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ON THE FEASIBILITY OF POWER EXTRACTION FROM LUNAR MINI-MAGNETOSPHERES

Abstract

In this paper we will examine the feasibility of extracting power from the action of the solar wind against Lunar mini-magnetospheres. Significant challenges exist for the implementation of existing power source technologies on the harsh Lunar surface environment. Solar cells must contend with damaging radiation and energetic particle fluxes, extreme surface temperatures, and Lunar dust coverage. Nuclear fission reactors seem better equipped to handle the challenges of the Lunar environment, but they come with a significant increase in cost, complexity, and launch payload risk. Despite these challenges, it appears likely that power sources based on these technologies, built on Earth and launch to the Moon, will support the next wave of human operations. However, long-term growth on the Lunar surface will eventually require low-cost, low-complexity power system technologies that can be constructed primarily from Lunar materials, thus breaking the launch, land, and leave paradigm.

The interaction between the solar wind and Lunar magnetic anomalies generates small-scale (100's of km) magnetospheric plasma structures. A key feature of these structures is a relatively strong (0.1-1 V/m) polarization electric field. It is possible to extract power from this field using electrodes placed on either side of the potential drop, however, the current draw would be severely limited due to low solar wind particle fluxes in this region, yielding a power density of only 100 W/km2 of electrode area. To overcome this challenge, we are investigating a novel configuration wherein a virtual plasma cathode is used to increase current draw by many orders of magnitude. Preliminary estimates suggest that a 5-cm diameter hollow cathode could form a virtual cathode capable of extracting 1-10 kW of power. Such a concept could provide over an order of magnitude reduction in cost, mass, and complexity compared to existing power source technologies, making an extensive Lunar surface power architecture possible on the timescale of one-to-two decades.

The paper will present our recent results that combine reduced-order theoretical modeling, 3D particle-in-cell (PIC) simulations, and laboratory experimentation. Using these results, we have examined the basic physics, feasibility, and scaling of power generation from the polarization electric field of mini-magnetospheres. Emphasis will be placed on providing novel insight into the fundamental physical processes that govern power extraction. The resulting discoveries will provide the foundational knowledge needed to assess the net useful power and scaling of the proposed concept.