Harvesting Water Ice on Mars Using Focused Solar Radiation

The Fresnel-Aided Ice Trailing Harvester (FAITH)

June 6, 2025

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Water ice blankets the surface at high latitudes seasonally

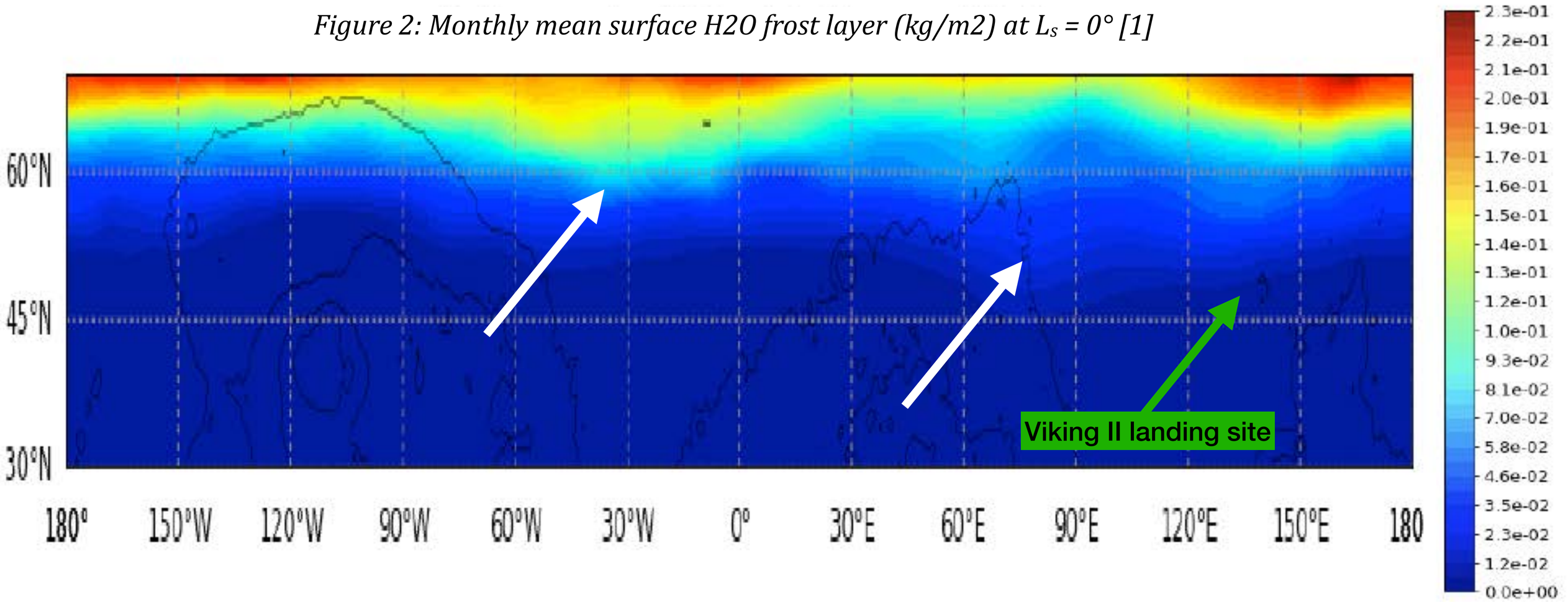
Image from Viking II

100s of μm to 1 mm of ice

47.64°N 225.71°W

Ls = 288.7°

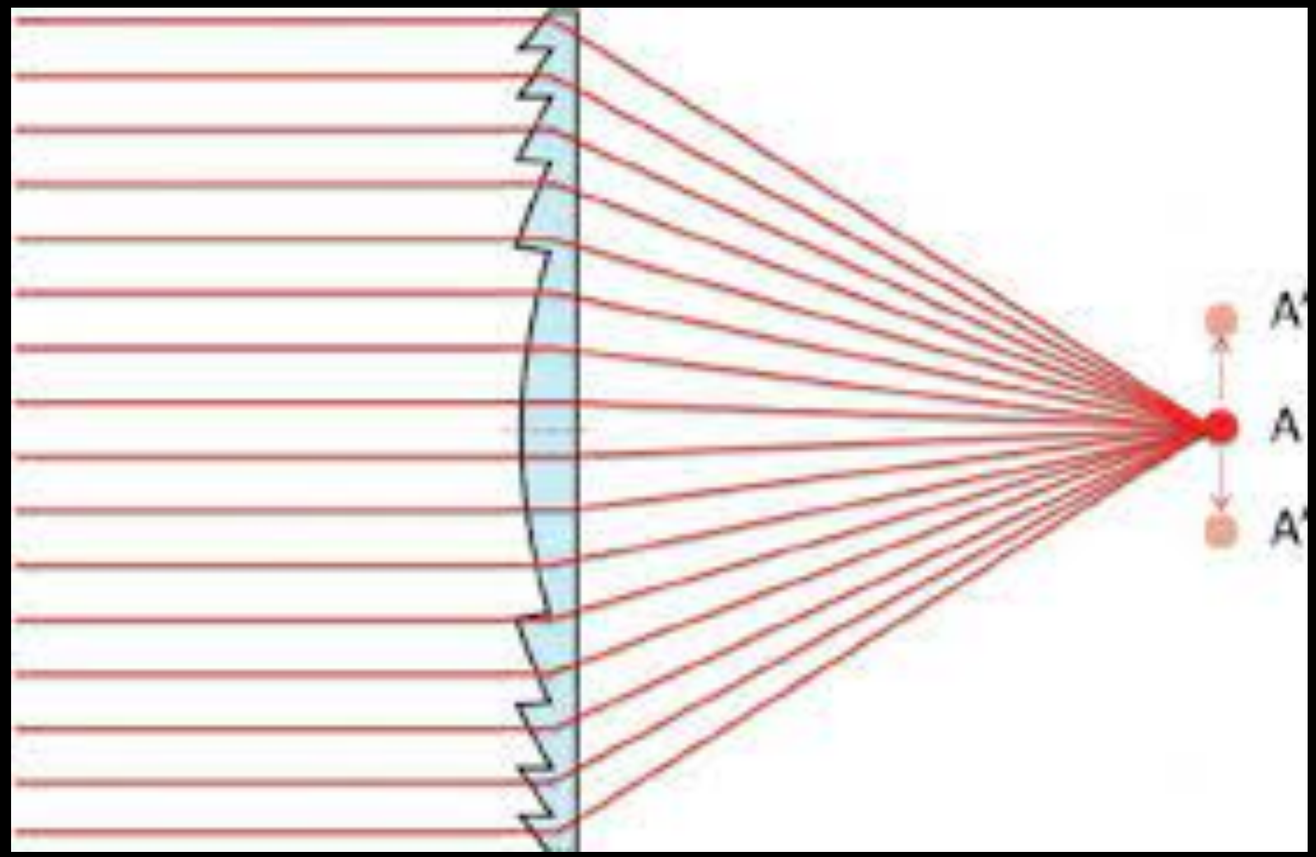
Figure 2: Monthly mean surface H2O frost layer (kg/m2) at L_s = 0° [1]



Locations at moderate latitudes may have as much as 0.1 kg/m² of ice on the surface after winter

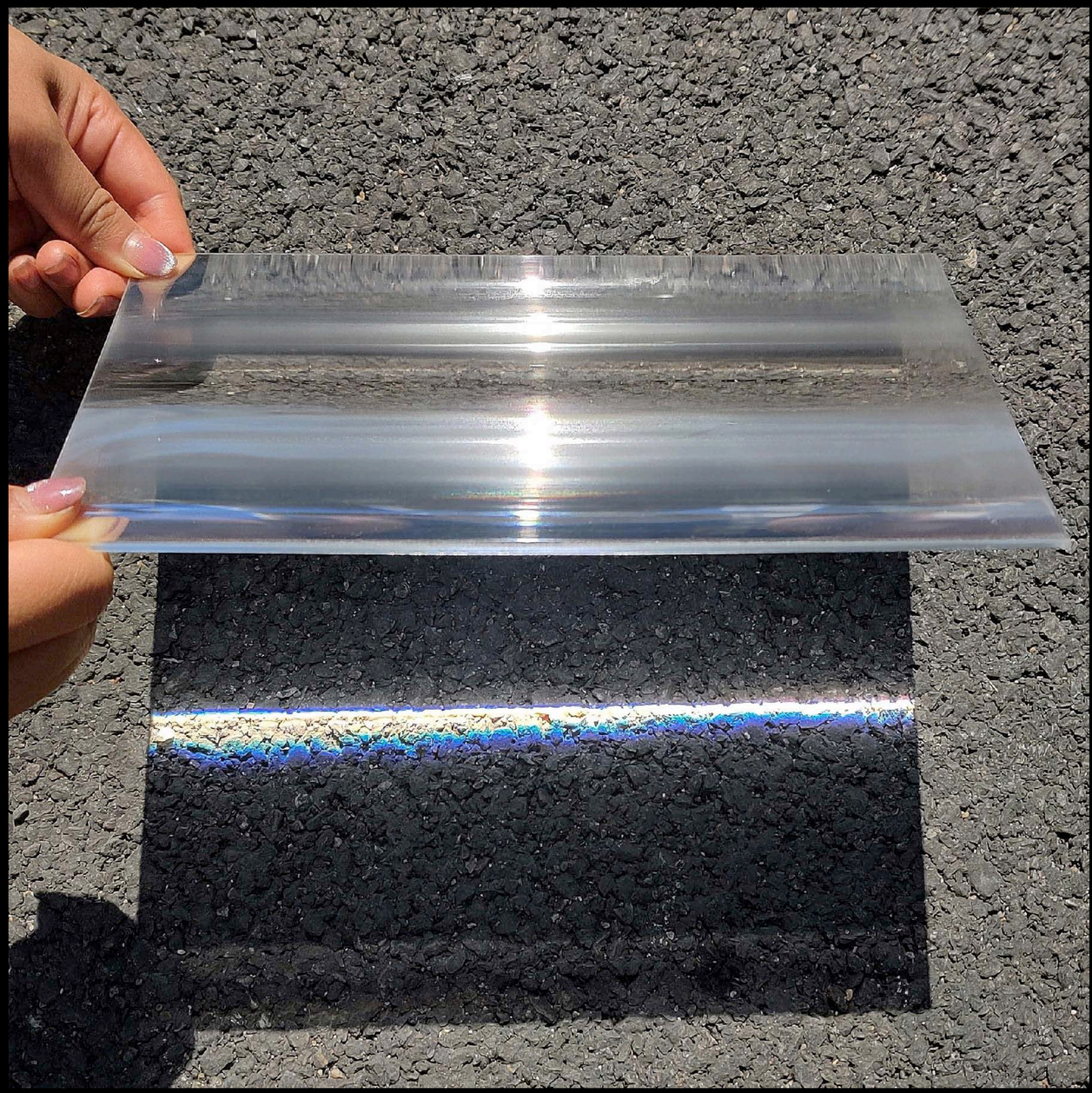
This ice is on the surface and freely available. There are win themes with harvesting this ice

1. Available on the surface, so no digging required
2. Water comes from the atmosphere, not a habitable environment
3. Can be harvested passively



Fresnel lenses can be designed to set the focal length and concentration

Fresnel lens that focuses light onto a narrow swath



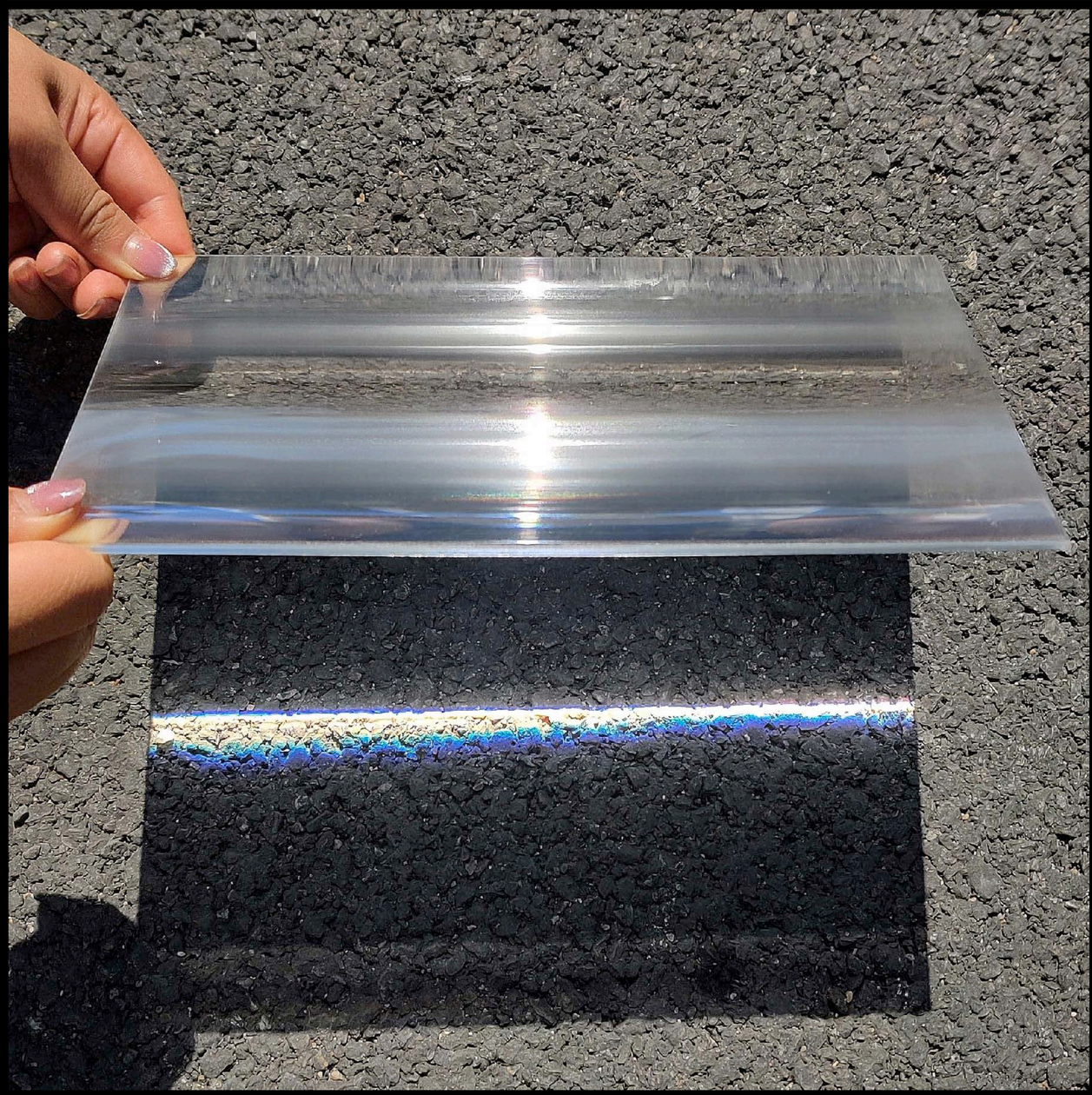
The Fresnel lens could focus the Martian solar constant of 590 W/m^2 along the drive direction to higher values in a thin strip

This example has >20x concentration (used commercially to burn/etch wood)

20x590 W/m^2 ~ 12,000 W/m^2 or ~10 suns

Larger lenses could enhance that significantly

Fresnel lens that focuses light onto a narrow swath

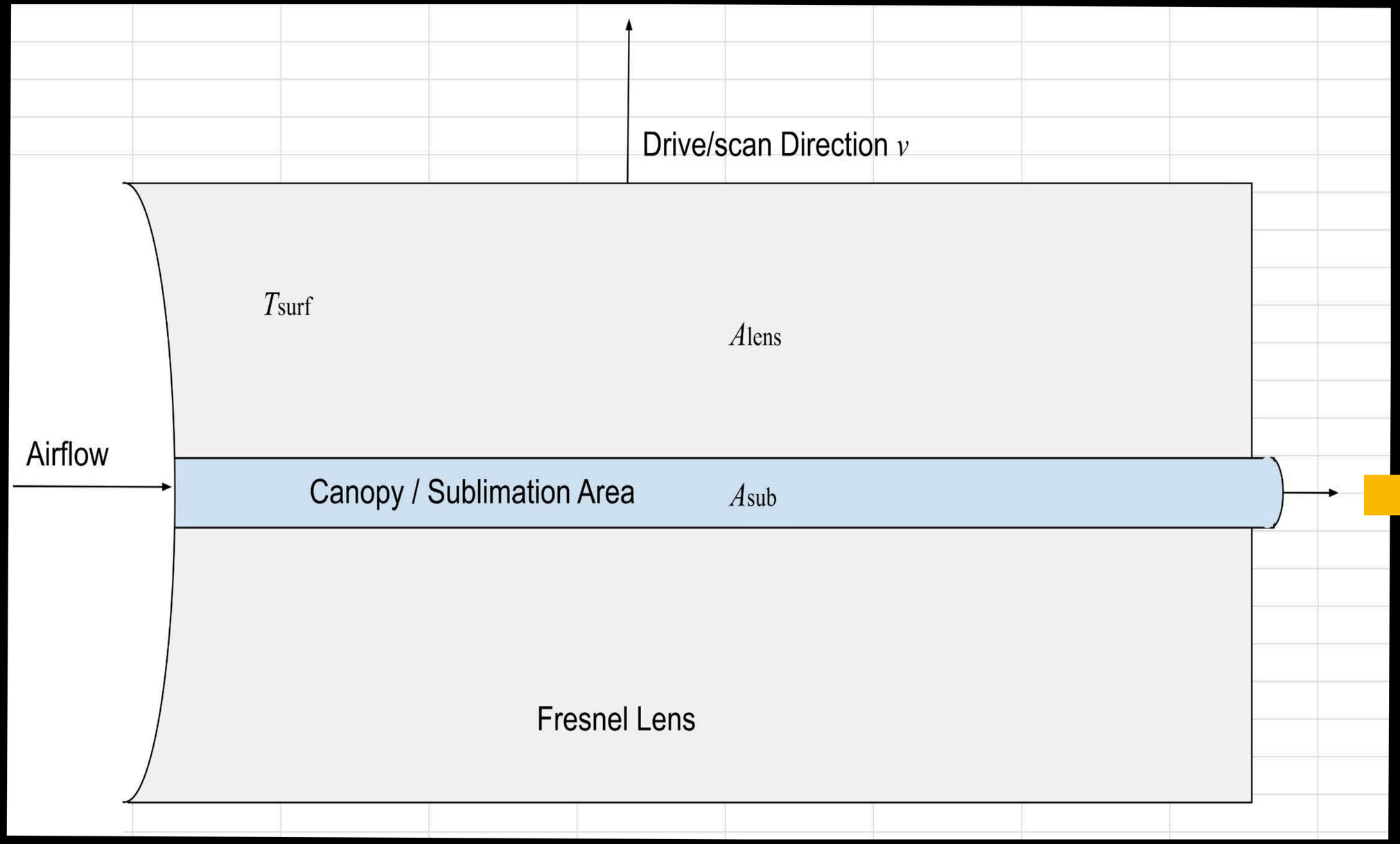


<200 g

“Scanning” the ground with concentrated sunlight

AI Generated images

Moving the lens northward would “scan” the ground



The Fresnel-Aided Ice Trailing Harvester (FAITH)

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The bubble is to retain water vapor, and a cold trap would be on the side of FAITH to deposit ice.

This artistic conception is too heavy with big metal wheels, heavy trailer hitch, and an unnecessary deck. Any prototype would be designed to minimize weight. FAITH could feasibly be <50 kg

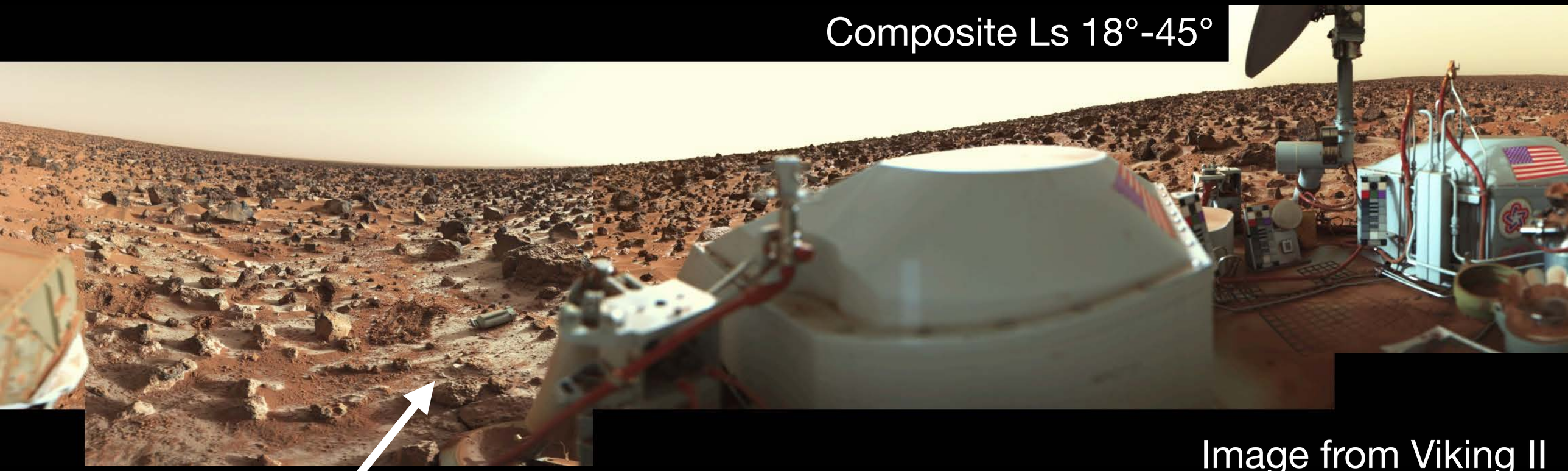
The Fresnel-Aided Ice Trailing Harvester (FAITH)

The concept is a trailer that has a plastic bubble containing a Fresnel lens on the front and back side (to go north and south)

FAITH is a trailer that can be pulled by a tractor / rover autonomously or remotely from orbit.

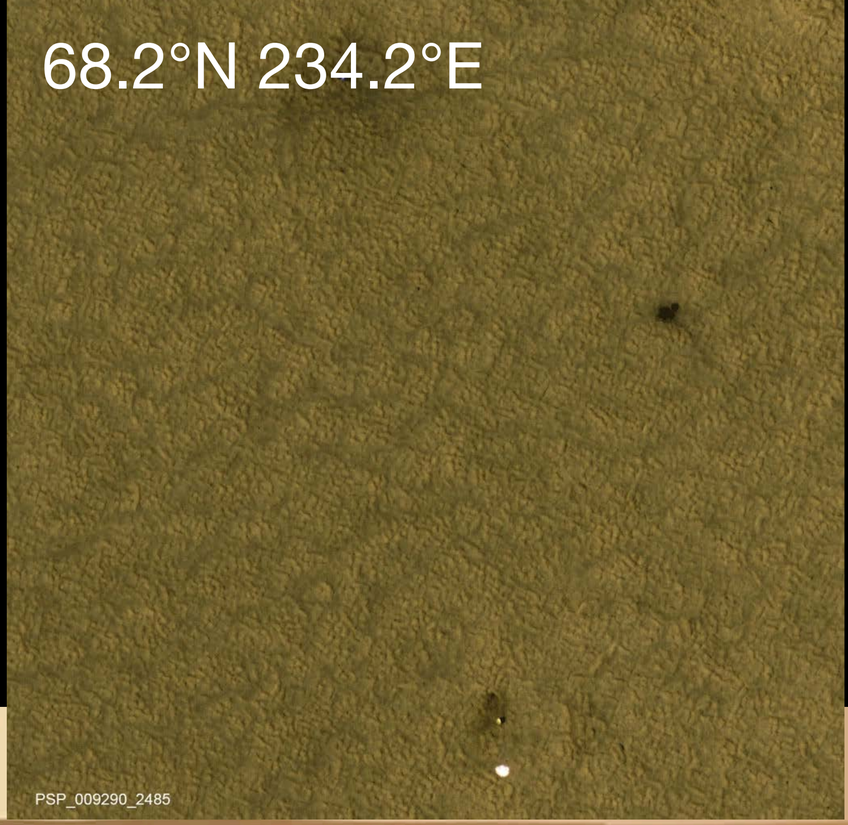
During other seasons, or after the sun goes down, the tractor could have other applications, including delivering the collected ice

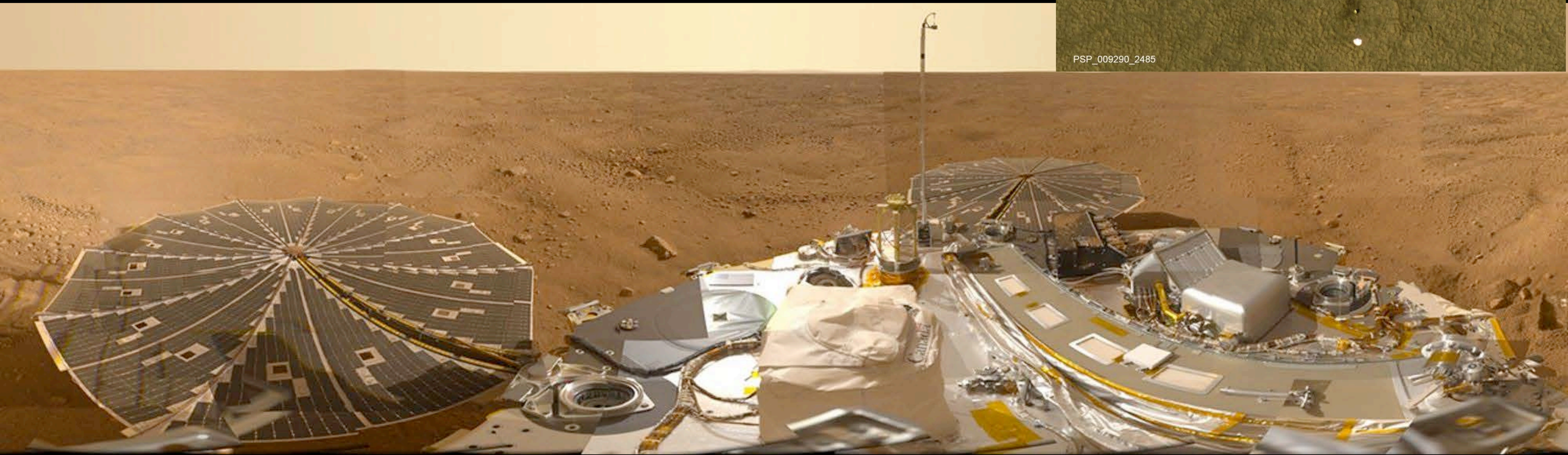
Viking II Landing Site was rocky, which makes mobility more difficult



47.64°N 225.71°W

Phoenix had a much smoother landing site (and would expect to have more frost because of higher latitude)





Frost at the Phoenix Landing site

Depending on mission context, specifically latitude, FAITH could begin work in mid-summer and continue until mid-spring.

Of course duration of day matters (solar elevation angle matters less because the Fresnel lens could change angle based on SEA)

Peak harvest would be ~ Ls = 0°

68.2°N 234.2°E Ls = 137.9°

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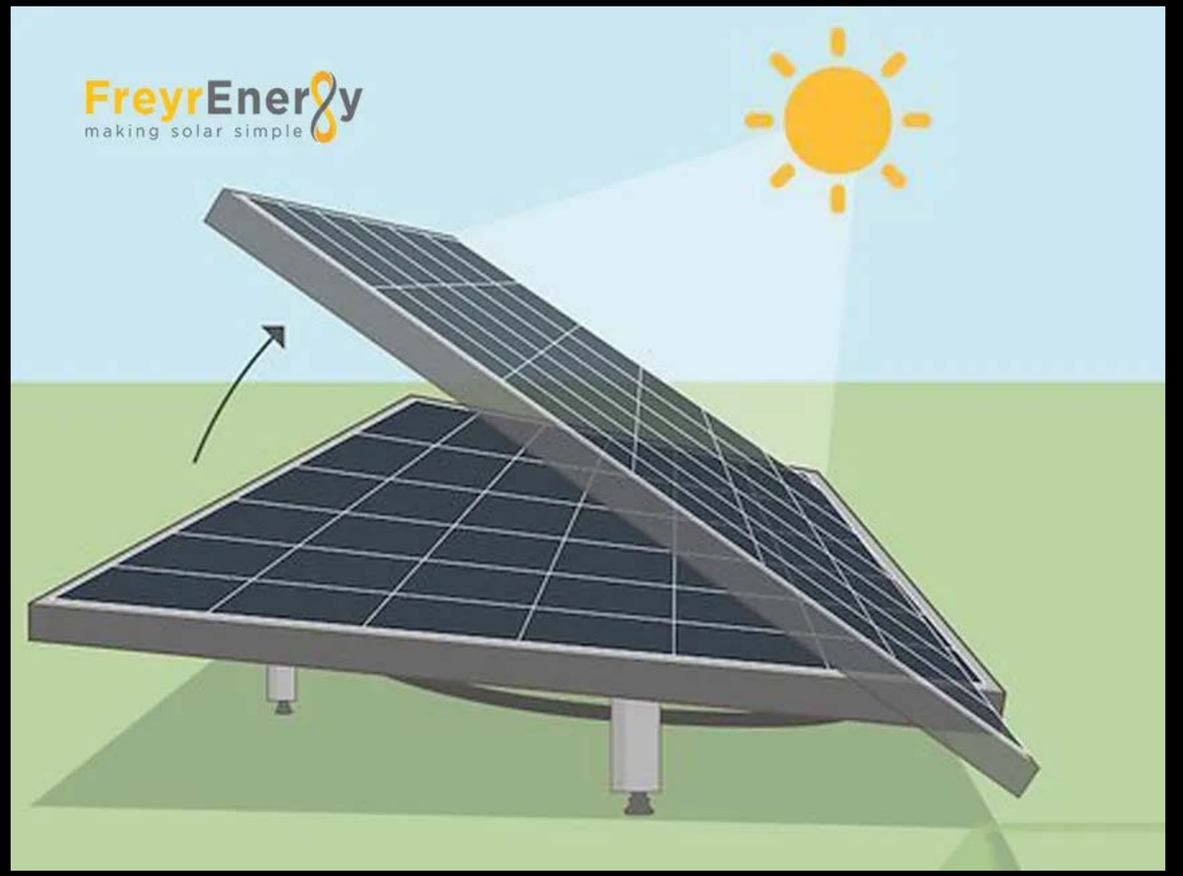


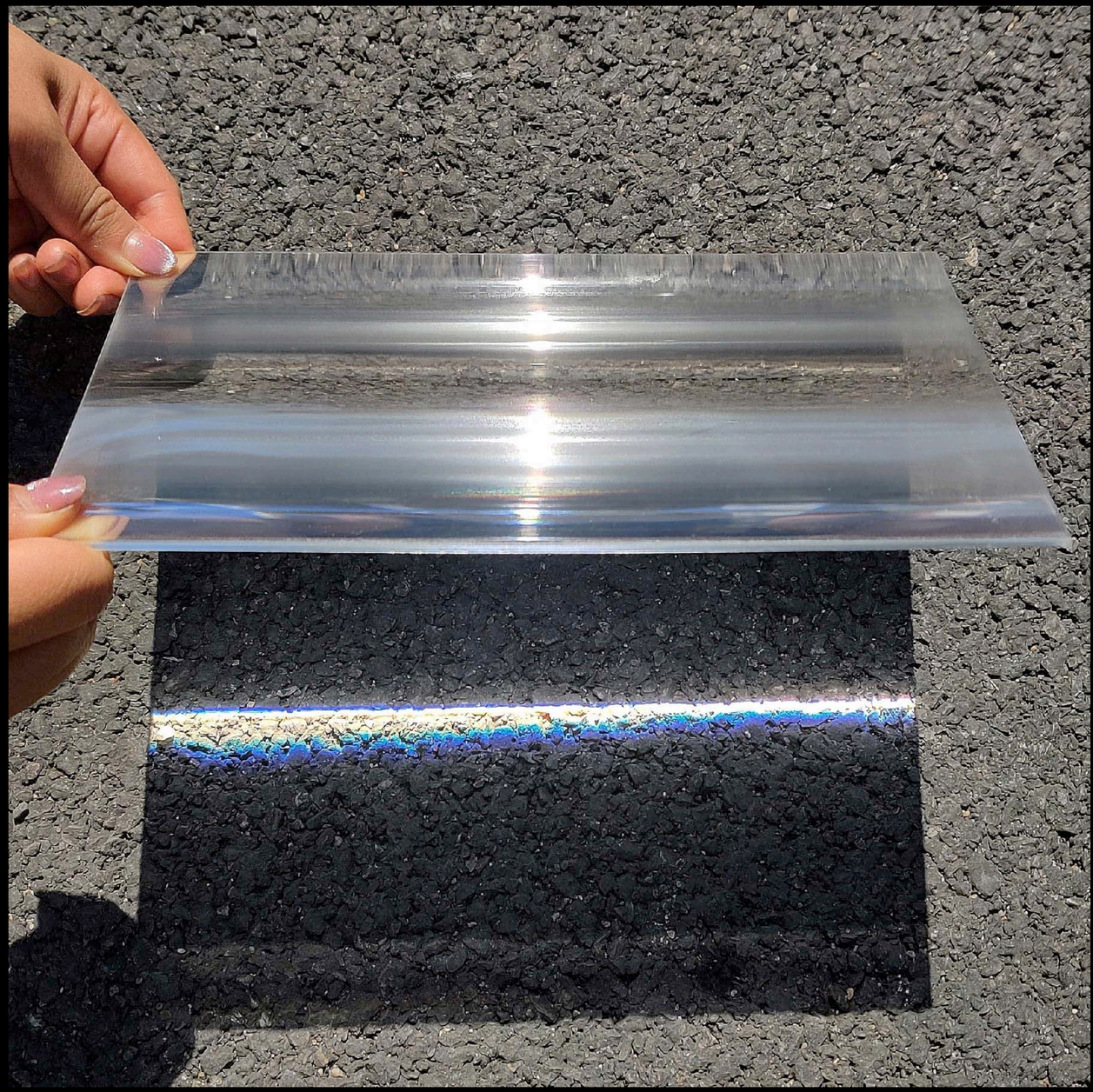
Yield:

Including the sensible heat of ice (2090 J/kg/K) and the latent heat of sublimation (2.838x106 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 sol

This modest amount can be integrated over hundreds of sols

Easy to imagine much greater yield with more trailers or much larger lens



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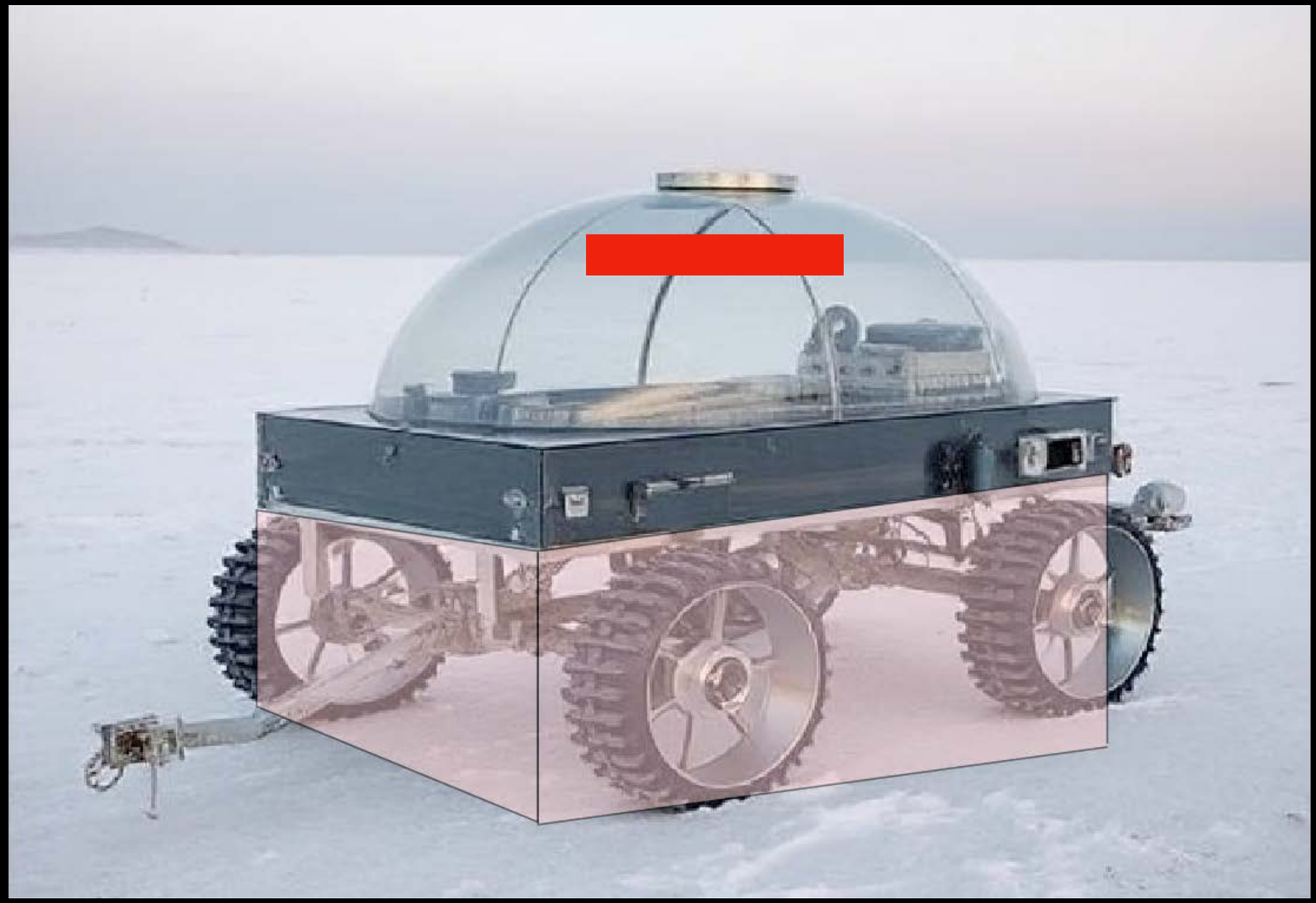
Because the drive/scan rate is less than 1 m/hr, the rover is never far from a base station (~10 kg / 100 m^2). When not in use, the multi-purpose tractor would serve numerous applications for the landed site, perhaps in developing infrastructure or scientific investigations

Increasing Yield

Adding a heater to the inside of the dome would enhance the sublimation rate, allowing for a faster rate of travel and greater yield per day.

Power could be delivered from the tractor, a tether to a home base, or via concentrated EM radiation

e.g. VOLTA



Increasing Yield

It is feasible to increase the mass of the frost layer.

Laying a high emissivity tarp on the surface would decrease the temperature when compared to the natural surface.

The colder surface would attract more ice.

This ice could be harvested more frequently and even in warmer seasons

Increasing Yield

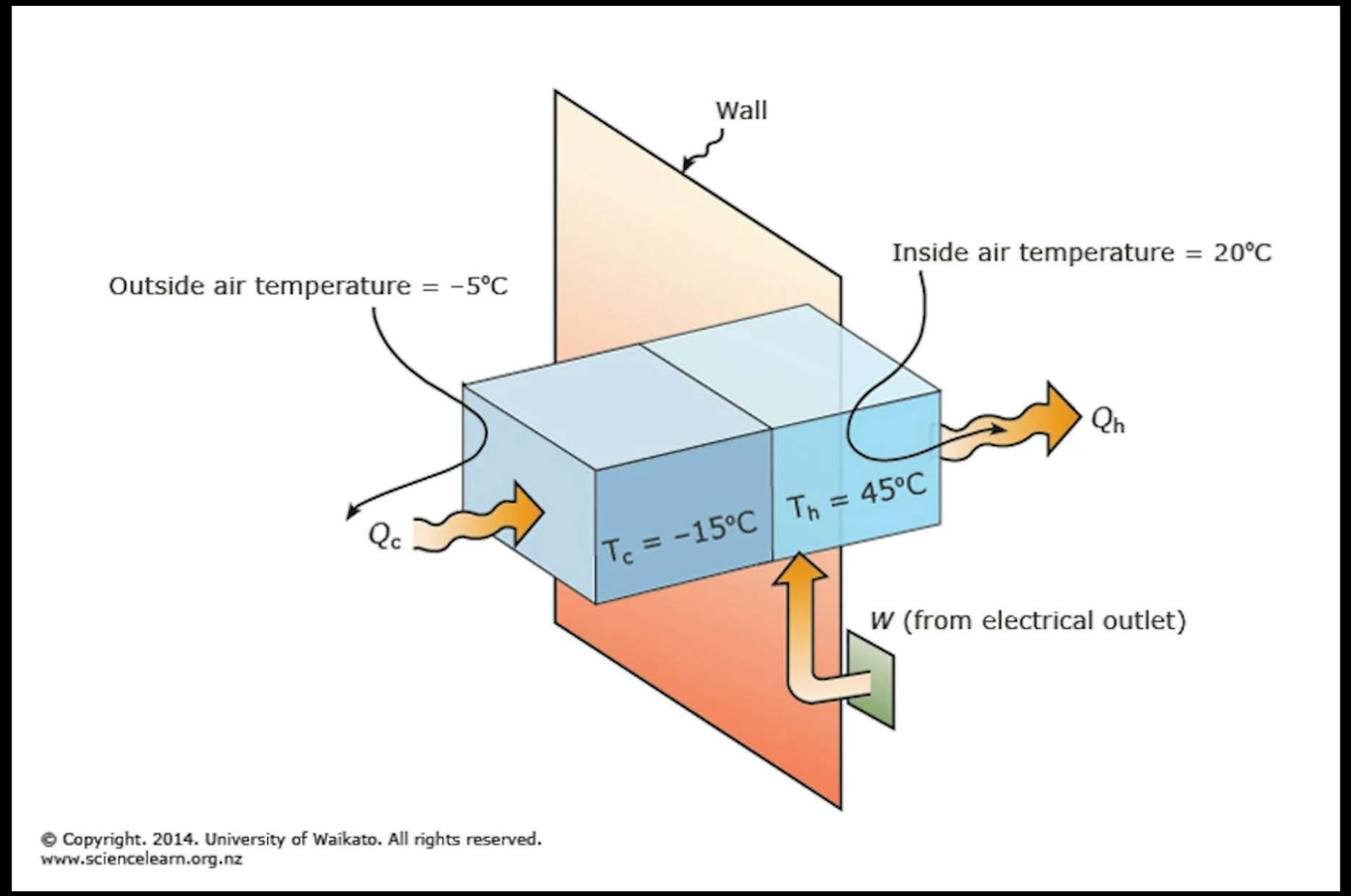
It is even possible to roll out a tarp that could then be re-rolled under a Fresnel lens. This would require some articulation but no mobility.

Increase Yield and Create a Cold Trap Via Heat Pump

There are numerous methods for cold trapping. Some generate waste heat that can be pumped into the FAITH Dome

Cooling a pipe that is attached to FAITH would create a cold trap for the sublimated water vapor.

Later, reversing the heat pump would warm the pipe, and the water vapor could be sent to another cold trap in a containment unit.



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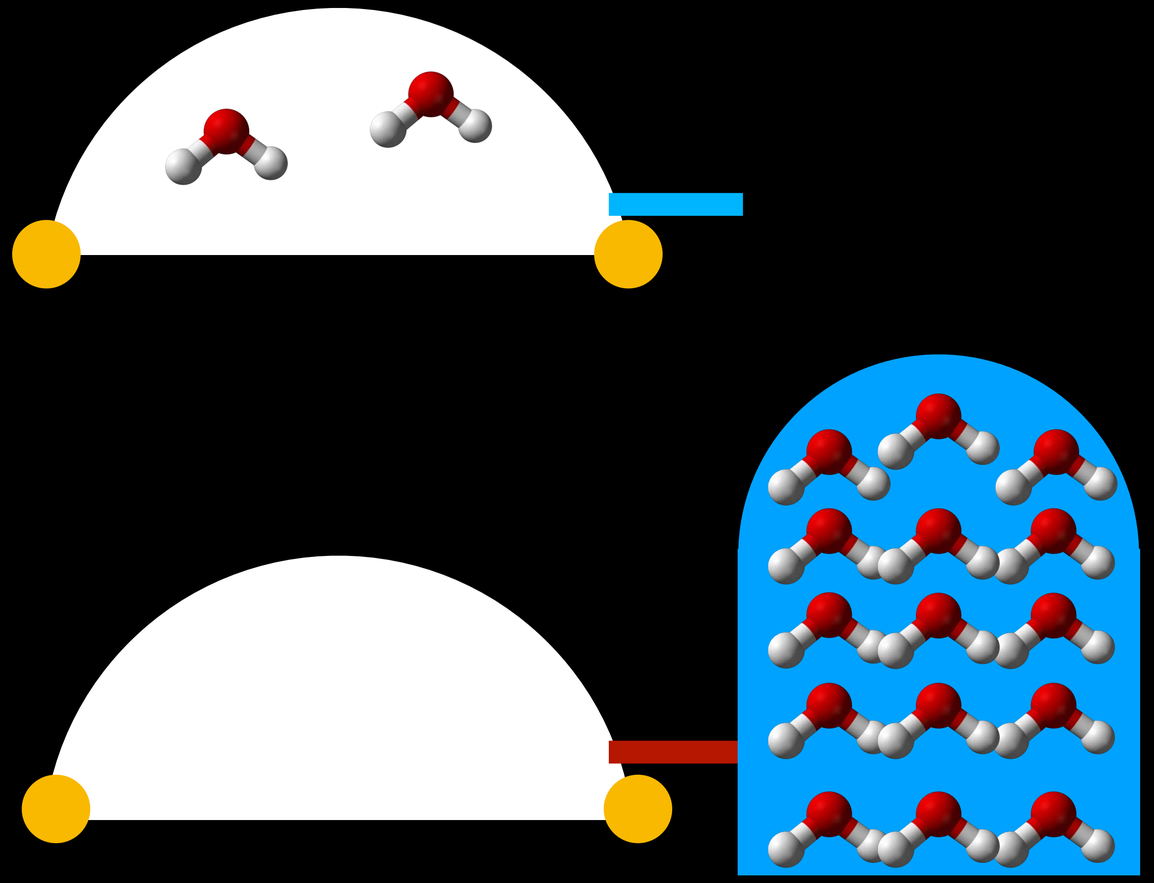

FAITH Win Themes

1. No humans are require to pull the trailer (as compared to other extraction techniques
2. Low Cost compared to alternative methods (Rodriguez well, bull dozer)
3. Low Power (0 W required for FAITH, some for tractor)
4. Low Mass (tens of kg for trailer and cold trap)
5. Low Volume (collapsable dome to fit in fairing)
6. Easy Concept of Operation (use during day, autonomous or remote piloting)
7. Scales well (increase area for x^2 scale, or can employ multiple harvesters)
8. Does not contravene planetary protection:
    a. No special environment is created
    b. Does not disturb subsurface
    c. Water comes from the atmosphere, not a habitable environment
    d. No melt
9. Harvests pure/distilled ice, no impurities (salt, dust, or regolith) to separate out.

This water may not support a colony or even a return trip, both of which require 10^5 kg of ice, but it could support a crewed outpost that needs only a few kg of ice per day.