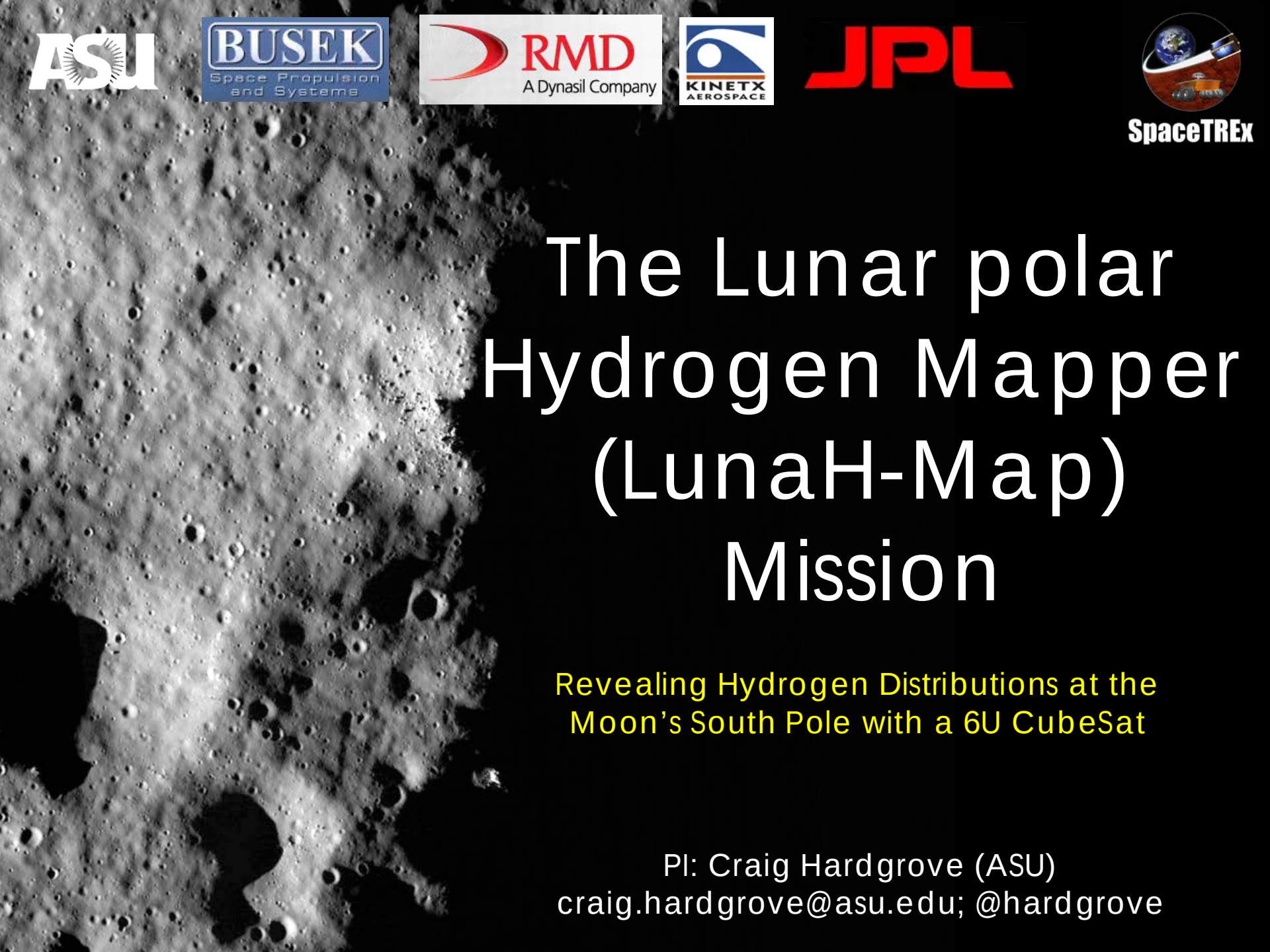

The Lunar polar Hydrogen Mapper (LunaH-Map) Mission

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

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Outline

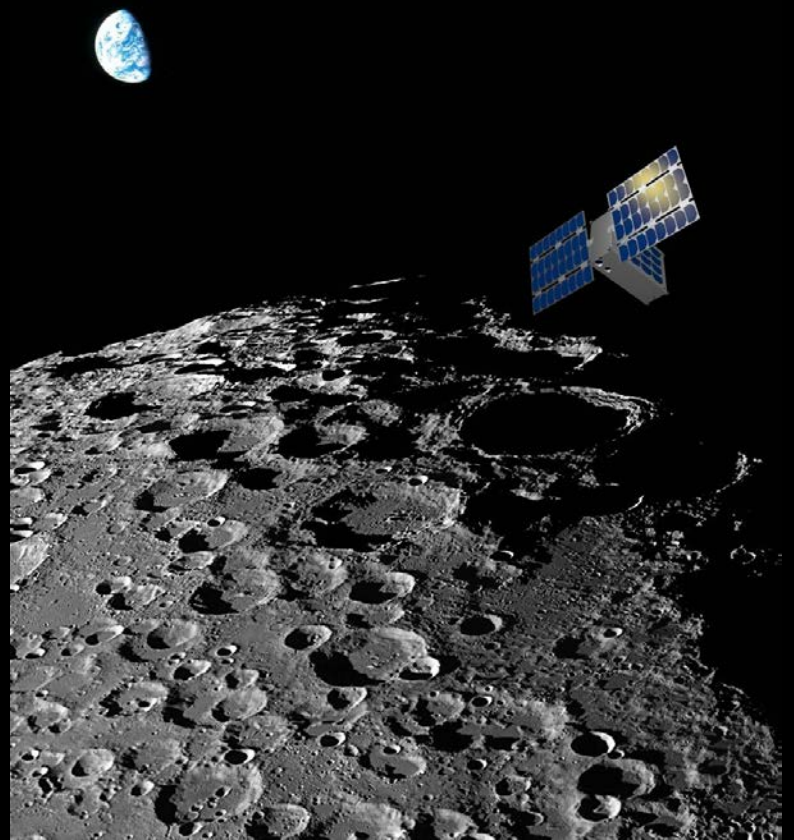
1. Small Innovative Missions for Planetary Exploration (SIMPLEx)

2. Science Goals

3. Mission

4. LunaH-Map Status

5. Thoughts



1. SIMPLEx

- Small, Innovative Missions for PLanetary Exploration Proposal Program from NASA Science Mission Directorate (SMD) ROSES 2015
- Science Goals: Must be responsive to *2014 NASA Science Plan*
  - *LunaH-Map is responsive to 2014 NASA Science Plan, LEAG Strategic Knowledge Gaps, and NASA Decadal Survey*
- May target any body in the Solar System, except for the Earth and Sun
- Supports a 1U, 2U, 3U or 6U CubeSat launch on SLS EM-1

2. Goals of the LunaH-Map Mission

- Understand the quantity of H-bearing materials in lunar cold traps (at spatial scales <10km)
- Determine the concentration of H-bearing materials with depth at 1m scale
- Constrain the vertical distribution of H-bearing materials

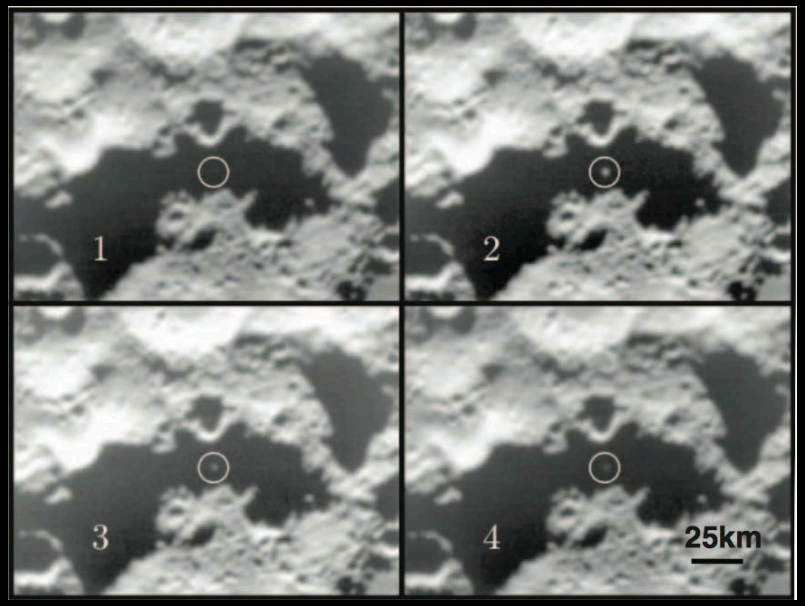
2. How will we accomplish those goals?

- Utilize a 6U CubeSat
- Enter a low altitude polar orbit with perilune centered on South Pole
- Use two high-efficiency neutron spectrometers
- Orbit for two months

2. Observations of Lunar Hydrogen

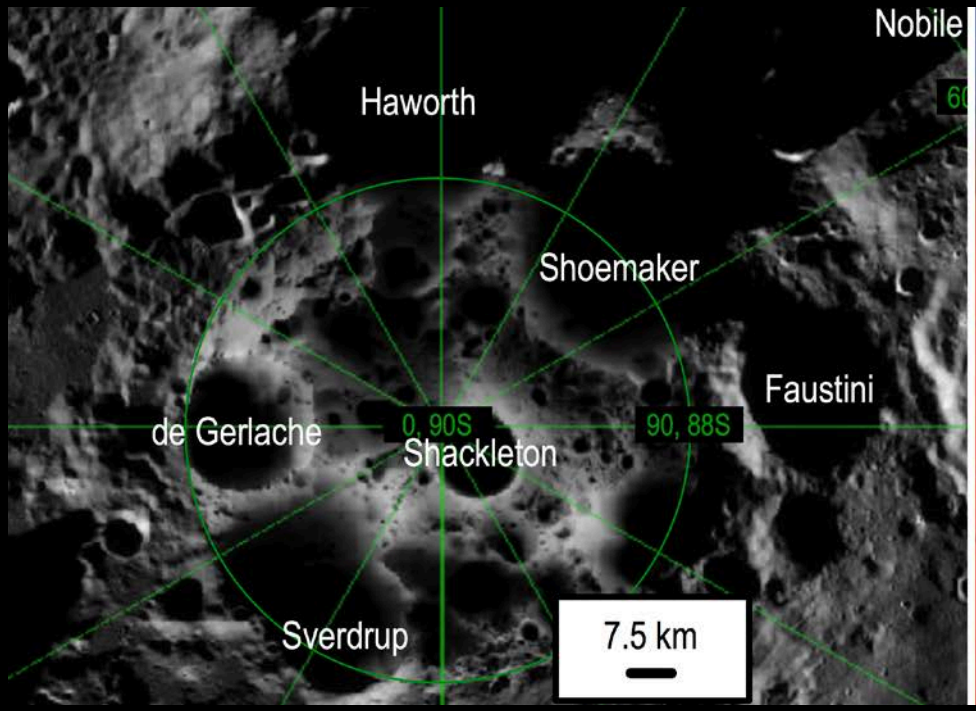
Near-surface (top ~meter)

- LCROSS impactor
  - ~0.5 wt.% H_2O in plume (Colaprete et al., 2010)
- LRO – LEND
  - 10km/pixel; Elevated H in some PSRs (Mitrofanov et al., 2010)
- Lunar Prospector – Neutron Spectrometer (Lawrence et al., 2006)
  - 45km/pixel; Data consistent with 200ppm H to 40 wt.% H_2O in some regions
  - Average H abundances between 100-150pppm

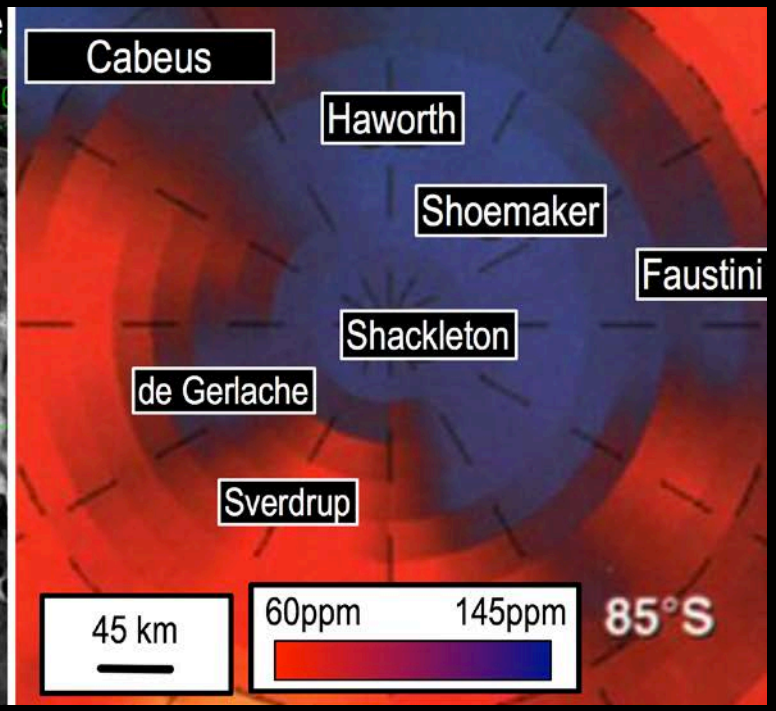


Schultz et al., 2010

2. Polar Hydrogen – Local



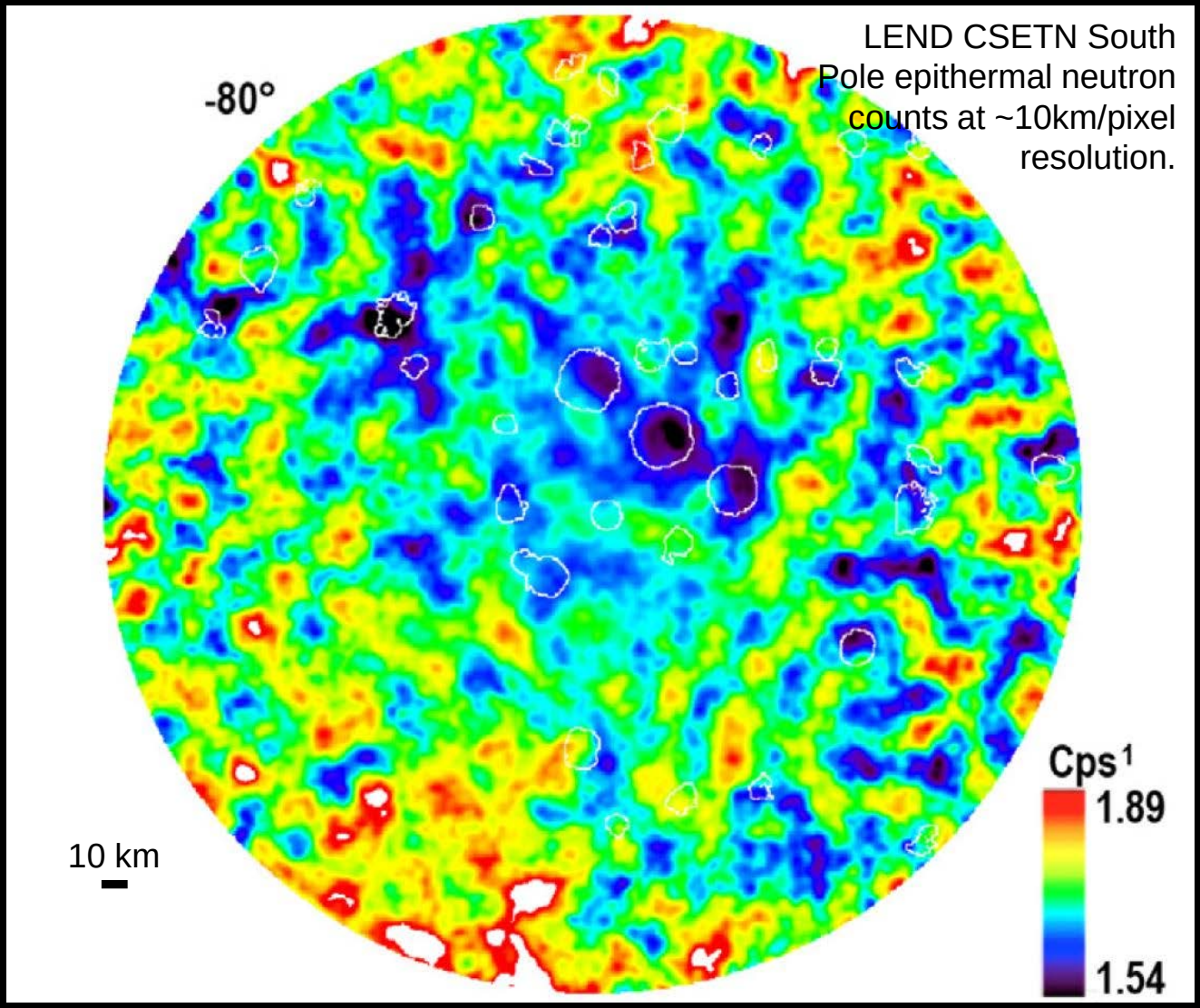
South Pole illumination map of craters observable by LunaH-Map at 7.5km resolution (Speyerer and Robinson, 2013).



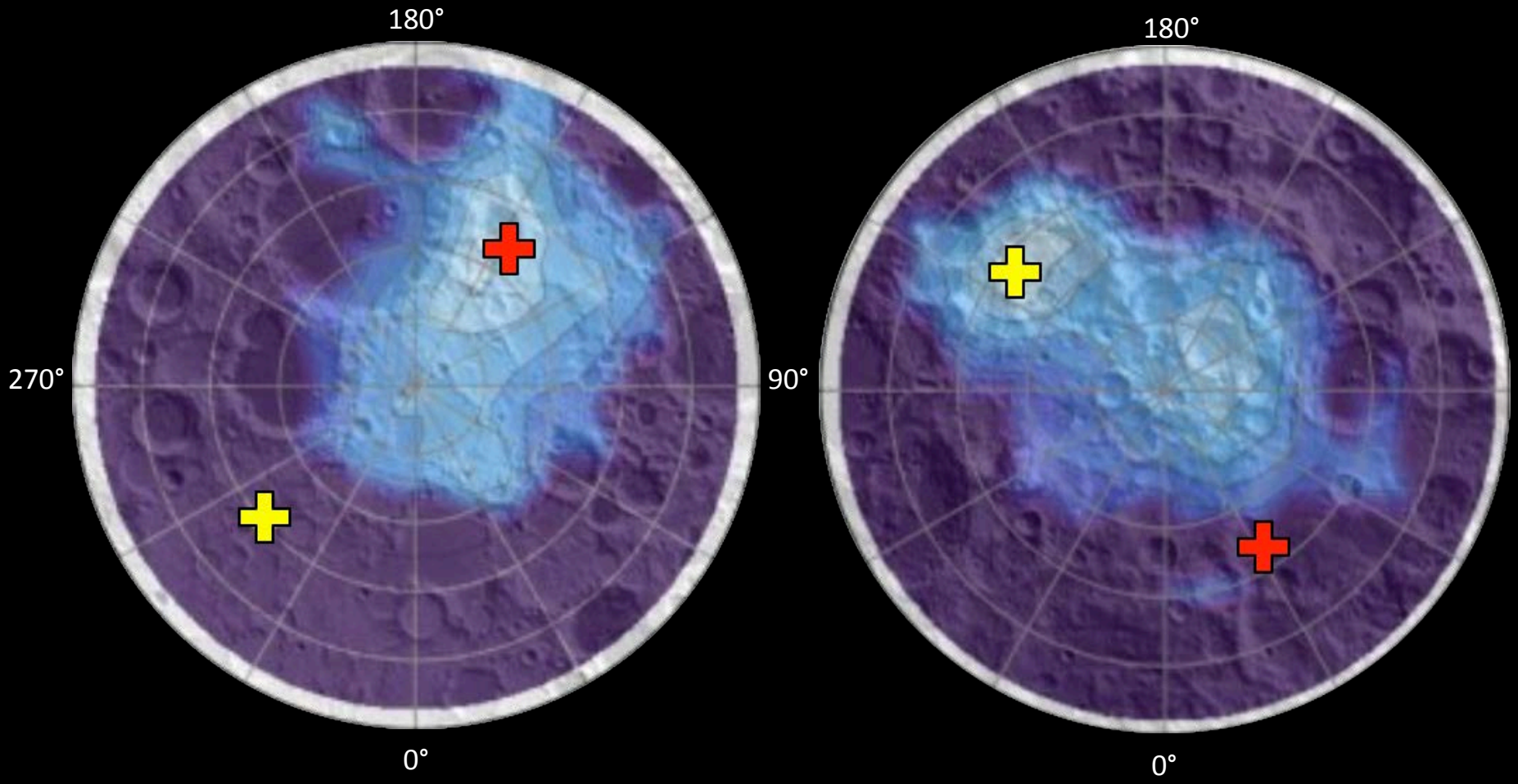
Lunar Prospector Neutron Spectrometer (LPNS) South Pole epithermal neutron counts at 45km/pixel resolution (Feldman et al., 1998)*. The approximate hydrogen abundances derived from LPNS data are shown in the color scale.

*Also see Lawrence et al., 2006; Elphic et al., 2007 and others

2. Polar Hydrogen - Local

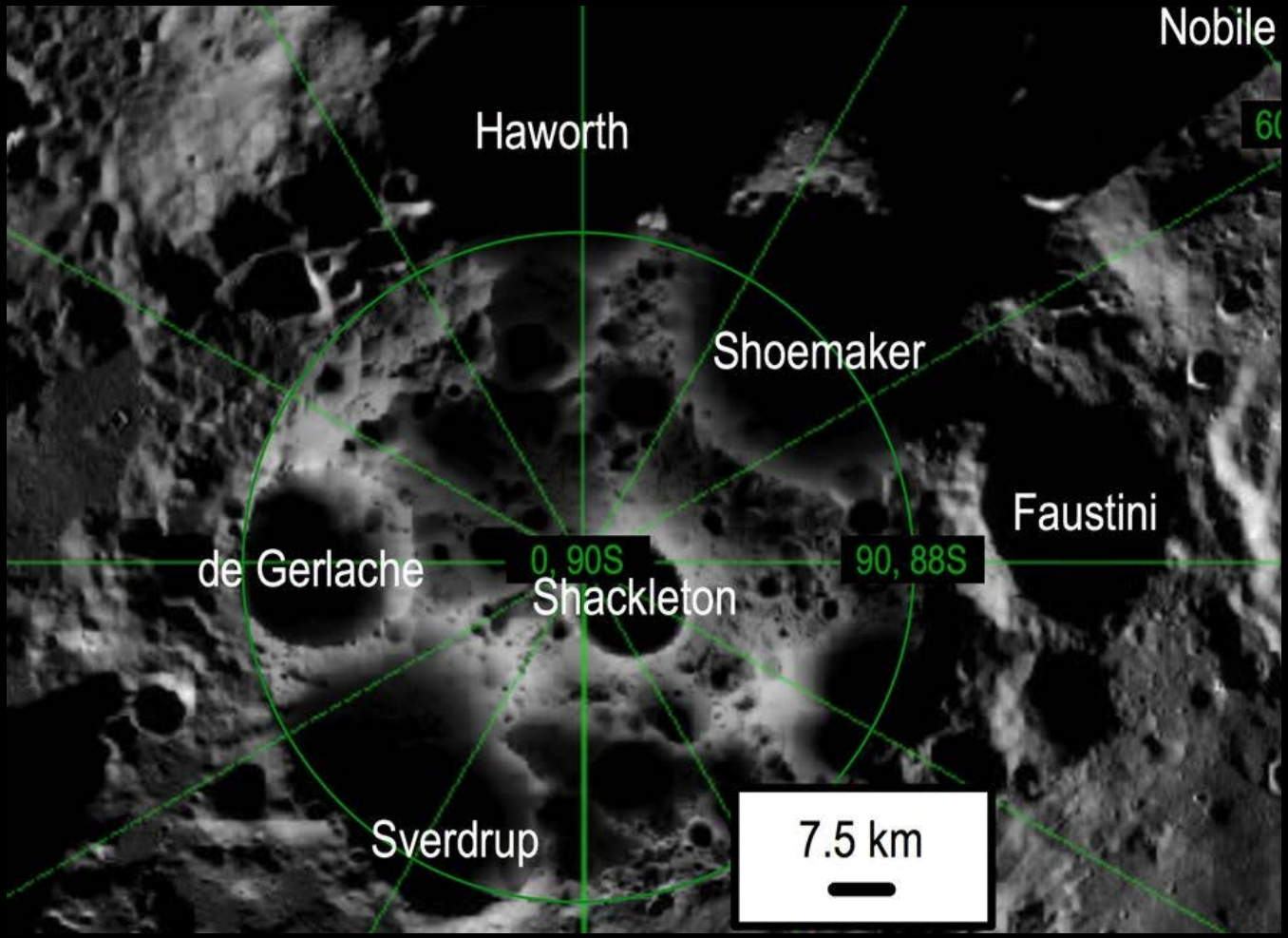


2. Polar Hydrogen - Regional



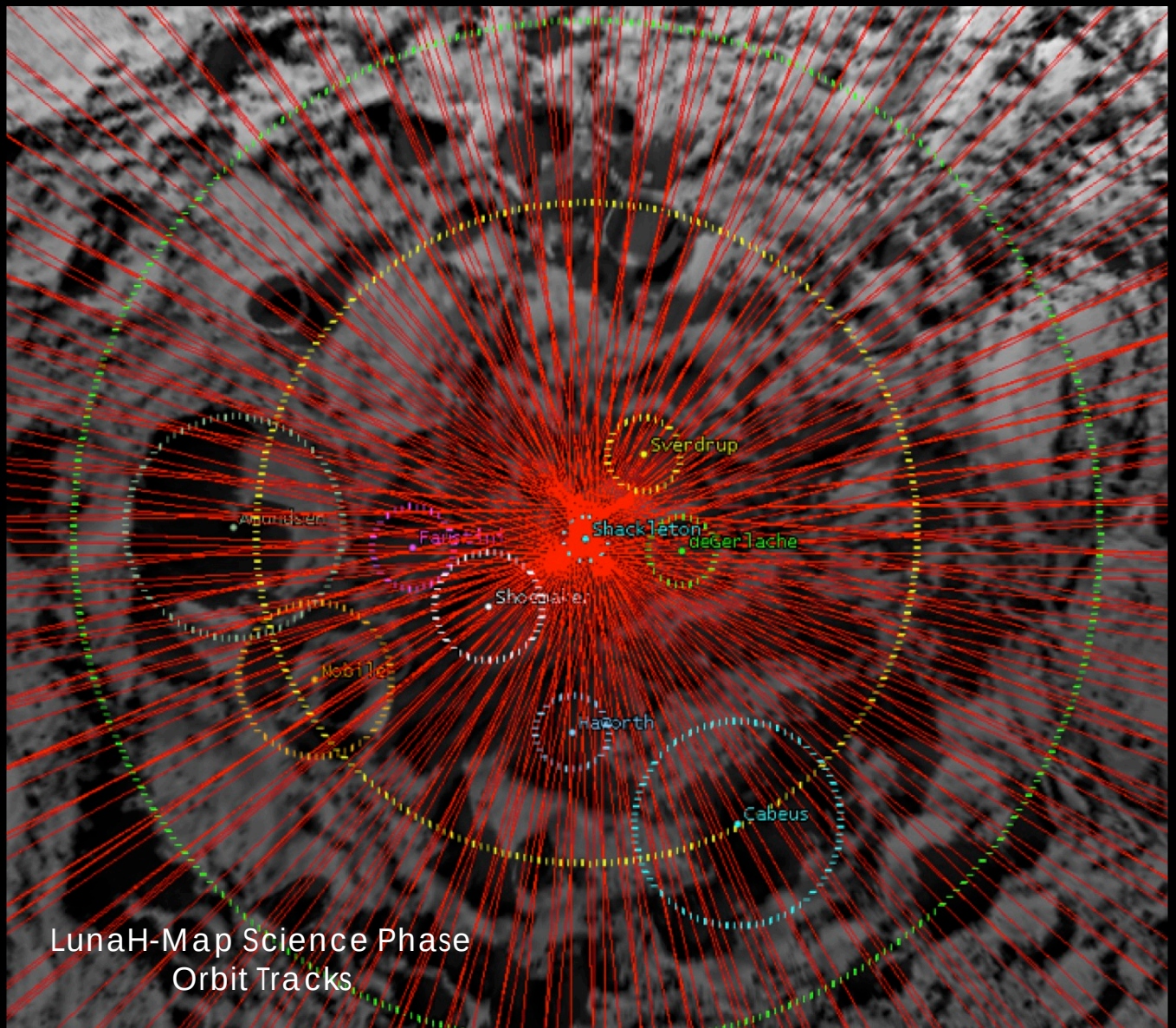
Ancient H-enrichments following true polar wander?
(Siegler et al., 2015)

3. LunaH-Map



Projected LunaH-Map resolution

3. LunaH-Map

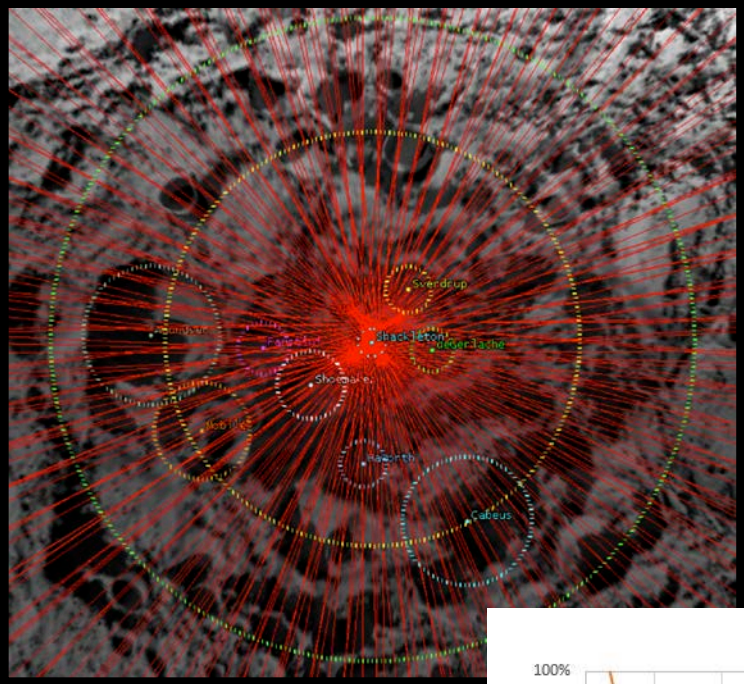


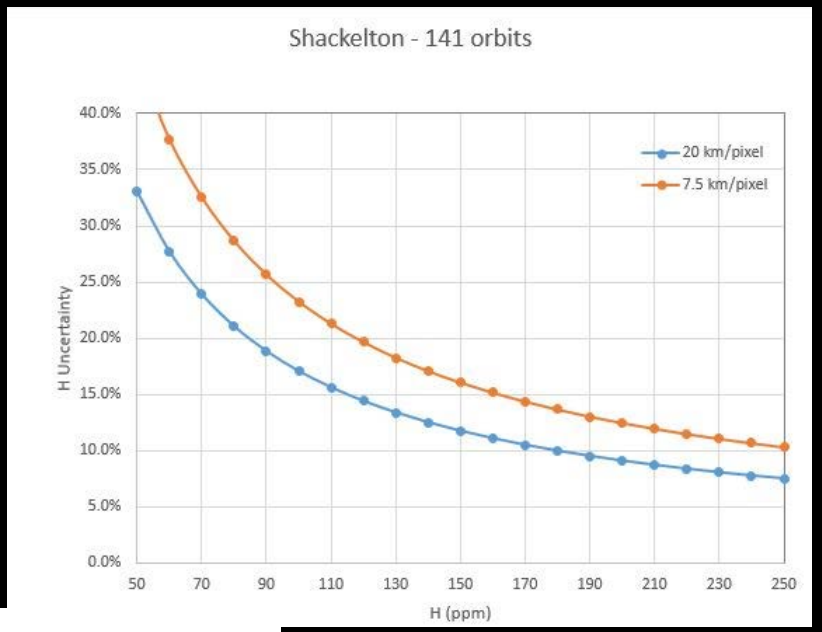
LunaH-Map Science Phase Orbit Tracks

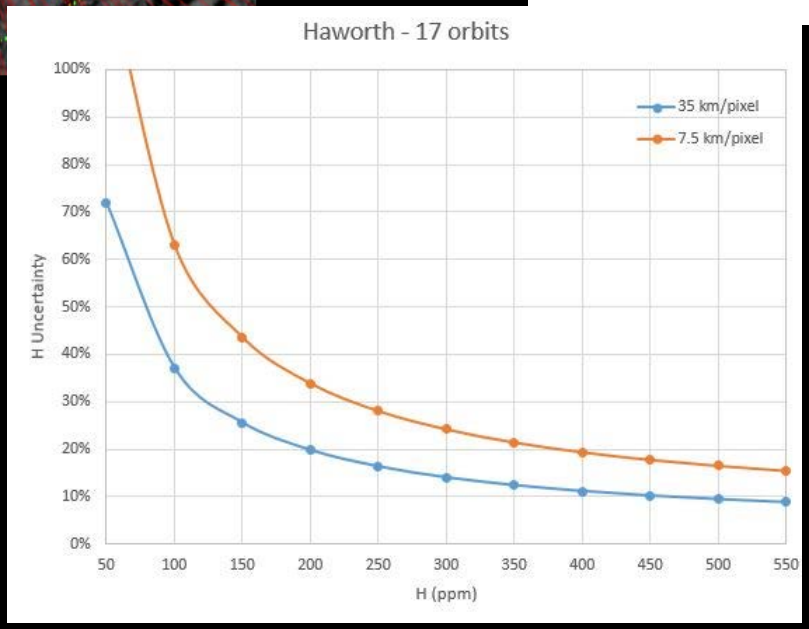
Science Mission

- 141 Orbits
- 10 hour period
- Perilune <10km

3. LunaH-Map Science Phase

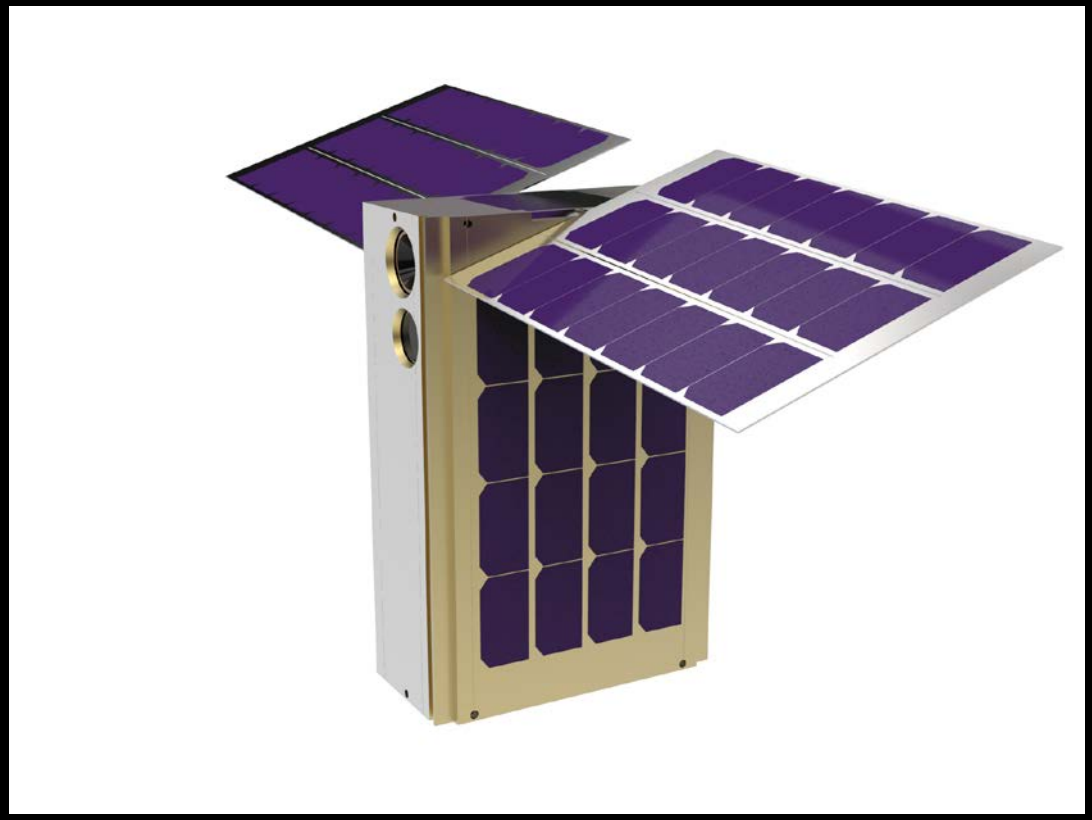






H abundances could be several thousand ppm at small spatial scales.

3. The LunaH-Map Spacecraft



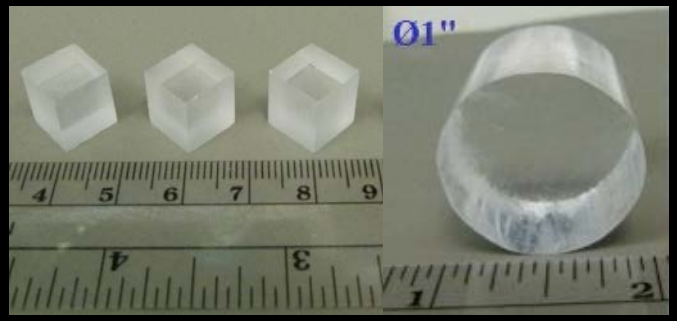
30 cm tall X 10 cm wide X 20 cm thick (~shoebox)

Components

- MMA Hawk Solar Panels
- Navigation Camera
- BCT XACT Attitude Control
- Neutron Spectrometers (x2)
- Busek cold-gas propulsion
- JPL IRIS X-Band Radio & Antenna
- Tyvak Intrepid CD&H
- SAFT 140 Wh Li-Ion Battery

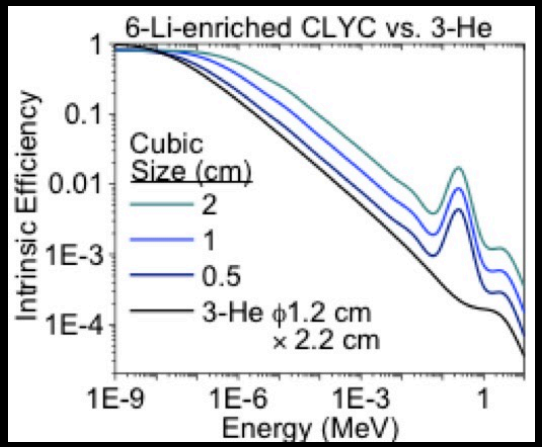
3. New Detector Materials

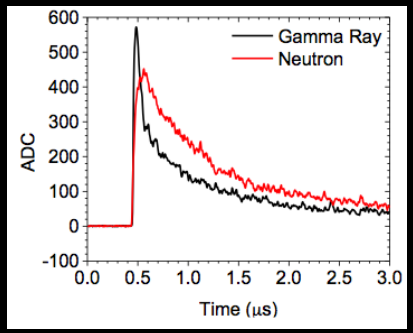
- Developed through NASA & DOD SBIR/STTR awards
- Similar efficiencies to thermal and epithermal neutrons as ^{3}He



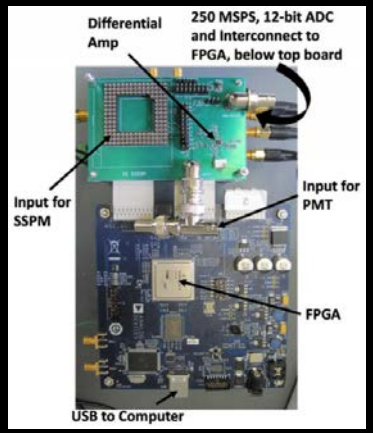
CLYC can be grown into a variety of shapes and sizes. Has been rad (~200 MeV and very high dose rates >50 rad/s), vacuum and pressure tested. Can operate at -40C.

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

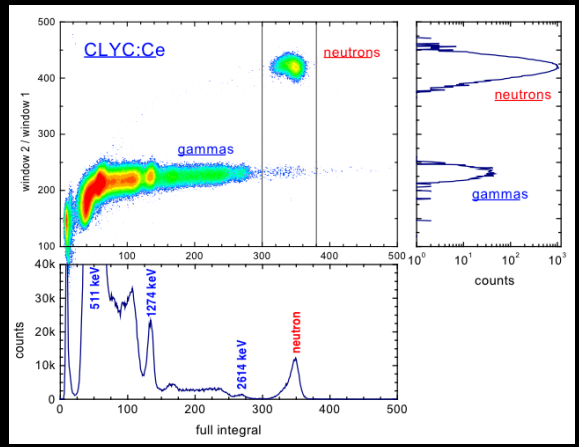




CLYC light pulses are different for gamma rays and neutrons

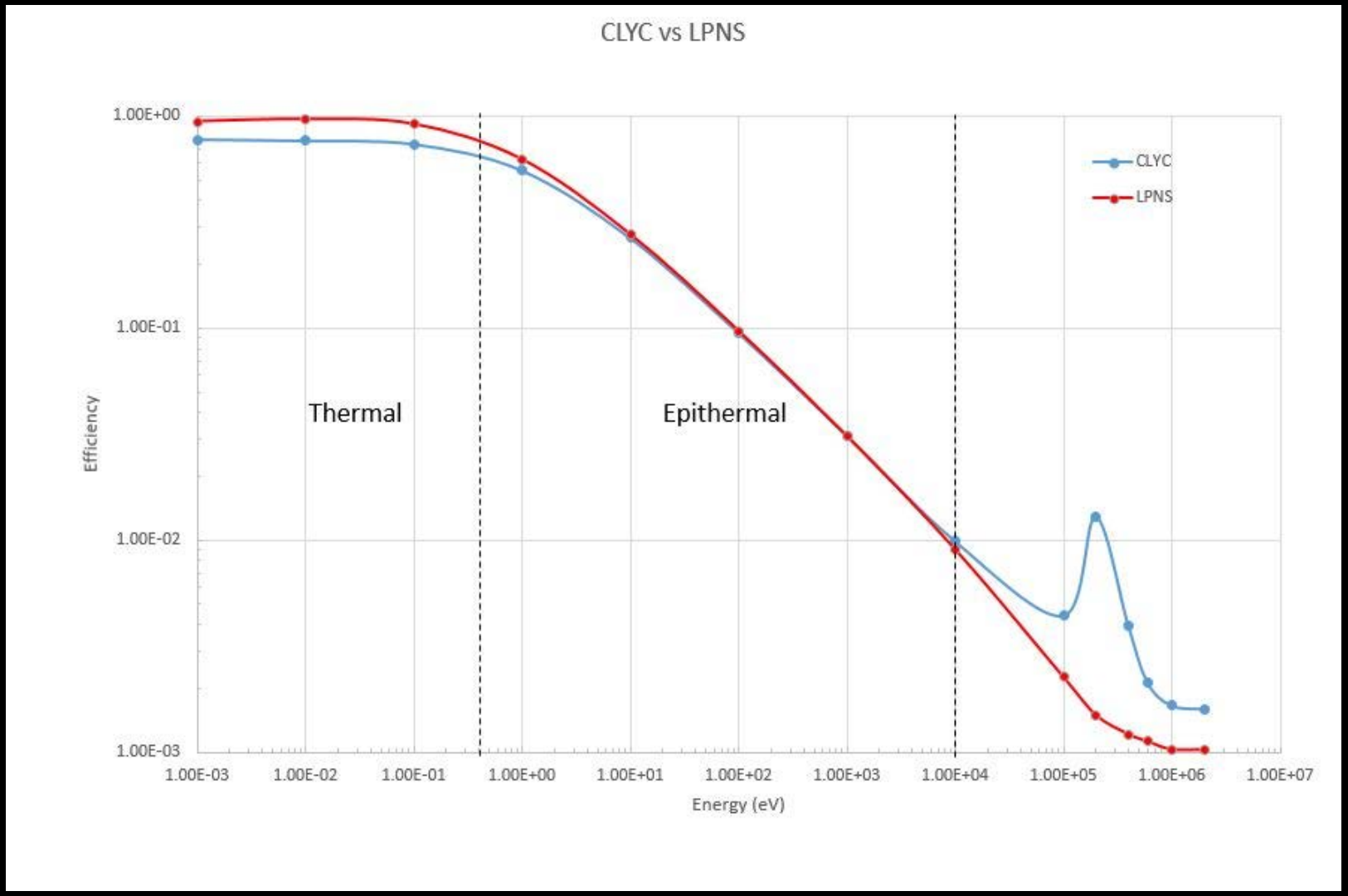


DAQ System developed for NASA SBIR/STTR



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

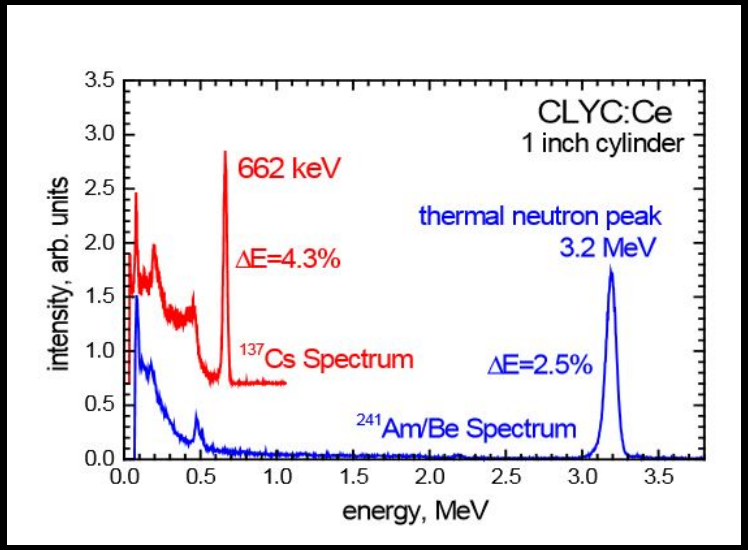
3. LunaH-Map neutron detector (2cm) compared to 5.7-cm diameter LPNS ^{3}He counter



from Richard Starr

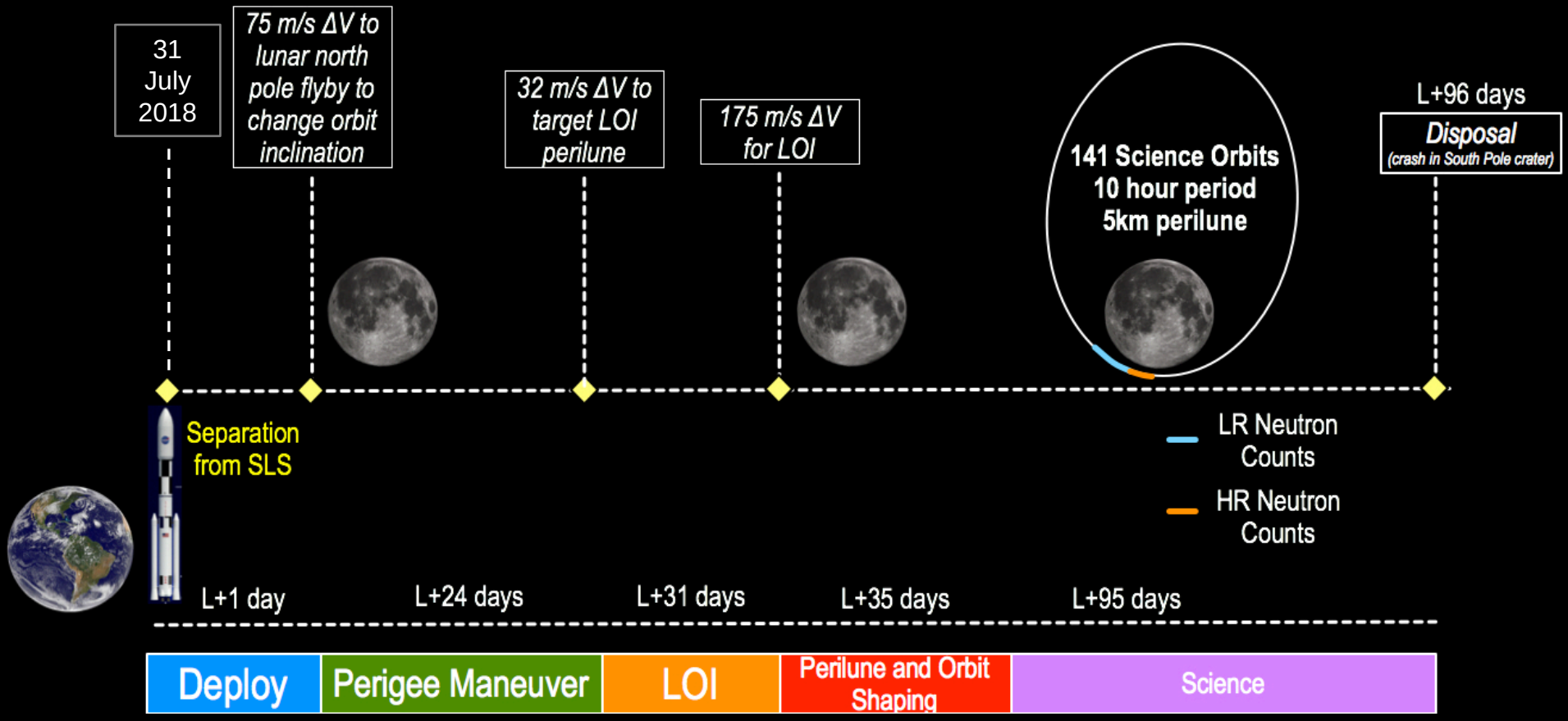
3. Neutron Detector for Small Spacecraft

LunaH-Map will have two identical 100-cm^2 CLYC arrays. Each of the 16 crystals in one array will be covered by a thin Cd foil.



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

3. LunaH-Map Concept of Operations



4. LunaH-Map Status

- Selected in August
- Currently in ~Phase A
- Preliminary design and preparation for upcoming Kick-Off
- Initial audits and requirements reviews in December

5. Impact of Small Satellites on Planetary Science

- SIMPLEx requires an *innovative* solution to address long-standing questions in planetary science
  - Targeted science mission, shorter schedules, smaller teams, more iteration
- LunaH-Map combines a high-heritage technique in planetary science with new detector materials (developed through NASA SBIR/STTR)
- LunaH-Map is University-led with many small businesses partners serving key roles.
- LunaH-Map demonstrates the potential planetary exploration on small satellites for scientific discovery, scouting, and resource utilization.

To the Moon!