MAGIC STAFF: A PORTABLE SUBSURFACE VOLATILE ANALYSIS TOOL FOR ARTEMIS ASTRONAUTS. T. Horvath[1] D. A. Paige[1], S. Bailey[2], R. May[3], S. Price[4], [1]Department of Earth, Planetary and Space Sciences, University of California, Los Angeles (tylerhorvath@ucla.edu), [2]BASS LLC, [3]Port City Instruments, Senior Consultant[4]

Introduction: "Magic Staff" is a concept for a simple tool that will allow Artemis astronauts to quickly assess the presence of near surface frozen volatiles. The astronauts returning to the Moon in the next decade will likely have a primary objective of finding, characterizing, and collecting volatiles near the lunar south pole. Because much of the ice may be buried within the top meter of the regolith, the astronauts will require the ability to assess the presence of volatiles quickly and definitively, primarily when there are no volatiles directly visible to the astronaut on the surface.

Magic Staff can also be used to fulfill scientific objectives in-situ. This tool will be capable of determining how volatile abundance varies with depth, the results of which will allow models to be developed for predicting the abundance of volatiles across the polar region and how they are emplaced. These measurements may be important as current methods for volatile sample return will likely not retain any depth dependent information, only the overall composition and abundance of volatiles within the sample. [1]

Design: Magic Staff will consist of four systems: an evolved gas analysis system using a Tunable Diode Laser (TDL) with IR Detector, a MEMS Pirani Pressure Sensing system, a heater, and an interface for the astronauts to read or record data. TDL spectroscopy is currently one of the quickest, most reliable, and easy-to-use method for volatile detection and characterization that can be used at low pressures [2]. MEMS Pirani sensors have incredible accuracy and can be tuned for pressures ranging from near perfect vacuum to over 1 bar [3]. A heater is required as the volatiles need to be made gaseous in order to be measured. Once the soil is heated to a temperature much higher than the sublimation point of the volatiles it may contain (~300 K), the volatiles will evolve into their gaseous form and be ready for analysis by the TDL and Pirani sensors within the chamber at the staff's tip. If there are no volatiles present, no gas will be produced when the soil is heated and nothing will be measured.

Because humans are using this tool to determine the adequacy of a potential sampling region, they will need immediate feedback from the onboard electronics in the form of an on-board display or a wireless relay of information directly to the astronaut. Once the constraints and limitations of the astronaut's suits are detailed, either of these approaches can be adopted with no change to the rest of the tool. Magic staff will also need to be ergonomic and easy to insert into the lunar surface while wearing a suit with limited mobility. For this reason, the device will be approximately 150 cm long, 1 cm in diameter at the penetrating end, and will

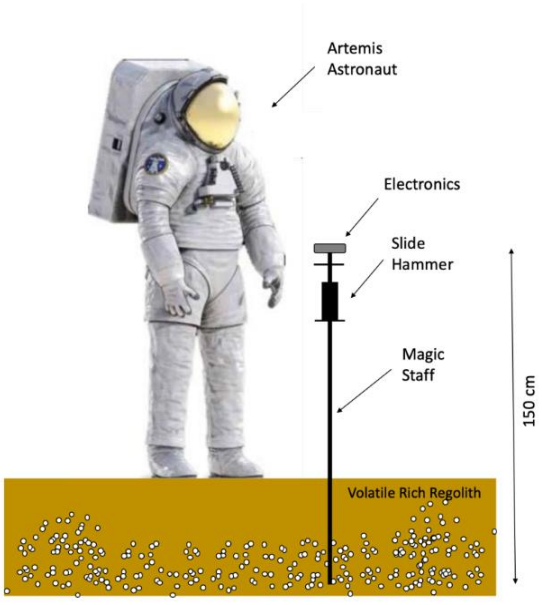

Figure 1: Magic Staff scall drawing.

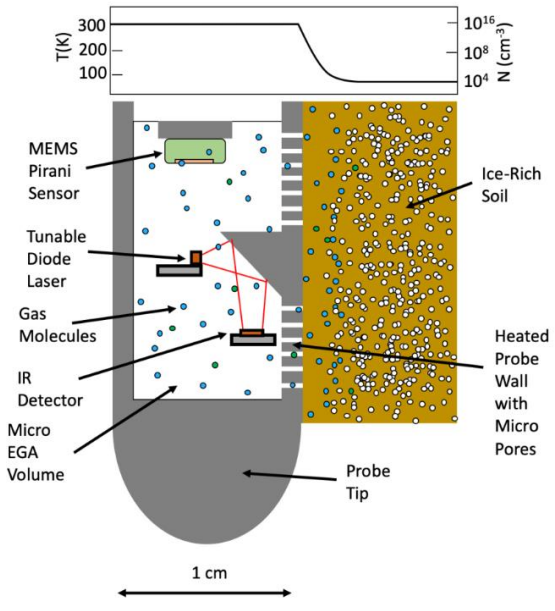

Figure 2: Magic Staff micro evolved gas analysis package detail.

contain a slide hammer, as shown in Figure 1. The slide hammer will sit roughly at the height of the astronaut's arm when bent at a 90-degree angle to account for the limited mobility of the suit. This will enable the astronaut to exert significant percussive force to enable insertion and retraction of the staff in a low gravity environment.

Operation: Deploying Magic Staff is incredibly simple. The astronaut will place the staff upright and use the slide hammer to insert the staff at the desired depth, up to 50 cm deep. Once the desired position is reached, the astronaut will turn on the integrated heater and the measurements will be displayed to the astronaut. The heater will rapidly heat the surrounding soil, liberating any of the volatiles that may be present. If both sensors read zero after the soil has been heated, then it can be assumed there are little to no volatiles present at that location. If there are volatiles present, the Pirani sensor would provide an indication of the total volatile content, while the TDL sensor would provide an indication as to what volatiles are present, most notably water.

After the measurement is concluded, likely within a minute of activating the heater, the staff can then be removed with the heater on to evacuate any remaining volatiles within the measurement chamber. After the sensors read zero, the heater can be turned off and it will be ready for its next measurement. The staff should not require any additional cleaning, it contains no consumables other than battery power, and should be capable of being reused hundreds of times.

Additional Science: Magic Staff readings at varied depths and locations can be coupled with thermal models derived from the results of the Lunar Reconnaissance Orbiter's Diviner Lunar Radiometer Experiment [4][5] to ascertain the emplacement and subsurface transport methods of volatiles at the lunar poles. These results are important to advance our understanding of which mechanisms deliver water and other volatiles to the lunar surface, to assess when the volatiles were delivered to the Moon, and to allow us to make predictions of ice abundance across the polar regions. These results will also aid the study of other solar system bodies known or believed to contain volatiles.

References: [1] Artemis Science Definition Team Report [2] Webster C. R. (2016) 3rd IPM International Workshop, Abstract #4013 [3] Xu S. (2022) *Micromachines*, 13, 945 DOI : 10.3390/mi13060945. [4] Hayne P. O. (2017), *JGR: Planets*, 122, 2371-2400 DOI: 10.1002/2017JE005387. [4] Landis M. E. (2022), *PSJ*, 3, 39 DOI: 10.3847/PSJ/ac4585.