**HARVESTING WATER FROST ON MARS USING FOCUSED SOLAR RADIATION.** I.B. Smith[1,2] and O. Aharonson [2,3], P. O. Hayne[3] [1]York University, 4700 Keele St, Toronto, Ontario, Canada (ibsmith@psi.edu), [2]Planetary Science Institute, Lakewood, Colorado, USA, [3]University of Colorado, Boulder, USA.

**Introduction:** Water ice is present in many locations and forms on Mars. To date, reconnaissance for in-situ resource utilization of water ice has focused on buried glaciers or ground ice. Either of these potential sources would require heavy equipment and large power supplies to acquire the quantity of ice sought to support human exploration [1, 2]. These mass, power, volume, and cost (MPVC) constraints may fundamentally limit the future access of the water sources. Further, each of these sources will have unknown quantities of potentially toxic impurities, likely in the form of dust, regolith, or salt, that must be removed before the water can be used for human purposes [3].

**Motivation:** We aim to develop and demonstrate an alternative method of harvesting water or water ice with reduced MPVC constraints, that is scalable to mass production and has a robust operational concept.

**Opportunity:** Each year, at middle latitudes, water frost covers the surface of Mars with up to millimeters of $H_2O$ ice. This naturally occurring phenomena creates a surface reservoir that can be exploited quickly and for low MPVC budget. Figure 1 is an example from the Viking II lander that has a rocky surface, but this ice also deposits on smooth terrain that could be sought for harvesting this ice.

Available ice varies by location, but quantities approximating 0.1 kg/m² are available near 50° north (Figure 2).

**Concept:** The Fresnel-Aided Ice Trailing Harvester (FAITH) concept uses a Fresnel lens (Figures 3 and 4) to focus light onto the surface. The light warms and then sublimates the ice to form vapor, which travels across the system toward a cold trap, where it can be collected and stored (Figure 3).

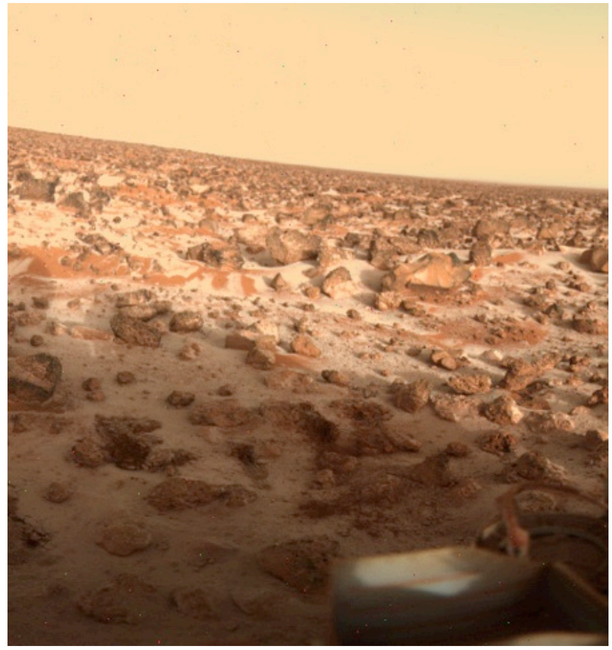
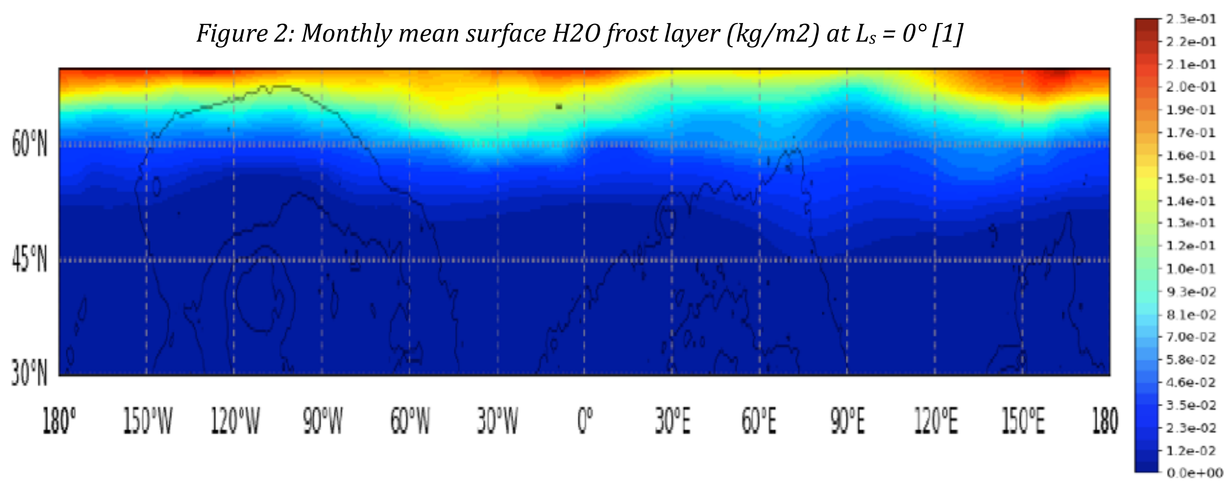


*Figure 1: Photos from the Viking II landing site at 47.64°N in Utopia Planitia. Water frost covers the surface on May 18, 1979 (Ls = 288.7°).*

The Fresnel lens could focus the solar constant 590 W/m² along the drive direction to higher values in a thin strip, to enhance sublimation (Figures 3 and 4). The enhancement scales with area ratio of the Fresnel lens to the illuminated area. The width of the lens and scanning rate determine the yield.

A modestly sized Fresnel lens of 1.0 m wide x 0.5 m tall could yield ~300 W on a narrow strip 0.01 m wide, sufficient to warm and sublimate the ice that is in equilibrium with the atmosphere.

*Figure 2: Monthly mean surface H2O frost layer (kg/m2) at $L_s$ = 0° [1]*



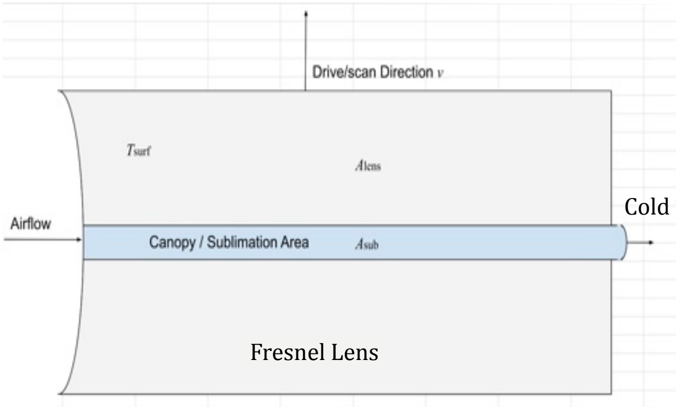



*Figure 3: Scanning system with Fresnel lens above the surface to focus light onto the ice (viewed from above). The concentrated solar energy falls on a line (Figure 4) and sublimates the ice to vapor, which is delivered across the dome into a cold trap. Passive solar energy does the work.*

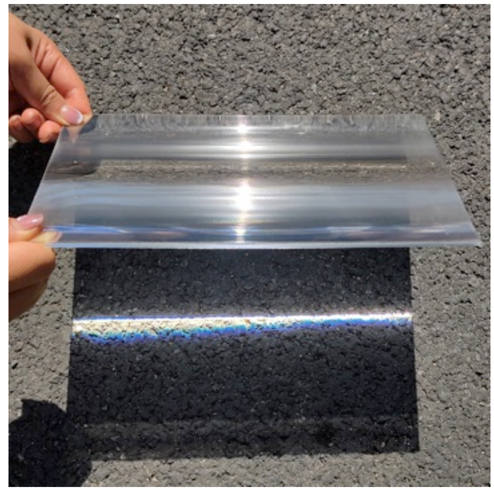


*Figure 4: Fresnel lens (2 mm thick, 30 cm x 20 cm, ~0.2 kg [5]) will focus the solar radiation onto a narrow swath for sublimating the ice.*

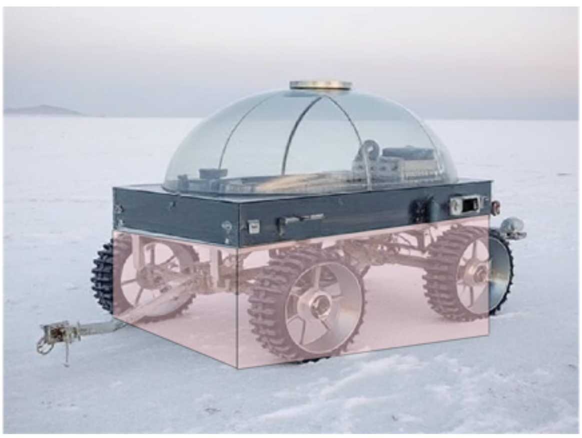


*Figure 5: An artistic conception that visualizes the essential elements. A Fresnel-lens dome would be close to the ground to focus the light and act to trap the newly released water vapor. Water vapor in the canopy would find a cold trap and deposit. Later, the cold trap could be skimmed or even warmed to collect the H2O molecules into a better container for transport or long-term storage.*

**Yield**: Including the sensible heat of ice (2090 J/kg/K) and the latent heat of sublimation ($2.838 \times 10^6$ J/kg), only ~80 W of power are required to yield 0.1 kg/hr.

At a scanning rate of 0.1 m/h, yields for this very modestly sized lens would reach 0.24 kg/day. Larger lenses (e.g. 2 x 1 m) would enable faster scanning and increased yield to greater than 1 kg per day

This concept is a trailer that can be towed by a multi-purpose utility rover (Figure 5). During the harvesting season, the rover would focus on acquiring water, returning to a base station each night to deposit the daily harvest. Because the drive/scan rate is less than 1 m/hr, the rover is never far from a base station. Post harvest season, the multi-purpose rover would serve numerous applications for the landed site, perhaps in developing infrastructure or scientific investigations.

**Win Themes:** FAITH has several advantages over more traditional ISRU extraction techniques:

1. No humans are require to pull the trailer
2. Low Power
3. Low Mass
4. Low Volume (collapsable to fit in fairing)
5. Low Cost compared to alternative methods
6. Easy Concept of Operation (use during day)
7. Scales well (area for $x^2$ scale, or can employ multiple harvesters)
8. Does not contravene planetary protection:
    1. No special environment is created
    2. Does not disturb subsurface
    3. Water comes from the atmosphere, not a habitable environment
    4. No melt
9. Harvests pure ice, no impurities (salt, dust, or regolith) to separate out.

**References:** [1] https://ntrs.nasa.gov/citations/20205011353 [2] https://www.nasa.gov/wp-content/uploads/2015/06/mars_ice_drilling_assessment_v6_for_public_release.pdf [3] https://ntrs.nasa.gov/api/citations/20180005542/downloads/20180005542.pdf [4] Mars Climate Database https://www-mars.lmd.jussieu.fr/ [5] https://www.amazon.com/Fresnel-300x200mm-Project-Optical-Education/dp/B0D9R4DSSL?gQT=1