LunaH-Map CubeSat

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The Lunar Polar Hydrogen Mapper (LunaH-Map) CubeSat Mission

Revealing Hydrogen Distributions at the Moon’s South Pole with a 6U CubeSat
SIMPLEx

- Science Goals: Must be responsive to 2014 NASA Science Plan
- May target any body in the Solar System, except for the Earth and Sun
- Supports a 1U, 2U, 3U or 6U CubeSat
- $5.6M cost cap
- July 31st 2018 launch from NASA SLS EM-1
Observations of Lunar Water Ice

• Surface (top ~microns)
  • Chandrayaan-1 – M$^3$ (*Pieters et al.*, 2009)
  • Cassini (*Clark et al.*, 2009)
  • Deep Impact (*Sunshine et al.*, 2009)
  • LRO – Diviner (*Paige et al.*, 2010)
  • LRO – LAMP (*Hayne et al.*, 2010)

• Subsurface (top ~meter)
  • LCROSS impactor (*Colaprete et al.*, 2010; *Gladstone et al.*, 2010)
  • LRO – LEND (*Mitrofanov et al.*, 2010)
Neutron spectroscopy is used to determine the bulk hydrogen abundance (H) of planetary surfaces.

**Previous Spacecraft Missions with Neutron Detectors**

- **Mars**
  - Mars Odyssey Neutron Spectrometer (NS), Mars Odyssey High Energy Neutron Detector (HEND)
- **Moon**
  - Lunar Prospector Neutron Spectrometer (LPNS), Lunar Reconnaissance Orbiter Lunar Epithermal Neutron Detector (LEND)
- **Mercury**
  - MESSENGER Gamma-Ray and Neutron Spectrometer (GRNS)
- **Vesta and Ceres**
  - Dawn Gamma-Ray and Neutron Detector (GRaND)

**Lunar Polar H Abundance Maps from LPNS** *(Feldman et al., 1998)*

**Mars Odyssey Neutron Spectrometer Epithermal Neutron Counts** *(Boynton et al., 2002)*
Hydrogen on the Moon

Results in homogenous distribution within permanently shadowed regions

Lucey P., 2009, Elements
Hydrogen on the Moon

Results in heterogeneous distribution within permanently shadowed regions

Siegler et al., 2015 LPSC
The Lunar South Pole

Permanently shadowed regions (Paige et al., 2010, Science)

Neutron count rates from LPNS (Feldman et al., 1998, Science)
The Lunar South Pole

Lunar Prospector Neutron Spectrometer (LPNS) South Pole epithermal neutron counts at 45km/pixel resolution. The approximate hydrogen abundances derived from LPNS data are shown in the color scale. (Nozette et al., 2001; Feldman et al., 1998)

South Pole illumination map of craters observable by LunaH-Map at 7.5km resolution. (Speyerer and Robinson, 2013)
New Detector Materials

- Similar efficiencies to thermal and epithermal neutrons as $^3$He
- Sensitive to both gamma-rays and neutrons

CLYC (elpasolite) is a new scintillator materials that can be grown into a variety of shapes and sizes. Has been rad (~200 MeV and very high dose rates >50 rad/s), vacuum and pressure tested. Can operate at -40°C.

Comparison of CLYC to $^3$He efficiency. CLYC shows a greater efficiency above 0.01 eV, saturating at 80%.

CLYC light pulses are different for gamma rays and neutrons

DAQ System developed for NASA SBIR/STTR

Gamma-rays and neutrons are discriminated by energy and light pulse shape

*Glodo et al., 2008  **Whitney et al., 2011  ***Johnson et al., 2014  ****Johnson et al., 2013
CLYC-Based Neutron Detector System for Small Spacecraft

**Neutron and Gamma-Ray Instrument Specifications**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector</td>
<td>4x4 Detector Array of CLYC (each 2.5cm x 2.5cm x 2cm)</td>
</tr>
<tr>
<td>Sensitivities</td>
<td>Thermal (&lt;0.3 eV) and epithermal (with Cd shield) neutrons and 3.9% FWHM at 662 keV</td>
</tr>
<tr>
<td>Dimensions</td>
<td>12cm x 12cm x 8cm</td>
</tr>
<tr>
<td>Mass</td>
<td>828 grams</td>
</tr>
<tr>
<td>Power</td>
<td>2 Watts (during data acquisition); 0.35 Watts (idle)</td>
</tr>
<tr>
<td>Data Acquisition Times</td>
<td>Counts binned every 3 seconds</td>
</tr>
<tr>
<td>Data Volume</td>
<td>&lt;1 Mbit for mission duration</td>
</tr>
</tbody>
</table>

**Data from CLYC detector (with GCR-Passive neutron source) on the surface of a planetary body (CI Chondrite)**
The LunaH-Map Spacecraft

- MMA Hawk Deployed Solar Panels
- MSSS NAV Camera
- XACT Attitude Control & Determination
- RMD Neutron Spectrometers
- IRIS X-band Antenna
- Cold-gas ACS Thruster
- Neutron Spectrometer Interface Electronics
- Power Boards 1 & 2
- Space Micro CSP Peripheral Computer 1 & 2
- Tyvak Intrepid CD&H 1 & 2
- IRIS X-band Elec.
- SAFT 140 Wh Li-Ion Battery
- Liquid NH₃ tank
- Busek Warm Gas & Resistojet Propulsion
- Cold-gas ACS Thruster
LunaH-Map Concept of Operations

- **Separation from SLS**
  - L+1 day

- **75 m/s ΔV to lunar north pole flyby to change orbit inclination**

- **32 m/s ΔV to target LOI perilune**

- **175 m/s ΔV for LOI**

- **141 Science Orbits**
  - 10 hour period
  - 5km perilune

- **L+96 days**
  - *Disposal (crash in South Pole crater)*

- **Deploy**
- **Perigee Maneuver**
- **LOI**
- **Perilune and Orbit Shaping**
- **Science**
In just one orbit, LunaH-Map is capable of detecting a decrease in epithermal count rates of 20% at a spatial scale of 7.5 km, equal to a ~580 ppm increase in H abundance (0.06 wt%).

H abundances could be as high as 20 – 40 wt.% at small spatial scales based on LPNS data.
Impact of LunaH-Map on Planetary Science

LunaH-Map directly addresses the 2014 NASA Science Plan goals and objectives to “determine water resources in lunar polar regions and near-Earth asteroids”, “Advance the understanding of how the chemical and physical processes in our solar system operate, interact and evolve”, and “Identify and characterize objects in the solar system that offer resources for human exploration”.

SIMPLEx requires an innovative (low cost) solution to address long-standing questions in planetary science.

LunaH-Map combines a high-heritage technique in planetary science with a new detector materials (developed through SBIR/STTR contracts). By partnering with small businesses LunaH-Map will demonstrate the potential of low-cost planetary exploration for scientific discovery, scouting, and resource utilization.
Impact of LunaH-Map on Planetary Science

• Leveraging SBIR/STTR technologies to develop a low cost instrument to find water on planetary bodies

• Leveraging SBIR/STTR small spacecraft technologies (propulsion, solar panels, CD&H)

• Leveraging university facilities and students at ASU to build and design spacecraft

Small teams producing and demonstrating technology for future planetary science missions will lower the cost of exploration

More missions
More research and discoveries
More Pis
More experience for students