THE IMPORTANCE OF NIGHTSIDE MAGNETOMETER OBSERVATIONS FOR ELECTROMAGNETIC SOUNDING OF THE MOON.

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Introduction: Understanding the current day structure, state, and composition of the lunar interior provides insight into origin and formation processes of the Moon. Knowledge of the lunar interior builds on an array of disciplines, observations, and various types of analyses such as geochemistry, geophysics, geodynamics. Current understanding of the lunar interior lacks precise constraints on the composition and structure including layers of mantle material (upper mantle, middle mantle, and lower mantle regions), a possibly partially molten ilmenite layer, above a differentiated core enriched in light elements [1-4]. Additional observations and analyses are required to be able to answer fundamental planetary science questions including the thickness of the Procellarum KREEP terrane, the existence of a melt layer at the core mantle boundary, and the thickness of the inner and outer core layers. Electromagnetic (EM) Sounding is capable of answering these key questions through analysis of magnetometer observations at the surface of the Moon and surrounding environment. EM Sounding isolates induced magnetic fields to remotely deduce lunar material properties at depth [2,5].

Recent analyses of plasma and field observations provide a wealth of understanding about the dynamics of the lunar plasma environment [6-8]. These characterizations improve the boundary conditions acting on induced magnetic fields from the interior. Plasma hybrid models suggest the induced fields are not confined within the lunar wake cavity [9-11] as previously proposed [5]. Thus, the first step of performing Time Domain EM (TDEM) Sounding at the Moon is to characterize the dynamic plasma environment, and to be able to isolate geophysically induced currents from concurrently present plasma currents. The TDEM Sounding transfer function method focuses on analysis of the nightside observations when the Moon is immersed in the solar wind. This method requires two simultaneous observations: an upstream reference measuring the pristine solar wind, and one downstream at or near the lunar surface [2]. This method was last performed during Apollo and assumed the induced fields on the nightside of the Moon expand as in an undisturbed vacuum within the wake cavity [12]. TDEM sounding is particularly well suited for measurements from moving satellite platforms directly accounting for changing altitudes [2].

Our approach is to isolate induction from the plasma wake cavity by fully and self consistently characterizing both of these fields [11]. Thus, improving the accuracy of existing TDEM methods. Our models compare a plasma induction model capturing the kinetic plasma environment within the wake cavity around a conducting Moon, to an analytic expression of the geophysical forward model capturing induction in a vacuum. This method can be applied to any two point magnetometer measurement of the Moon or similar airless bodies. Nightside TDEM sounding has the capability to advance the state of knowledge of the field of lunar science forward. This requires magnetometer operations to withstand the harsh conditions of the lunar night.

Apollo and ARTEMIS Magnetometer specification comparison: For comparison, we include the specifications of two magnetometers that have been used to perform TDEM: Apollo 12 Lunar Surface Magnetometer with orbiting reference magnetometer, Explorer 35 [12,13], and currently orbiting twin ARTEMIS satellites. TDEM Sounding requires the use of a reference probe measuring the pristine and undisturbed solar wind conditions near the Moon.

Apollo 12 Lunar Surface Magnetometer [13, see Table 1]: Range 0-+/-400 nT, Resolution 0.2 nT, Frequency Range dc to 3 Hz, Power 3.4 W average daytime, Weight 8.9 kg, size 25 X 28 x 63 cm.

ARTEMIS Fluxgate Magnetometer [15, 16 see Tables 1 and 2]: DC magnetic field, Sampling rate & resolution: DC-128 Samples/s & 3 pT, Offset stability <0.2 nT/12 hr. Resources requirements: **Mass**: Sensor (75 g), Harness (150g or 60 g/m) Electronics(150g). **Dimensions:** Sensor (diameter 70 mm, height 45 mm), Board (100 mm × 120 mm). **Power consumption**: 800 mW. Temperature range: Sensor (−100◦ to 60◦ C), Electronics, (−55◦ to 80◦ C).

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