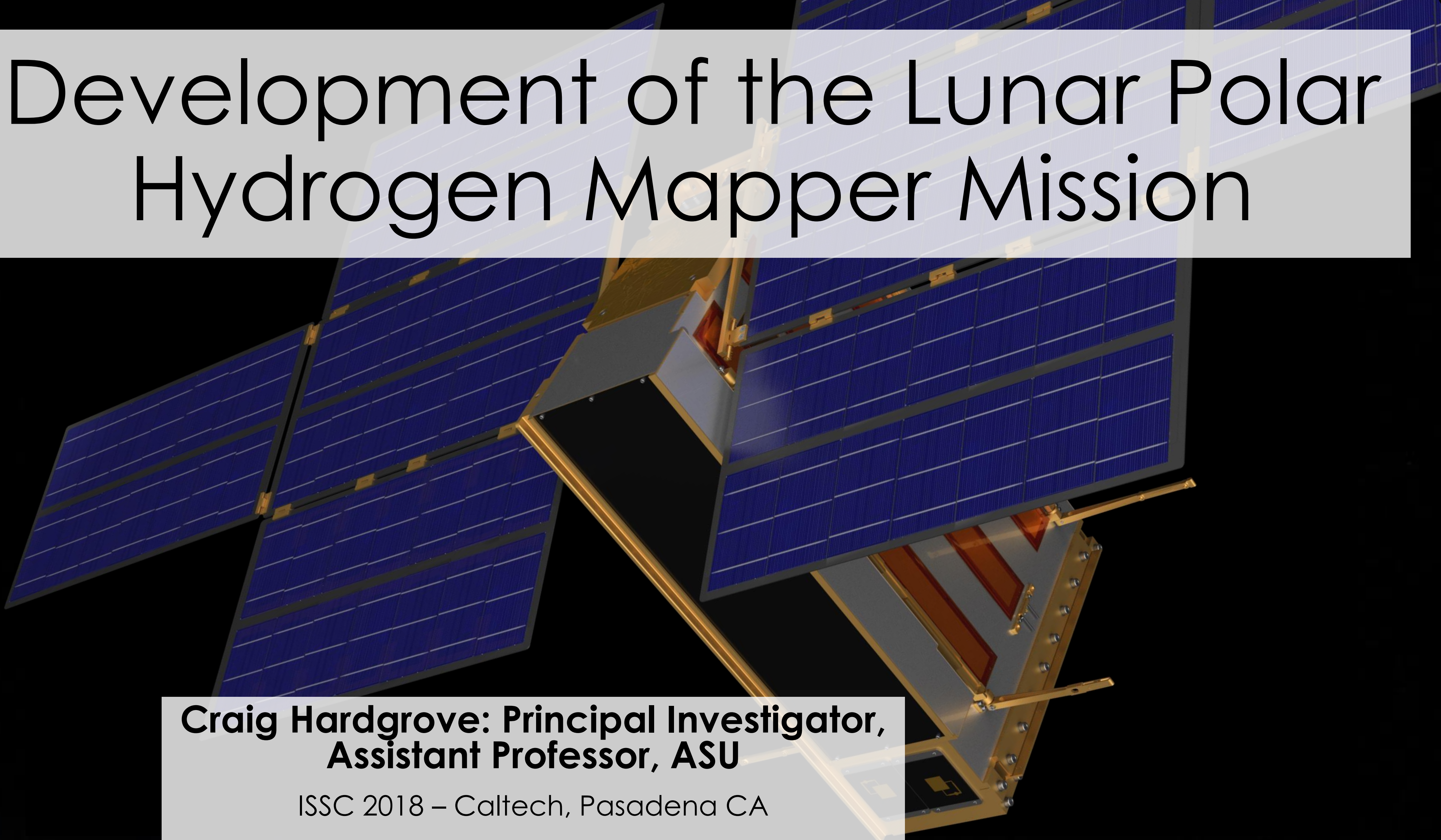
Development of the Lunar Polar Hydrogen Mapper Mission



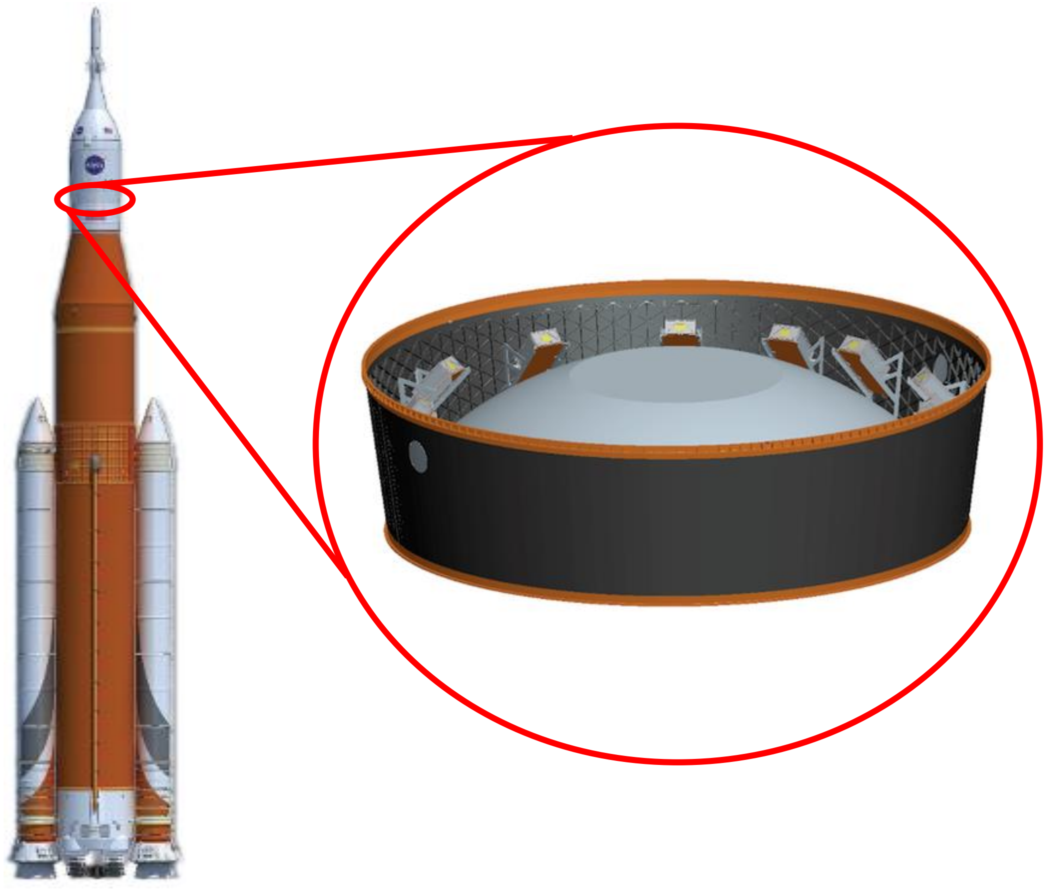
Craig Hardgrove: Principal Investigator, Assistant Professor, ASU

ISSC 2018 – Caltech, Pasadena CA

May 7, 2018

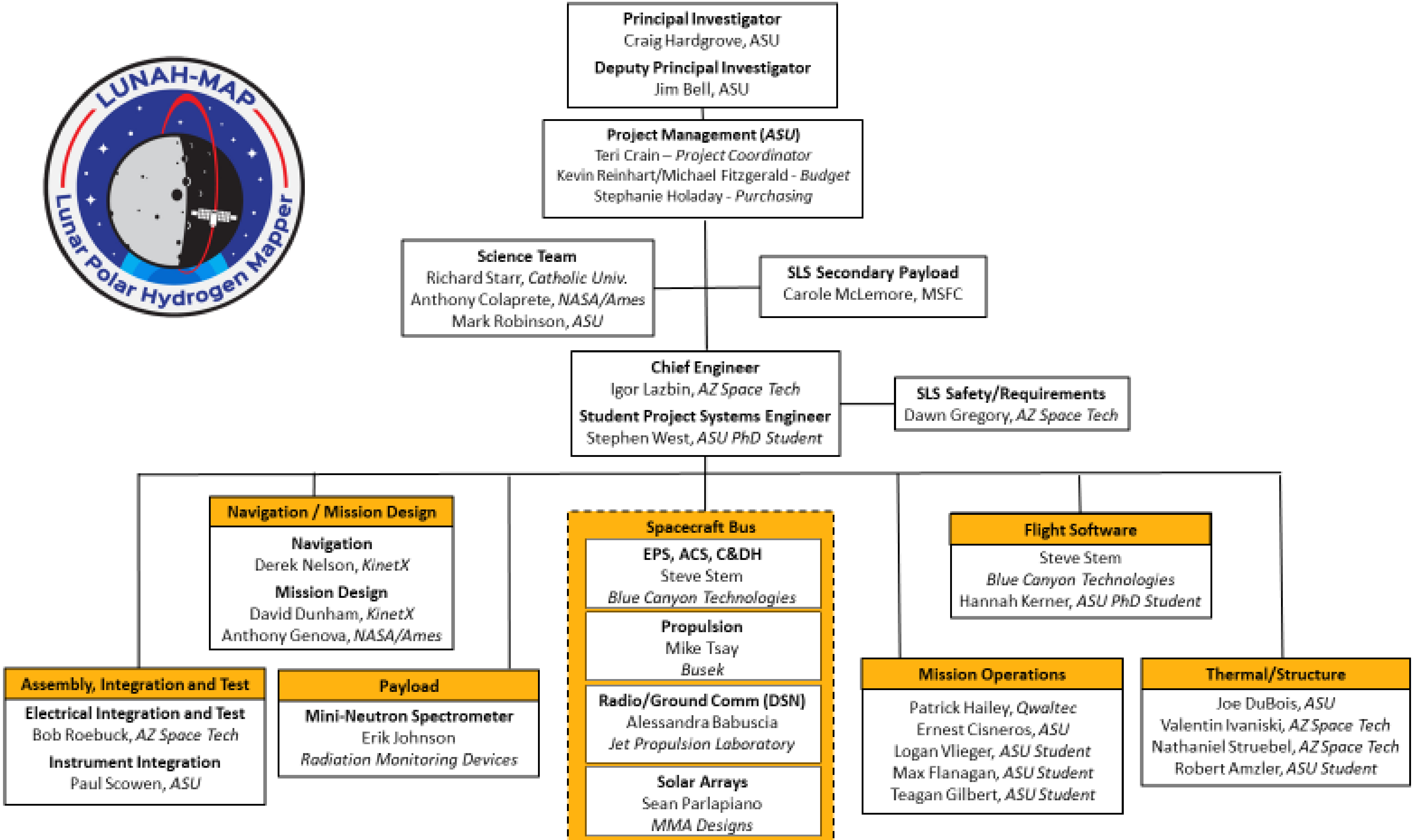
School of Earth & Space Exploration
Arizona State University

LunaH-Map Mission Overview

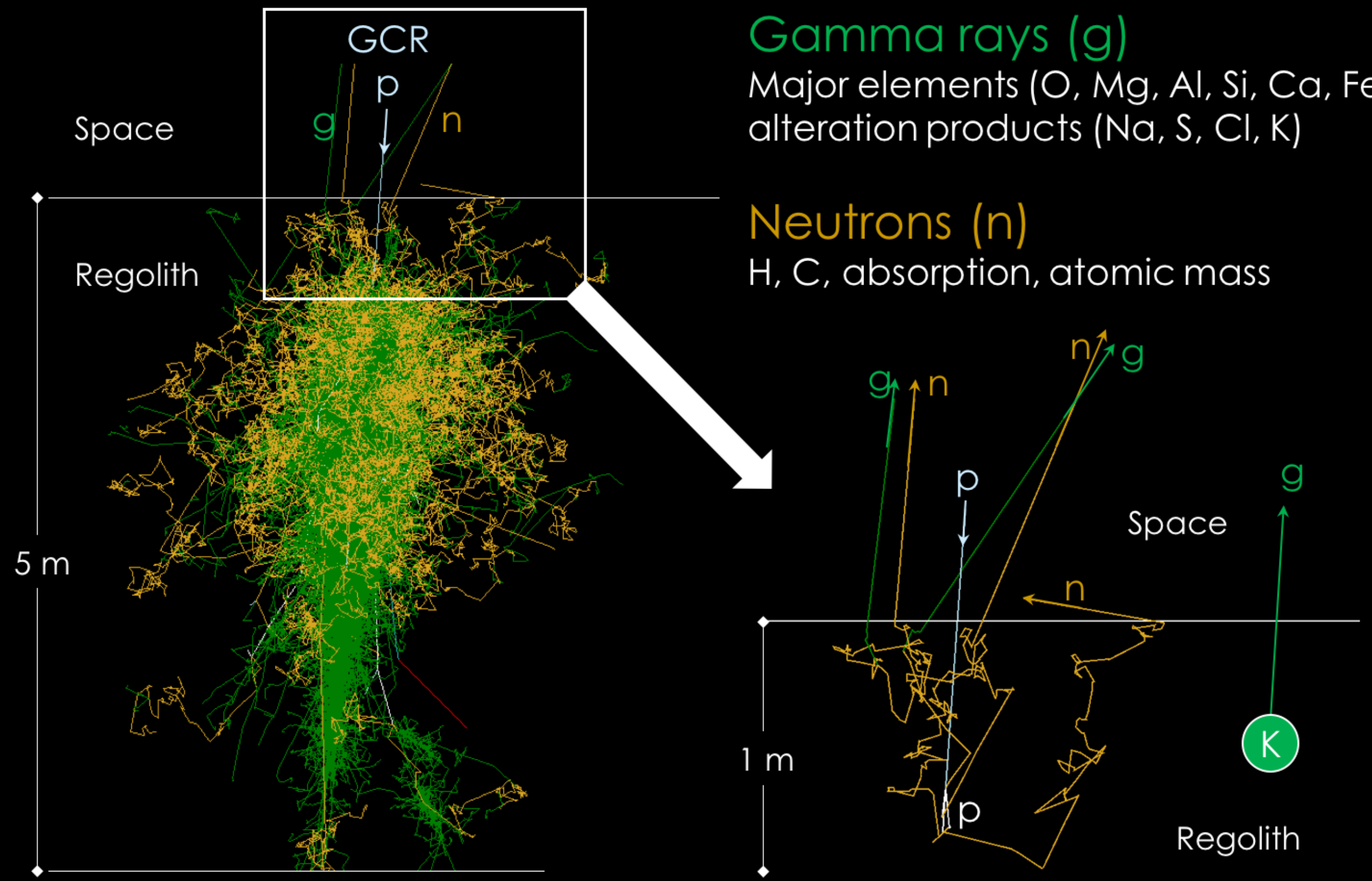


- NASA SMD SIMPLEx 2015 mission led by ASU
- 6U+ CubeSat form factor to launch on SLS EM-1
- **Science Objective**: Map hydrogen enrichments within PSRs at the lunar south pole
- **Tech Objectives**: Demonstrate neutron spectroscopy, deep space operations & propulsion from a small sat

LUNAH-MAP
Lunar Polar Hydrogen Mapper



Neutron Detection Physics



T. H. Prettyman, 2016

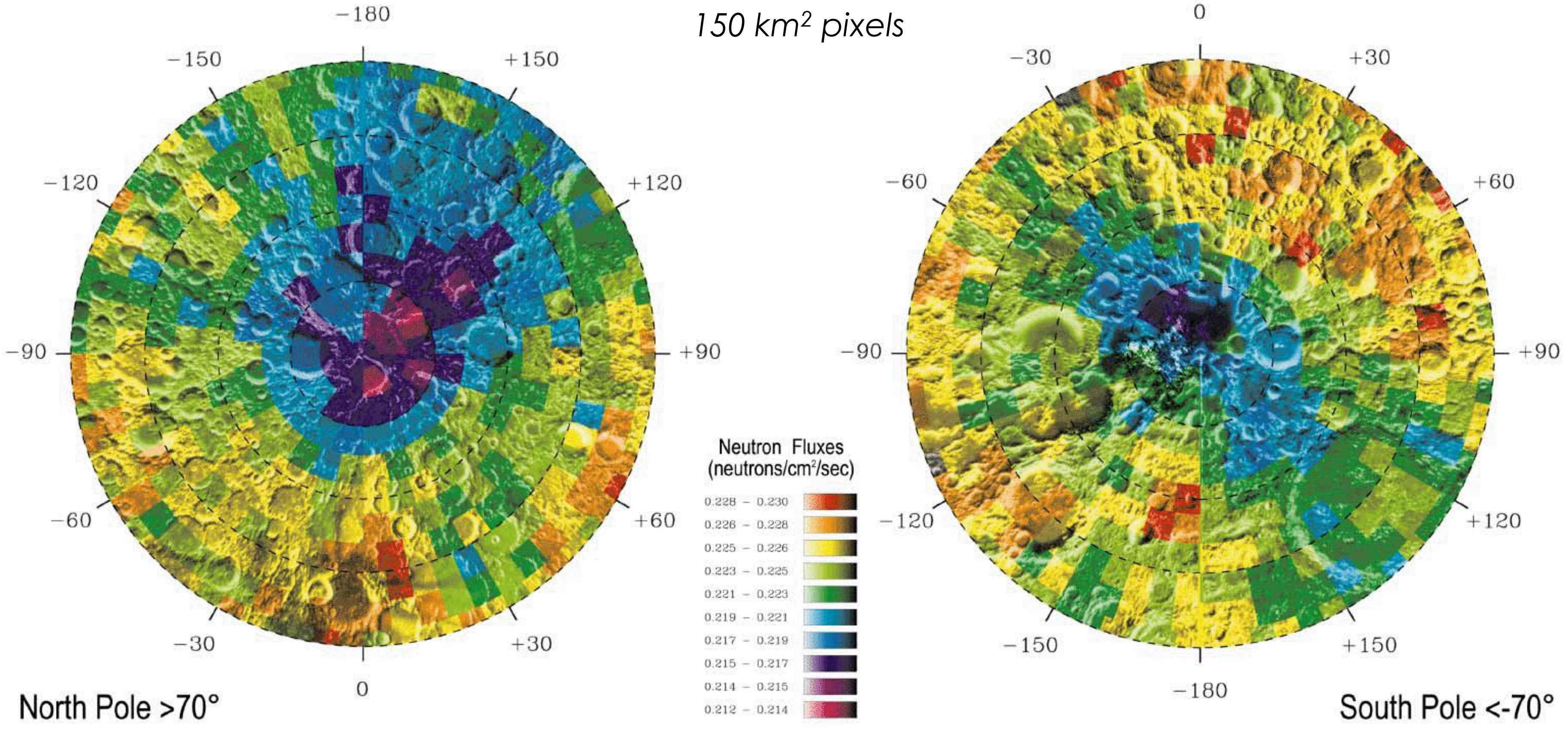
Gamma rays (g)

Major elements (O, Mg, Al, Si, Ca, Fe), alteration products (Na, S, Cl, K)

Neutrons (n)

H, C, absorption, atomic mass

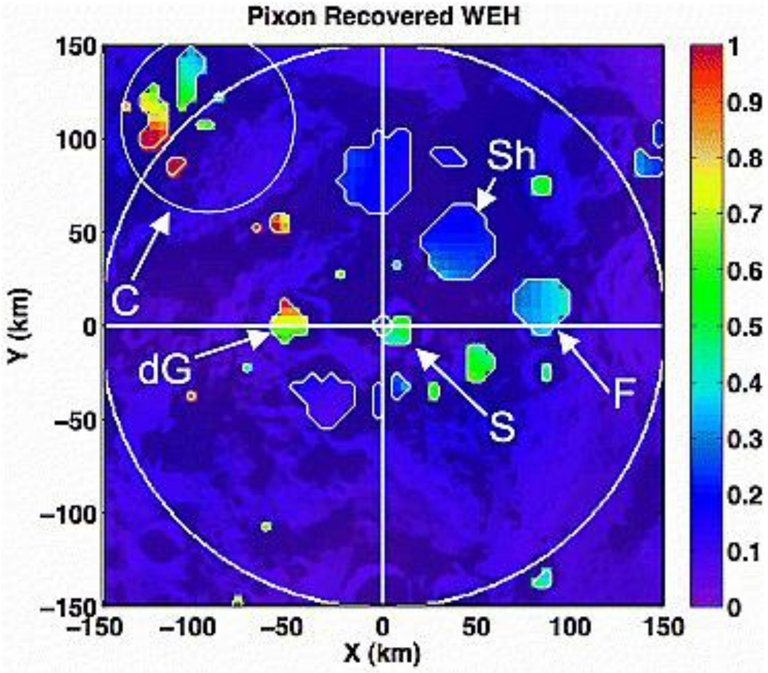
Polar Volatile Distributions from Neutron Spectroscopy



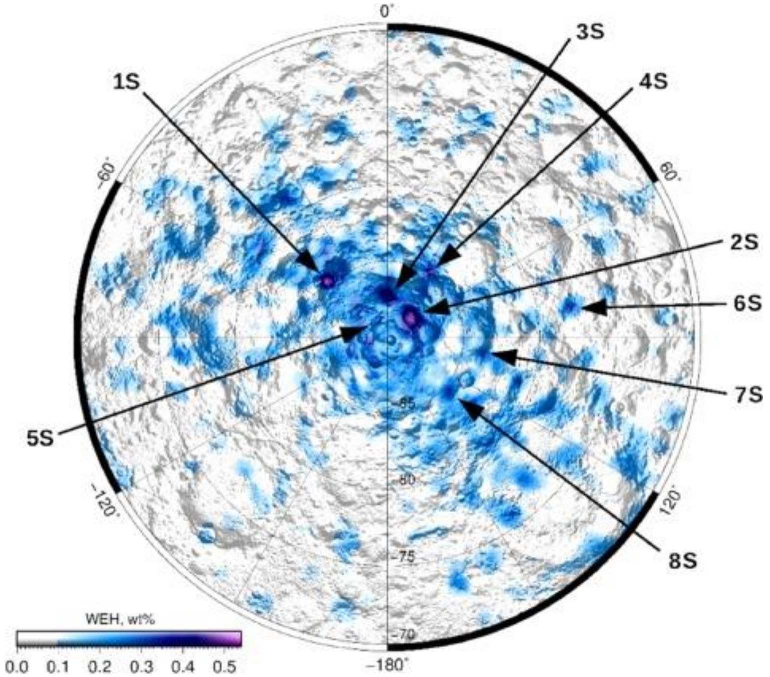
*Feldman et al., Science, 281, 1496, 1998

- Neutron measurements are sensitive to **bulk** hydrogen distributions at 1 meter depth
- Uncollimated neutron detector 'footprints' are approximately 1½ times orbital altitude
- Lunar hydrogen abundances within PSRs broadly ranging from 200 ppm up to almost 40 wt% could be consistent with LPNS data depending on spatial distribution, extent of coverage, and burial depth [Lawrence et al 2006].

Lunar Neutron Spectroscopy



35 km^2 pixels

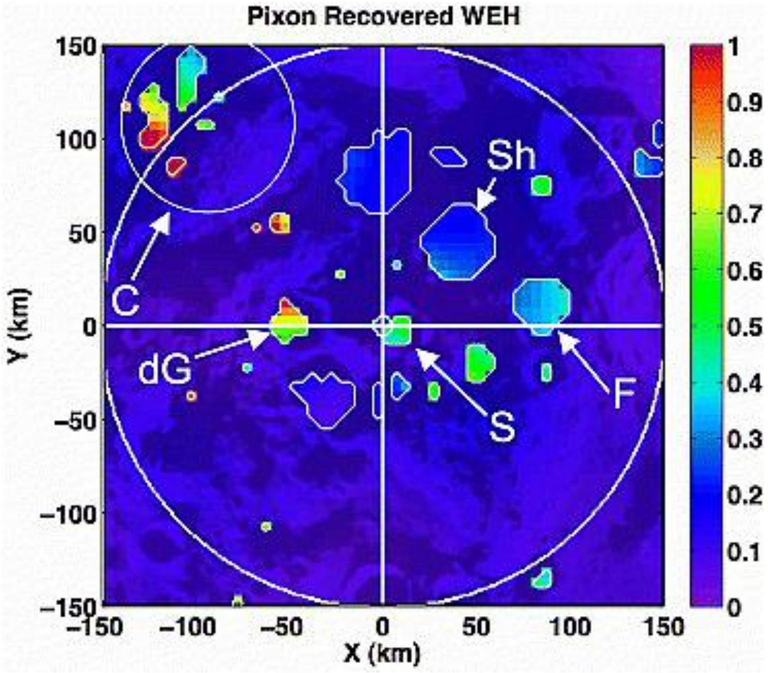


15 km^2 pixels

Pixon-based reconstruction of LPNS data (Elphic et al 2007) reveals high WEH abundances in Cabeus (near 1 wt%) and lower abundances in Shoemaker, Haworth, and Faustini (~0.3 wt%)

Analysis of LEND data (Sanin et al 2017) reveals higher WEH abundances (~0.5 wt%) in south polar craters Shoemaker, Haworth, and Faustini

Lunar Neutron Spectroscopy



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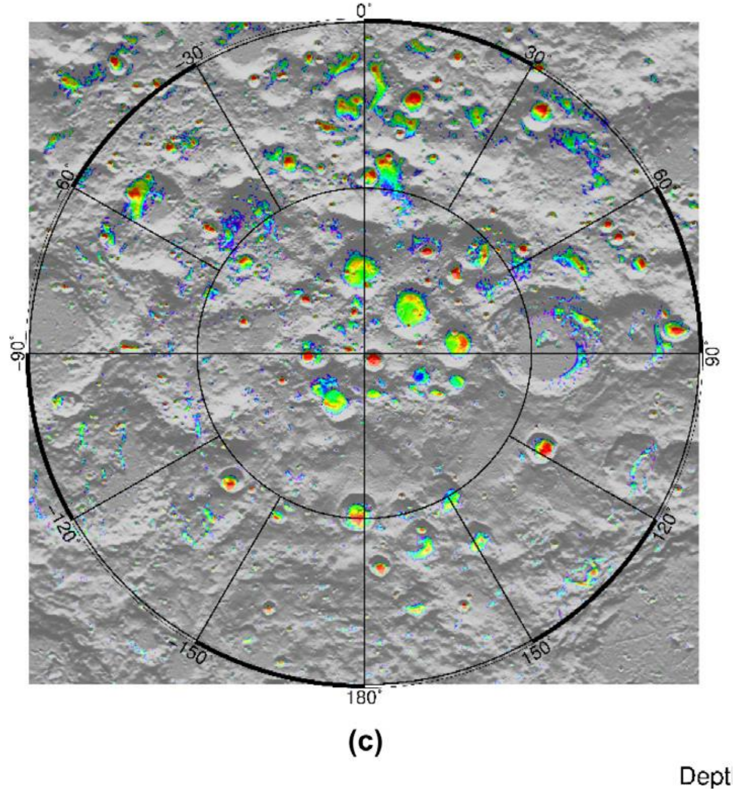
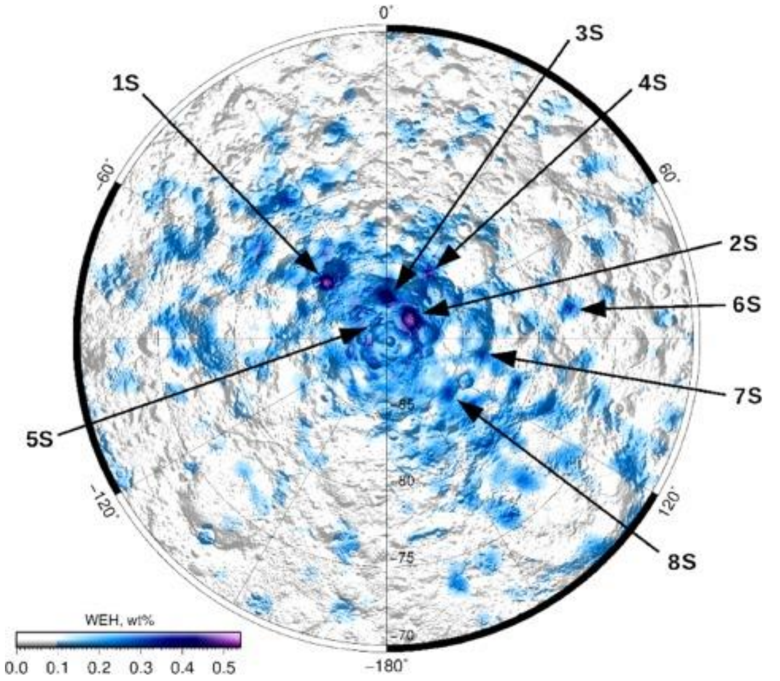


Figure 1 Map of current day ice stability depth from Siegler et al [2015] as used in constraint map development



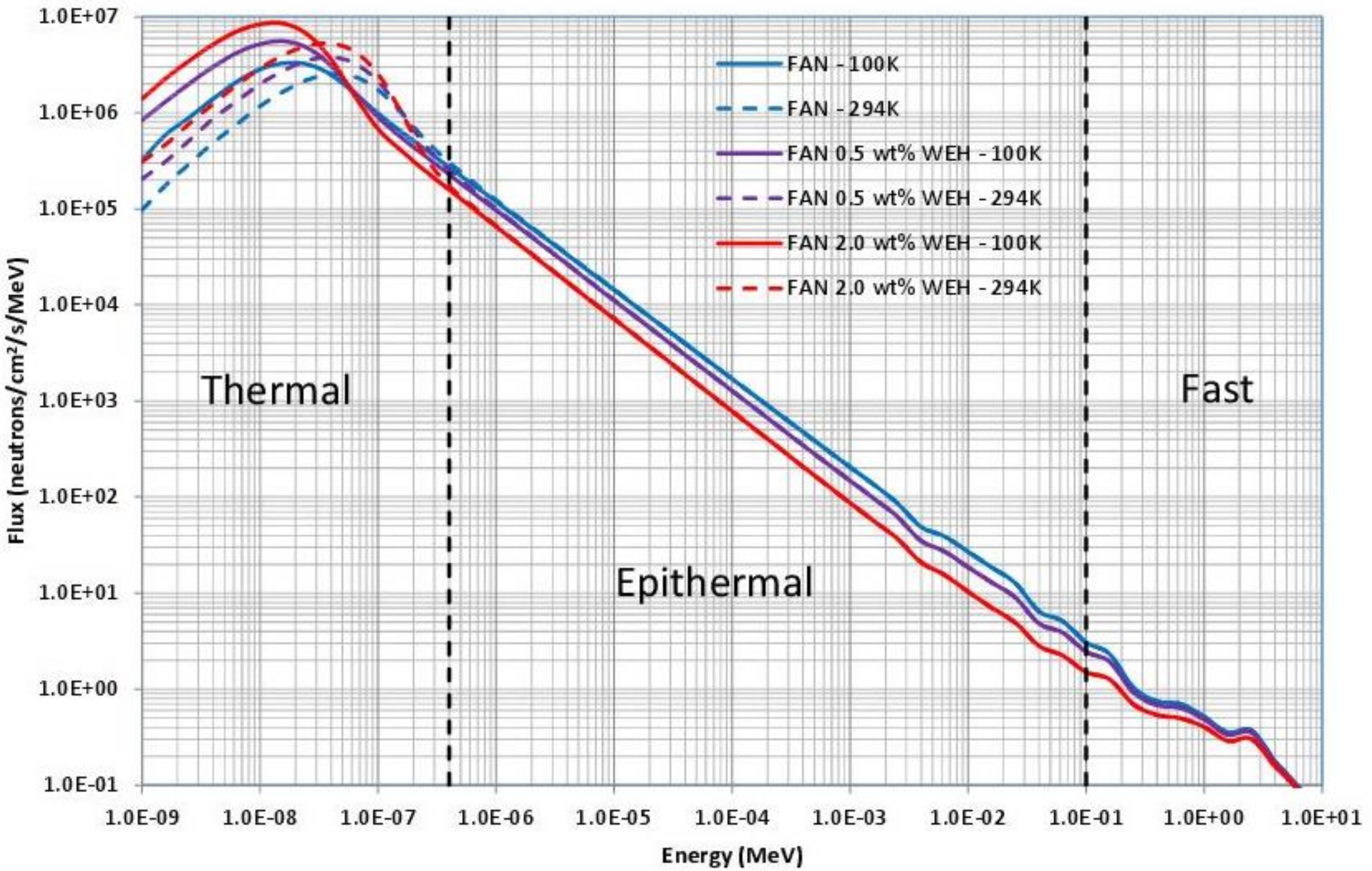
Analysis of LEND data (Sanin et al 2017) reveals higher WEH abundances (~0.5 wt%) in south polar craters Shoemaker, Haworth, and Faustini

Neutron Measurements of the Moon

- Low-altitude (< 20 km) uncollimated measurements of lunar neutrons can be used to:
  - Determine the bulk hydrogen content and depth *within* PSRs (Diameter < ~35km)
- These data can be used to constrain:
  - Sources and sinks for polar volatiles

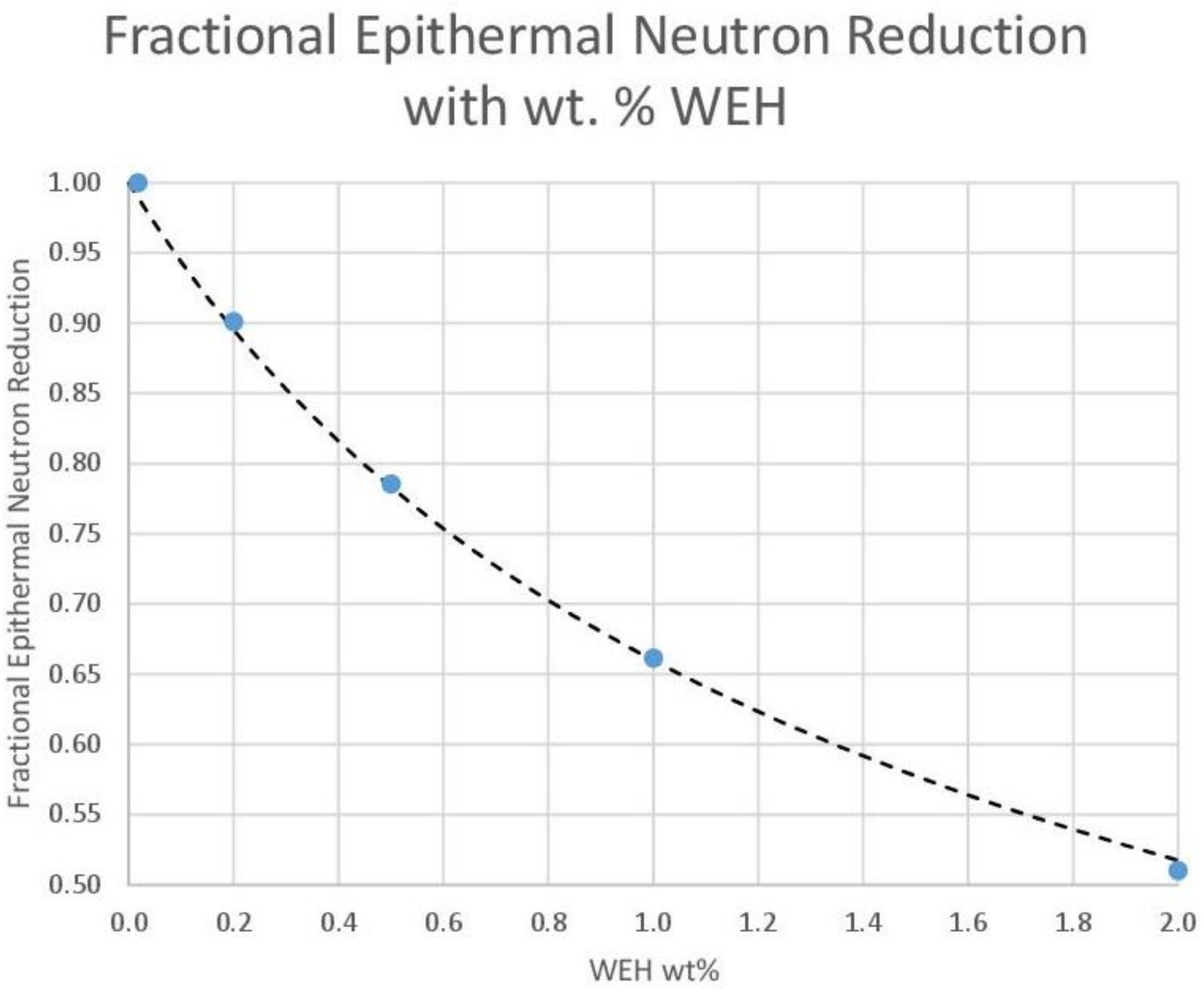
- LunaH-Map measures *only* epithermal neutrons:
  - Using a large (200 cm^2) detector array
  - To constrain abundance of hydrogen within PSRs
  - To provide complementary data to LP-NS and LRO LEND

FAN Neutron Energy Spectrum



Increased hydrogen suppresses epithermal neutrons (E > 0.4 eV) and increases thermal neutrons (E < 0.4 eV)

LunaH-Map's *signal* is the difference between **dry** epithermal count rate and **enriched** epithermal count rate



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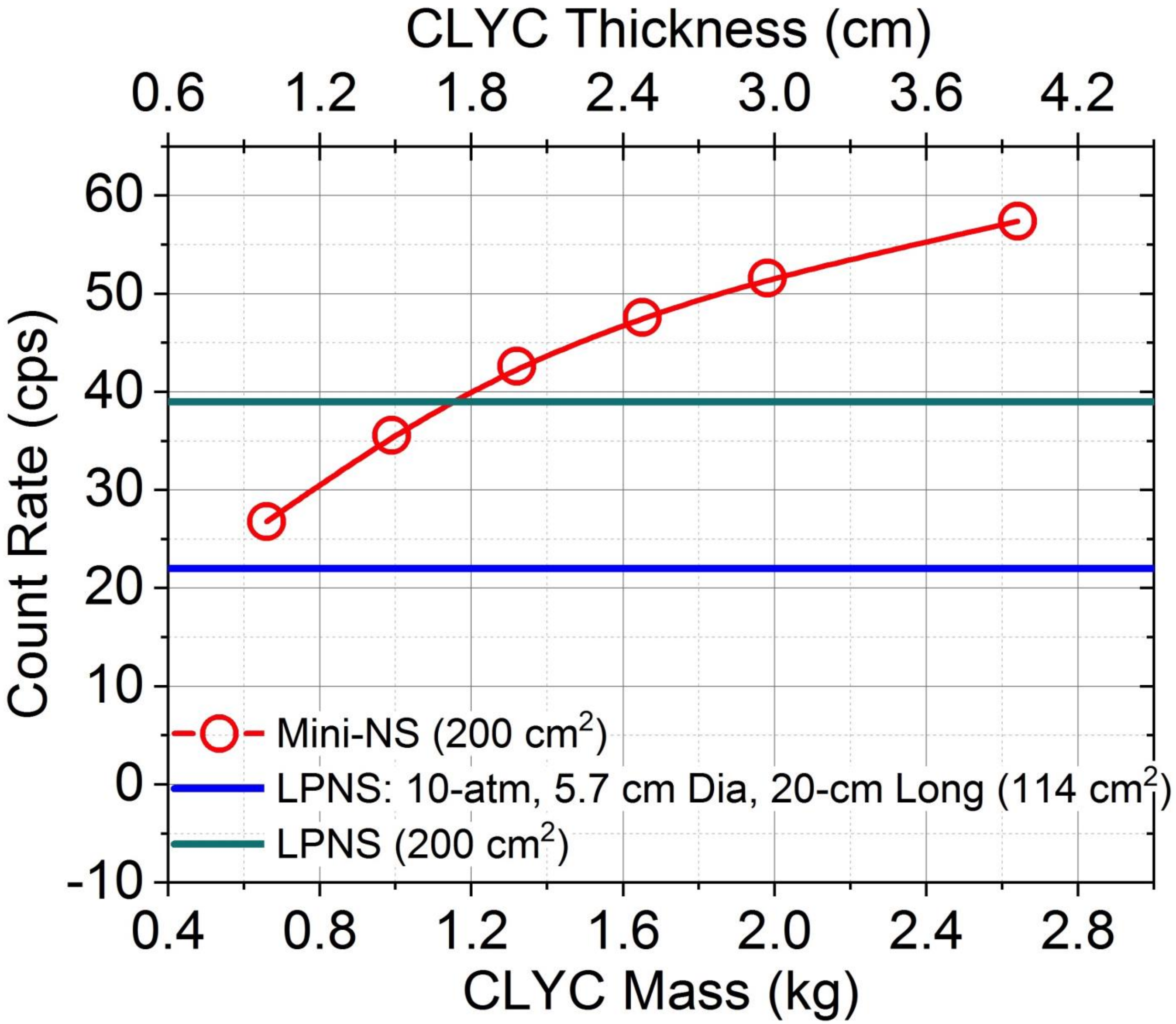

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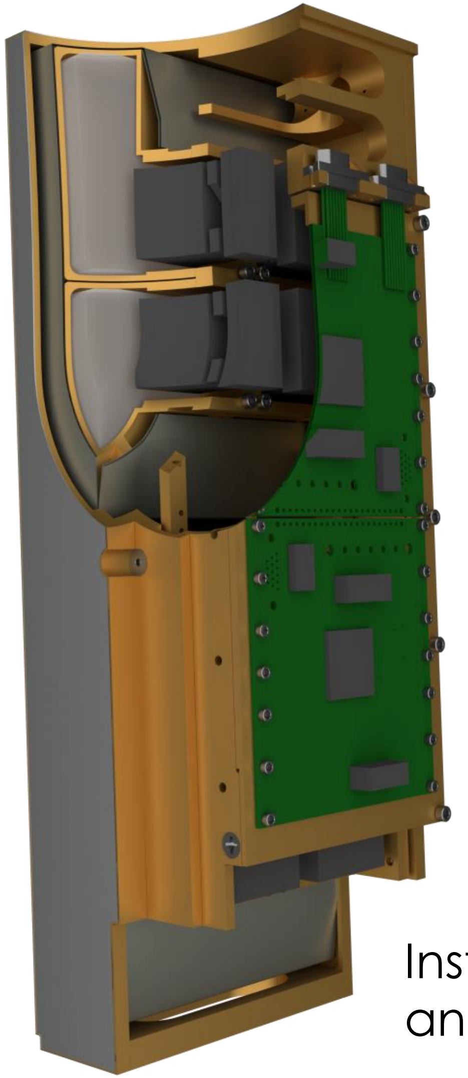
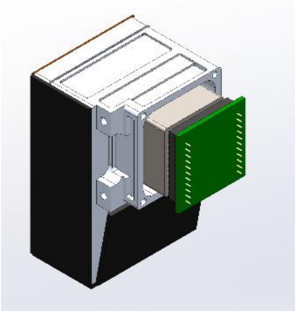
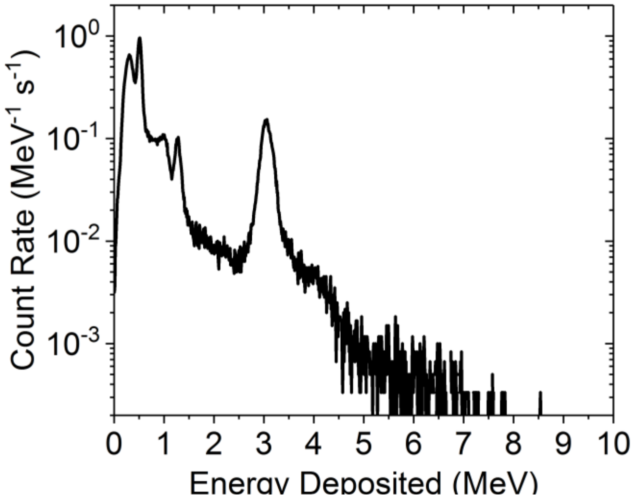
Miniature Neutron Spectrometer

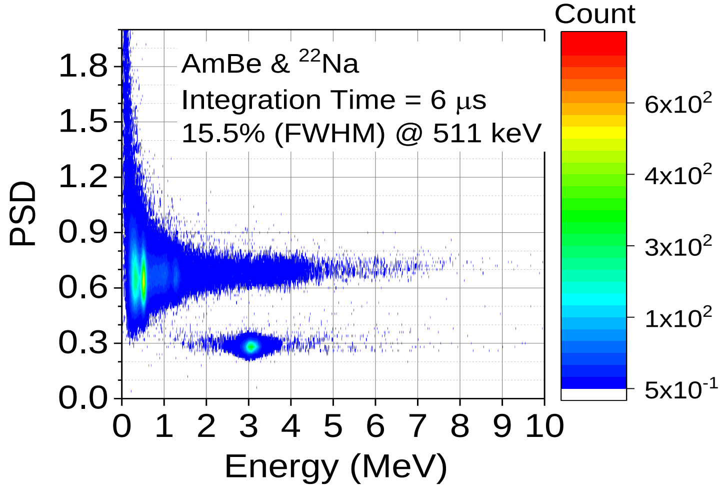


Instrument Housing and Electronics



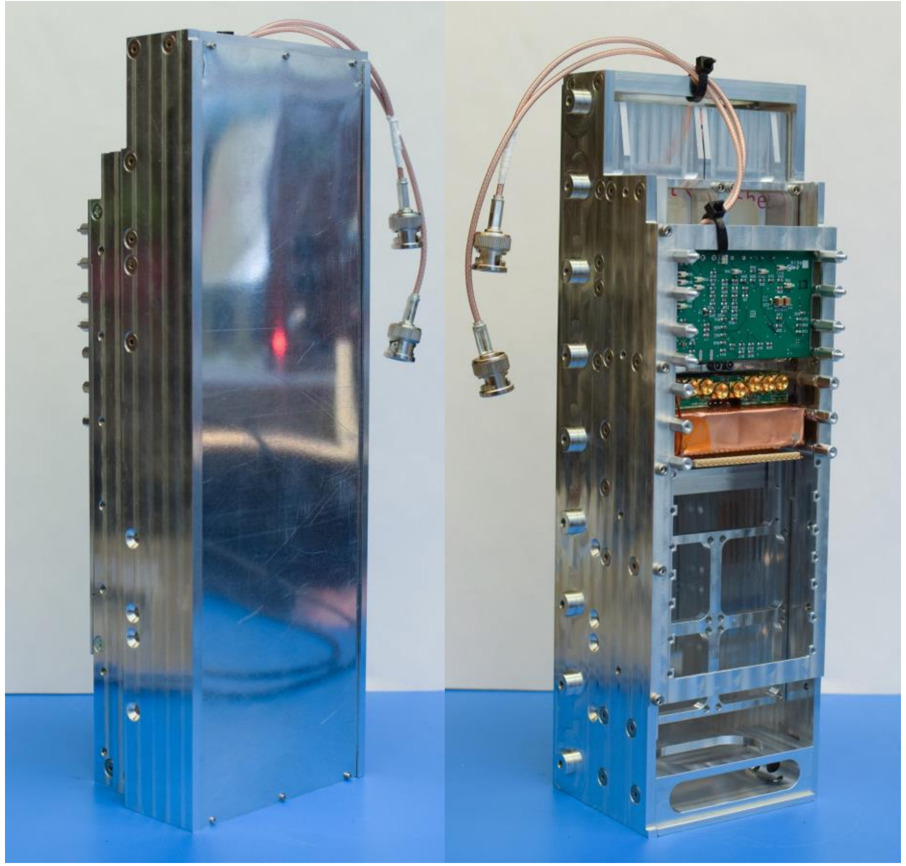
CLYC Module

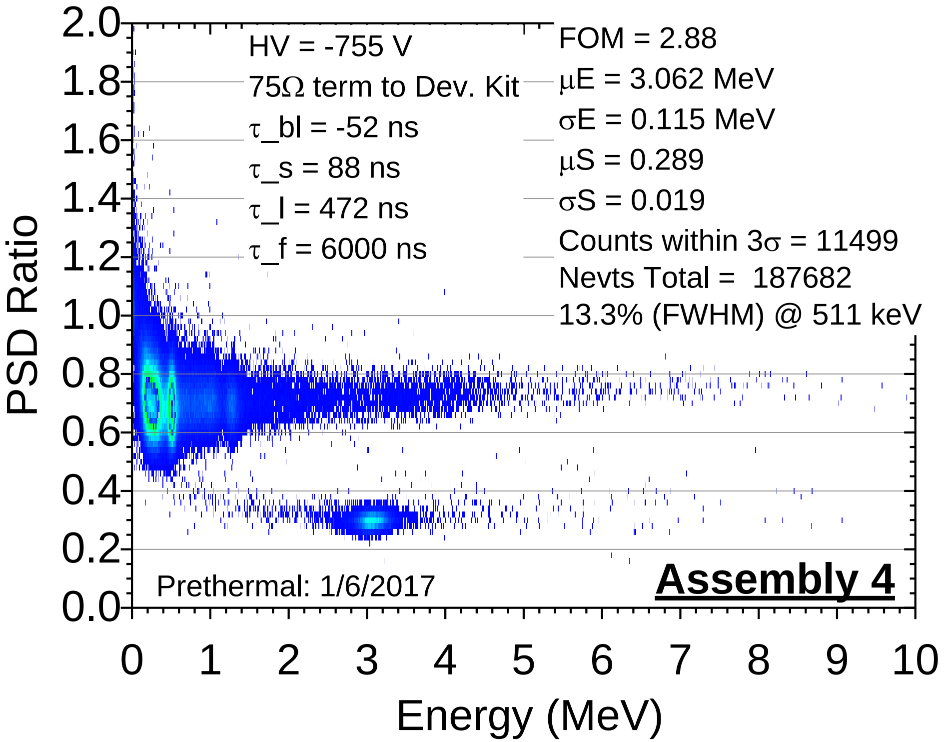




Detector	2x4 array of CLYC (elpasolite scintillator, Cs_2LiYCl_6:Ce) crystals, each crystal 4 cm x 6.3 cm x 2 cm
Dimensions	25 cm x 10 cm x 8 cm
Mass	3.3 kg
Power	10W (min), 22W (max)
Data Acquisition	Counts binned every 1 sec

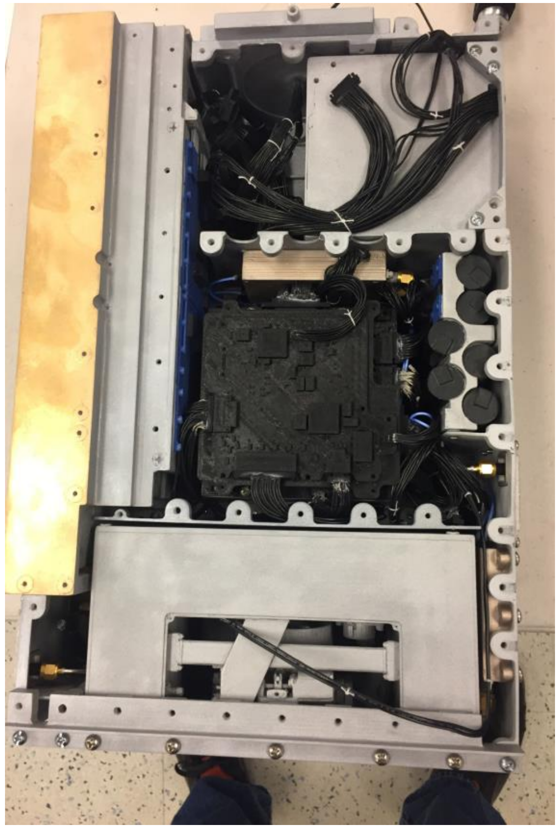
Mini-NS EDU





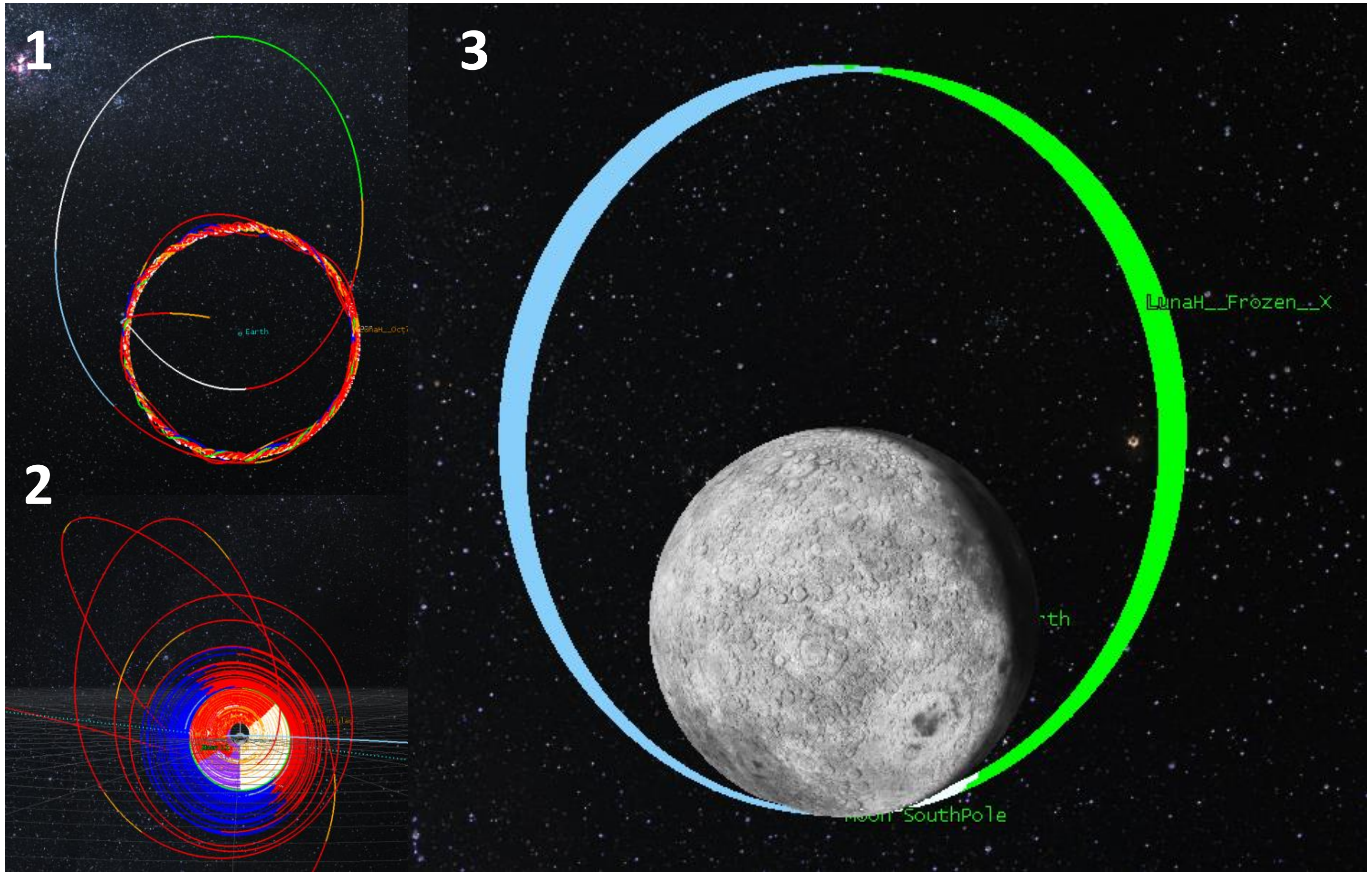
Test results from single EDU module exposed to Na-22 and AmBe

Mini-NS Flight Unit and Calibration



- Flight instrument chassis machined for fit checks in spacecraft EDU at ASU
- Mini-NS Flight Unit delivery in early summer 2017
- Mini-NS Flight Unit calibration at Los Alamos National Lab Neutron Free In-Air (NFIA) facility in late summer

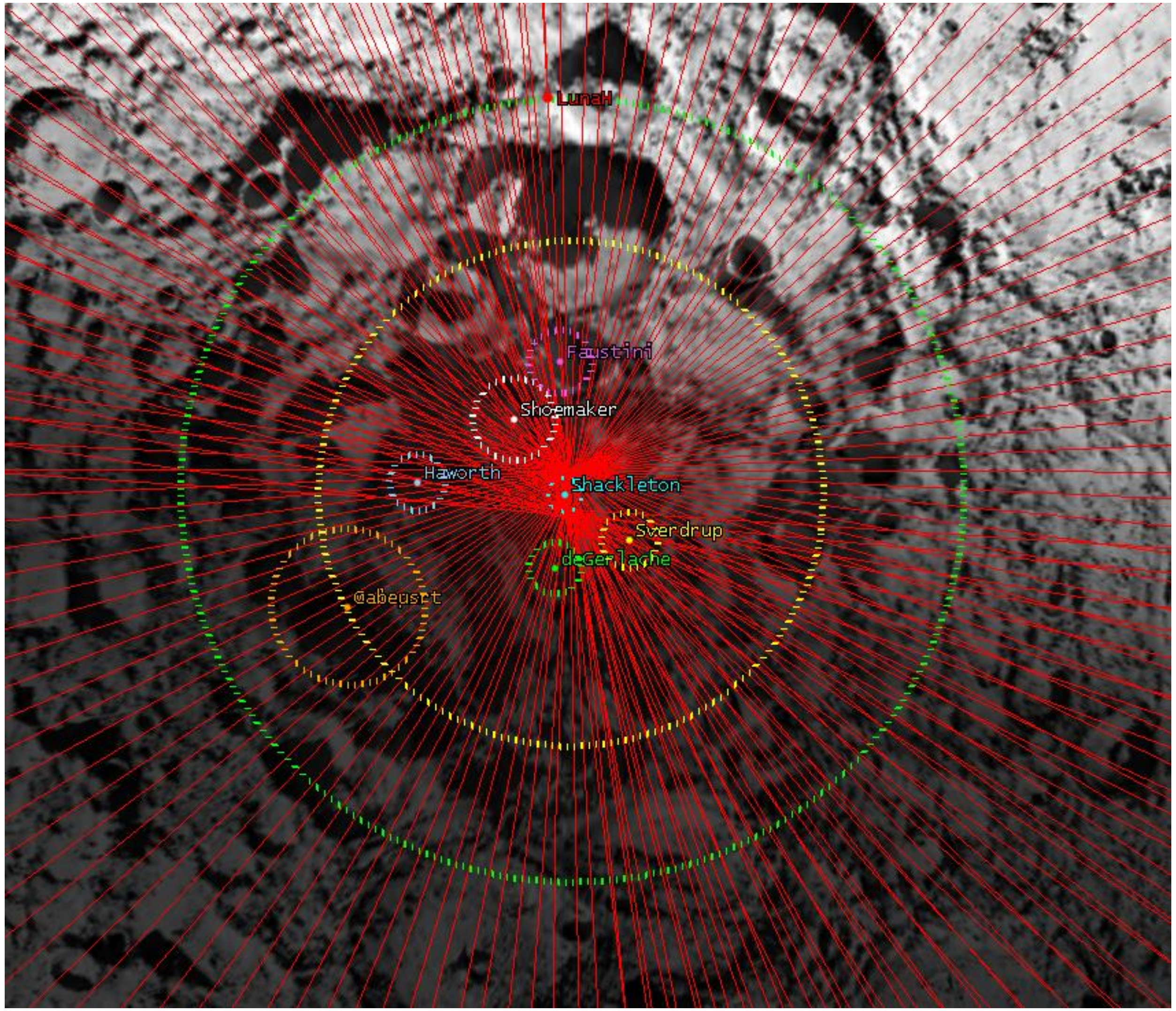
Trajectory Design



Period	4.76 hour
Aposelene Altitude	3150 km
Periselene Altitude	RAAN dependent 15-25 km
Inclination	90°
Argument of Periselene	273.5°

Genova, A. L. and Dunham, D. W. (2017) 27th AAS/AIAA Space Flight Mechanics Meeting 17-456.

Science Phase



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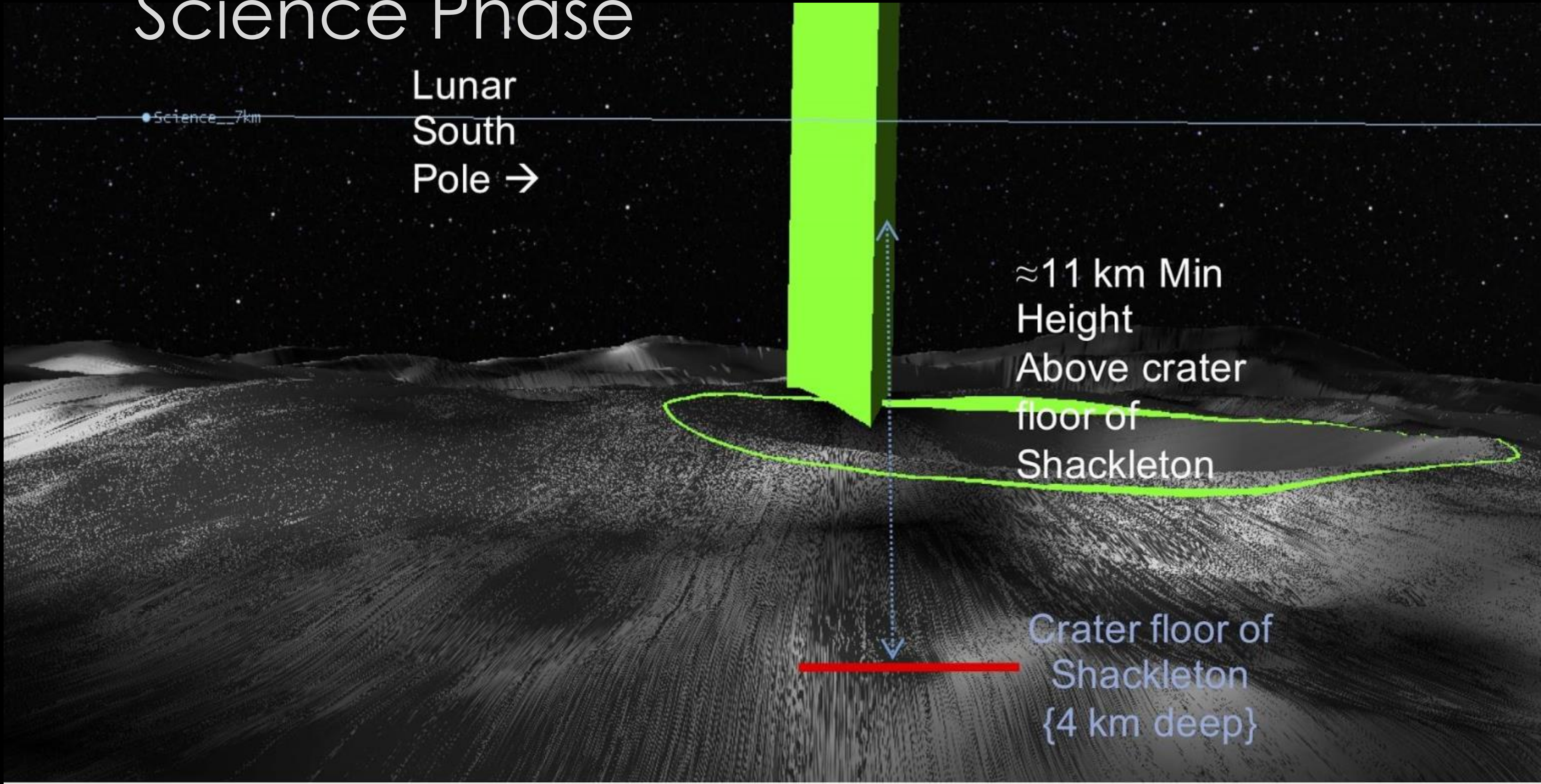
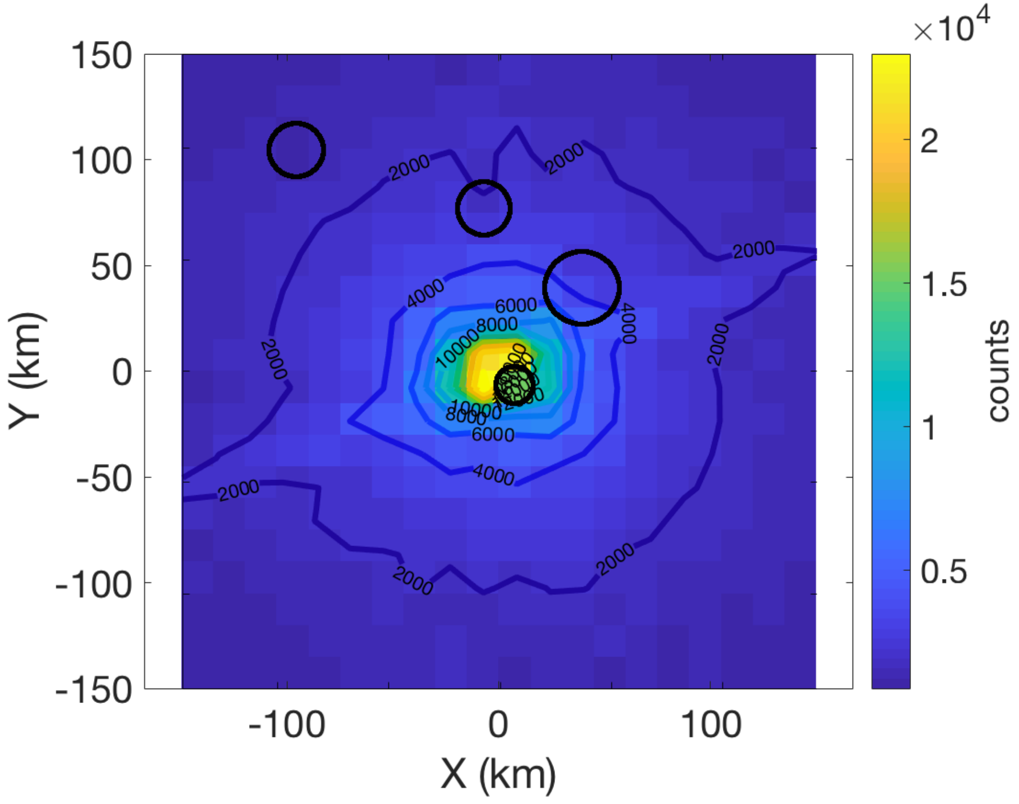
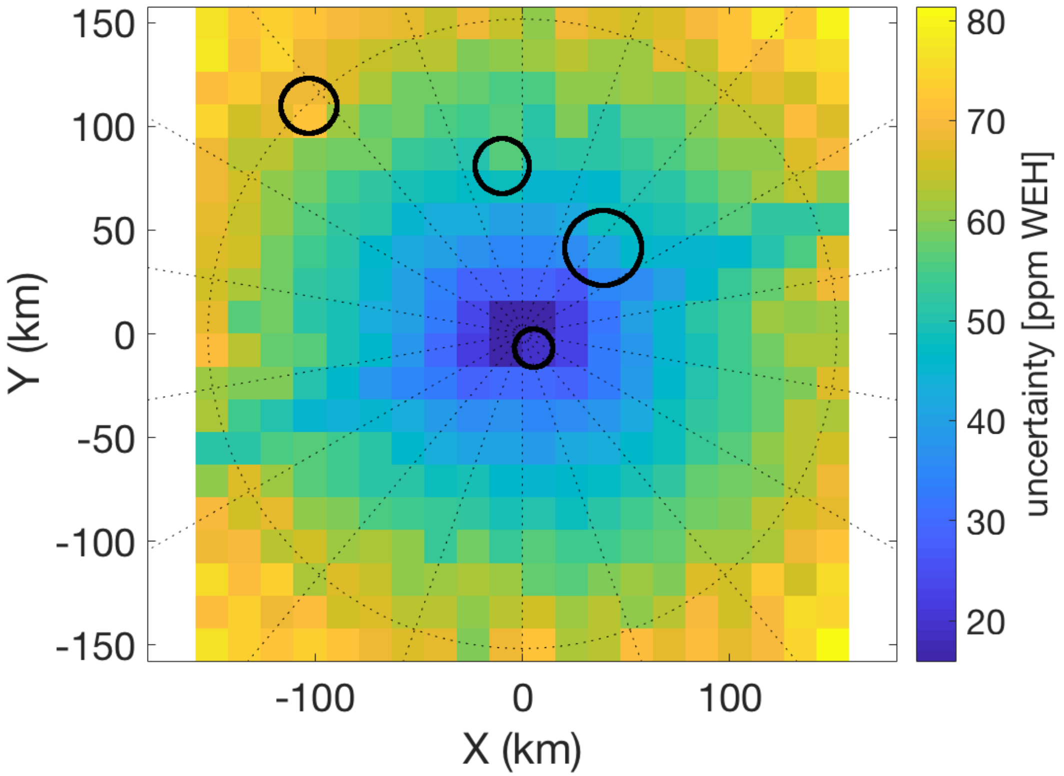


LunaH-Map Sensitivity

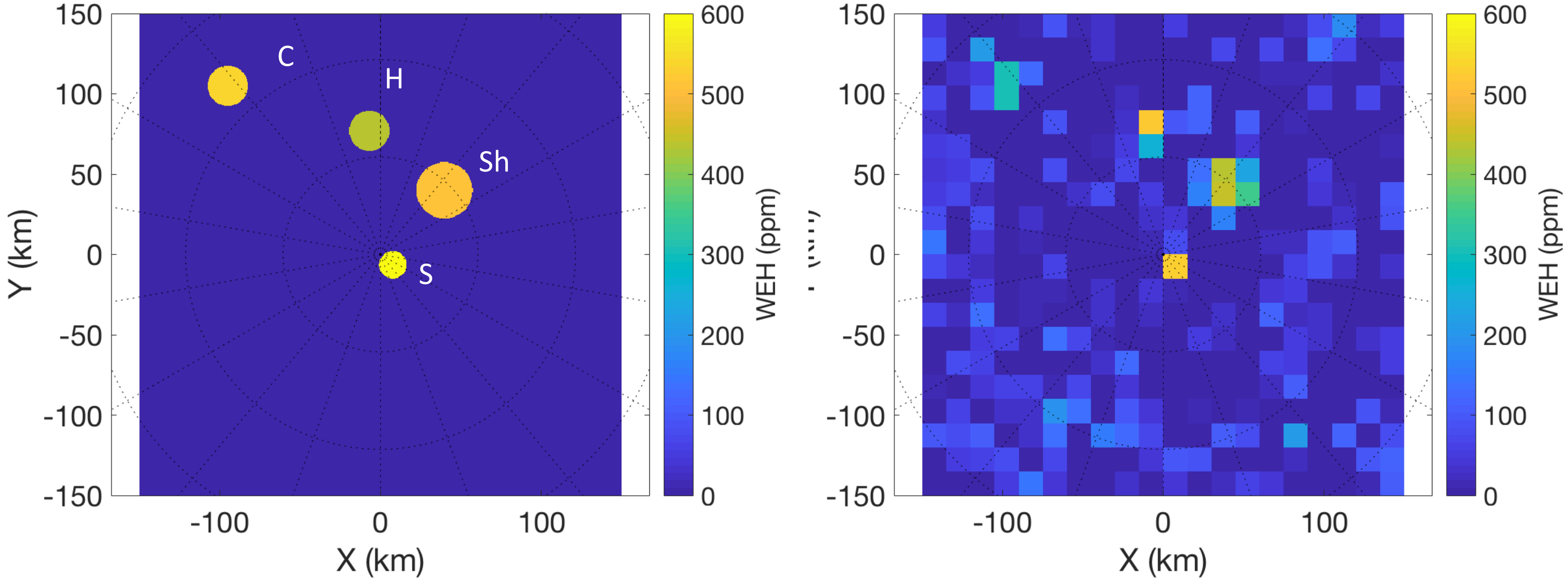




Enrichments of 600 ppm +/- 120 ppm WEH are detectable for ~94% of the surface poleward of 85°S in spatial bins of 15km x 15km.

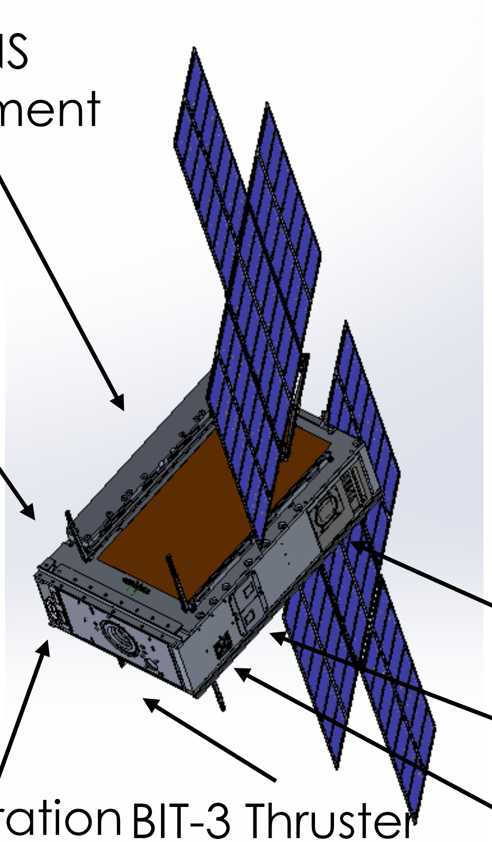
South Polar Volatile Mapping

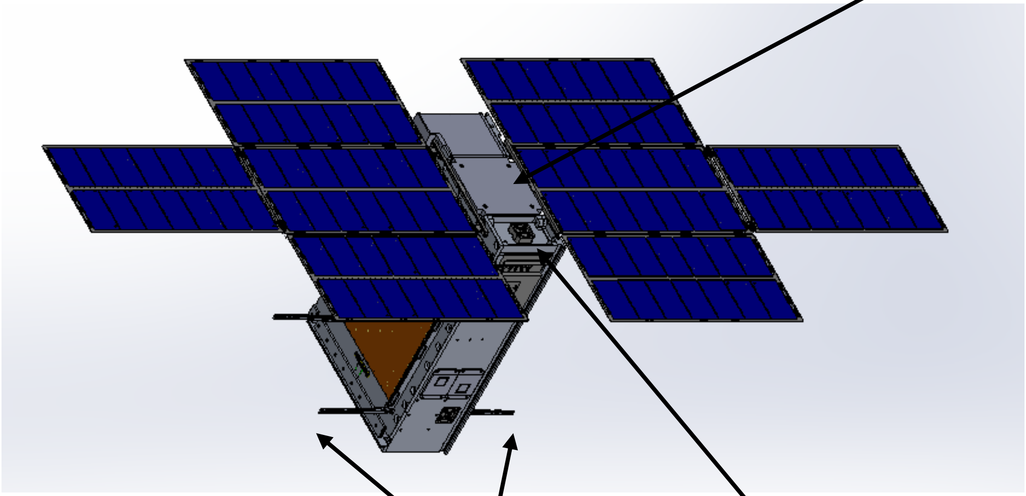
LUNAH-MAP
Lunar Polar Hydrogen Mapper



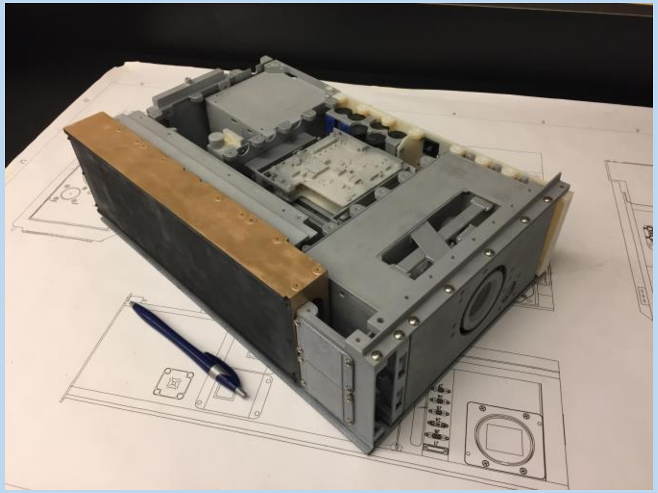
Simulations of maps made from 15x3150km science orbit. Basemap combines LEND high H regions (Sanin et al., 2017) and the Shackleton enrichment from pixon-reconstructed LPNS data (Elphic et al, 2007) to illustrate the type of map LunaH-Map will be able to create.

LunaH-Map Spacecraft



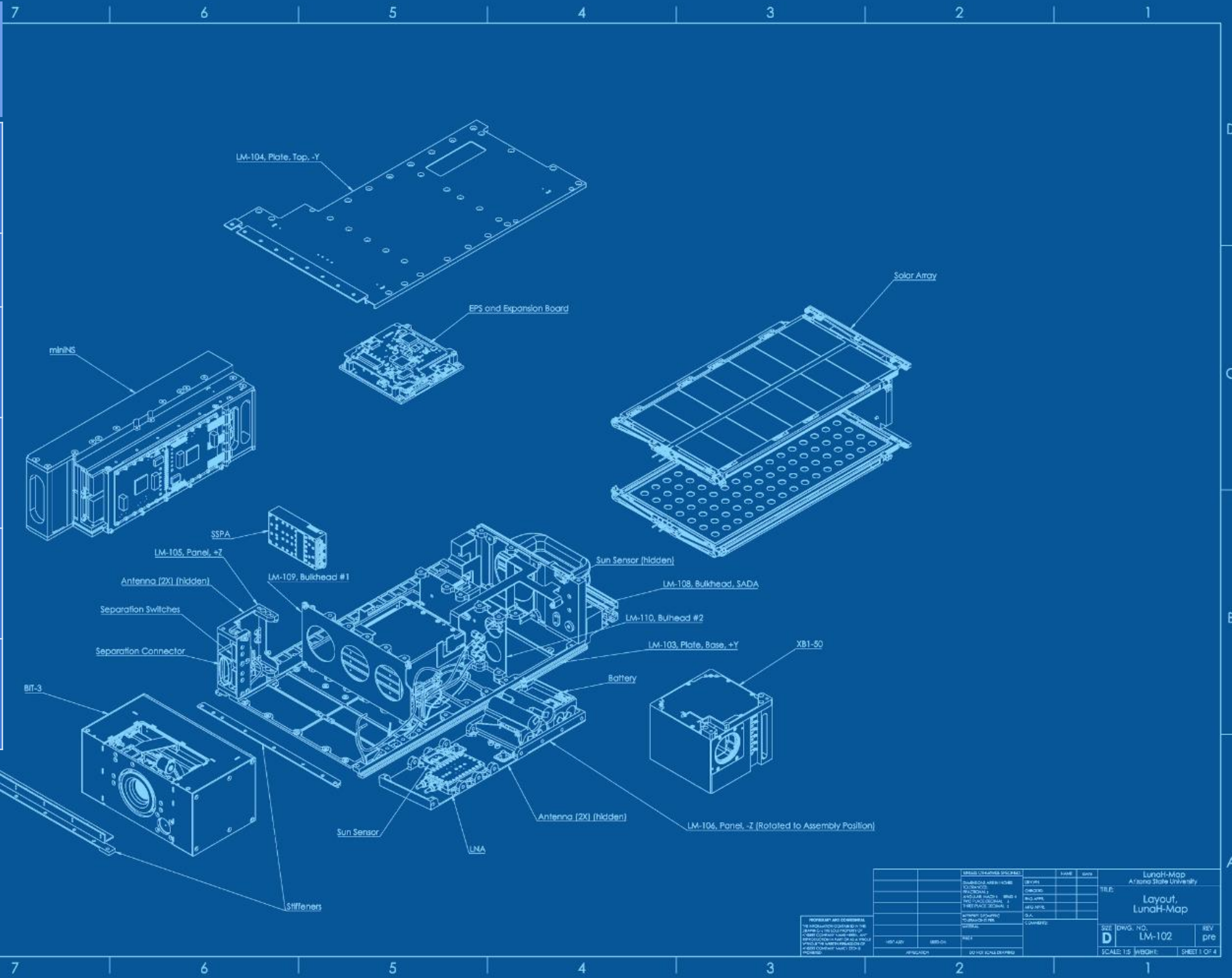


1:1 3D Printed Model of
LunaH-Map Flight System

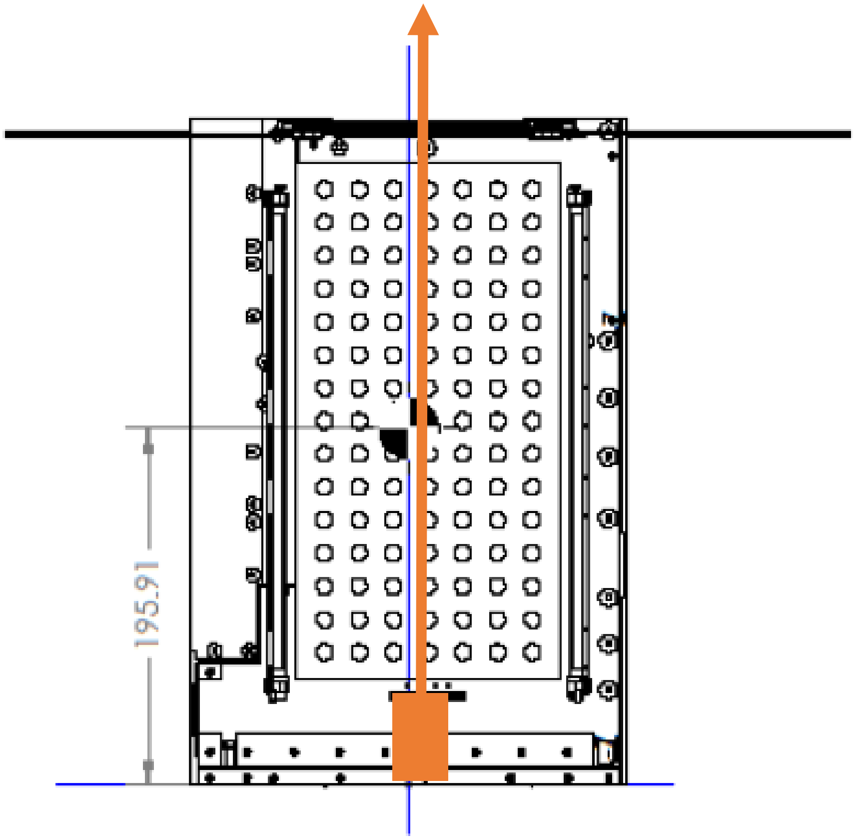


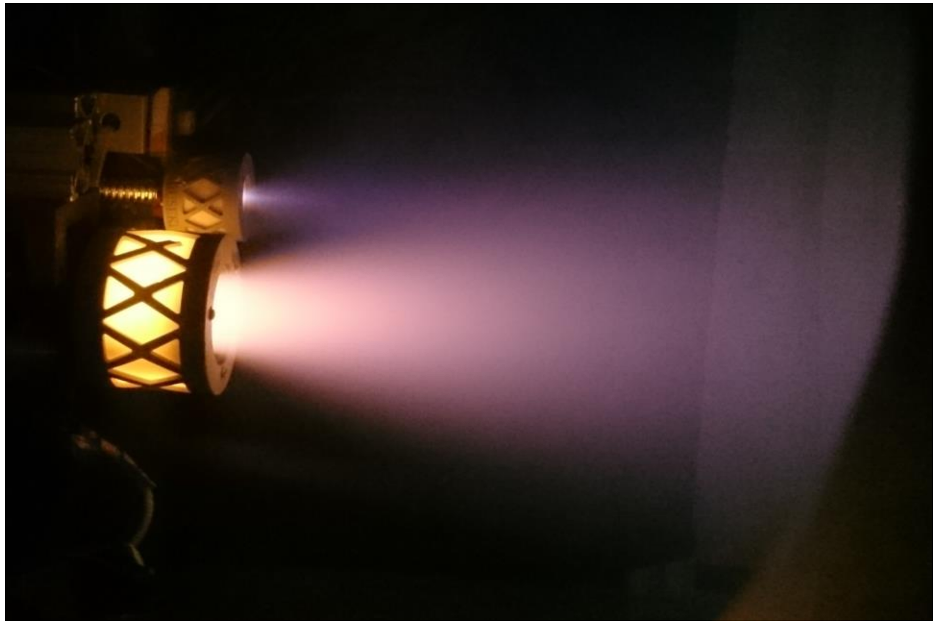
Spacecraft Specs

Dimensions: (stowed)	10x20x30cm
Mass	14 kg
Power	90W BOL 56W-hr Battery
Propulsion	Busek BIT-3 Ion Thruster
Comm.	JPL Iris Deep Space Transponder
C&DH / GN&C	BCT XB1-50



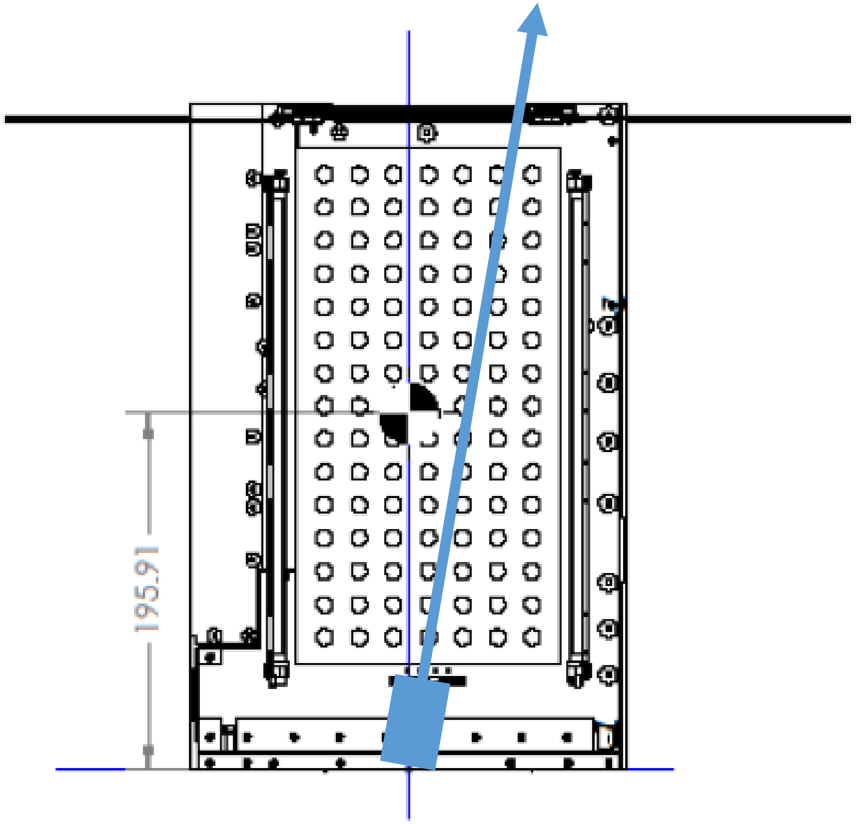
Propulsion

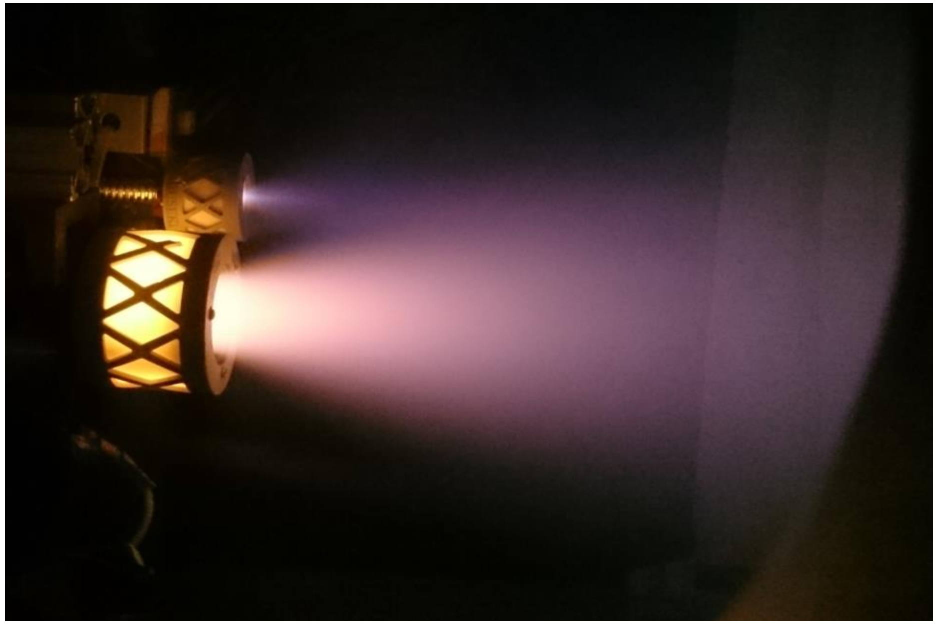




- Busek BIT-3 ion thruster
- Iodine propellant
- 10° gimbal for momentum management

Propulsion





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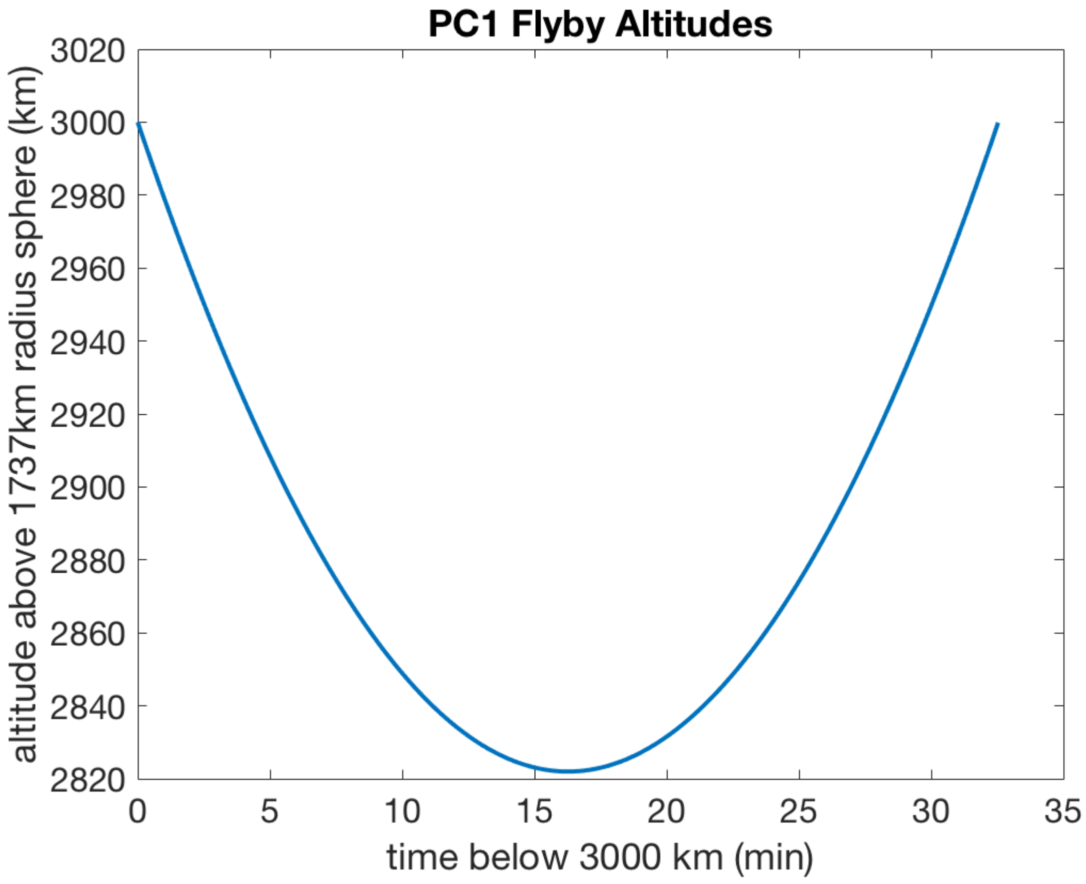
PC1 – Instrument Qualification

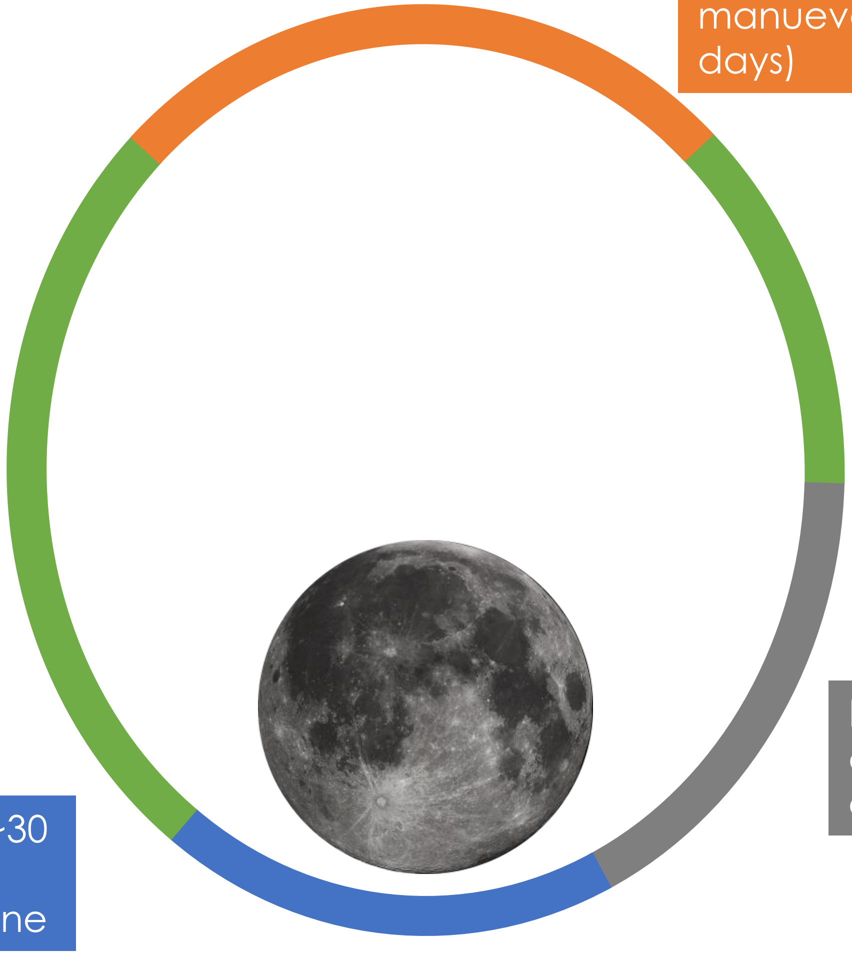
During first lunar flyby, LunaH-Map will observe the lunar neutron count rate of ~3.15 cps at the PC-1 flyby altitude of ~2800 km.

LunaH-Map is below 3000 km altitude for >30 minutes. The predicted epithermal neutron count rate of 3.15 cps can be measured to +/-0.04 cps.

Demonstrate Mini-NS operation in the lunar environment



Day in the Life - Science



Mission/Science Operations

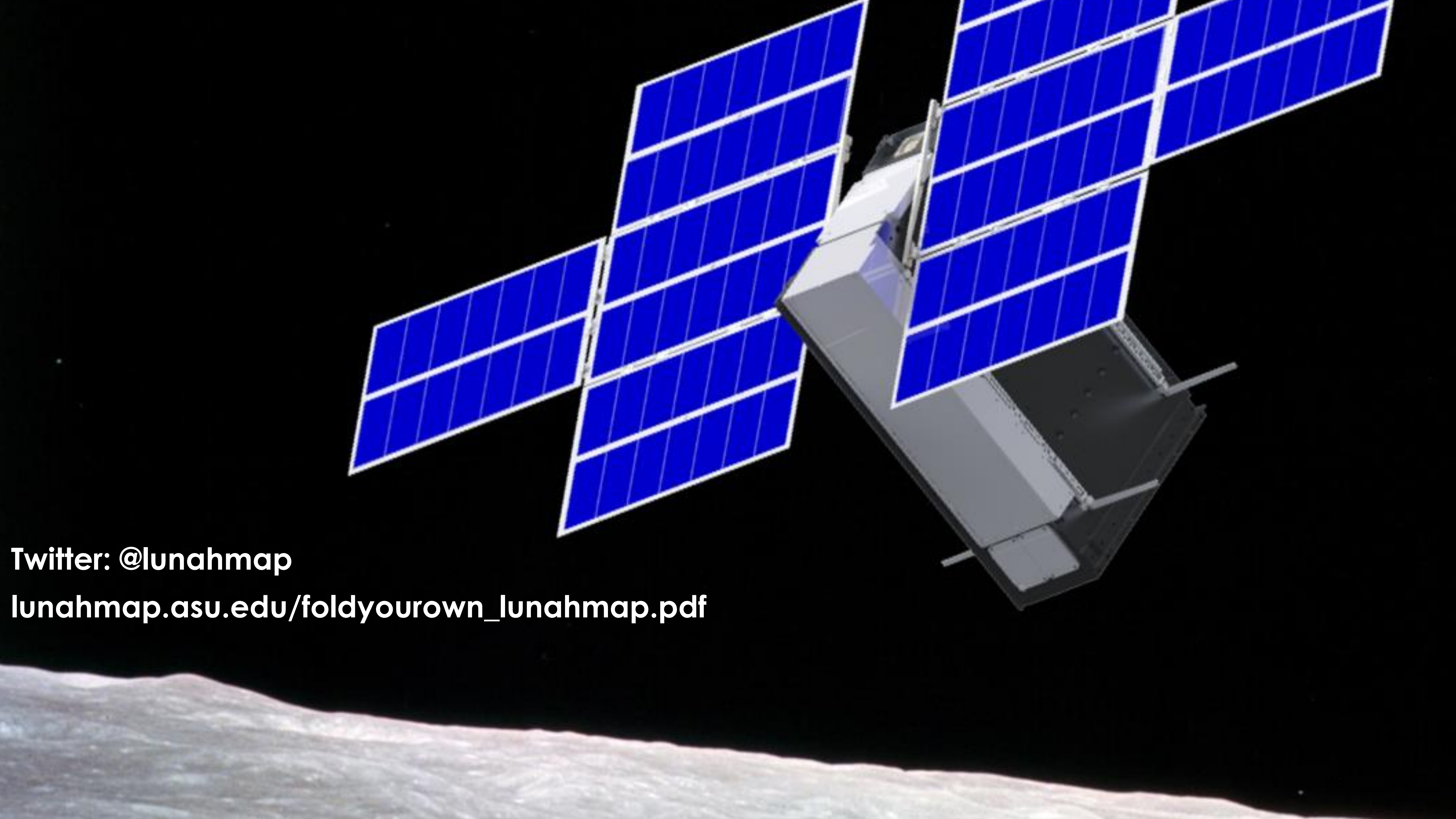
- Co-located in ASU’s shared operations facility
- JPL AMMOS/AMPCS for uplink and downlink
- Science/instrument ops heritage from MER, LROC, and MSL
- Science/instrument ops development coincident with Mars 2020 and Psyche missions

Road to Launch

- Critical Design Review – Completed June 29, 2017
- Phase 2 Safety Review – August 8, 2017
- Enter Assembly, Integration, and Test – Q4 2017
  - AI&T Review/Workshop with review board
- Launch – SLS EM-1, December 2019

LunaH-Map Program Milestones to Date		
IAA	11 December 2015	Δ-IAA REQUIRED
Δ-IAA	24 February 2016	PASSED with RFAs
SRR	8 April 2016	PASSED with RFAs
I-PDR	9 June 2016	PASSED with RFAs
Phase 1 SR	21 June 2016	PASSED
M-PDR	25 July 2016	PASSED with RFAs
CDR	29 June 2017	COMPLETED
Phase 2 SR	11 Nov 2017	COMPLETED
Integration Workshop	8 Dec 2017	COMPLETED

Review Board Members: Dr. Andrew Klesh, Jet Propulsion Laboratory (Review Board Chair), Dr. Thomas Werne, JPL, Dr. Travis Imken, JPL, Dr. Juergen Mueller, JPL, Dr. Eric Gustafson, JPL, Dr. Thomas Prettyman, Planetary Sciences Institute, Dr. James Bell, Arizona State University, Dr. Jordi Puig-Suari, California Polytechnic State University, Richard Elphic, NASA Ames.



Twitter: @lunahmap

lunahmap.asu.edu/foldyourown_lunahmap.pdf