THE LUNAR POLAR HYDROGEN MAPPER (LUNAH-MAP) MISSION: MAPPING HYDROGEN DISTRIBUTIONS IN PERMANENTLY SHADOWED REGIONS OF THE MOON'S SOUTH POLE

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Introduction: Lunar polar Hydrogen Mapper (LunaH-Map) is a 6U CubeSat that will enter a polar orbit around the Moon with a low altitude (5-12km) perilune centered on the lunar South Pole. LunaH-Map will carry two neutron spectrometers that will produce maps of near-surface hydrogen (H) at unprecedented spatial scales (~7.5 km/pixel). LunaH-Map will: 1) map H within permanently shadowed craters to determine its spatial distribution; 2) map H distributions with depth (< 1 meter); and 3) map the distribution of H in other permanently shadowed regions (PSRs) throughout the South Pole. These data will advance our understanding of lunar volatile distributions, and will inform future mission planning, specifically, landed missions and those that focus on in-situ resource utilization (ISRU). Previous lunar spacecraft have used neutron detectors, near-infrared spectrometers and impactors to reveal the presence of hydrogen (H) throughout the lunar surface. At the lunar poles hydrogen abundances commonly exceed 150 ppm, and abundances could be as high as 20-40 wt.% water-equivalent-hydrogen within certain permanently shadowed regions (PSRs) [1 - 5]. LunaH-Map will produce the highest spatial resolution maps of hydrogen abundance ever acquired by a neutron detector from orbit, and will demonstrate the capability of a CubeSat platform to acquire neutron spectra. This will be achieved by orbiting with a low perilune (5km altitude) above the South Pole of the Moon, centered at -89.9°S (Shackleton Crater). The implications for this measurement are significant, as it directly informs our understanding of how lunar volatile abundances are distributed within various lunar South Pole craters and regions. The observed antipodal distribution of hydogen with Lunar Prospector's Neutron Spectrometer may be related to the wander of the Moon's pole throughout its geologic history [6]. These studies, and others, have called for increased spatial resolution (<10km) measurements of epithermal neutrons at the lunar poles, specifically, to reveal the distribution of hydrogen within regions in and out of permanent shadow to test hypotheses related to true polar wander [7]. Previously acquired lunar neutron maps will also benefit from an improved understanding of the spatial distribution of hydrogen within PSRs, as these data can be used to reinterpret lower spatial resolution data.

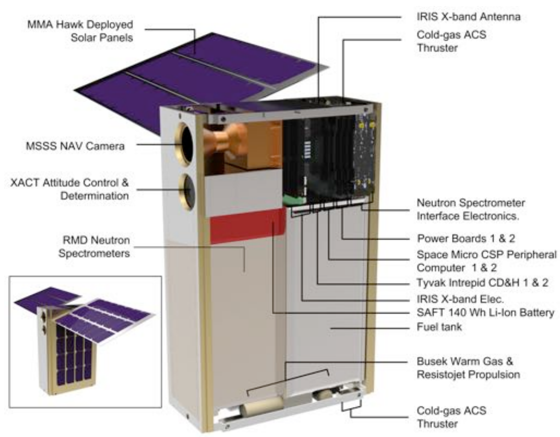

Figure 1: LunaH-Map cut-away showing spacecraft components and configuration. Inset image shows LunaH-Map deployed configuration.

Throughout the course of the 60-day science mission, LunaH-Map will acquire thermal and epithermal neutron counts over a total of 141 science orbits (**Figure 1**). Neutron count rates will be used to determine H abundances and distributions within Shackleton Crater on each orbit (60ppm ± 12ppm H), and can additionally be used to map H distributions within several nearby PSRs (Haworth, Shoemaker, Faustini, Shackleton, de Gerlache, Nobile, Amundsen and Sverdrup). LunaH-Map will be capable of mapping entire PSRs with an average precision of 85 ppm ± 17ppm H, and for spatial resolutions smaller than the crater diameter at an average precision of 180ppm ± 36ppm H. LunaH-Map will utilize an innovative new scintillator technology called an elpasolite, specifically Cs_2YLiCl_6:Ce (CLYC), with high neutron detection efficiency across a wide energy range [8-10]. These detectors are easily accommodated within a CubeSat due to their small form fator, as each instrument occupies just 1U of the 6U spacecraft (**Figure 2**). Two 2-cm thick (100 cm^2) CLYC-based detector arrays (one covered in a thin layer of Cd) will be used to achieve

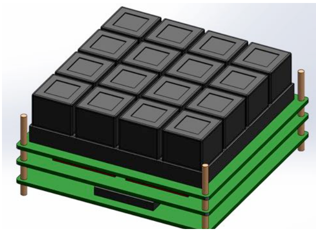

Figure 2: Radiation Monitoring Devices (RMD) 4x4 CLYC detector array, photomultiplier tubes and signal processing boards for CLYC-based neutron detector system. Each instrument is 1U.

neutron detection efficiencies equal to that of Lunar Prospector's ^{3}He tubes.

Development, Spacecraft, and Science Mission: The 6U LunaH-Map CubeSat will be developed at Arizona State University, utilizing the facilities in the Space and Terrestrial Robotic Exploration (SpaceTREx) Laboratory at Arizona State University (space.asu.edu) in partnership with the Jet Propulsion Laboratory and a variety of other commercial providers supplying space-qualified hardware. Onboard propulsion will provide ΔV sufficient for lunar orbit insertion (LOI), all orbital maneuvers and station keeping throughout the science phase of the mission. Solar panels will generate 30 W of power. Attitude control consists of a set of 3-axis Sinclair reaction wheels. Communications use IRIS 3 X-band (MarCO CubeSat heritage) combined with Doppler for spacecraft tracking. LunaH-Map will also include a wide-angle engineering camera system (from Malin Space Science Systems (MSSS)) for outreach and non- essential engineering images.

LunaH-Map development will take place over a 3-year period, and will undergo design audits to prepare the spacecraft and instruments for flight readiness. The spacecraft will be designed and built at Arizona State University (ASU). The neutron spectrometers will be designed, built and tested by Radiation Monitoring Devices (RMD) and delivered to ASU for integration into the spacecraft. The spacecraft will be delivered to the primary launch vehicle in July of 2018 and the nominal mission will begin 6 days after launch. LOI will take place 1-month after launch and separation. The Science Mission (Phase E) will take place over the next 60 days, after which the spacecraft will deorbit into a permanently shadowed crater at the South Pole.

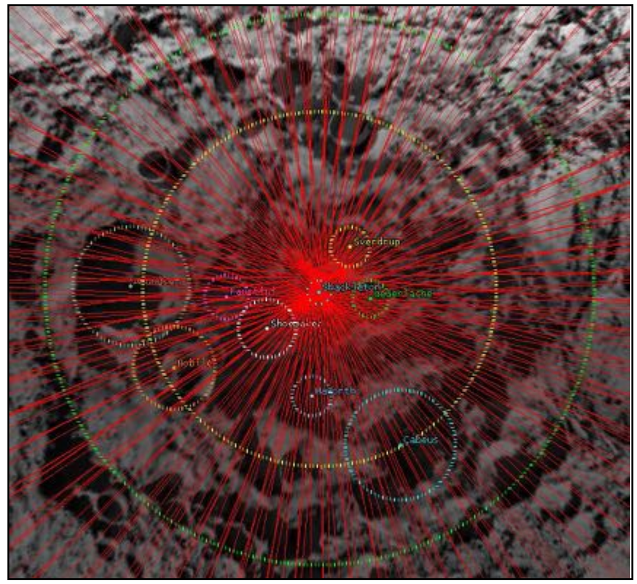

Figure 3: Orbit ground track shown for entire 60 (Earth) day science phase: 141 passes over target area initially (and periodically) centered on Shackleton Crater (-89.9 degree latitude), with close-approach of 5 km at each perilune crossing. Yellow circle denotes LunaH-Map altitude of 8 km; green circle denotes LunaH-Map altitude of 12 km.

References:

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