A Solar Electric Propulsion Mission with Lunar Power Beaming

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Abstract

As the NASA Vision for Space Exploration evolves, a key issue that affects lunar exploration is the ability to provide electric power at various surface locations. This power should be available through daylight times as well as at night. It is the purpose of this paper to describe an electric propulsion mission to the moon that will use laser power beaming to provide power to multiple locations on the lunar surface within ±45º of the lunar equator. Beaming to polar locations is not included in this study due to the likelihood of substantial sunlight at those locations. Nuclear power options are not discussed.

The major benefit of solar electric propulsion (SEP) is that more payload can be delivered to the moon for less cost that by chemical means. In addition, SEP allows orbital adjustment to permit a range of characteristics to fit the mission requirements at small fuel expenditures. However, one disadvantage of SEP is that it takes longer to reach the moon, but this is not a limiting factor for this case. This paper will describe a solar electric propulsion mission to the moon, insertion into an elliptical orbit and beaming laser power to the surface.

Many options exist for orbits around the moon that could be used for power beaming. Beaming power from the L1 point leads to a beaming distance of about 56,000 km. The constraints on laser power beaming over this distance lead to substantial losses. If a Molniya-type, highly elliptical orbit were chosen for the power beaming location, the apogee may be only about 12,000 km which substantially reduces beaming distance, hence losses. However the length of time the lunar surface site is in view becomes important in order to keep the mass of the energy storage system on the surface small. In the same way, circular orbits of varying heights will encounter the same view time issue. So maximum elevation of the beaming spacecraft, the precession of orbits around the moon and the perturbations of lunar gravity all combine to complicate the analysis, and the results of these options will be presented.

For both the laser beaming spacecraft and the lunar surface receiving photovoltaic array, the Stretched Lens Array (SLA) on the SquareRigger platform design will be used. For the orbiting spacecraft, triple junction cells will be used in the array. Figure 1 shows a single cell test module with a triple junction cell and overall efficiencies of 29% have been demonstrated for this case. For the surface array, GaAs cells will be used to receive the beamed laser power. Testing of GaAs solar cells with a ~800 nm laser under the SLA has yielded efficiencies over 45% at room temperature. This equates to over 800 W/kg and 800 W/m^2 at a 70-75ºC operating temperature that is typical of a solar array in GEO. Temperature of an array orbiting the moon will depend upon its altitude and view angle of the lunar surface. This temperature will be between LEO and GEO temperatures. Of course, the lunar

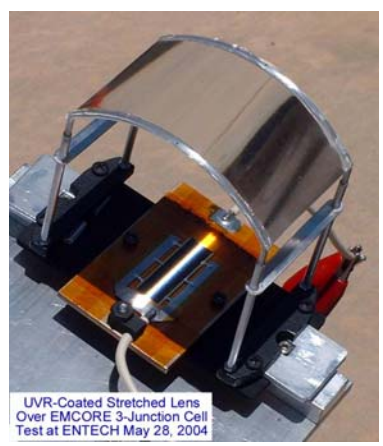

Figure 1: Sunlight testing of laser receiver assembly

surface temperature will markedly impact the surface array and those results are included in this study. As cell efficiency increases, the amount of waste heat decreases thus leading to an overall temperature reduction for a lunar surface array. This paper will present the results using one and two beaming spacecraft that will beam power only when the target site(s) are in darkness and the satellite is in sunlight. The impact of the Van Allen trapped radiation belts on the solar array power output will also be presented. The amount of power delivered to the surface is dependent upon the power level of the SEP spacecraft and will be presented for a nominal 100 kW BOL array.