Waste Heat-Based Thermal Corer for Lunar Ice Extraction. Kuan-Lin Lee[1], Quang Truong[1], Sai Kiran Hota[1], Calin Tarau[1] and Kris Zacny[2], [1]Advanced Cooling Technologies, Inc., Lancaster, PA, 17601, [2]Honeybee Robotics, Altadena, CA, 91001. (Contact: kuan-lin.lee@1-act.com, quang.truong@1-act.com)

Introduction: The water/ice accumulated in the Permanently Shadow Regions (PSR) of the Moon is considered to be the most valuable resource, since it can be processed to generate Oxygen for life-supporting and converted into LH2 and LO2 for satellite and spacecraft refueling. Such water can be extracted from icy-soil through in-situ heating and then collected by re-freezing the sublimated vapor within a cold trap container. Under this research, a thermal management system (TMS) for Lunar Ice Miners was developed, which consists of a waste heat-based thermal corer that can strategically use the waste heat of on-board nuclear power sources for ice extraction, and a cold trap tank that can use the lunar cold environment as the heat sink for ice collection. The thermal corer includes embedded mini-channels into the drill's wall. The hot incoming fluid splits into 4 mini-channel passages near the top of the corer and flows downwards closer to the inner side of the thermal corer. This mechanism allows for more residence time of the hot fluid; thus, more heat is dissipated for sublimation. In order to investigate heat exchange between the corer and icy-regolith during the thermal extraction process, a two-dimensional transient model was developed and built-in ANSYS FLUENT environment as user de-fined functions (UDF). The UDF provides the user-defined material properties of the icy-regolith as a function of temperature and porosity, including specific heat, thermal conductivity, saturation pressure, and mass fraction of ice. Verification of the phase-change mechanism of the thermal model was performed by extracting the temperature profiles of three locations inside the corer at the same time frame, and parametric sensitivity study was performed with different flow rates, pumping powers, and back pressures. In addition, the model was validated against experimental water extraction of Mars regolith and Lunar regolith. Both experiment and simulation demonstrated a complete sublimation 10% wt of icy-soil within ~ 9 minutes, using a thermal corer with 6 inches in length, 0.6 inches in inside diameter, and wall temperature of 57 °C. The research work in this paper was performed as a part of on-going NASA Small Business Innovation Research Phase II (Contract: 80NSSC21C0564) program, awarded to Advanced Cooling Technologies, Inc.

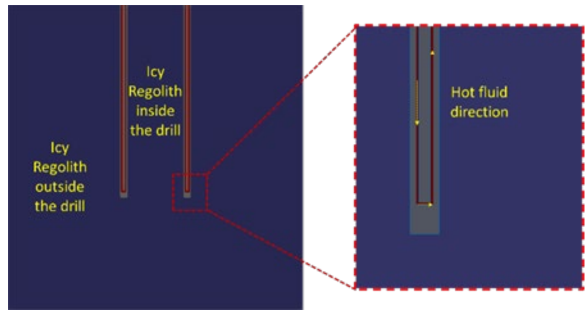

Figure 1. FLUENT Domain of the thermal corer in icy-regolith environment. The corer is in gray. The icy-regolith is in blue color. The heat transfer fluid is in red color. The arrows show the fluid direction, from top left to top right, to provide heat to the corer.

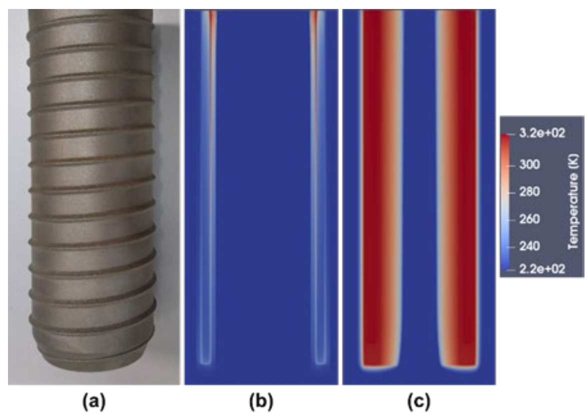

Figure 2. (a) Thermal corer 3D-printed in stainless steel, (b) Temperature profile of FLUENT simulation at time = 1s, (c) Temperature profile of FLUENT simulation at time = 300s.