical properties of icy regolith, experimentally compares the sublimation rates at various concentrations and depths from capture tent and thermal drill technologies, and presents the design, development and demonstration of an advanced thermal mining prototype that integrates vapor ionization and electrostatic transportation to the cold trap by electrostatic field, and re-capture 1 kg of ice on the evaporator of an engineered cryogenic heat pipe.

Measuring the Thermophysical Properties of Ice: This work focuses on measuring the effective specific heat and thermal diffusivity of icy regolith at temperatures ranging from -150 C to 25 °C. A lab scale thermal excavation system will be developed in this work based on the experimental characterization of sublimation rates for thermal drill and capture tent technologies.

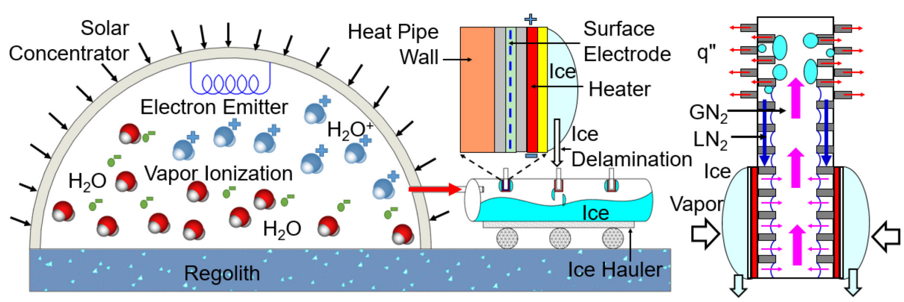

Figure 1: cSETR advanced thermal mining technology

Vaor Ionization and Electrostatic Transportation to the Cold Trap: The rarefied vapor transportation system focuses on the ionization of sublimated low-pressure vapor and transportation to the cold trap in electrostatic field. This work experimentally characterizes three ionization transport methods: (i) a tungsten filament electron emitter, (ii) a radio-frequency plasma source, and (iii) a tungsten filament with applied magnetic field for electron trapping. More than 450% increase in water collection rates has been estimated analytically based on a laboratory scale experiment using ionization transport methods.

High Capacity Cold Trap with Engineered Cryogenic Heat Pipe: This work fouces on developing a cryogenic heat pipe utilizing the micro/nano-scale surface engineering and experimentally collecting ice in cryogenic vacuum environment. Preliminary analytical studies show that 1 kg of ice can be collected in 11 hours using pulsed delamination of ice using the engineered heat pipe.

In Summary, this work develops a high capacity advanced lunar thermal mining system.

References: [1] Lunar Surface Technology Research Quarterly Progress Report, NASA Grant 80NSSC21K0768; [2] Heiken et. al., The Lunar Sourcebook: A User's Guide to the Moon, Cambridge University Press, Cambridge, 1991.