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ISRU-based development of a lunar water astroparticle observatory

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Abstract

Lunar Water Astroparticle Observatories are proposed to be fabricated at the Lunar North and South Poles by use of Lunar in situ resources. These observatories will consist, initially, of a 10 m × 10 m × 10 m basin excavated, to be filled with 1000 metric tons of water from the in situ resources at the Polar Regions. The water basin would be constructed by excavation of a cavity out of the regolith, lined with waterproof material and then filled with water extracted from the adjacent permanently dark crater regions. These permanently dark regions are believed to contain water (ice) at a 1–5% concentration level. This water would be extracted by microwave heating of the regolith, the evolved water vapor and other gases then captured, followed by condensation of the water vapor. The microwave heating would be done with a suspended source rastered over the ice field in a crater. The condensed water would be transported to the detector basins, would fill the basins, which would then be sealed to prevent evaporation to the Moon's environment. The energy for the construction of the cavity detectors and the water extraction would come from solar cell arrays fabricated on the surface of the Moon on crater rims to receive maximum sunlight, and integrated into an electric power system that would supply energy for the microwave melting of the ice, for the motive power for the cavity excavation and, later, for the operation of the detection and measurement systems deployed in and around the water observatory and the processing and the transmission of the data to Earth.

1. Introduction

Astroparticle observatories have over the past 30 years contributed immensely to the knowledge of high-energy physics and origin of the universe. There remain, however, important gaps in parts of the electromagnetic spectrum when observing ultra-high energy gamma and cosmic rays from Earth. In the next decade and beyond, it has been proposed by Spillantini [1] amongst others that this gap in observational data be closed by "water observatories" deployed on the Moon, where interference from the Earth's atmosphere and magnetosphere would no longer hamper measurements.

The challenge for such a water observatory for the Moon is not only the availability of the infrastructure needed for an observatory, but also the ability to transport enough water (of the order of 1000 metric tons or more) to realize such an observatory. This latter challenge can be mitigated by the knowledge that at the lunar poles there exist cold-traps that are proposed to contain frozen water ice [2]. There is still some discussion as to whether the data indicating excessive hydrogen content in craters at the poles is due to water ice or hydrogen in another form. However, the majority of

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experts believe that there will be a major component of water ice in the polar cold traps.

Our approach is to extract that water from the cold traps, collect it into a basin to form a water tank, and have the 'tank' initially lined with detectors to create a cosmic ray observatory on the Moon.

In this development most of the materials needed would be generated on the Moon. The only components brought from the Earth would be the tools needed to fabricate the needed power source, some nominal regolith mover to create the water 'tank', the detector arrays needed for lining the water 'tank' and the read-out electronics to gather the data from the observatory. This in situ resourced utilization (ISRU) approach to working on the Moon is critical for cost effective utilization of the Moon.

The first need for any operations on the Moon is electrical energy. A system to supply energy could theoretically be brought from the Earth; however, for the 200+ kW capacity needed for the fabrication and operation of the observatory, bringing either solar cells or a nuclear reactor to the Moon will be a costly route.

It is well to realize that the surface of the Moon is an ultra-high vacuum, and hence is a semi-infinite vacuum chamber that can be used directly for the fabrication of thin film materials and devices. The lunar regolith also contains all of the materials necessary for the fabrication of silicon solar cells. Thus, we plan to fabricate thin films silicon solar cells on the surface of the Moon by direct evaporation of materials onto the lunar regolith.

We have previously shown [3] that such thin film solar cells can be fabricated on melted lunar regolith glass, and we use that experience to generate the power needed for the construction and operation of the Astrophysical Observatory.

A major benefit of operating at the lunar poles (in addition to the possible presence of water ice) is the availability of near 100% illumination at regions near the poles. These 'peaks of everlasting light' will allow for mitigation of the severe thermal environment associated with the lunar day and night, and resultant simplification of infrastructure required for a lunar installation. Further, the possibility of continuous exposure of solar cells located at the poles will all but negate the need for significant energy storage.

The solar cell arrays will power a unique system to extract the water. This incorporates microwave transmitters suspended in the cold trap crater to heat the regolith, a vapor collector integrated with the microwave antennas and a vapor transport system to move the water vapor from the crater to the rim, and then to a fabricated 'cold trap' inside of the observatory 'tank' to collect the water vapor as ice. Microwaves have been discussed previously for sintering/melting lunar regolith [4,5]; however, we propose only to heat the regolith from it projected 40–60 K state to $\sim$ 250 K to evaporate the ice. After all of the collection is complete (10^6 kg), the ice that is in the observatory 'tank' will be melted by solar irradiation through a Teflon film cover that will prevent the liquid water from evaporating to the lunar atmosphere.

2. Observatory facility

As noted the observatory will be supplied by electrical energy for both fabrication and operation by an array of thin film silicon solar cells fabricated on the surface of the Moon. The cells will be fabricated by a mechanical Cell Paver, which will slowly move over the surface depositing thin film solar cells on top of the regolith by solar thermal evaporation. To assure that the observatory has continuous energy during the lunar daily cycle, the thin film solar cells will be deposited on the inside rim of a moderately sized crated yielding a good 'look angle' for the cells to the Sun, and resulting in a portion of the crater rim always being under solar illumination. Since the Cell Paver will move at a rate of 1–5 m/h, a crater of $\sim$ 1 km diameter will assure a Cell Paver motion that will 'track the Sun' thereby resulting in continuous layout of solar cells without interference from the darkness of night (Fig. 1).

The Cell Paver will be fed raw materials from a Regolith Processor unit, which will supply the silicon and metals needed for the thin film solar cell fabrication.

Once the Cell Paver completes fabrication of $\sim$ 300 kW of total capacity ($\sim$ 7 months of operation at $\sim$ 5% efficient cells), the extraction of water can begin

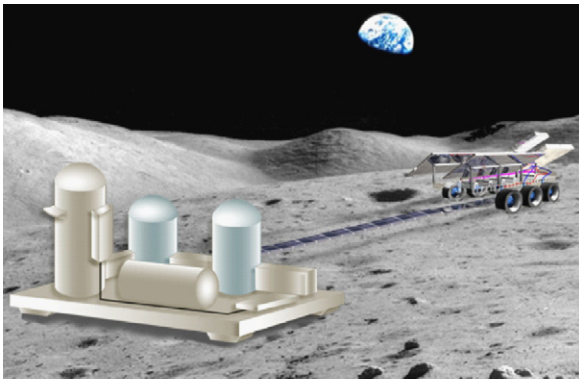

Fig. 1. Cell Paver (in the background) and Regolith Processor (foreground) operating on the Moon and paving the surface with thin film silicon solar cells.