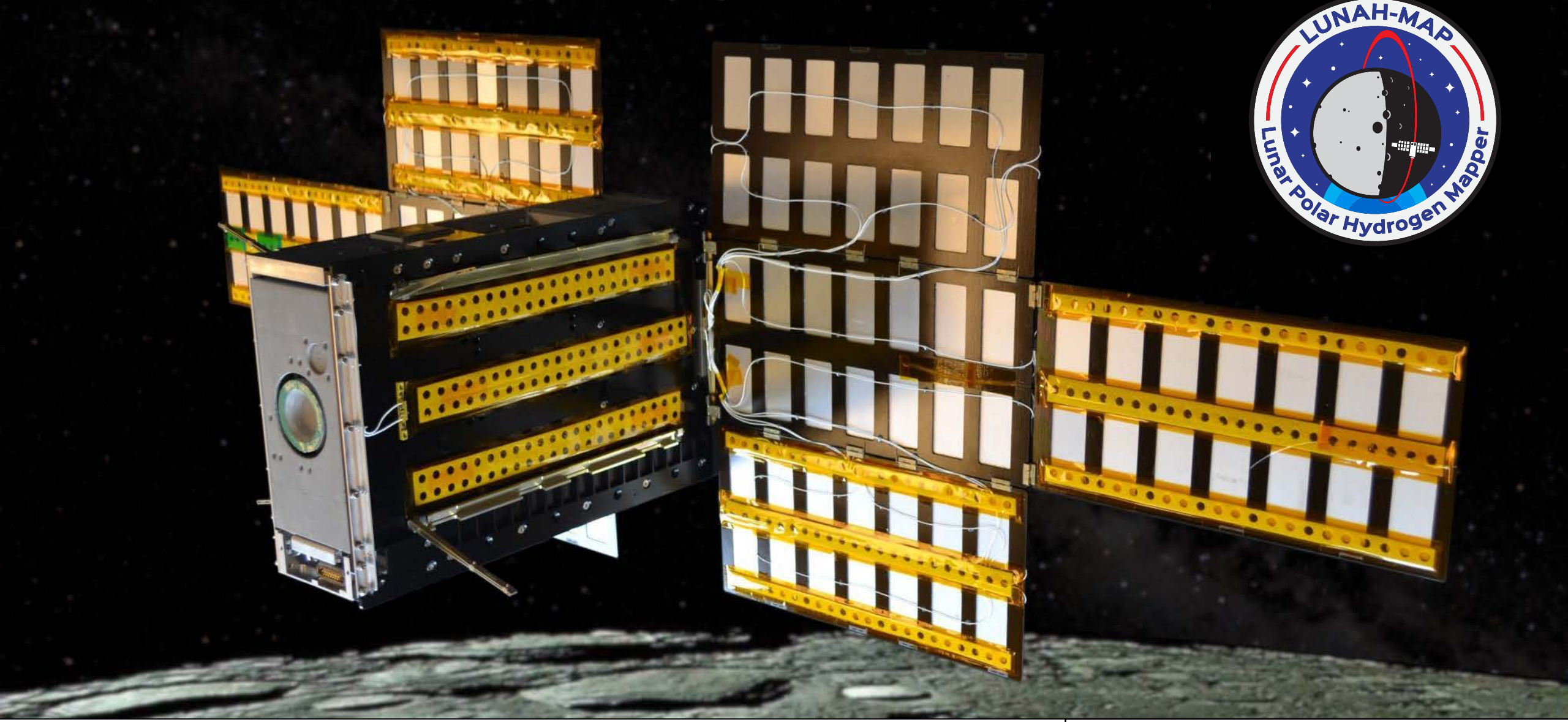


The Lunar Polar Hydrogen Mapper Mission (LunaH-Map)

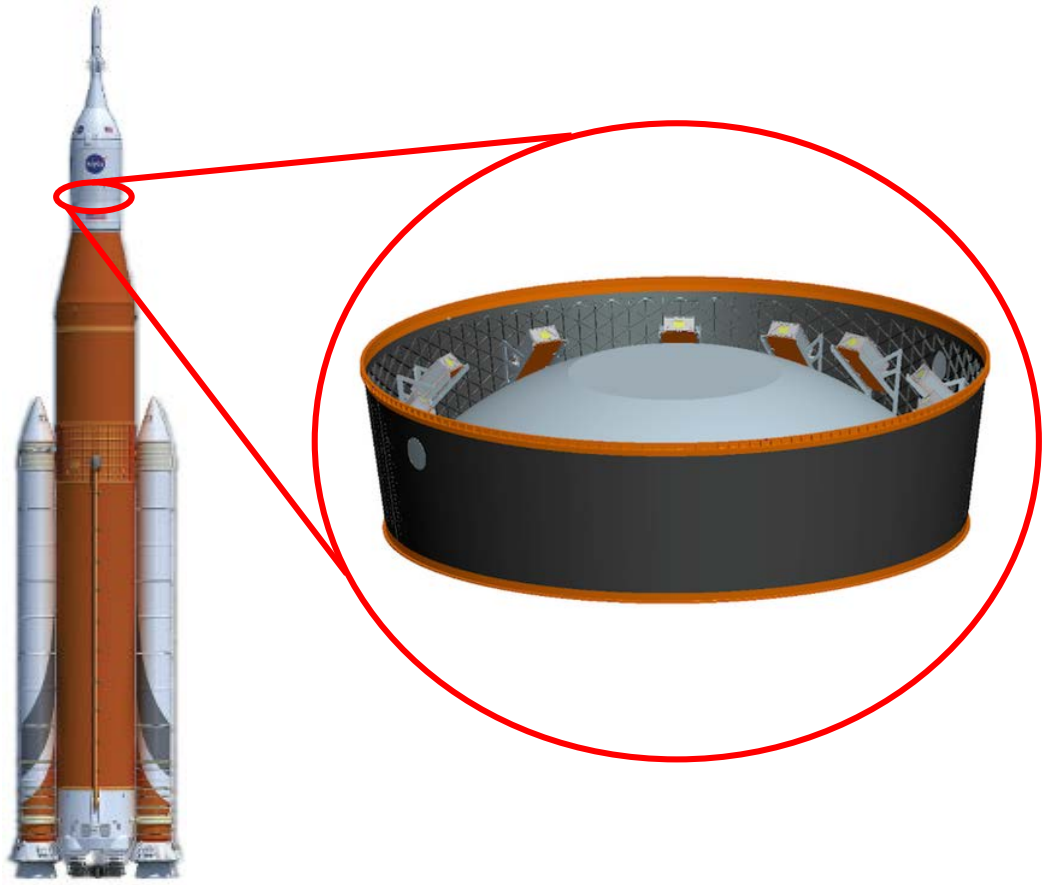
Igor Lazbin, LunaH-Map Chief Engineer

Craig Hardgrove

LunaH-Map Principal Investigator – Assistant Professor, School of Earth and Space Exploration, ASU

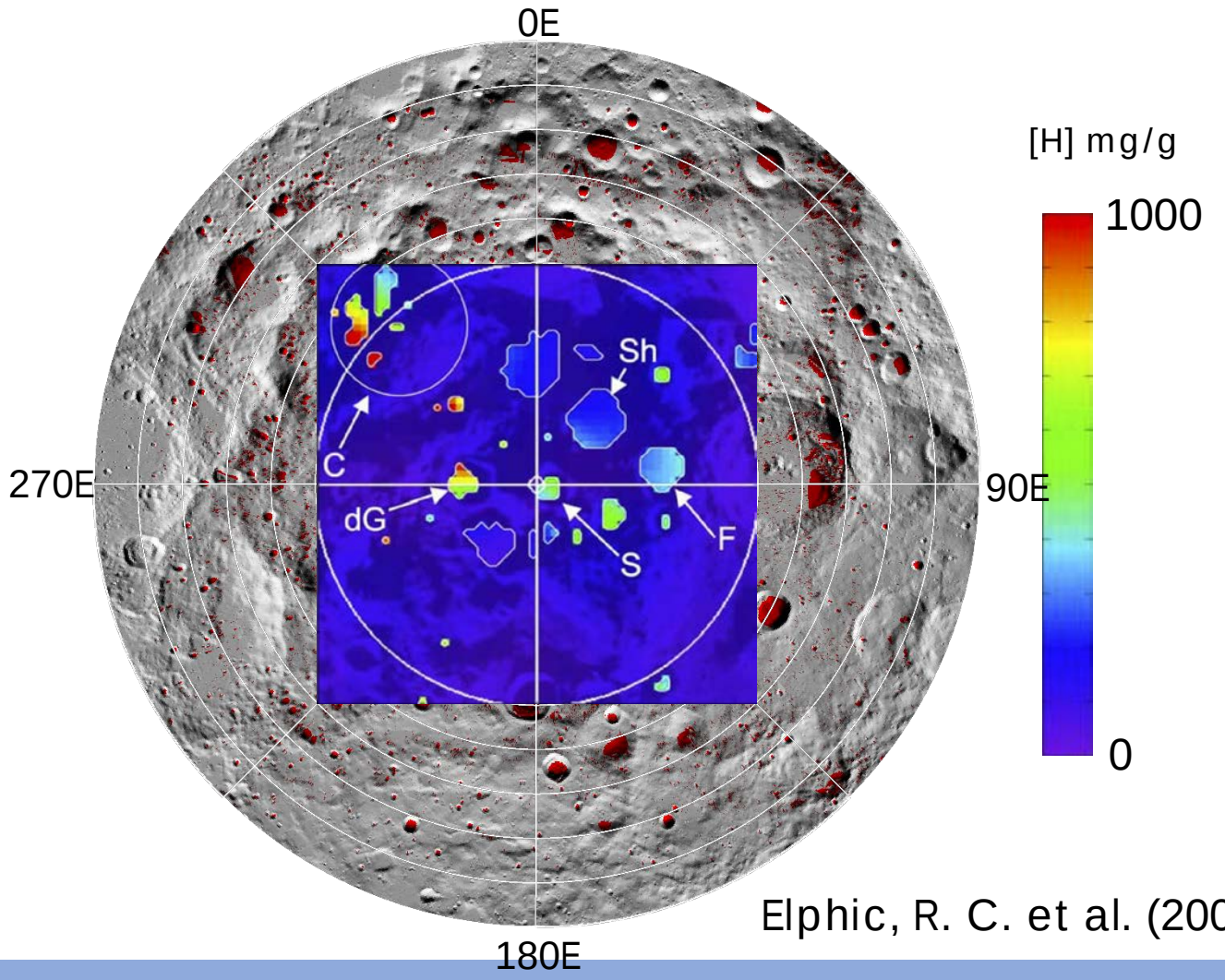
ASU School of Earth & Space Exploration
Arizona State University

LunaH-Map Mission Overview



- NASA SMD SIMPLEx 2015 mission led by ASU
- 6U+ CubeSat form factor
- Manifested on SLS *Artemis-1*
- **Science Objective**: Map lunar south pole hydrogen enrichments within PSRs at spatial scales <20 km^2
- **Tech Objectives**: Deep space navigation and operations using ion propulsion on a small (very small) sat

Lunar south pole – hydrogen

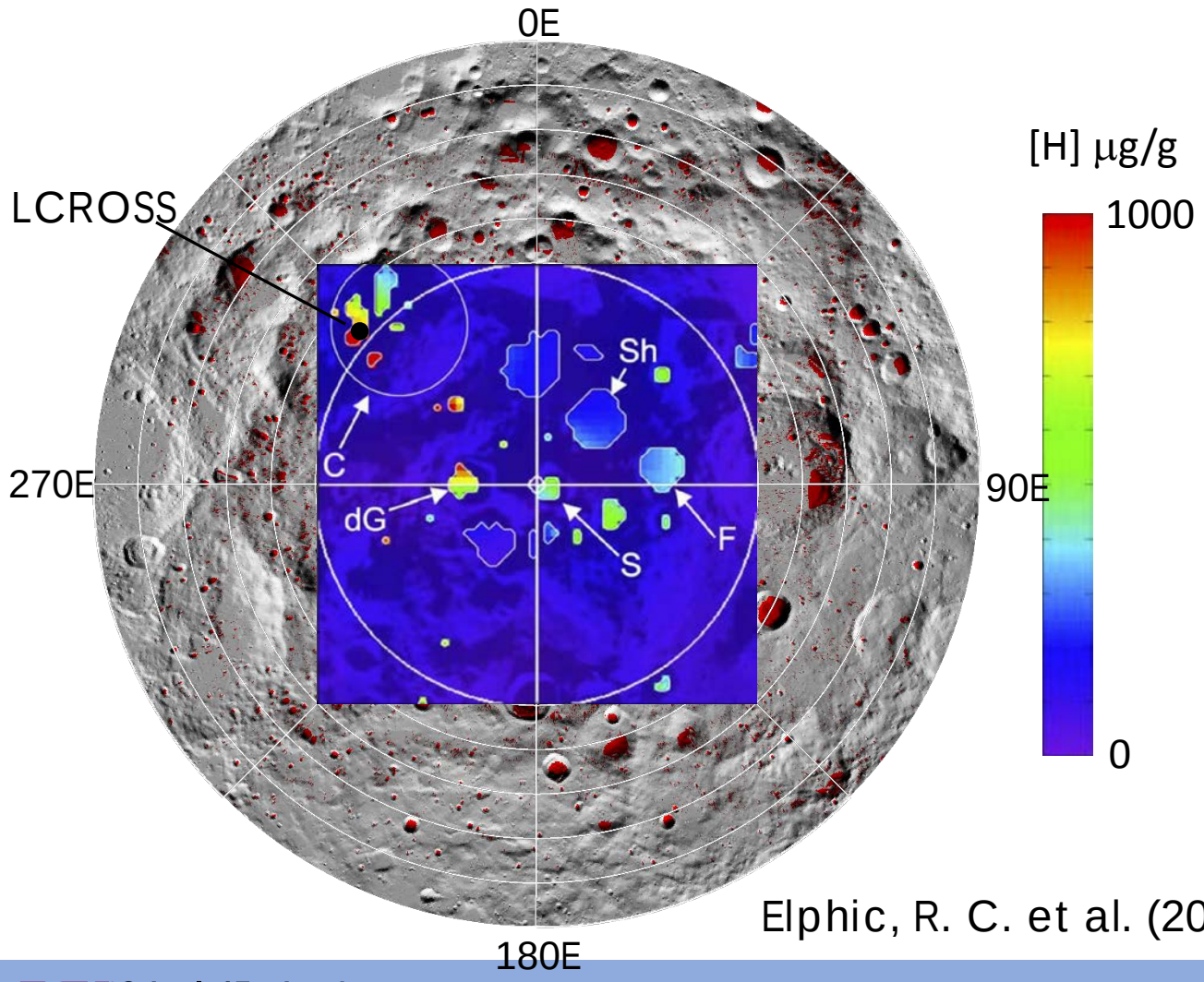


Lunar Prospector

- Spatial deconvolution of the epithermal counting data suggest H concentrations greater than 0.5 wt.% in some PSRs

Elphic, R. C. et al. (2007) GRL

Lunar south pole – water ice



LCROSS

- Probed deeper than LP/LEND
- Data imply 5 wt.% water in regolith
- Volatiles other than water are more abundant than expected
- Both comet/meteorite origins and in situ formation of volatiles on cold grains are possible

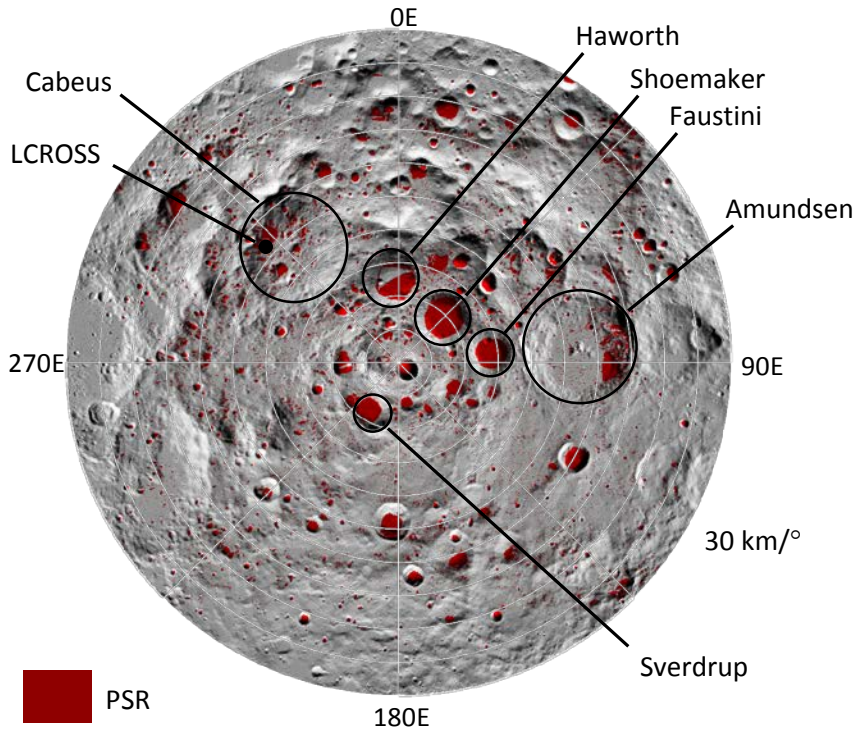
Elphic, R. C. et al. (2007) GRL

Colaprete, A. et al. (2010) Science

Bulk Lunar Hydrogen at Smaller Spatial Scales

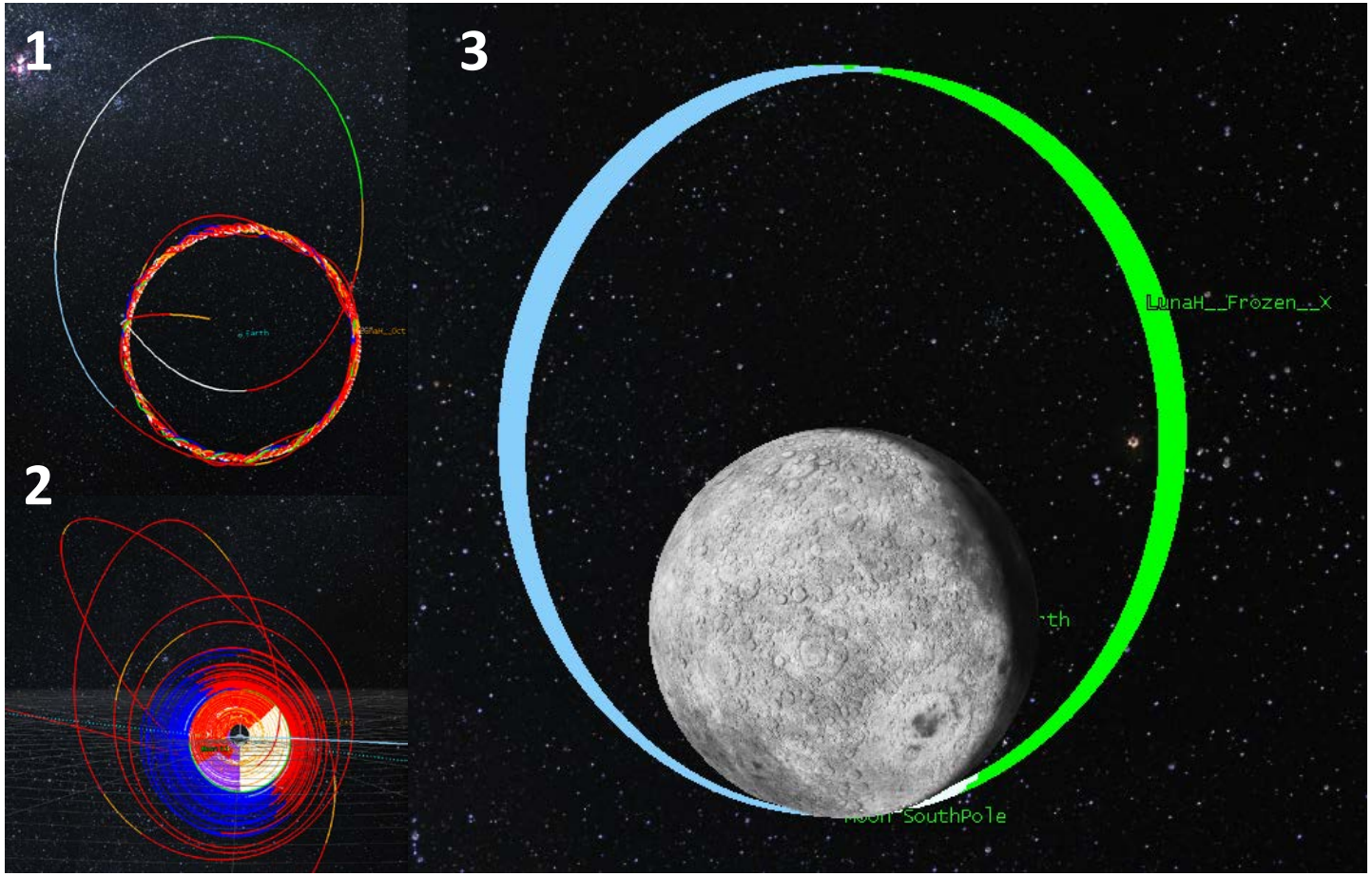
- The Dawn Gamma-Ray and Neutron Detector (GRaND) investigation showed that a combination of sublimation and impacts control the distribution of subsurface ice on Ceres (AGU2019 P54A-05).
- Similar processes may occur in and around permanently shadowed regions near the lunar south pole (e.g., Rubanenko et al., 2019).
  - Thick ice deposits (delivered by water rich asteroids or comets) may be pervasive at high southern latitudes.
  - Impact gardening could vertically redistribute the ice, bringing it closer to the surface.
- High spatial resolution measurements by LunaH-Map can test this hypothesis, e.g.
  - Is the observed distribution of hydrogen consistent with that predicted by ice stability modeling?
  - If not, other processes such as impact gardening may influence the vertical distribution of subsurface ice.

LunaH-Map south pole study areas



Based on LOLA shape models by Mazarico, E. *et al.* (2011), *Icarus*; see also NAC data, Cisneros, E. et al., *LPS* 48.

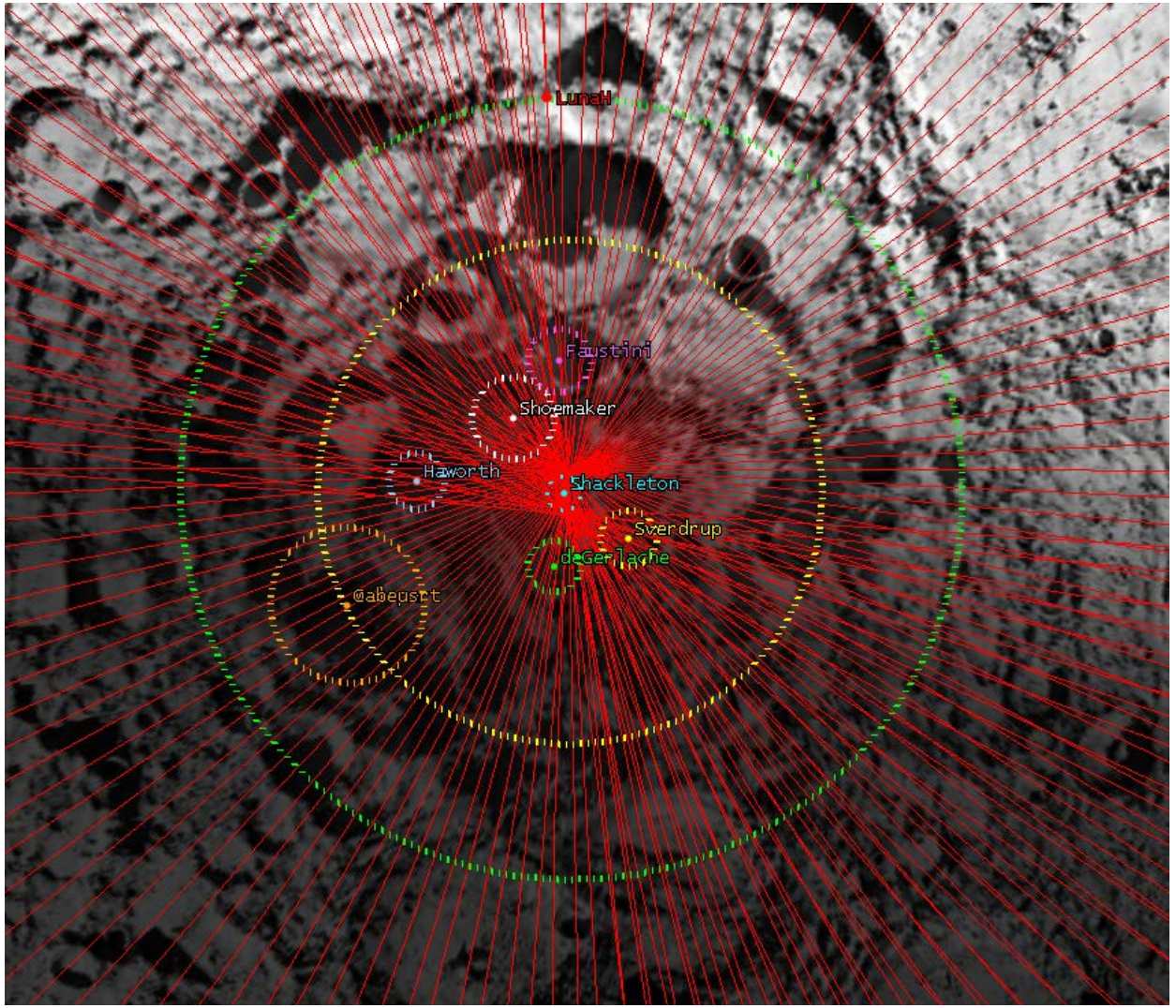
LunaH-Map Navigation and Trajectory Design



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.

LunaH-Map Science Phase



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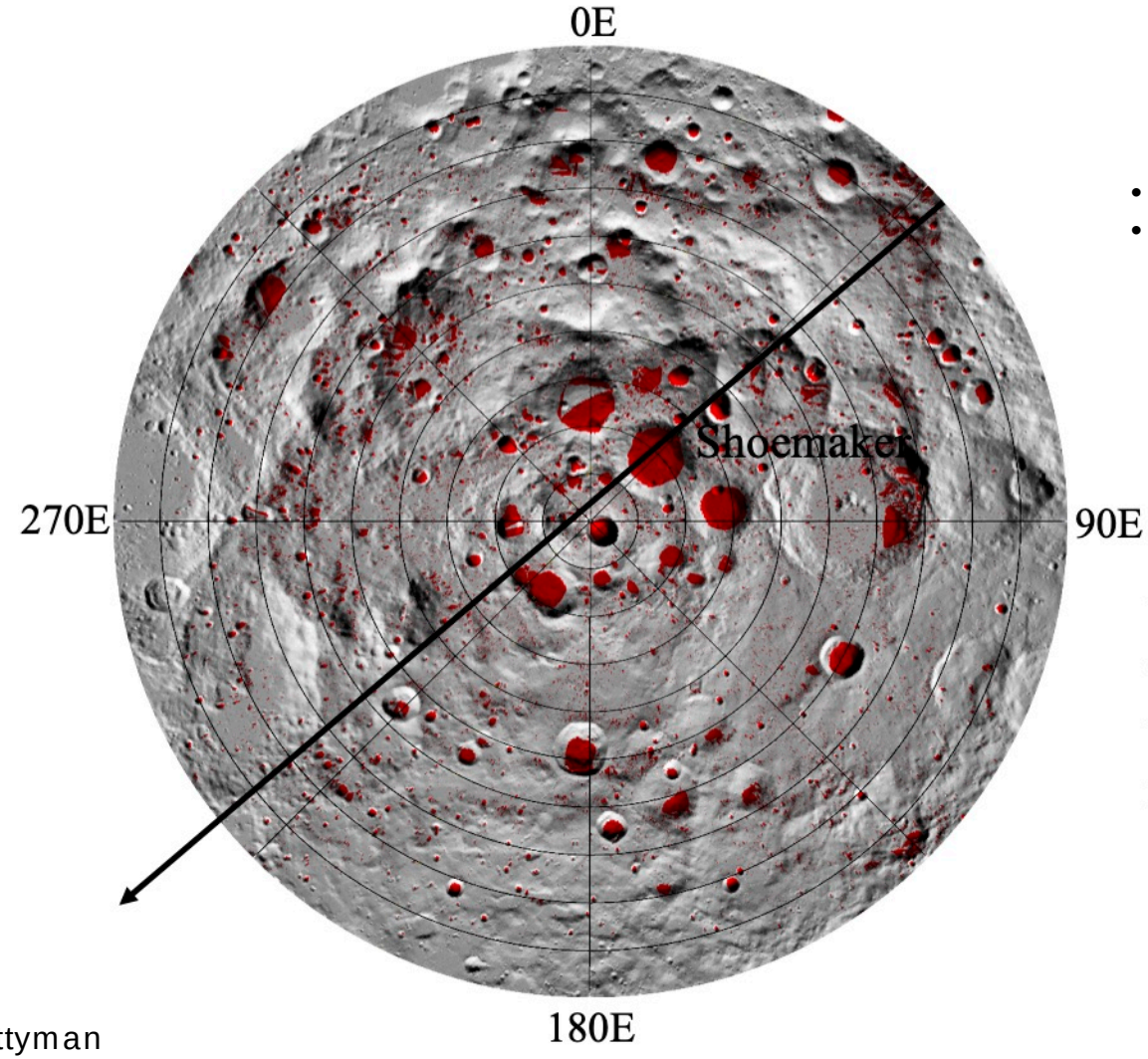
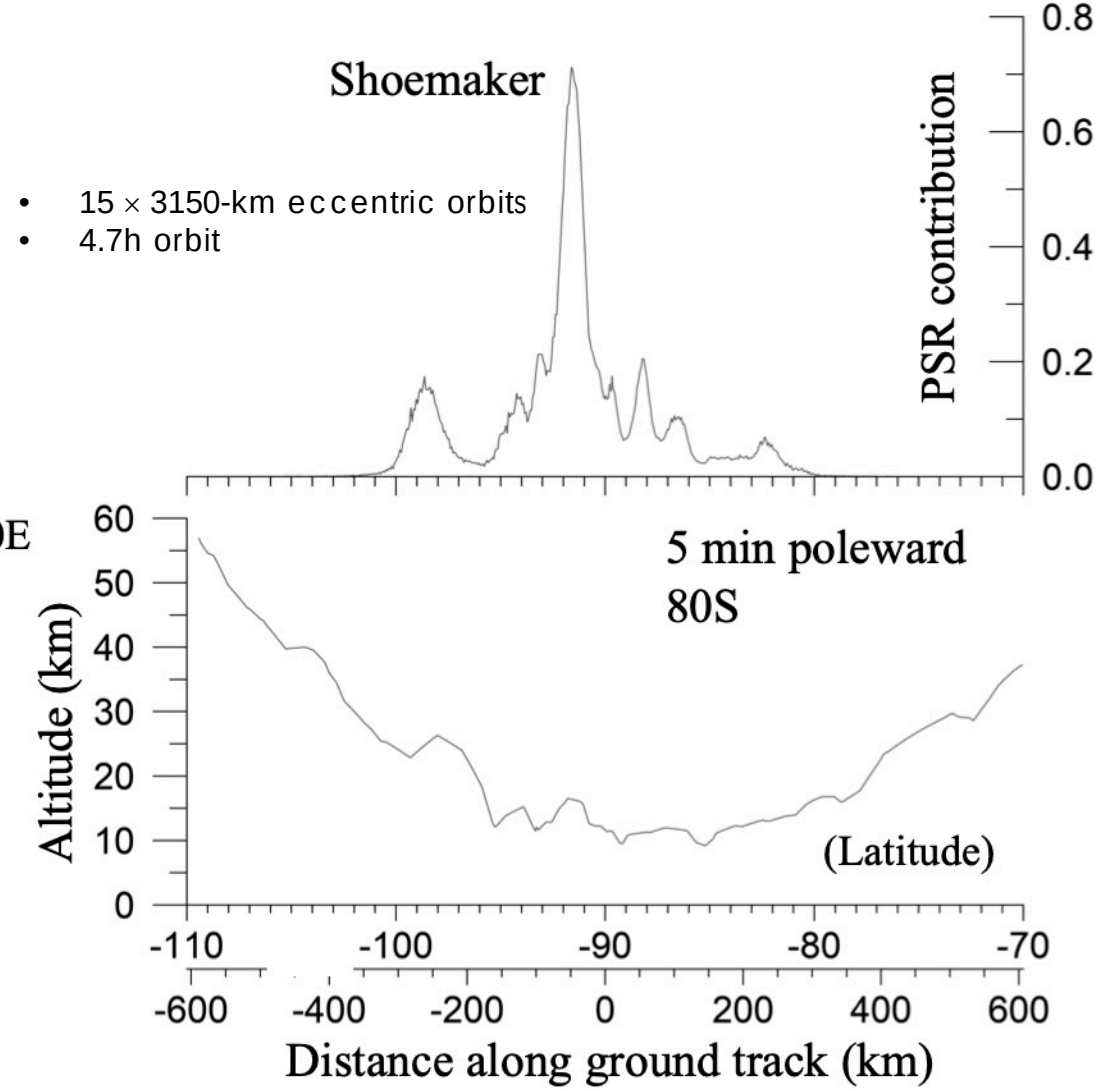
Genova, A. L. and Dunham, D. W. (2017) 27th AAS/AIAA Space Flight Mechanics Meeting 17-456.

LunaH-Map: Example orbits



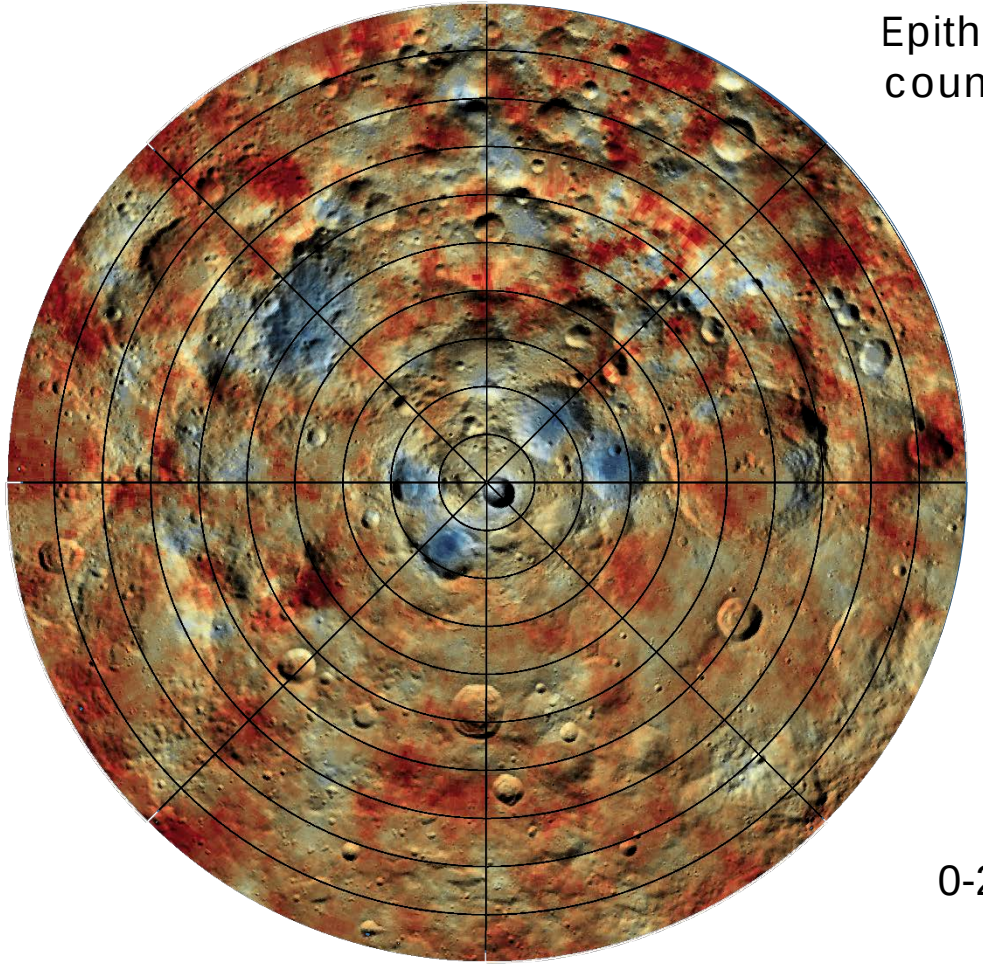
- 15 × 3150-km eccentric orbits
- 4.7h orbit



T. Prettyman

LunaH-Map H Mapping Capabilities

- LunaH-Map can detect expected H concentrations in PSRs
- PSRs are resolved; although, full contrast is not achieved
- Low altitude measurements enable high spatial resolution mapping of PSRs and surrounding permafrost
- Enables verification of results of previous missions (LP/LEND)



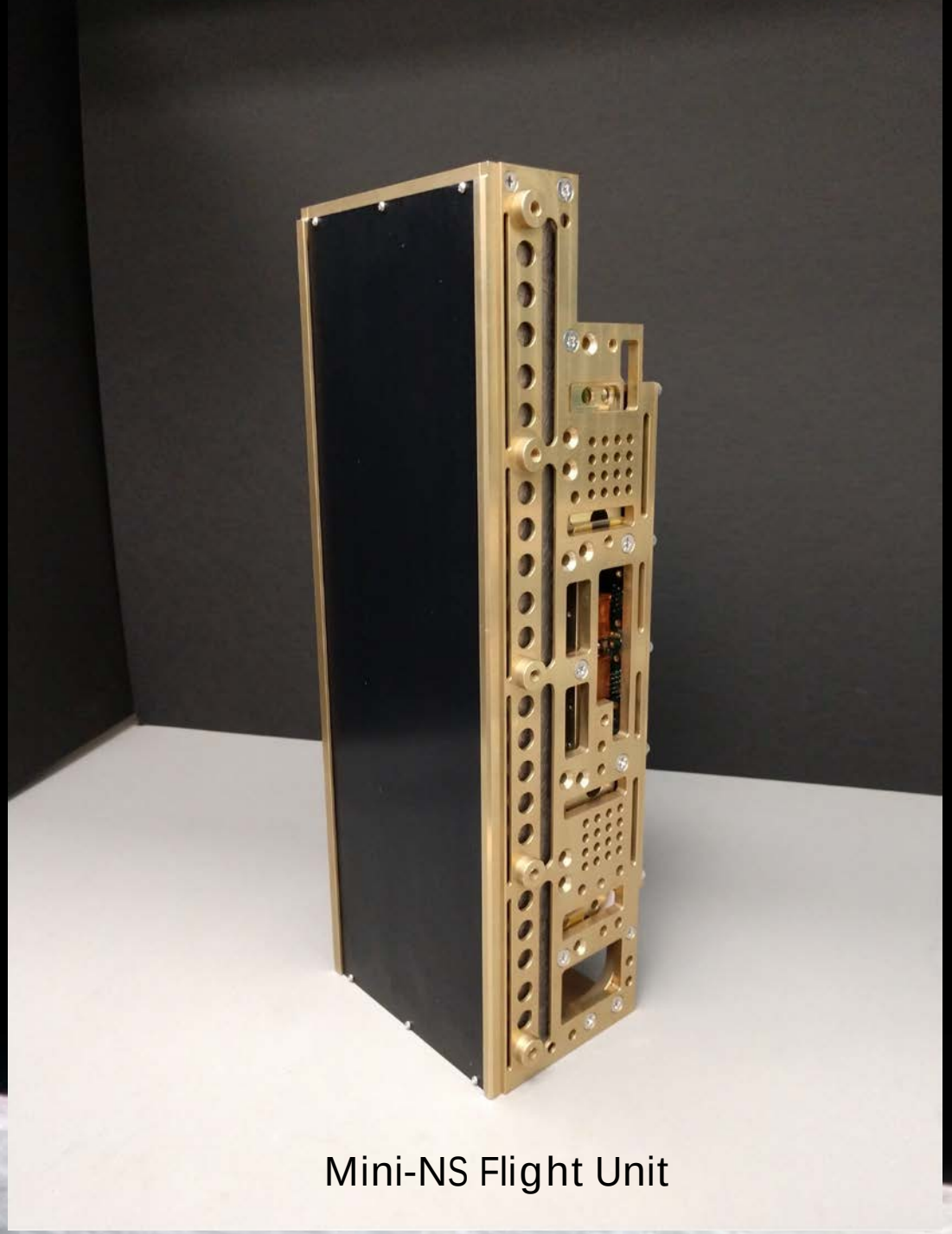
Epithermal counts (relative)

1

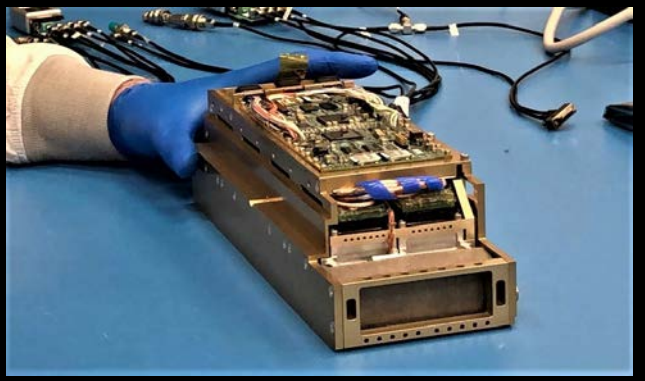
0.95

0.9

0-220 μg/g H



Mini-NS Flight Unit



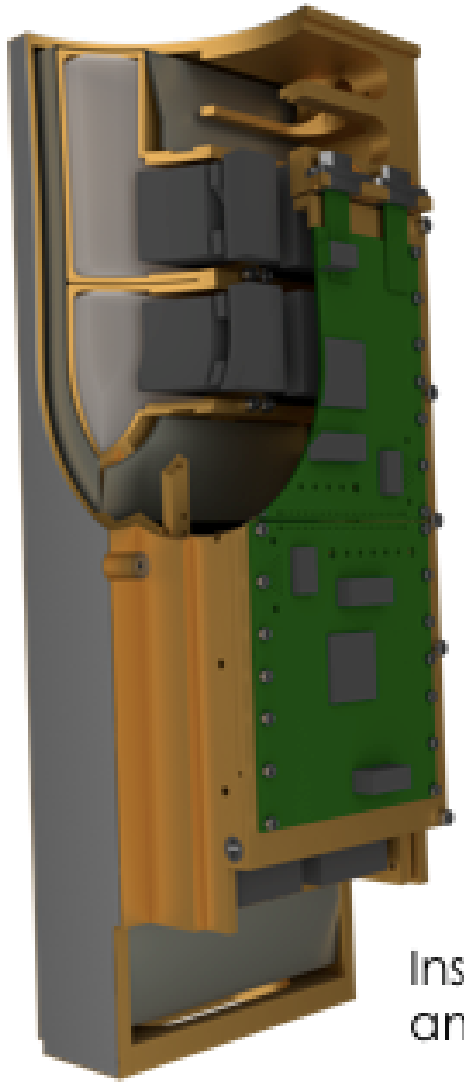
Mini-NS: Miniature Neutron Spectrometer

Miniature Neutron Spectrometer for CubeSats and SmallSats – Flight Unit

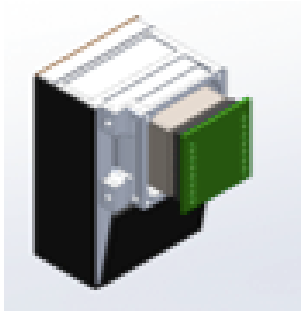
Detector	2x4 array of CLYC (elpasolite scintillator, Cs_2LiYCl_6:Ce) crystals, each crystal 4 cm x 6.3 cm x 2 cm
Dimensions	25 cm x 10 cm x 8 cm
Mass	3.3 kg
Power	10W
Data Acquisition	Counts binned every 1 sec

- Mini-NS Flight Unit delivered and calibrated at Los Alamos National Lab Neutron Free In-Air (NFIA) facility in late Fall 2018

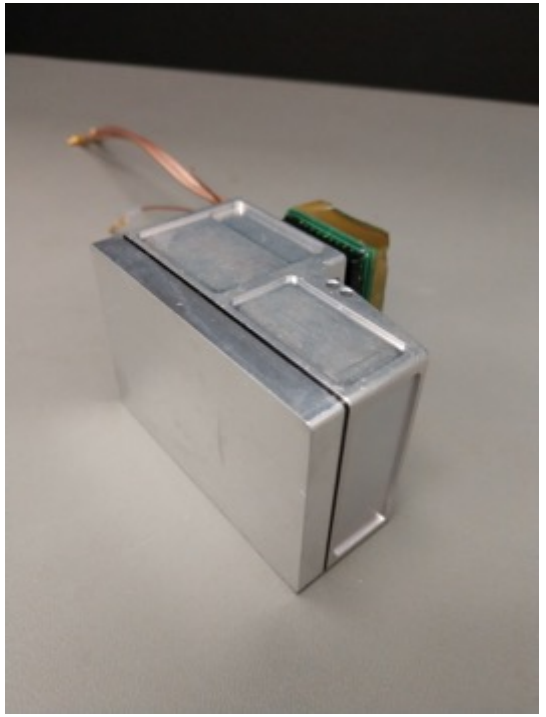
Miniature Neutron Spectrometer for CubeSats and SmallSats



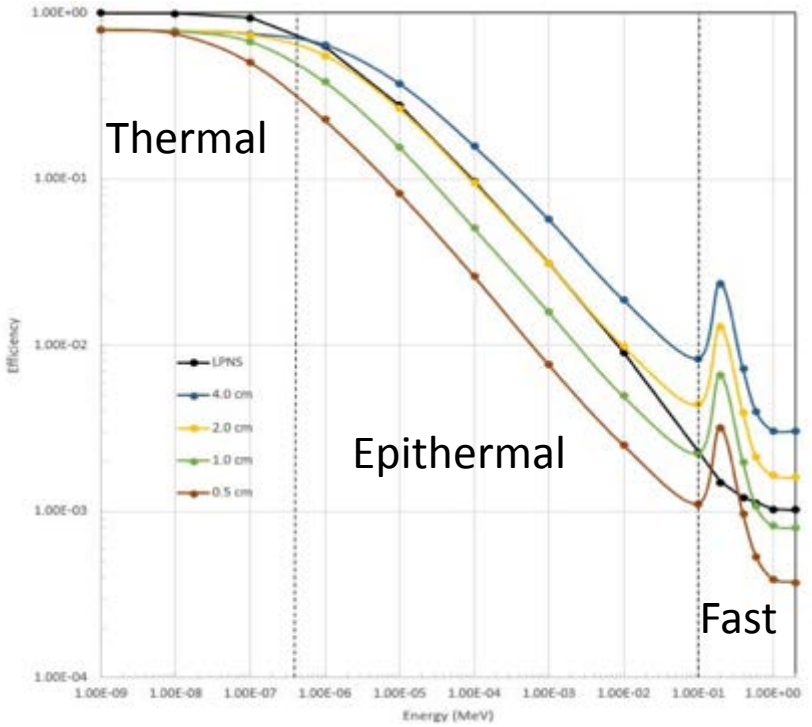
Instrument Housing and Electronics



CLYC Module



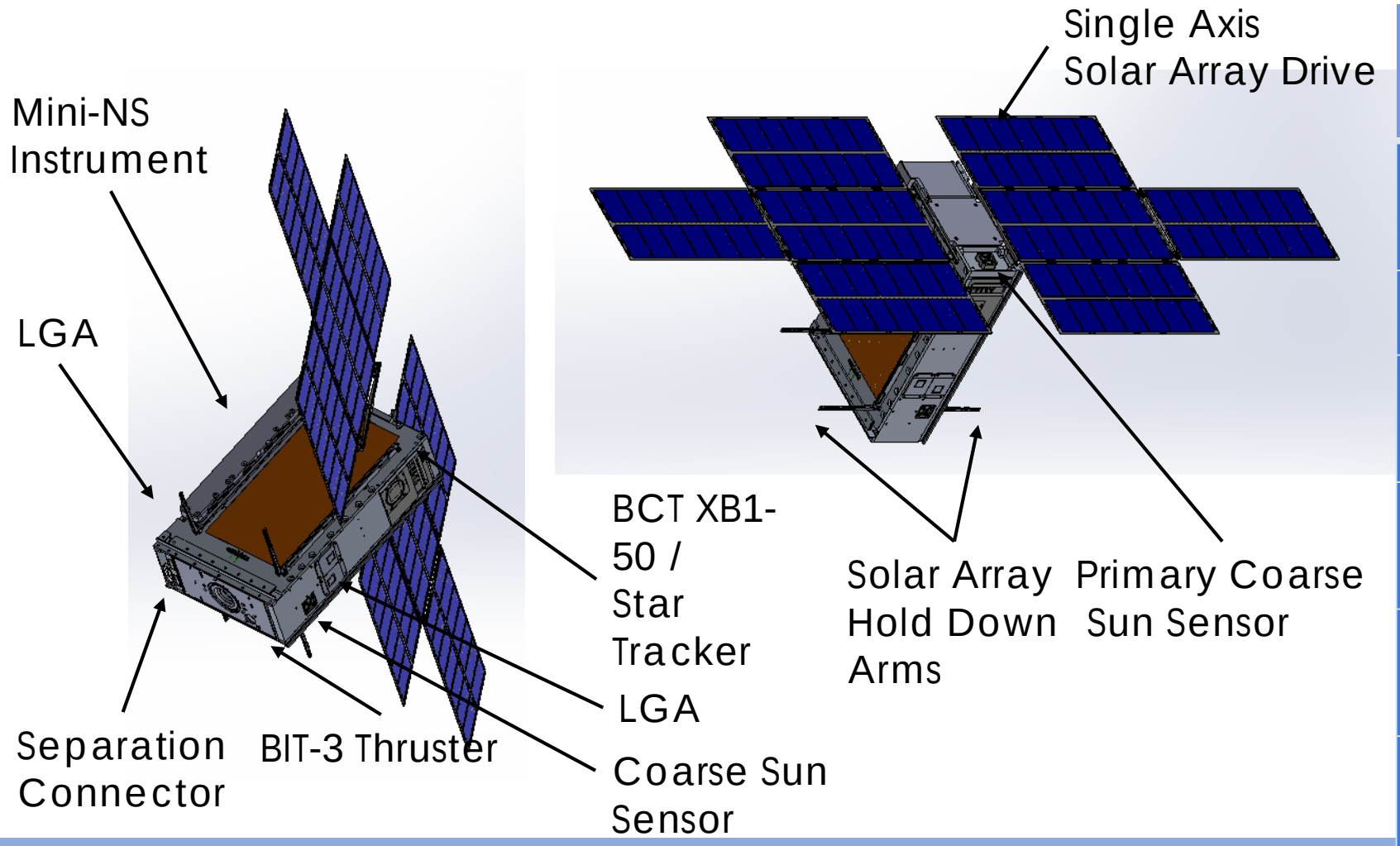
Individual CLYC module, PMT and housing (x8)



Mini-NS calibration team at Los Alamos National Laboratory Neutron Free In-Air Facility – December 2018

left to right: Lena Heffern (ASU), Erik Johnson (RMD), Tom Prettyman (PSI), Joe DuBois (ASU), Richard Starr (NASA GSFC), Bob Roebuck (AZST), Katherine Mesick (LANL), Graham Stoddard (RMD), Craig Hardgrove (ASU)

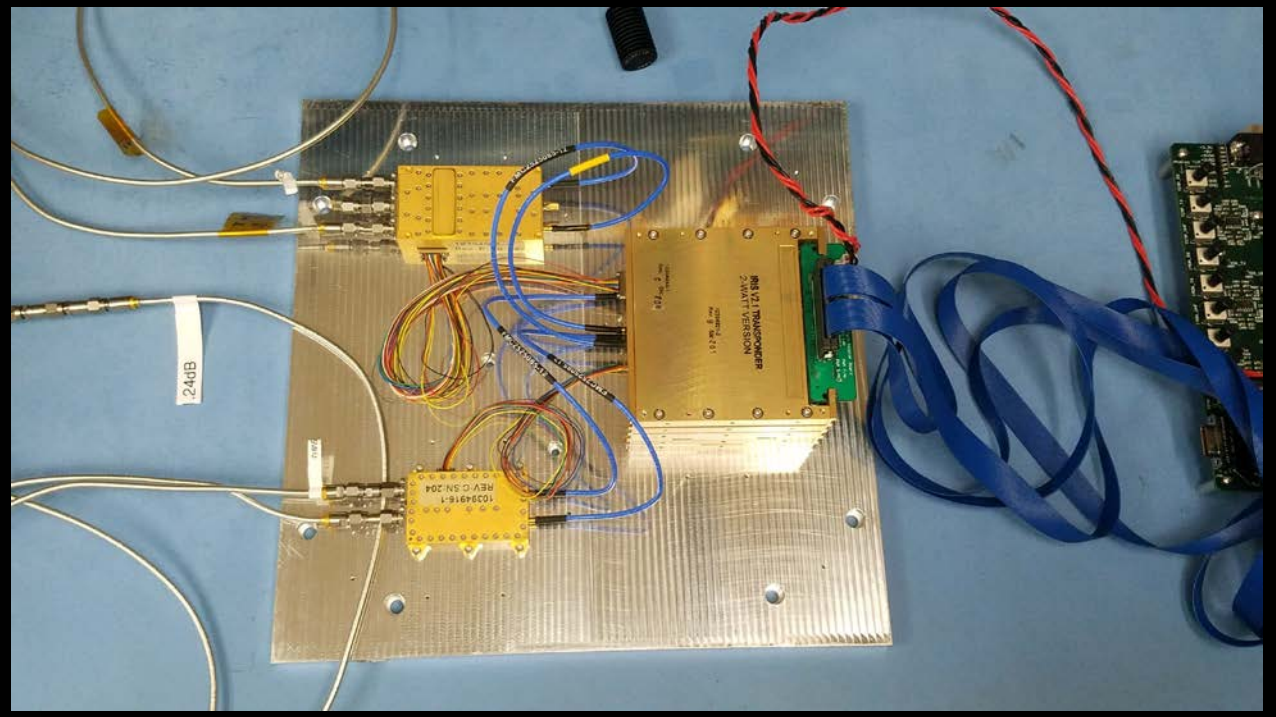
LunaH-Map Spacecraft



Spacecraft Specs

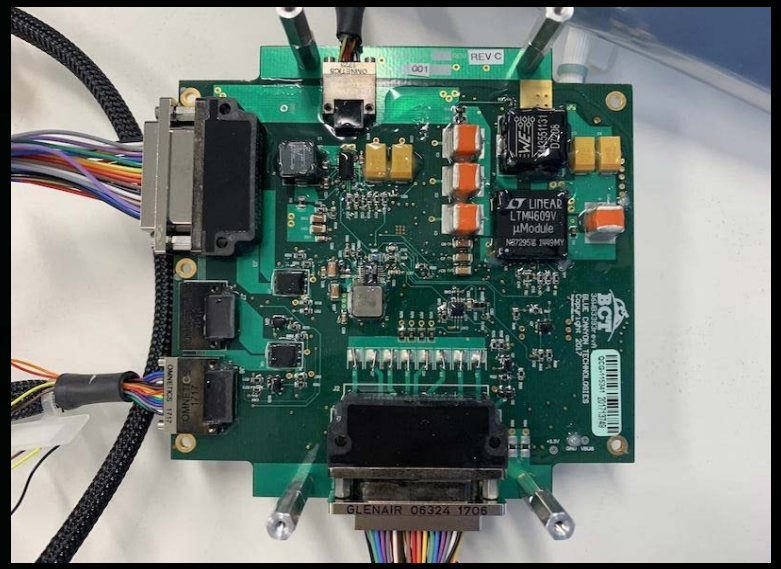
Dimensions: (stowed)	10x20x30cm
Mass	14 kg
Power	90W BOL Solar Array 112 W-hr Battery
Propulsion	Busek BIT-3 Ion Thruster
Comm.	JPL Iris Deep Space Transponder
C&DH / GN&C	BCT XB1-50

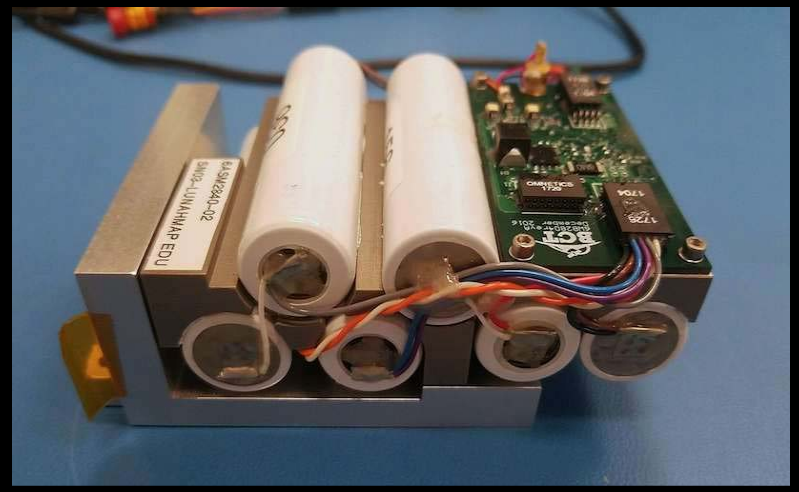
LunaH-Map MMA eHawk+ Flight Solar Arrays – Delivered February 2019



LunaH-Map Flight Iris radio – Delivered February 2019

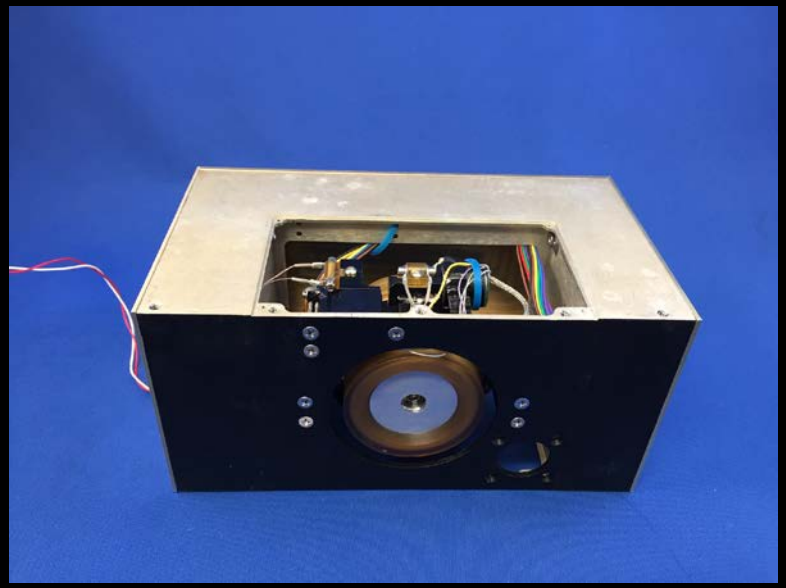
LunaH-Map Flight Battery (1 of 2), Power Distribution and XB1-50





BLUE CANYON TECHNOLOGIES

LunaH-Map Flight BIT-3 propulsion system – Delivered December 2019



LunaH-Map Flight BIT-3

BIT-3 QM Hot Fire Iodine Testing

BUSEK
Space Propulsion and Systems

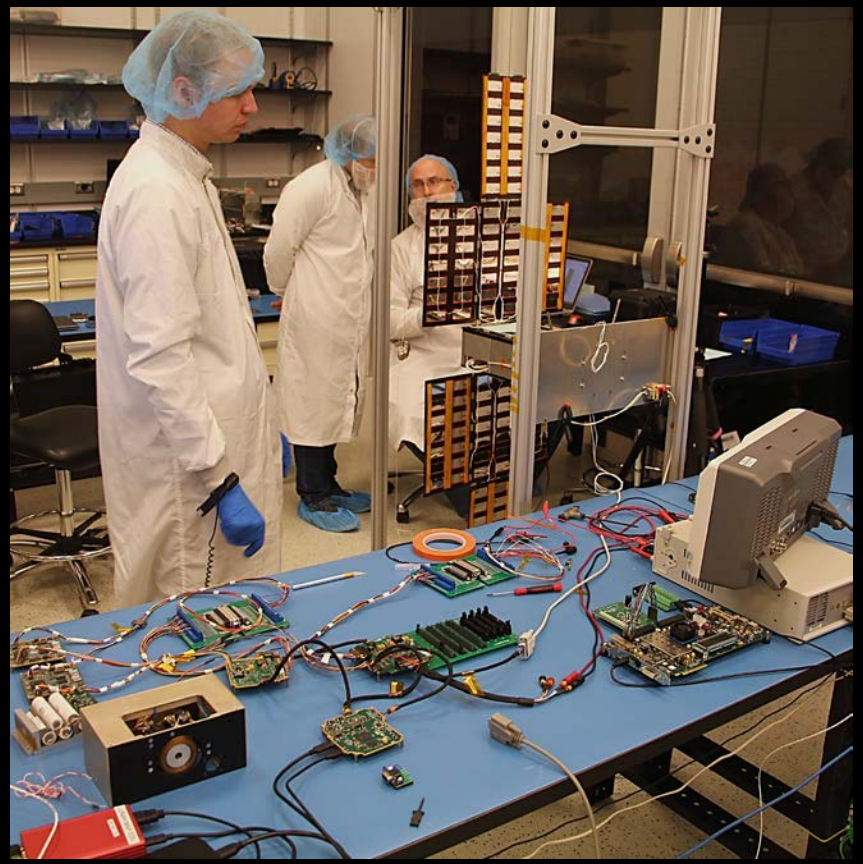
- MOC co-located in ASU's shared operations facility
- JPL AIT for spacecraft uplink and downlink
- KinetX provides mission navigation
- ASU science/instrument ops development coincident with Mars 2020 and Psyche missions

AZST Role in LunaH-Map Development

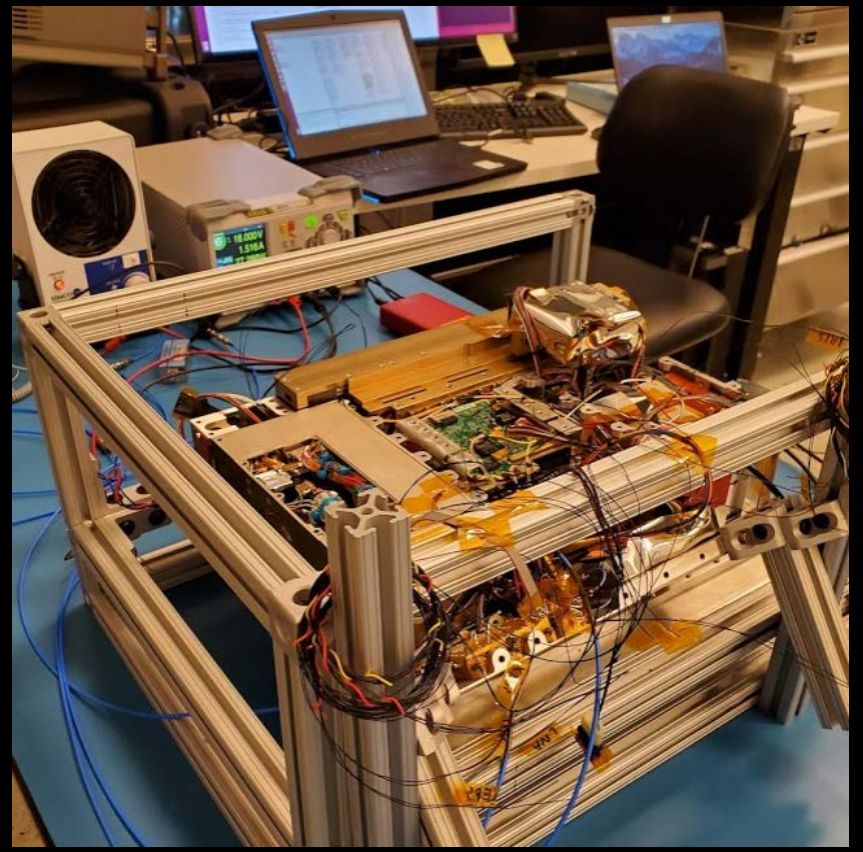
AZST staffed Chief Engineer, Mechanical Engineer, Software Engineer, Systems Engineer, and Integration Technician roles for this Cubesat project

Mechanical and thermal design, systems engineering, instrument software, safety engineering, harness design, I&T support

AZST has decades of experience in integration and testing of spacecraft level systems and avionics



Flatsat Testing



Preparing for top panel closeout

AZ SPACE TECHNOLOGIES

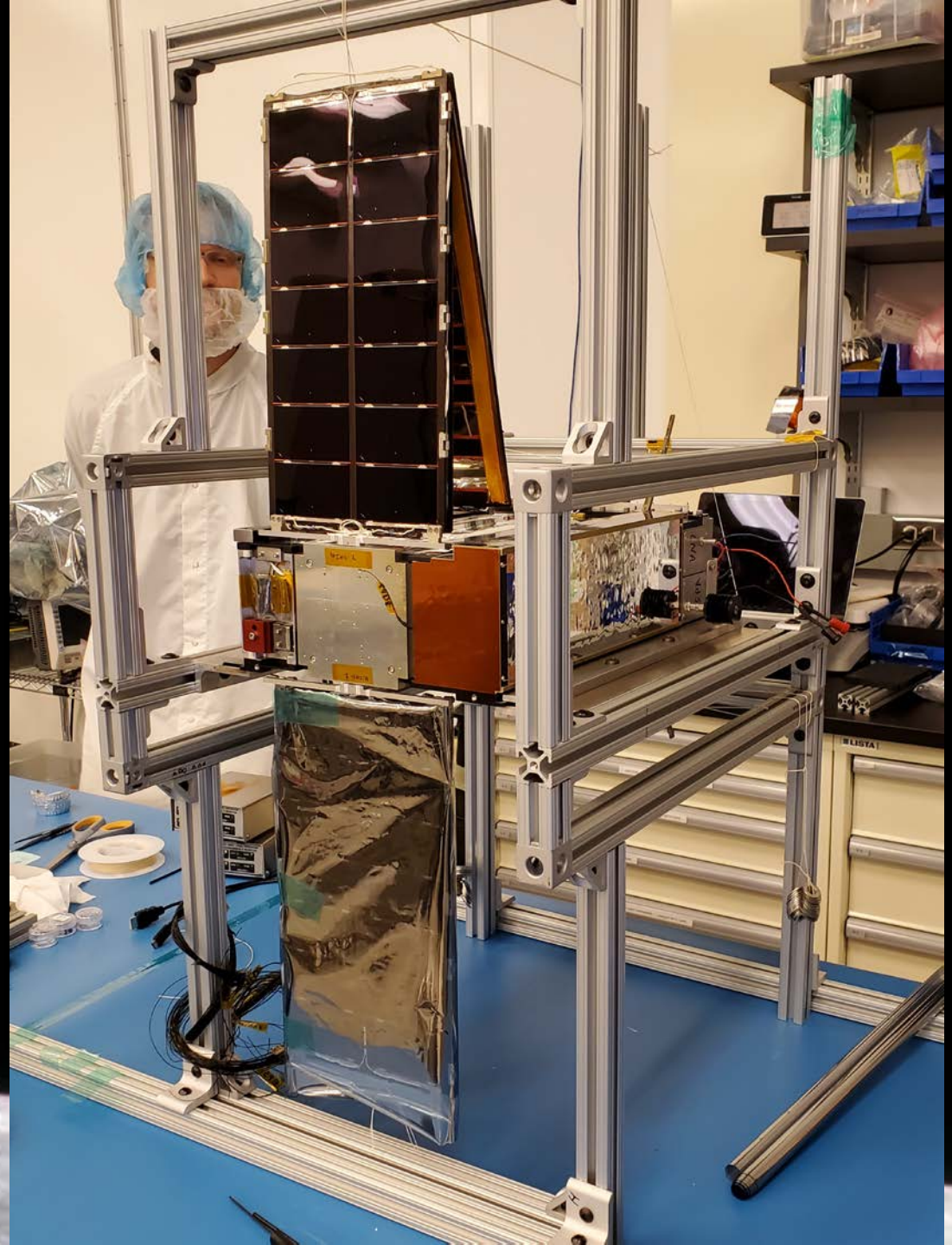
LunaH-Map Status

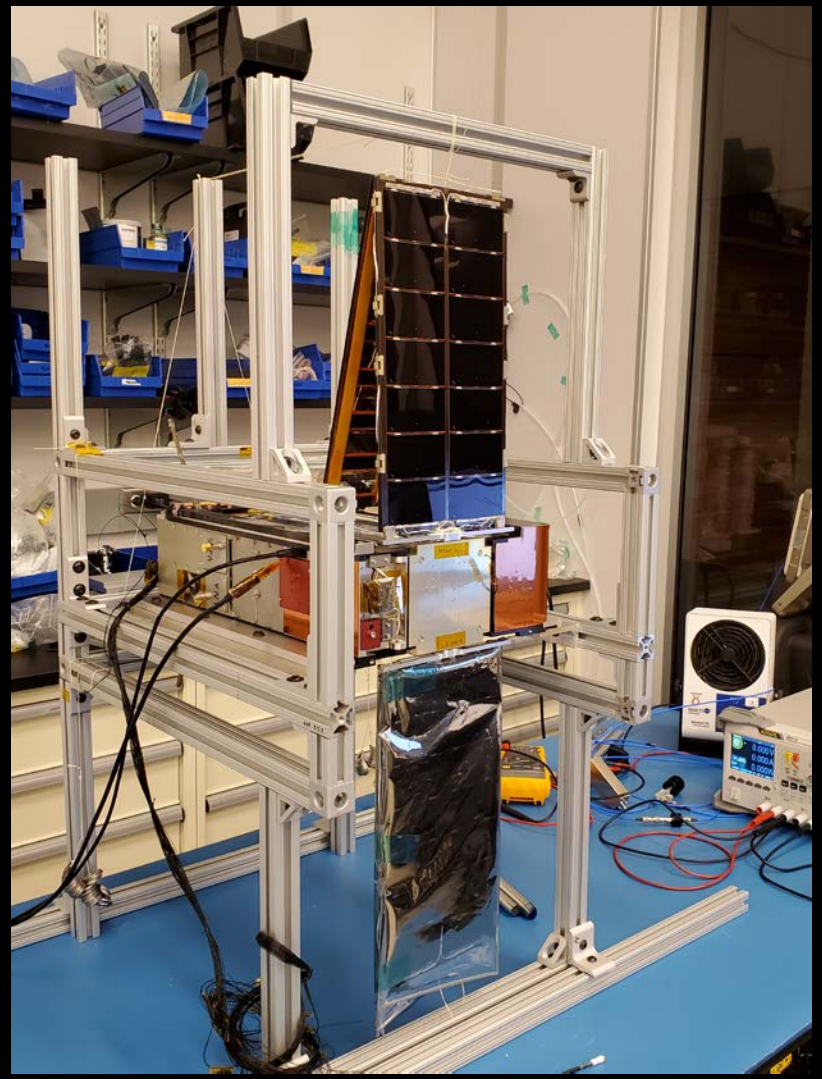
All subsystem EM and FM units delivered! EMs integrated into the LunaH-Map flatsat

Flight S/C on schedule for delivery in mid 2020

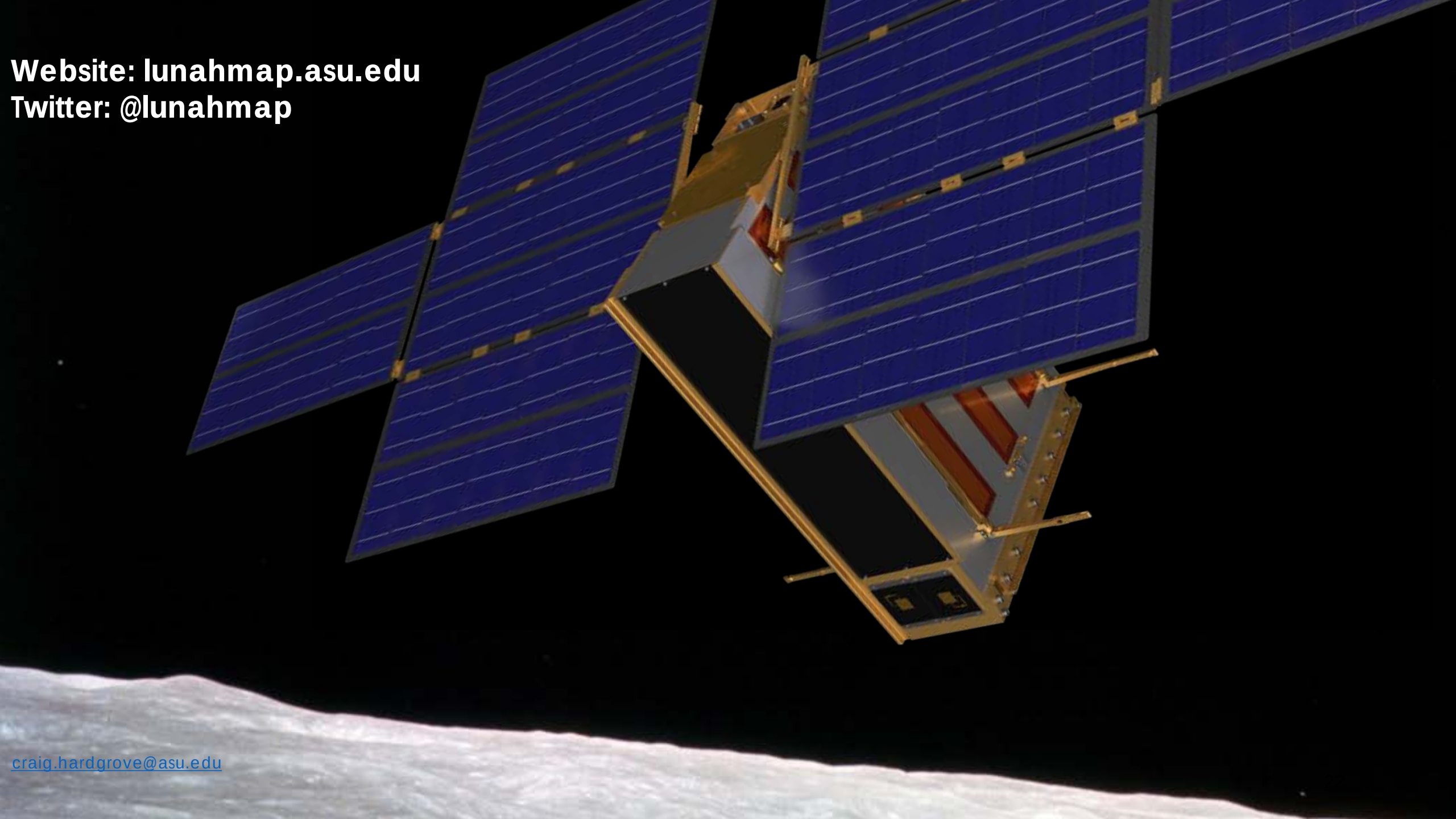
<u>Current Engineering Team Activities</u>

- Electrical and mechanical integration complete
- Preparing for environmental test campaign staring in May





Fully integrated spacecraft undergoing functional tests



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craig.hardgrove@asu.edu