Proposed Experiment for Prospecting and Mining Water from Lunar Permafrost from Boreholes using RF Energy. E. C. Ethridge¹, ¹InSpace Resources (3708 Nolen Ave, Huntsville, AL edwin.ethridge@rocketmail.com)

Introduction: Our proof of concept extraction of water from cryogenic lunar permafrost simulant (JSC-1A) was first demonstrated at NASA MSFC [1]. Starting with a cryogenic regolith simulant containing water ice in a high vacuum, RF energy was delivered into the regolith. The regolith heats and water ice begins to sublime at rates increasing as the regolith heats. The water vapor flows from the regolith down the water pressure gradient out to the surface. Water vapor can then be captured with a cold trap external to the regolith. The proof of concept experiment proved that microwaves will couple to cryogenic regolith simulant and the water vapor was captured in the coldtrap with high efficiency. The process is suitable to recover water from the moon, Mars, and asteroids.

Higher fidelity experiments, such as from a borehole [2] were much more difficult to accomplish. Subsequently, FEM Numerical Simulation of the RF heating of lunar simulant was developed to simulate heating experiments. For the calculations, dielectric properties (electric permeability and magnetic permittivity) were measured at 3 RF frequencies (900 MHz, 2.45 GHz, and 10 GHz) at temperatures from cryogenic to above normal room temperature for all of the lunar and Mars regolith simulants available [3]. COMSOL Multiphysics simulation illustrated the ability of RF heating of different regoliths [4], different RF frequencies as a function of time for several different RF delivery methods [5]. Dr. Ethridge left NASA and founded InSpace Resources to further develop the experimental methods for practical extraction of water from planetary regoliths.

Simulating experiments on Mars, microwaves were beamed into the surface of Mars regolith simulant containing 10% water ice. The vacuum level and temperature was representative of Mars. Water was rapidly extracted from the mars regolith simulant and captured in the external cold trap. In another experiment, a simulated carbonaceous chondrite asteroid was fabricated consisting of oxides (JSC-1A lunar and Mars simulants), charcoal, clays, carbonates, and sulphates. All the constituents were preheated to >100°C to remove adsorbed water. 15% water was then added to the asteroid simulant and molded into a spheroidal shape and frozen (-78°C). Microwave energy was beamed at the sample in a containment bag in a vacuum chamber. Liberated water vapor flowed through tubing from the containment bag through the cold trap pumped by the vacuum chamber. After one hour 100% of the added water was extracted, further heating resulted in the extraction of water chemically bound in the clay and other minerals.

Our recent NASA SBIR research project permitted further development of the extraction of water from a borehole in the regolith simulant under simulated Mars (lunar) conditions. Our prototype microwave delivery device was used to deliver microwaves down a “borehole” that was sealed with the regolith at the surface. Initially the regolith had to be heated sufficiently to begin the sublimation of the water ice. Subsequently, water was collected in the cold trap with the extraction rate increasing with processing time.

A 3U cubesat is proposed to test the water extraction method using a simulated asteroid in LEO. With our prototype high efficiency small footprint GaN microwave power amplifier we will test the method in microgravity, thereby increasing the TRL. This can be followed with a small light weight water extraction demonstration experiment at the lunar pole. The experiment can be performed with a low mass apparatus using our GaN microwave power amplifier, a drilling apparatus, and in-situ microwave delivery system. The method can be used for in-situ water prospecting and subsequent mining directly from the regolith below the lunar surface. Excavation and strip mining equipment will not be required.