Methodology for optimizing a lunar VSAT installation accounting for self-shading. W. H. Butler[1], [1]Shell (retired) 831 Silvergate Dr. Houston TX 77079, wbutler831s@gmail.com

Introduction: The Vertical Solar Array Technology, or VSAT, is a strong candidate for modest powered missions to the Lunar Poles [1]. It features an elevated, vertically oriented panel which rotates to always face the Sun. For sites very near the poles, the Sun remains very close to the horizon, which allows a rotating vertical panel to continually receive almost normal-incidence sunlight, therefore maximizing its insolation. However, if multiple VSATs are combined to form an array, this same feature causes a maximal shade behind each panel, potentially decreasing the insolation of the other ones. This paper describes a novel methodology for quantifying such self-shading, maximizing power from the array design, and applies it to the 'Connecting Ridge' site very close to the lunar south pole.

Sky bitmask method: Previous modelling studies (e.g. [2], [3]) modeled the local horizon as a single-valued, slowly changing function of azimuth (the elevation of the horizon as seen from the panel). Ross [4] developed a methodology to estimate the upper limit of available illumination in the presence of self-shading, and applied it to many different heights of VSAT installations. This work describes a different methodology to optimize a particular VSAT array with real locations. A binary sky bitmask is used to represent both the azimuthally slowly varying horizon and the quickly varying neighboring panels. This allows extremely fast computation of the insolation accounting for near-by panel shading.

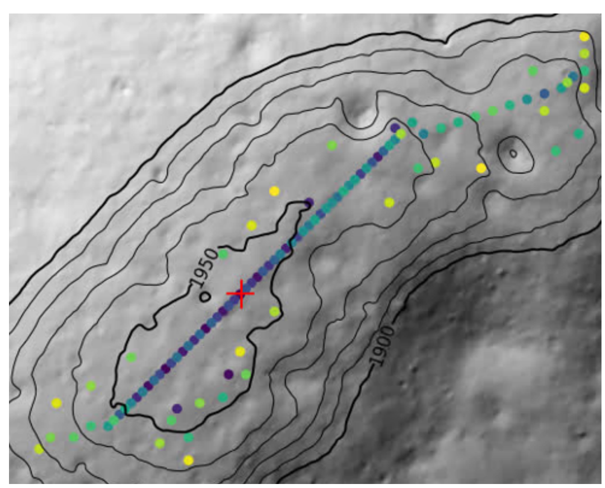
Optimizing total energy: The VSAT array is built up by one location at a time adding the best candidate location at each step. As panels are added, their shadows are added to the sky bitmasks of all the others. Optimizing on the total energy in the year 2030, the resulting array shows a prominent diagonal line along the apex of the Connecting Ridge. This maximum energy result is achieved by sacrificing significant power when the sun aligns with this diagonal, but results in higher insolation at all other times.

Mitigating the browouts: Although this configuration maximizes total energy, the twice-a-lunar-day brownouts are not desirable. If instead the *value* of the power is optimized, the result is only slightly less total energy (2%) but a more uniform provision of power. This approach rests on the idea that if there is already a lot of power being generated by the grid at a certain moment in time, an additional candidate panel that adds more power at that moment isn't very valuable. But if there is very little power generated at a certain moment in time, any additional candidate panel that can provide power at that moment is valuable. In this work the logarithm of the power is used as the value.

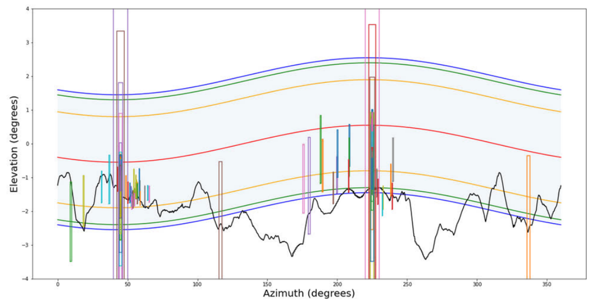
Conclusion: A specific configuration of VSATs is found that optimizes both total energy and uniformity of energy over time for the Connecting Ridge. Larger arrays do suffer from diminishing returns due to both self-shading and less-optimal siting, but the Connecting Ridge should support 100-500 panels generating 1-5MW of power on average before losses become significant.

References:

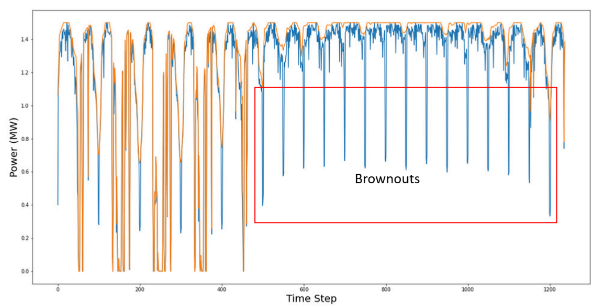
[1] Frazier, Sarah. https://www.nasa.gov/news-release/three-companies-to-help-nasa-advance-solar-array-technology-for-moon/. www.nasa.gov. [Online] Aug 23, 2022. [Cited: March 22, 2024.] https://www.nasa.gov/news-release/three-companies-to-help-nasa-advance-solar-array-technology-for-moon/. [2] Illumination conditions at the lunar polar regions by KAGUYA(SELENE) laser altimeter. Noda, H., et al. 2008, Geophysical Research Letters, Vol. 35. [3] Illumination conditions of the lunar polar regions using LOLA topography. E. Mazarico, G.A. Neumann, D.E. Smith, M.T. Zuber, M.H. Torrence. 2, 2011, Icarus, Vol. 211, pp. 1066-1081. [4] Preliminary quantification of the available solar power near the lunar South Pole. Ross, Amia K., et al. 2023, Acta Astronautica, Vol. 211, pp. 616-630. ISSN: 0094-5765.



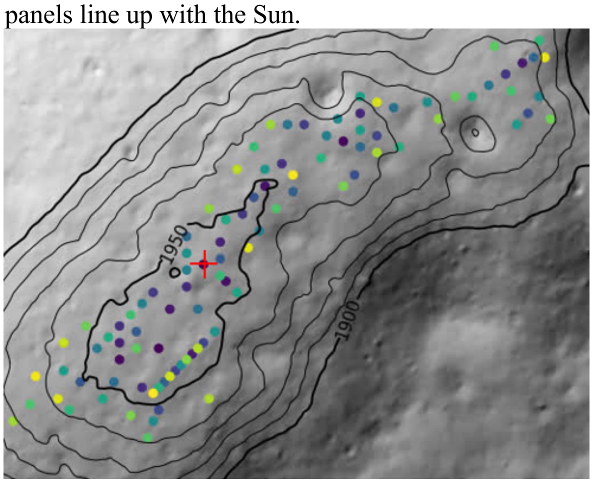
The positions of the first 100 panels chosen by maximizing total energy produced during the year 2030, colored by sequence number.



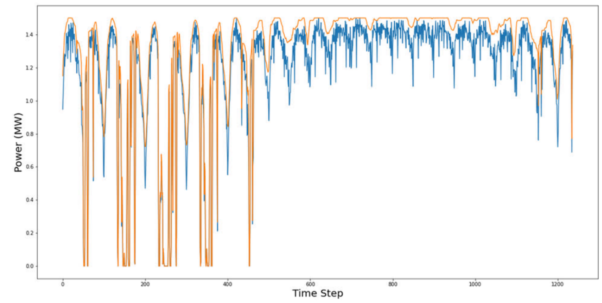
The view of the horizon as seen from the first placed panel (red plus), after the first 100 panels have been placed, maximizing total energy. Note how the alignment of the panels causes much of the shading to occur on already-shaded panels, maximizing the energy at other Sun positions.



The power produced by these panels, optimized by total energy, without shading (orange) and with shading (blue). The algorithm has naturally found a panel alignment that allows maximum energy productions except for a few limited times (twice a lunar day) when the panels line up with the Sun.



Position of first 100 panels optimizing for value rather than total energy.



Note the brownout troughs are gone.