Lunar Polar Hydrogen Mapper (LunaH-Map)

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LunaH-Map: Revealing Hydrogen Distributions at the Moon's Pole

- 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].

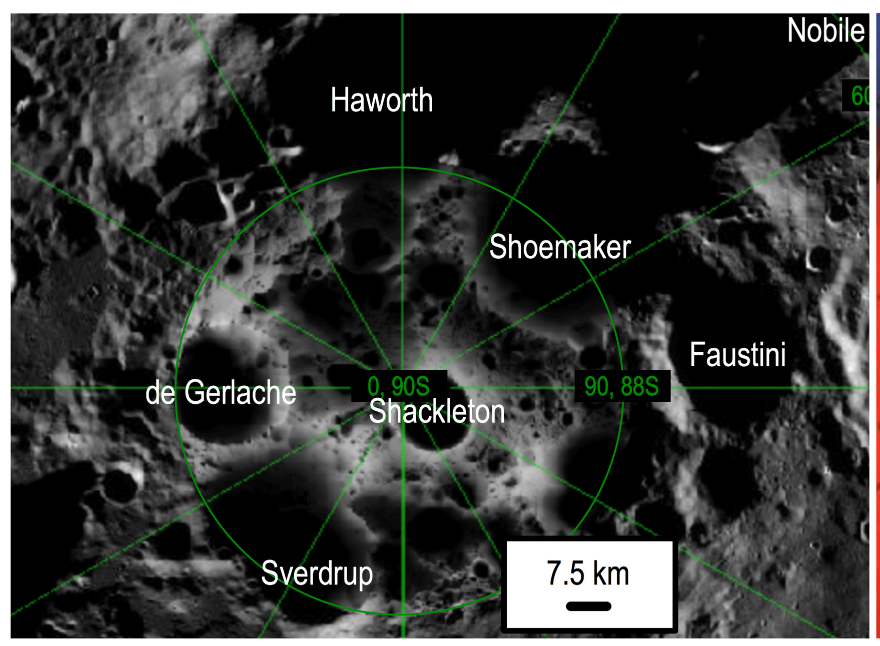

Figure 1: South Pole illumination map of craters and PSRs observable by LunaH-Map at 7.5km resolution. The image within the green circle denoting 88°S is the South Pole illumination map derived by [6]. The scalebar represents the highest resolution of LunaH-Map.

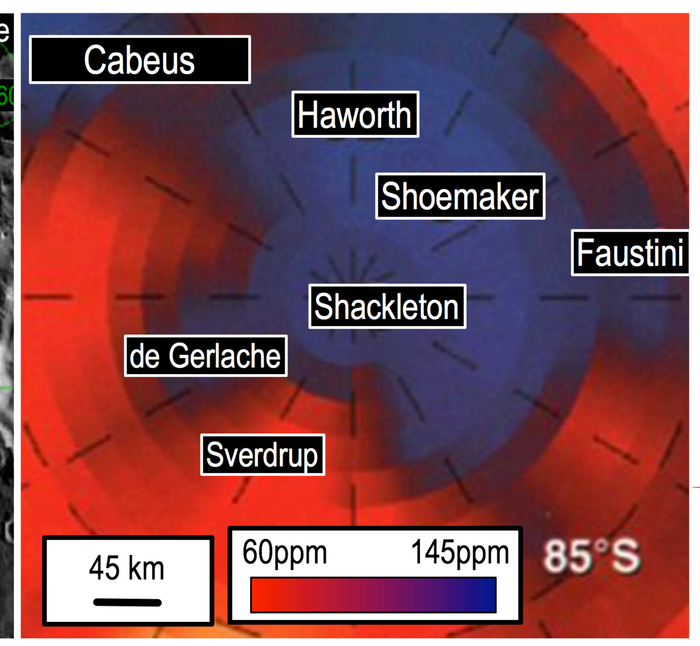

Figure 2: Map of Lunar Prospector Neutron Spectrometer (LPNS) South Pole epithermal neutron counts at 45km/pixel resolution adapted from [7] and [1]. The approximate hydrogen abundances derived from LPNS data are shown in the color scale [2].

- Neutron detectors are sensitive to the bulk H content in the top meter of lunar regolith and are capable of detecting as little as 50 ppm +/- 10 ppm. The sensing area of uncollimated neutron detectors, however, is limited by the spacecraft altitude above the Moon [8, 9].
- LunaH-Map will enter an elliptical orbit about the lunar South Pole. The perilune will be 5 - 8 km above the surface, allowing the neutron detectors to produce maps of H abundance at spatial scales of ~7.5 km².

Science Objectives

- The observed antipodal distribution of hydrogen with LPNS (Fig. 3) may be related to the wander of the Moon's pole throughout its geologic history [10]. 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 [11].

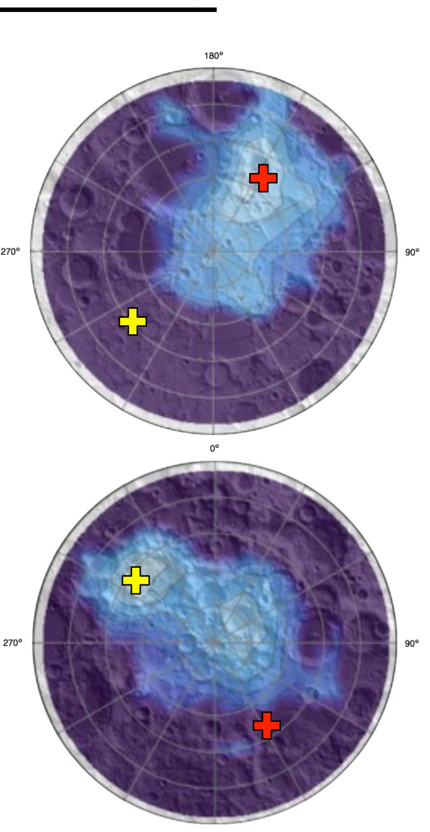

Figure 3: The lunar North (top) and South (bottom) Pole hydrogen distributions. Maximum H abundance denoted with red plus for North Pole and yellow plus for South Pole. Fig. adapted from [10]

LunaH-Map Concept of Operations

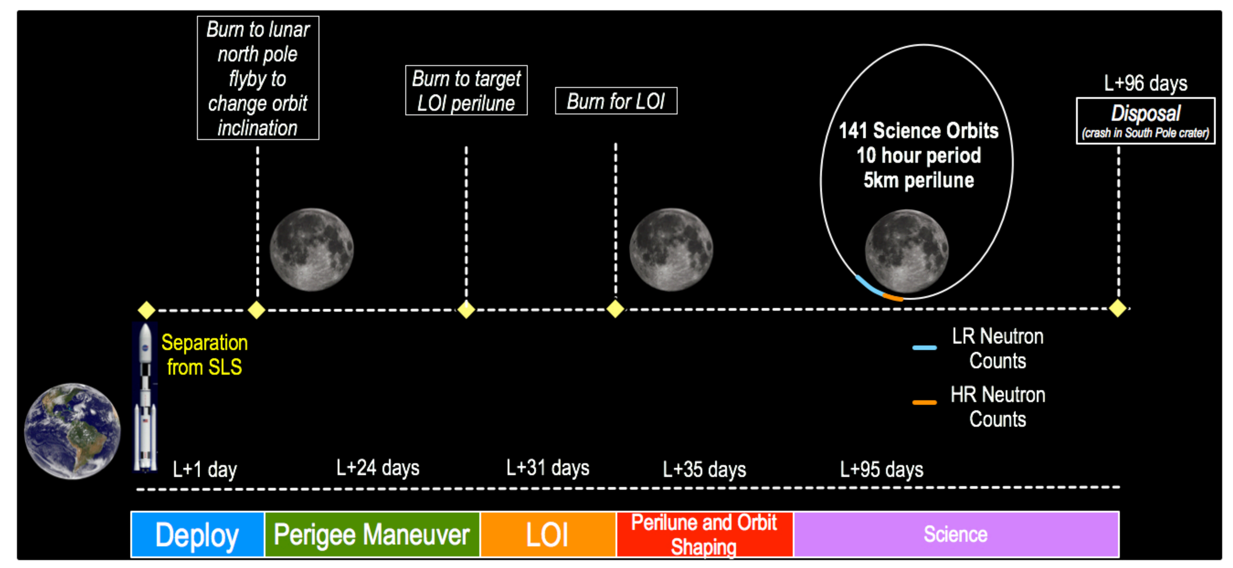

Figure 4: LunaH-Map Concept of Operations. The time from SLS separation to LOI is 31 days. Science operations takes place over the next 60 days, for 141 orbits.

- During the science phase (141 orbits), neutron counts will be binned into 3.5 sec intervals starting when the spacecraft descends below an altitude of 12km (Fig. 4). When the spacecraft ascends above 12km (~ 85S latitude) both neutron detectors will begin collecting data binned into 90 minute intervals. At the end of the mission the spacecraft will de-orbit and crash into a South Pole crater.

The LunaH-Map Spacecraft

- LunaH-Map is a 6U CubeSat, carrying two neutron detector arrays and an MSSS ECAM-50 engineering camera. LunaH-Map also carries an onboard computer, propulsion system, attitude control and determination system, X-band antenna, and solar panels (Fig. 5). The sensitivity of LunaH-Map's neutron detectors to H abundance is listed in Table 1.

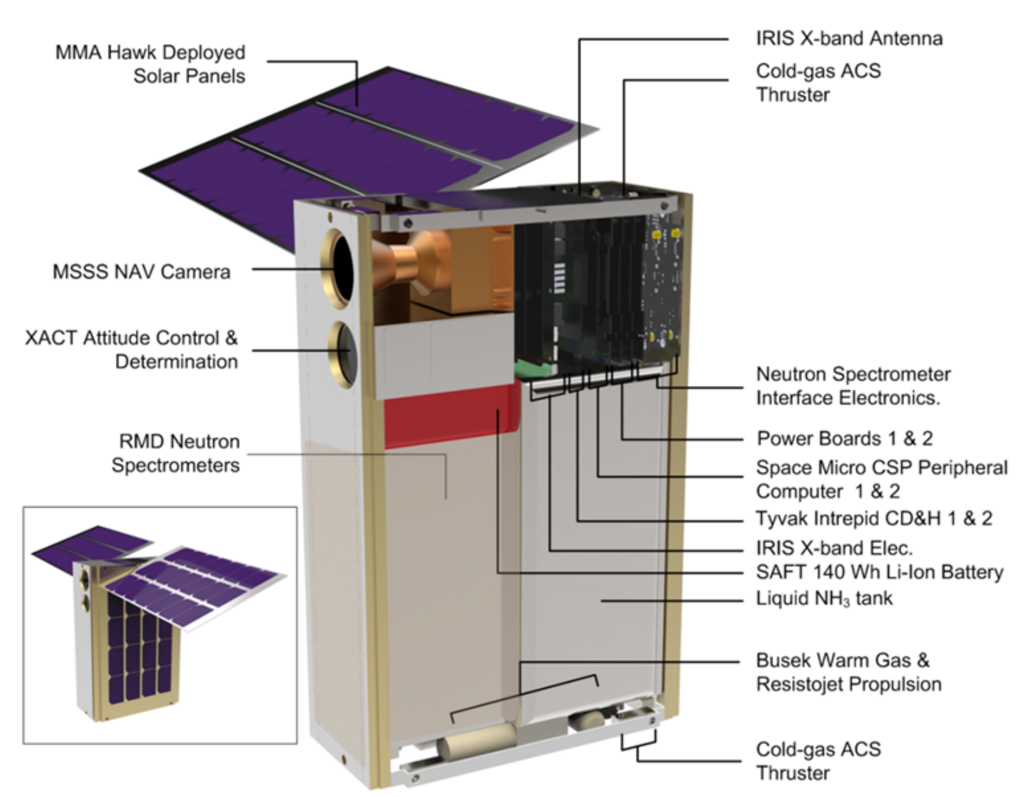

Figure 5: LunaH-Map spacecraft configuration cutaway with components labeled. The RMD Neutron Spectrometers will face the lunar surface during data acquisition. The inset image shows the deployed spacecraft configuration with solar panels extended.

			At 20% Uncertainty					
			Full Crater Diameter		Half Crater Diameter		Quarter Crater Diameter	
	Crater Diameter [km]	60 Day Mission Orbits	H [ppm]	(+/-) H [ppm]	H [ppm]	(+/-) H [ppm]	H [ppm]	(+/-) H [ppm]
Shackleton	21	141	60	12	80	16	100	20
de Gerlache	32	36	100	20	200	40	520	104
Haworth	35	17	140	28	300	60	780	156
Sverdrup	35	34	90	18	200	40	480	96
Faustini	39	27	100	20	250	50	500	100
Shoemaker	51	48	60	12	130	26	310	62
Nobile	73	19	90	18	200	40	450	90
Cabeus	98	27	60	12	130	26	280	56
Amundsen	105	27	70	14	150	30	320	64
Mean	54	29*	86	17	182	36	416	83

* doesn't include Shackleton

Table 1: A variety of South Pole PSRs have been identified as future targets of exploration [12]. The number of passes, the H detectability [ppm], and potential spatial binnings (7.5 – 100 km/pixel) for each target area are described.

Instruments

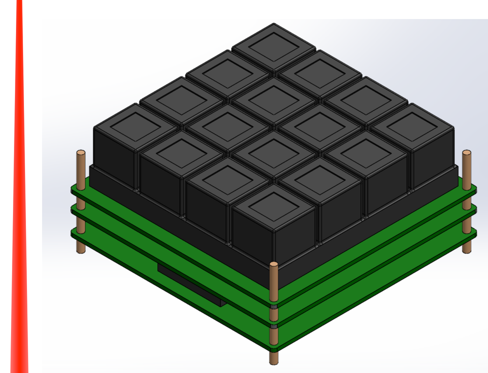

Figure 6: Radiation Monitoring Devices (RMD) 4x4 CLYC detector array, PMTs and signal processing boards for instrument prototype. Each instrument is 1U.

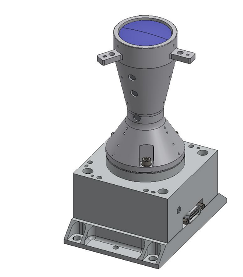

Figure 7: Malin Space Science Systems (MSSS) ECAM-50 camera model fits within <1U.

- Thermal and epithermal neutrons will be counted using two 4x4 arrays of CLYC scintillators (Fig. 6). One detector array will be sensitive only to epithermal neutrons, by coating the array with a thin layer of cadmium.
- LunaH-Map will utilize a new neutron detector material (Cs_2YLiCl_6:Ce or CLYC) that is highly sensitive to neutrons of a broad energy range (Fig. 8; thermal < 0.3 eV and epithermal > 0.3 eV) [13-15].

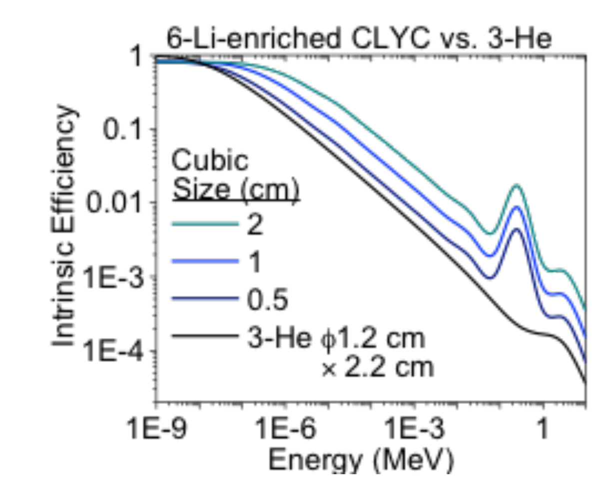

Figure 8: ³He efficiency compared to CLYC scintillators [yy]. ³He tube volume is 2.83 cm³, CLYC volume varies over 0.1-8 cm³. CLYC shows a greater efficiency above 0.01 eV, saturating at 80%.

- A high space heritage visible camera (Fig. 7; MSSS ECAM-50) will be utilized for secondary confirmation of engineering diagnostics, positioning and spacecraft orientation as well as acquisition of public outreach images.
- At apolune (~7500km) images can be acquired over the entire visible disk of the Moon (2.2 km/pixel). At the lowest altitude (~5 km) the resolution will be 1.4 m/pixel, slightly larger than LROC's Narrow Angle Camera.

Summary

- LunaH-Map combines a high-heritage technique in planetary science for deriving hydrogen abundances from orbit with a new detector material developed through Small Business Innovation Research (SBIR) and other small business contracts, LunaH-Map will demonstrate the potential of low-cost planetary exploration for scientific discovery, scouting, and resource utilization.

References

[1] Feldman et al., 1998, Science, 281. [2] Lawrence et al., 2006, Journal of Geophysical Research, 111. [3] Feldman et al., 2000, Journal of Geophysical Research, 105. [4] Elphic, et al., 2007, Geophysical Research Letters, 34. [5] Eke et al., 2009, Icarus, 200. [6] Speyerer and Robinson, 2013, Icarus, 222.; [7] Nozette et al., 2001, Journal of Geophysical Research, 106. ; [8] Feldman and Drake, 1986, Nuclear Instruments and Methods, 245. [9] Lawrence et al., 2010, Astrobiology, 10. [10] Siegler et al., 2015; [11] Lawrence et al., 2015, LPSC 2235. [12] Lemelin et al., 2014, PSS, 101. [13] Glodo et al., 2007, IEEE. [14] Glodo et al., 2008, IEEE. [15] Johnson et al., 2013, INMM Annual Meeting.