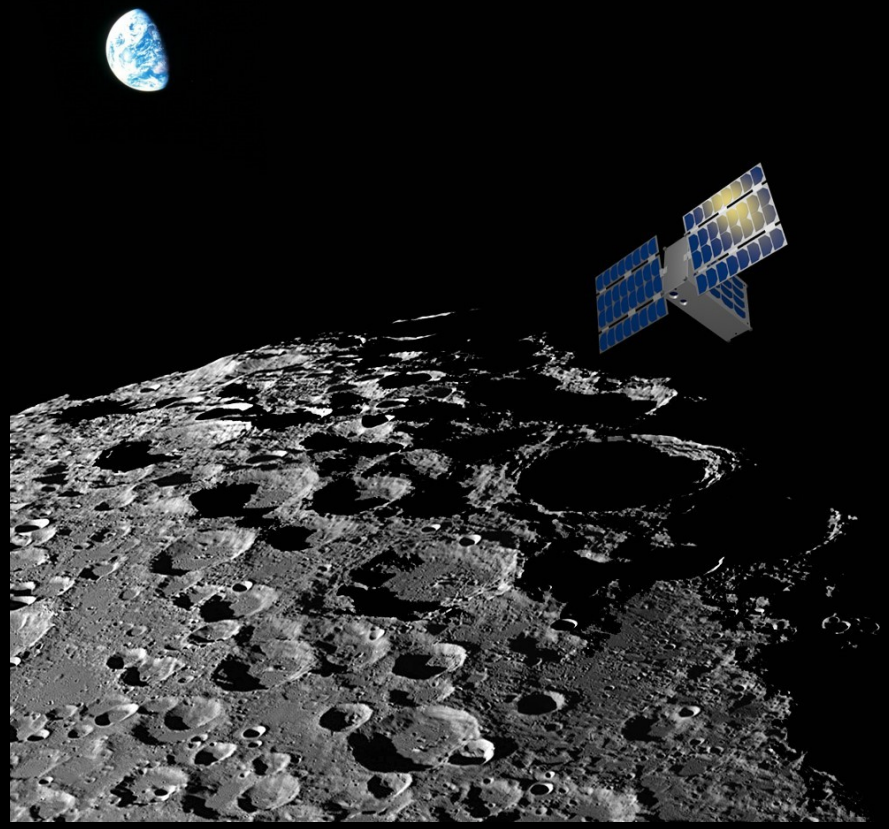
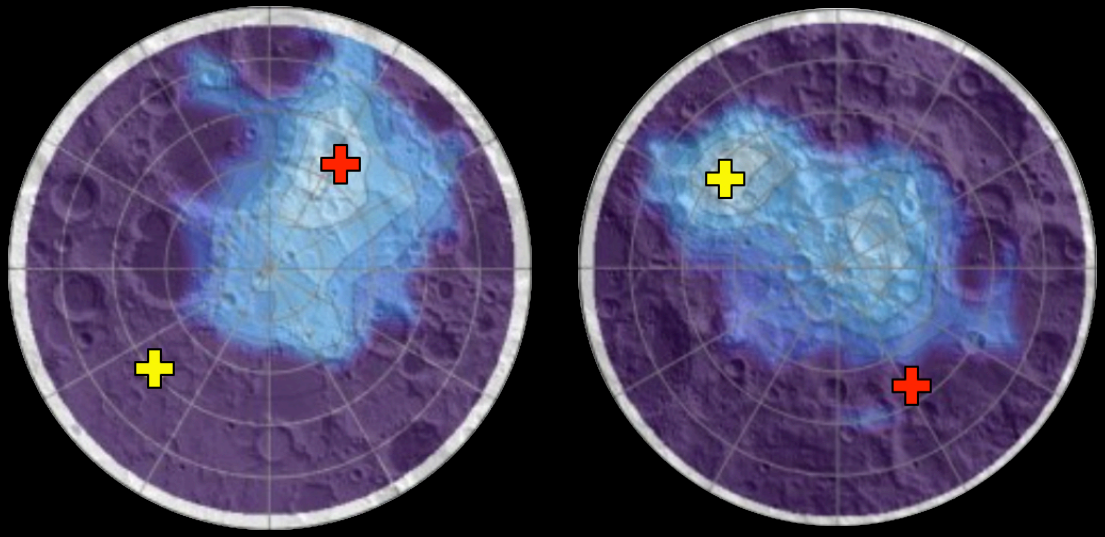
LunaH-Map CubeSat



PI: Dr. Craig Hardgrove; DPI: Dr. Jim Bell, (ASU); Co-I: Jekan Thanga, (ASU); A. Klesh, JPL; R. Starr, Catholic University; T. Colaprete, NASA Ames; M. Robinson, ASU; D. Drake; E. Johnson, RMD; J. Christian, RMD; A. Genova, NASA Ames; D. Dunham, KinetX; B. Williams, KinetX; D. Nelson, KinetX; A. Babuscia, JPL; P. Scowen, ASU; K.M. Cheung, JPL; M. Beasley, Planetary Resources; T. McKinney, ASU; A. Taits, ASU; V. Hernandez, ASU; P. Wren, ASU; A. Thoesen, ASU; A. Godber, ASU.

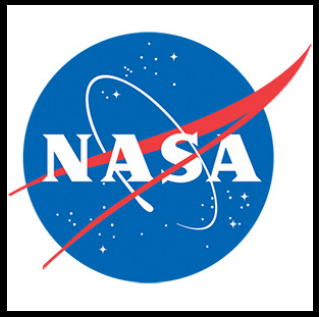
The Lunar Polar Hydrogen Mapper (LunaH-Map) CubeSat Mission

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



North Pole South Pole

SIMPLEx



- Small Innovative Mission for Planetary Exploration Proposal Program from NASA ROSES 2015 (announced in November 2014, proposals due April 2015)
- 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*)
  - Lunar Prospector – Neutron Spectrometer (*Feldman et al., 2000; Lawrence et al., 2006*)

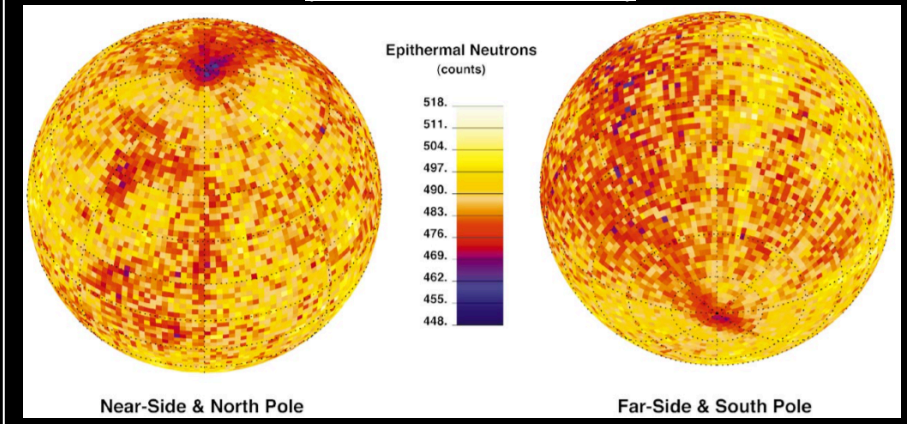
Neutron Spectroscopy In Planetary Science

Neutron spectroscopy is used to determine the bulk hydrogen abundance (H) of planetary surfaces

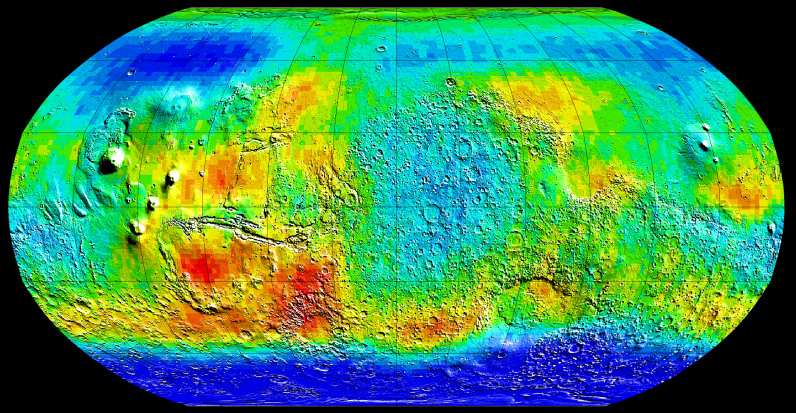
Previous Spacecraft Missions with Neutron Detectors

- 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)

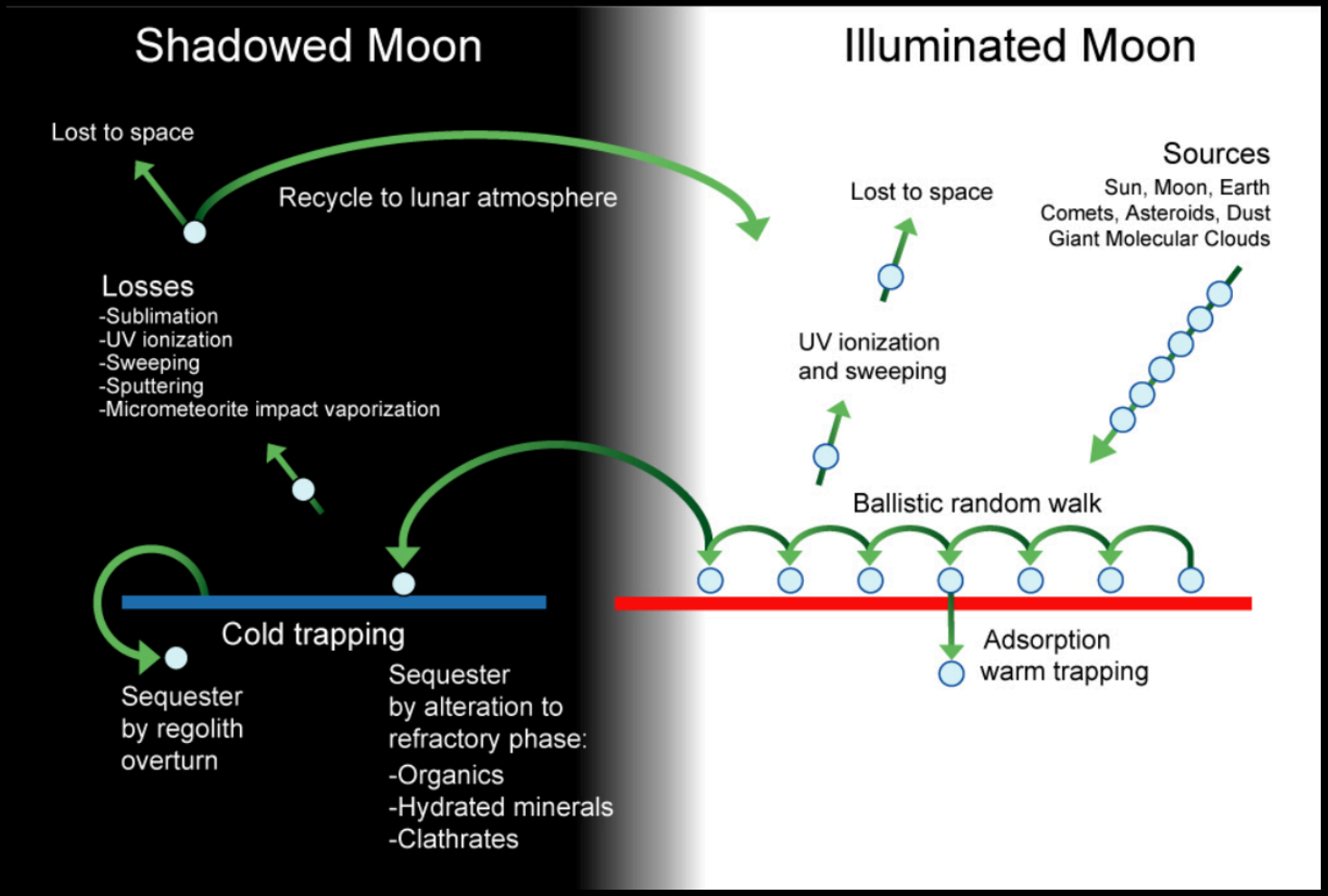
Lunar Polar H Abundance Maps from LPNS (*Feldman et al., 1998*)



Mars Odyssey Neutron Spectrometer Epithermal Neutron Counts (*Boynton et al., 2002*)



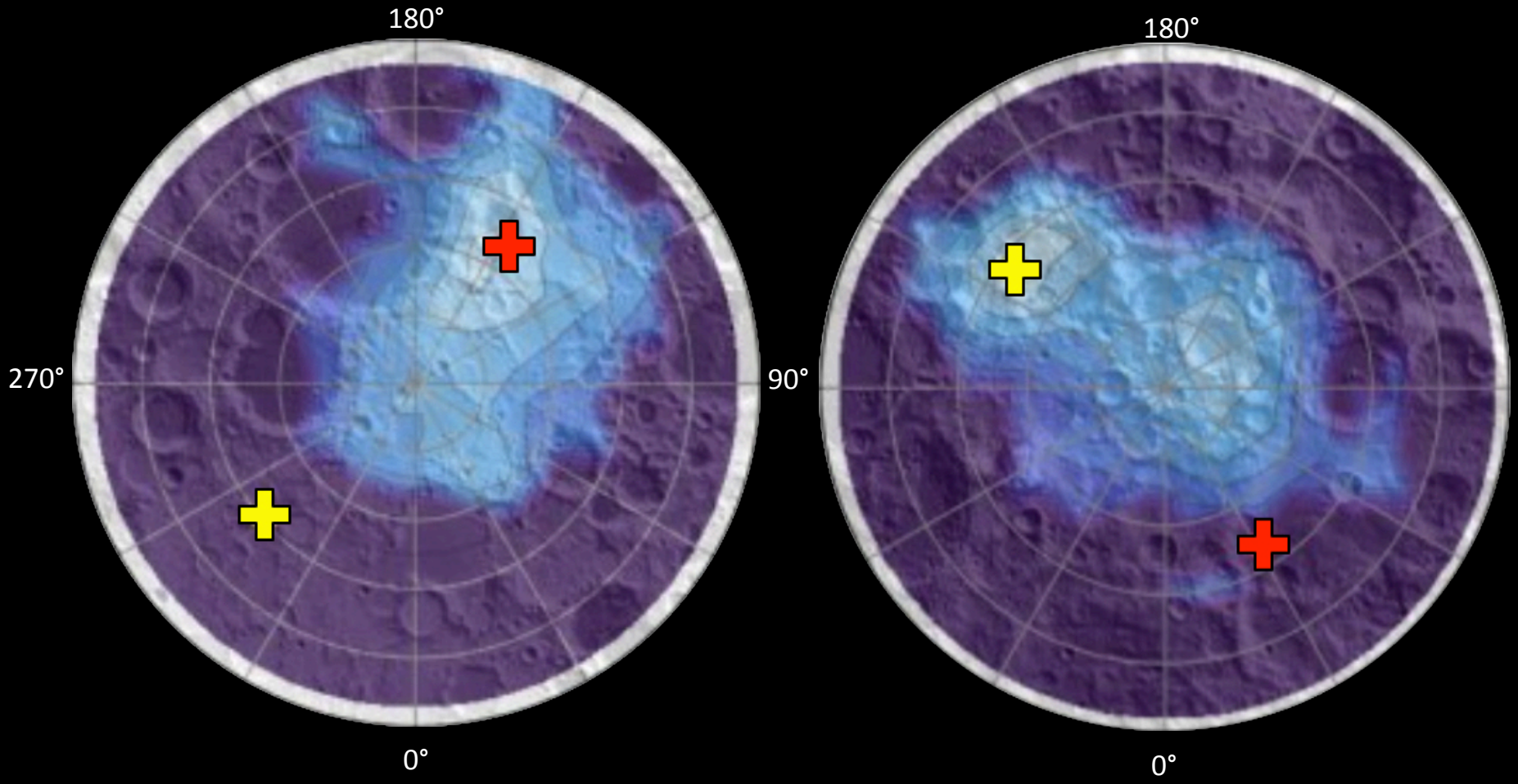
Hydrogen on the Moon



Results in homogenous distribution within permanently shadowed regions

Lucey P., 2009, Elements

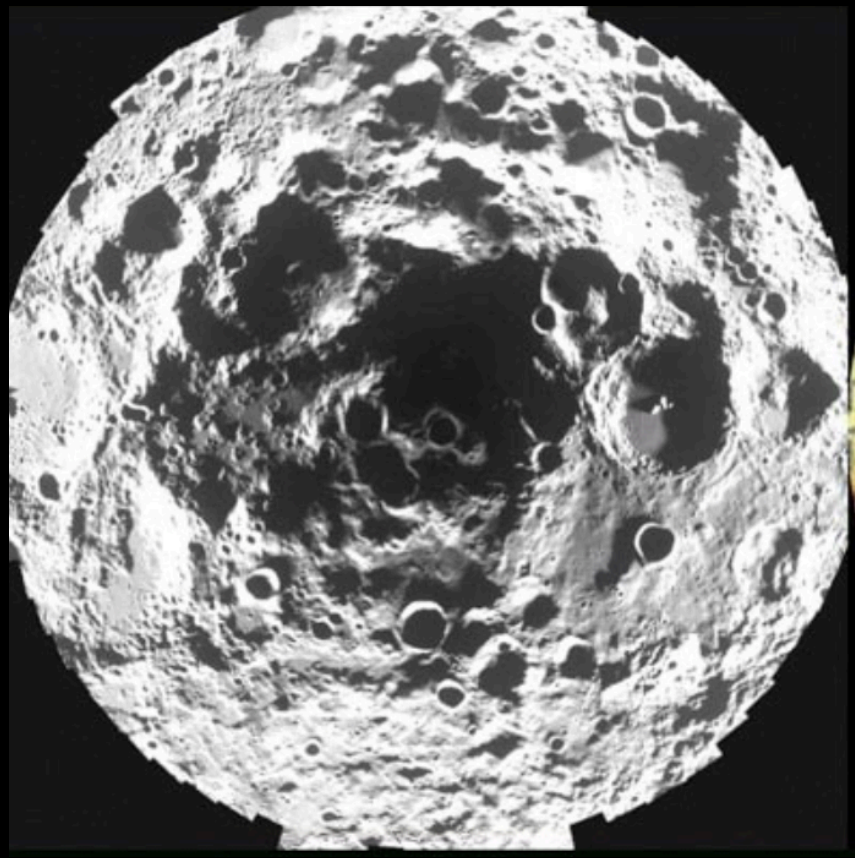
Hydrogen on the Moon



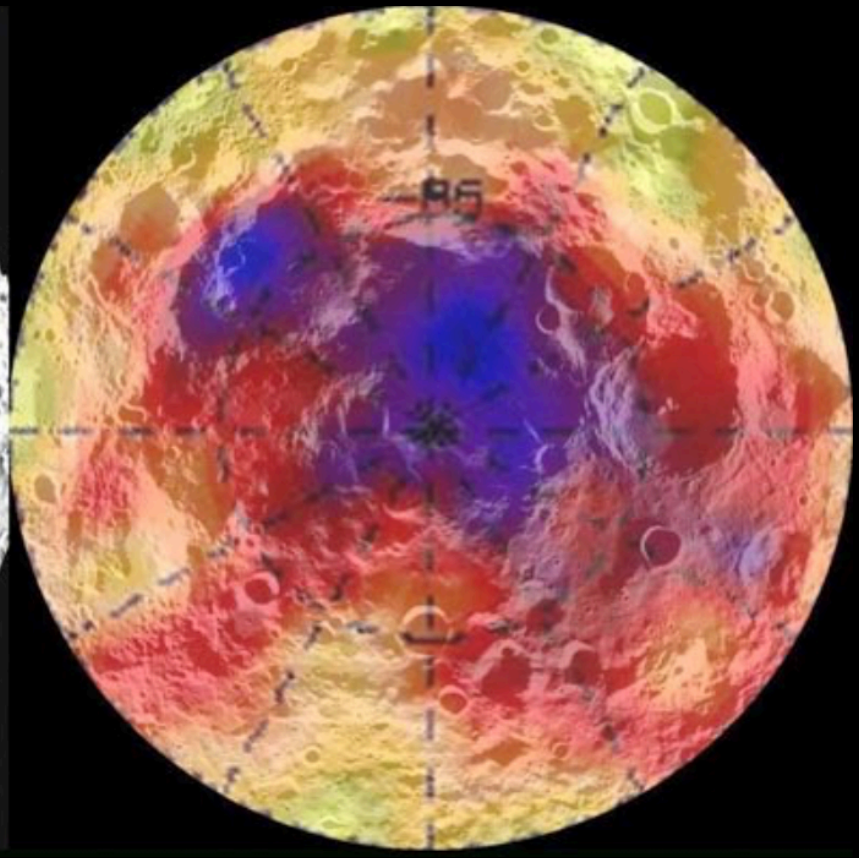
Results in heterogeneous distribution within permanently shadowed regions

Siegler et al., 2015 LPSC

The Lunar South Pole

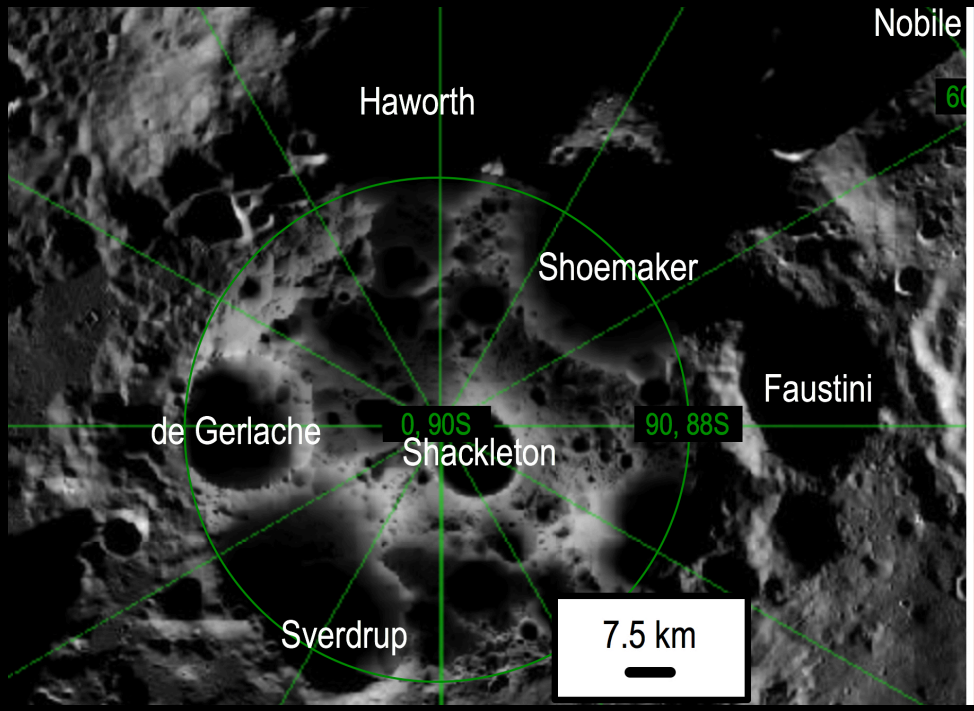


Permanently shadowed regions
(Paige et al., 2010, Science)

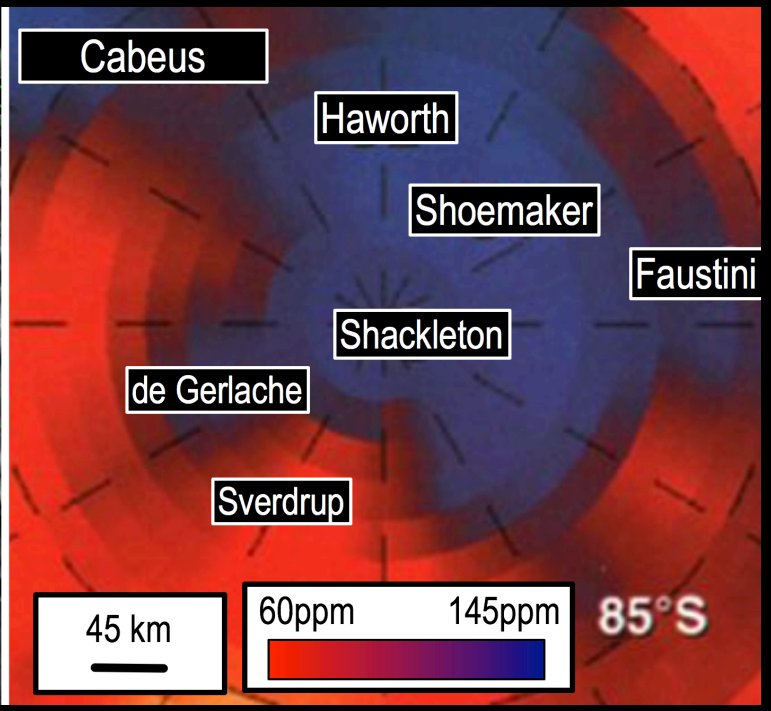


Neutron count rates from LPNS
(Feldman et al., 1998, Science)

The Lunar South Pole



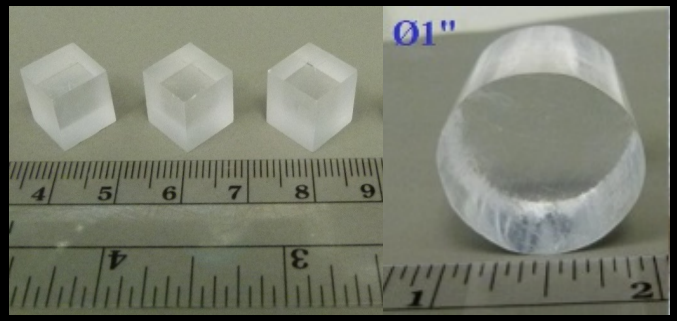
South Pole illumination map of craters observable by LunaH-Map at 7.5km resolution. (Speyerer and Robinson, 2013)



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

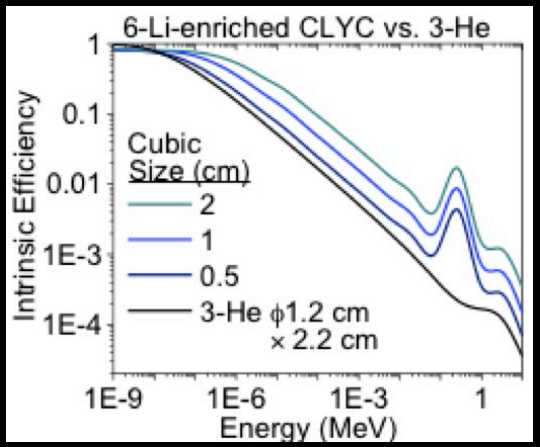
New Detector Materials

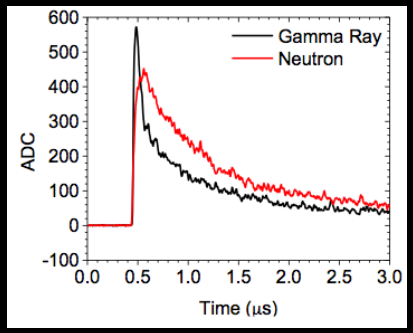
- Similar efficiencies to thermal and epithermal neutrons as ^{3}He
- Sensitive to both gamma-rays and neutrons*



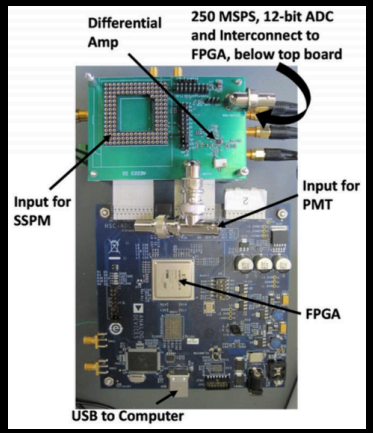
CLYC (elpasolite) is a new scintillator materials that can be grown into a variety of shapes and sizes. Has been rad (~200 MeV and very high dose rates >50 rad/s), vacuum and pressure tested. Can operate at -40C.**

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

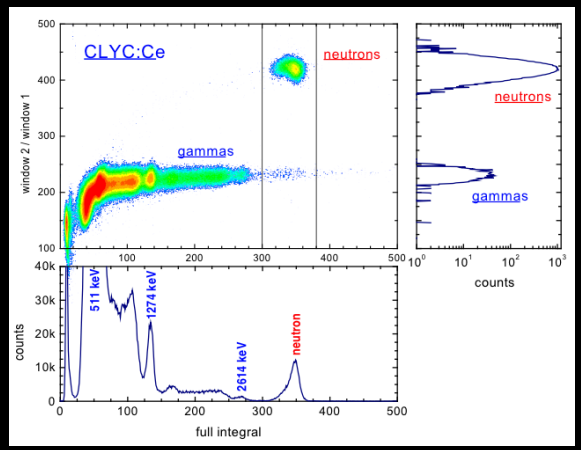




CLYC light pulses are different for gamma rays and neutrons***



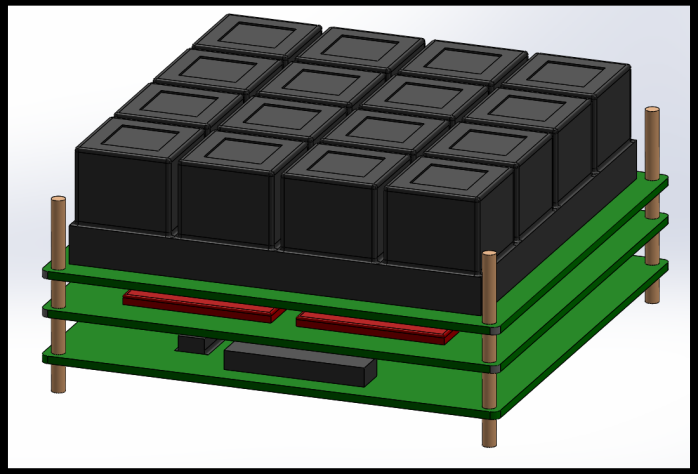
DAQ System developed for NASA SBIR/STTR****



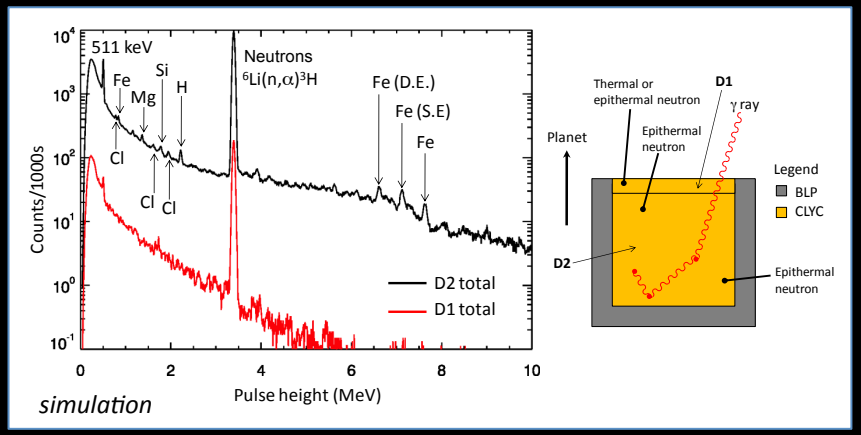
Gamma-rays and neutrons are discriminated by energy and light pulse shape

*Glodo et al., 2008
**Whitney et al., 2011
***Johnson et al., 2014
****Johnson et al., 2013

CLYC-Based Neutron Detector System for Small Spacecraft



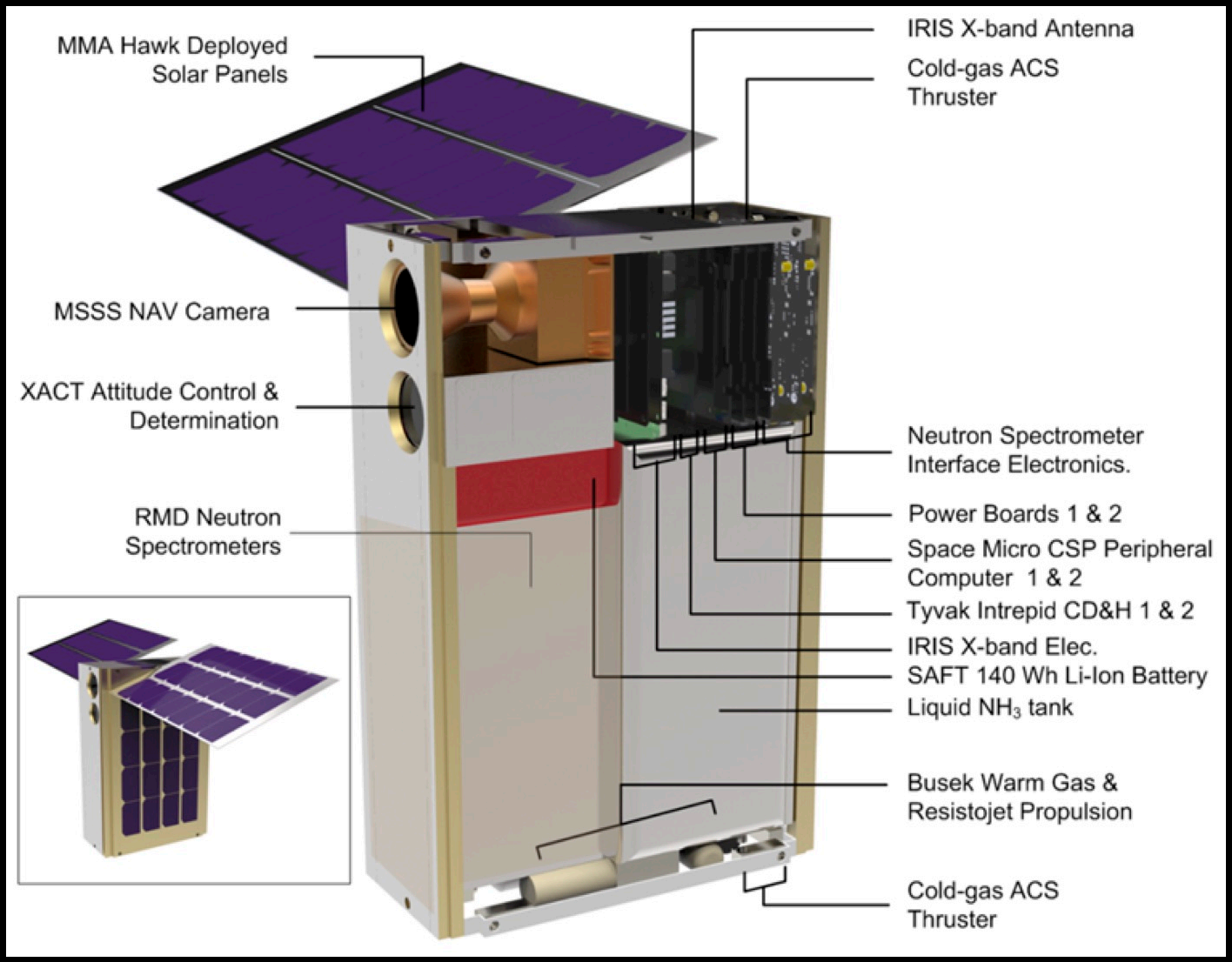
CAD Model of compact CLYC neutron/gamma-ray detector



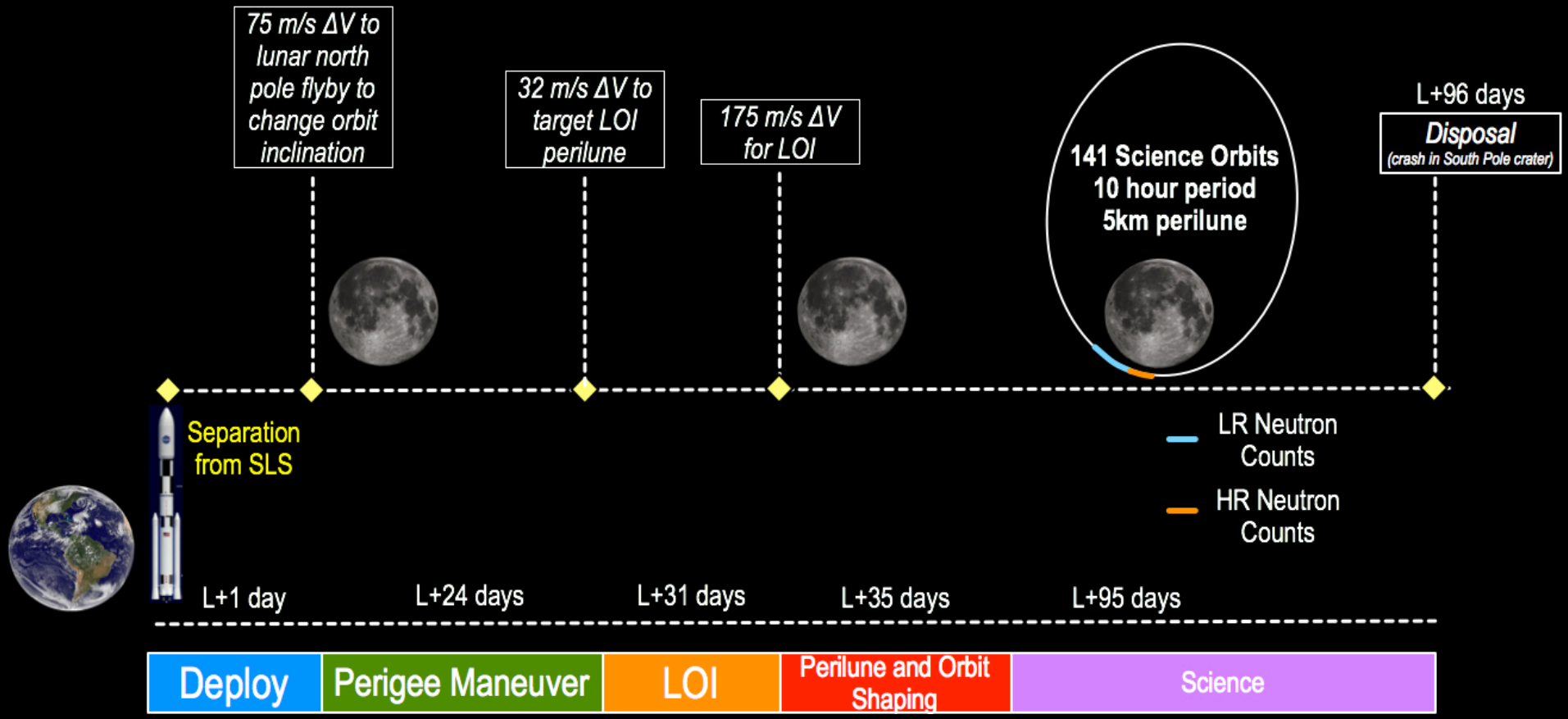
Data from CLYC detector (with GCR-Passive neutron source) on the surface of a planetary body (CI Chondrite)

Neutron and Gamma-Ray Instrument 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

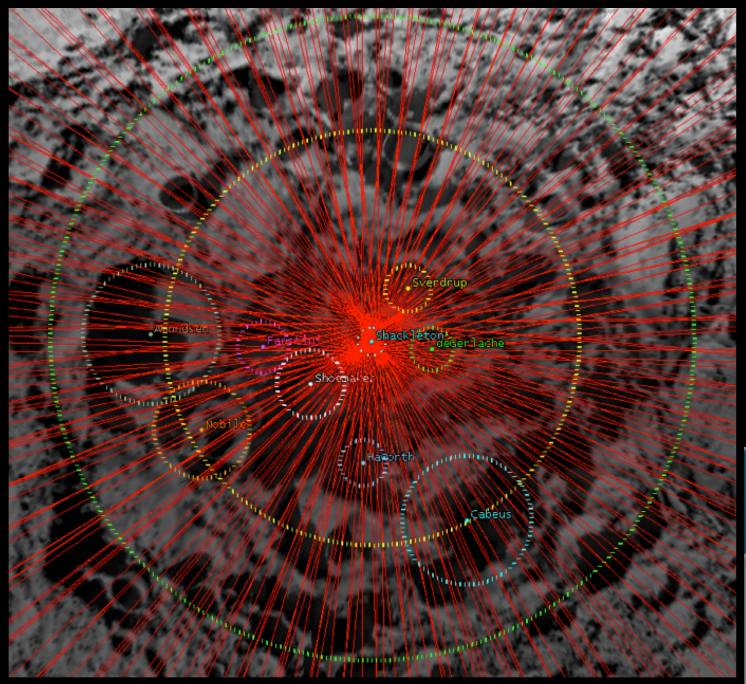
The LunaH-Map Spacecraft



LunaH-Map Concept of Operations



LunaH-Map Science Phase



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

			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

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