**BUSINESS CASE ANALYSIS OF LUNAR THERMAL MINING.** R. Shishko[1] and A. Stoica[2], [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, robert.shishko@jpl.nasa.gov, [2]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109 adrian.stoica@jpl.nasa.gov.

**Introduction:** A critical component of any business case for ISRU is a supply side model (i.e., the production function) for the selected mining technology. With growing interest in mining water on the lunar surface—most likely within the permanently shadowed regions near the lunar south pole, we joined several models needed to derive the production function (and ultimately the related cost function) for the thermal mining technology proffered by Colorado School of Mines (CSM) [1], [2]. In particular, we combined (a) a model needed to determine the rate of production as a function of the physical characteristics of the thermal tent, the available water within the top layer of regolith, the dwell time at a site, and the intersite move time with (b) a model of the percent illumination time and power delivered to the tent site as a function of the physical characteristics and quantity of the solar reflectors ("TransFormers") needed at the rim of the target crater [3], [4]. Such a combined model could help inform the many tradeoff that are possible.

**The Macro-Logistics Model:** The first model, which we call the macro-logistics model, is straightforward as seen by the equations that follow. Thermodynamic considerations, however, must be consistent with the macro-logistics model.

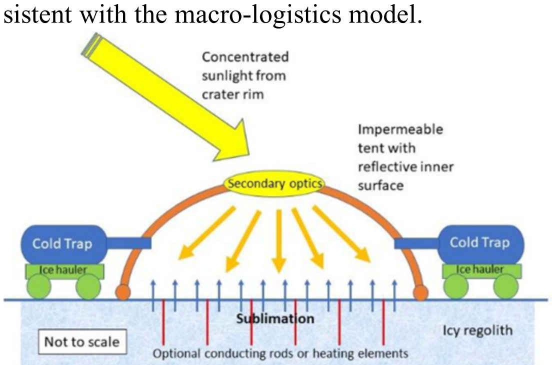


**Figure 1: Water Production Schematics with Sublimation under Thermal Tent**

$$\dot{m}_{deposition,\,loss} = p(t)A_{cold\ trap,\,loss}\sqrt{\frac{M_{H_2O}}{2\pi RT}}$$

$$Annual\ Harvest = (Deposition\ Rate)(Site\ Dwell\ Time)(Annual\ Moves)$$

$$Annual\ Moves = INT\left(\frac{(Hours\ Per\ Year)(Tent\ Availability)}{Site\ Dwell\ Time + Intersite\ Move\ Time}\right)$$

$$Annual\ Area\ Mined = (Effective\ Tent\ Area)(Annual\ Moves)$$

$$Water\ Production = (Annual\ Area\ Mined)(Ice\ Yield_{after\ losses})$$

$$Tent\ Availability = 1 - \left(\frac{(Monthly\ Downtime)(Months\ Per\ Year)}{Hours\ Per\ Year}\right)$$

$$Ice\ Sublimated_{before\ losses} = (Regolith\ \%\ Water\ by\ Weight)(Regolith\ Density)(Effective\ Depth)$$

$$Ice\ Yield_{after\ losses} = Ice\ Sublimated_{before\ losses}\left(1 - \frac{A_{loss}}{A_{loss} + A_{cold\ trap}}\right)$$

**The TransFormers Model.** The second model relies on complex terrain models and ray-tracing software. TransFormers could redirect sunlight to locations kilometers away, e.g., from the rim of the lunar south pole's Shackleton Crater to its bottom, where it could ensure operations of both prospecting rovers and in situ resource utilization (ISRU) equipment. A typical result of the model for the Shackleton Crater in which two Transformers are employed is shown in Fig. 2. For the purpose of rapid trades, this curve can be represented by the following function.

$$L = exp(2.26844 + 0.00504H)/(1 + exp(2.26844 + 0.00504H))$$

where $H$ is the tower height and $L$ is the resulting percent illumination.

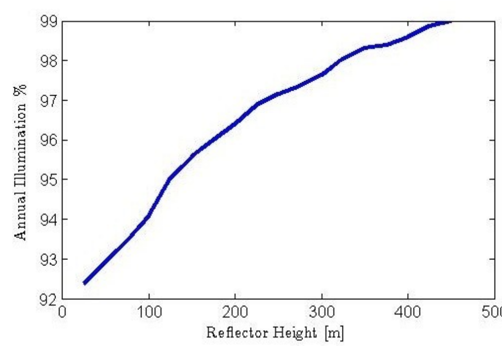


**Figure 2: Results for TransFormers Located at 89.9029°S 145.2301°W and 89.6876°S 162.8645°W**

**References:**

[1] Koruta D. and Abbud-Madrid A. (2018) "Commercial Propellant Lunar Architecture. [2] Sowers G., et al., (2019) Ice Mining in Permanently Shadowed Regions. [3] Henrickson J and Stoica A.

(2017) Reflector Placement for Providing Near-Continuous Solar Power to Robits in Shackleton Crater. [4] Stoica A. Wilcox B, et al. (2017) Trans-Formers for Lunar Extreme Environments Phase II Final Report.