

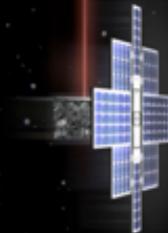
Lunar Flashlight and other Lunar Cubesats

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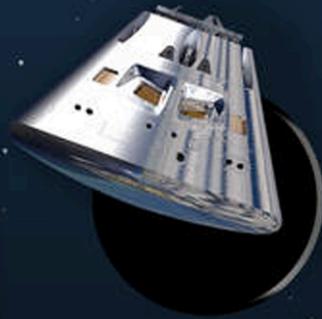
Barbara.a.cohen@nasa.gov



EXPLORATION MISSION-1: LAUNCHING SCIENCE & TECHNOLOGY SECONDARY PAYLOADS



ORION STAGE ADAPTER
SUPPORTS BOTH PRIMARY MISSION AND SECONDARY PAYLOADS

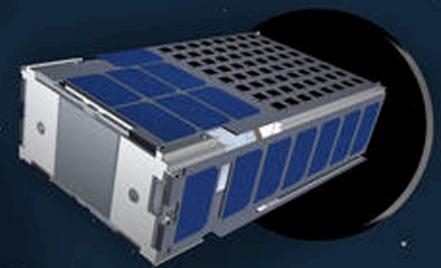


ORION SPACECRAFT
TRAVELING THOUSANDS OF MILES BEYOND THE MOON, WHERE NO CREW VEHICLE HAS GONE BEFORE

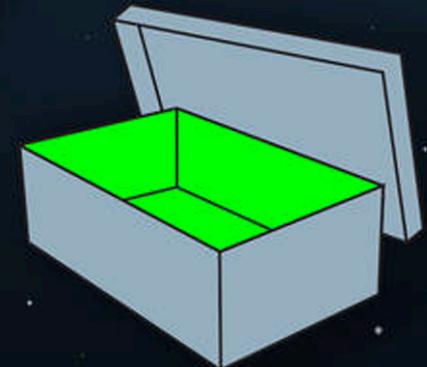


AVIONICS
(SELF-CONTAINED AND INDEPENDENT FROM THE PRIMARY MISSION)
SEND CUBESATS ON THEIR WAY

13 CUBESAT EXPLORERS
GOING TO DEEP SPACE WHERE FEW CUBESATS HAVE EVER GONE BEFORE.



SHOEBOX SIZE
PAYLOADS EXPAND OUR KNOWLEDGE FOR THE JOURNEY TO MARS



#RIDEONSLS

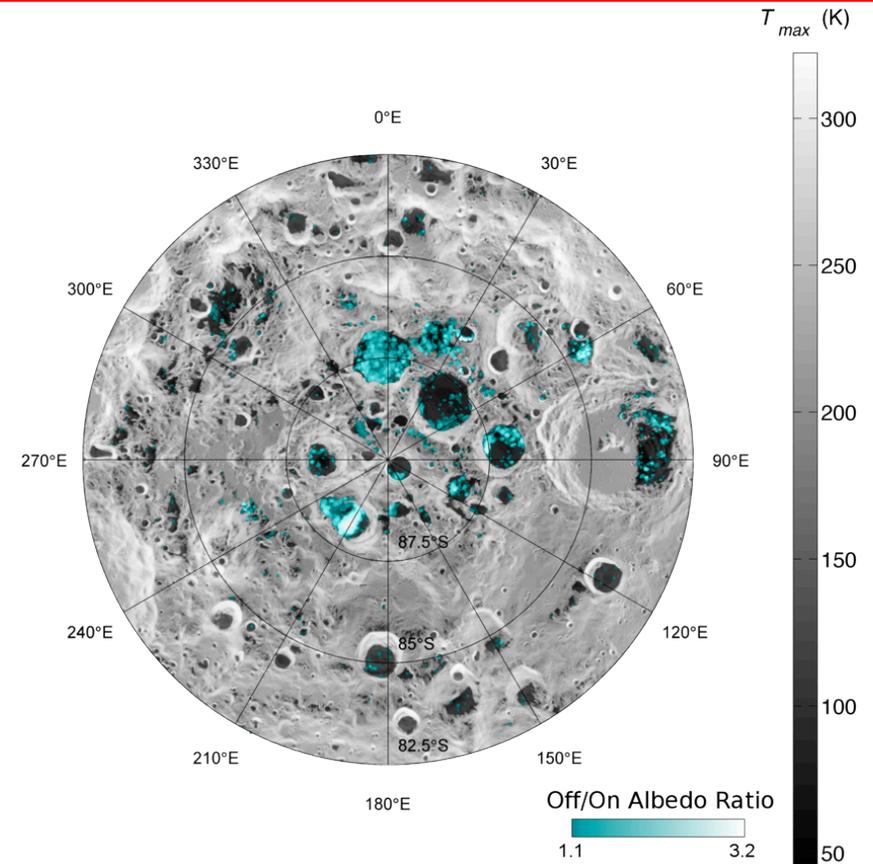
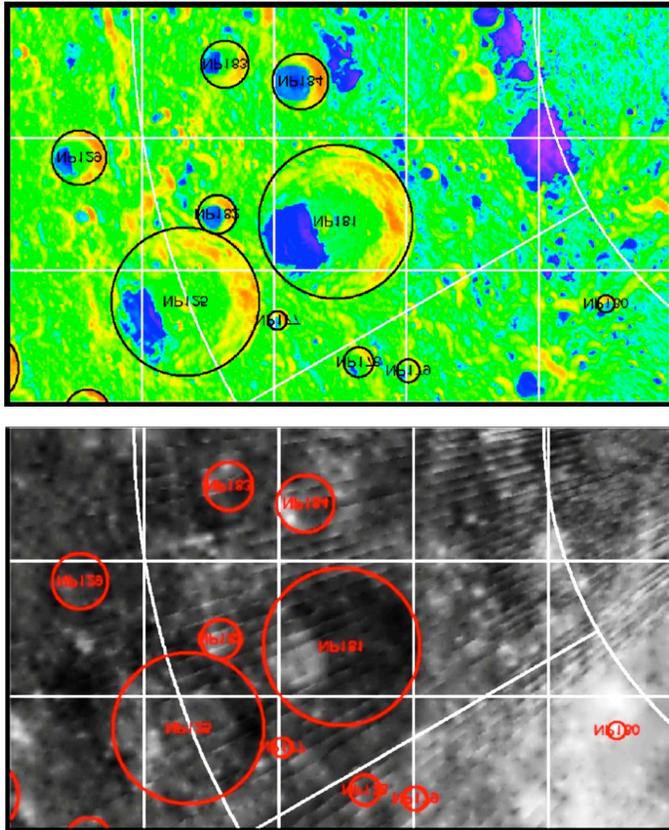
Resources for human exploration



- Humans exploring the Moon will need water:
 - Option 1: Carry it there. ↙ expensive (at \$10K/lb, 1 gal H₂O=\$80K)
 - Option 2: Use water that may be there already. ↙ “live off the land”
- Can mine O₂ from minerals and H from solar wind implantation, however, this is very energy intensive
- Life would be much easier and cheaper if we could use H₂O from the Moon
- **At the surface or near surface**
- **In “operationally useful” quantities**



Water ice frost on the lunar surface?



- Cold temperatures (Diviner) correlate with high albedo at $1.064 \mu\text{m}$ (LOLA) (Zuber et al. 2012, Lucey et al. 2014, Haruyama et al. 2013, Fisher et al. 2017)

- Also correlated with high ultraviolet albedo data from LAMP (Hayne et al. 2014)

Lunar Flashlight

Looking for surface ice deposits and identifying favorable locations for in-situ utilization in lunar south pole cold traps

Mission Approach

- JPL-MSFC Team
- 6U spacecraft, 14 kg
- Launch on SLS EM-1 in 2019
- Chemical propulsion system
- 1-2 micron spectrometer
- Near-rectilinear halo orbit (5 day period)
- Science phase: ~3 min passes, 13 orbits

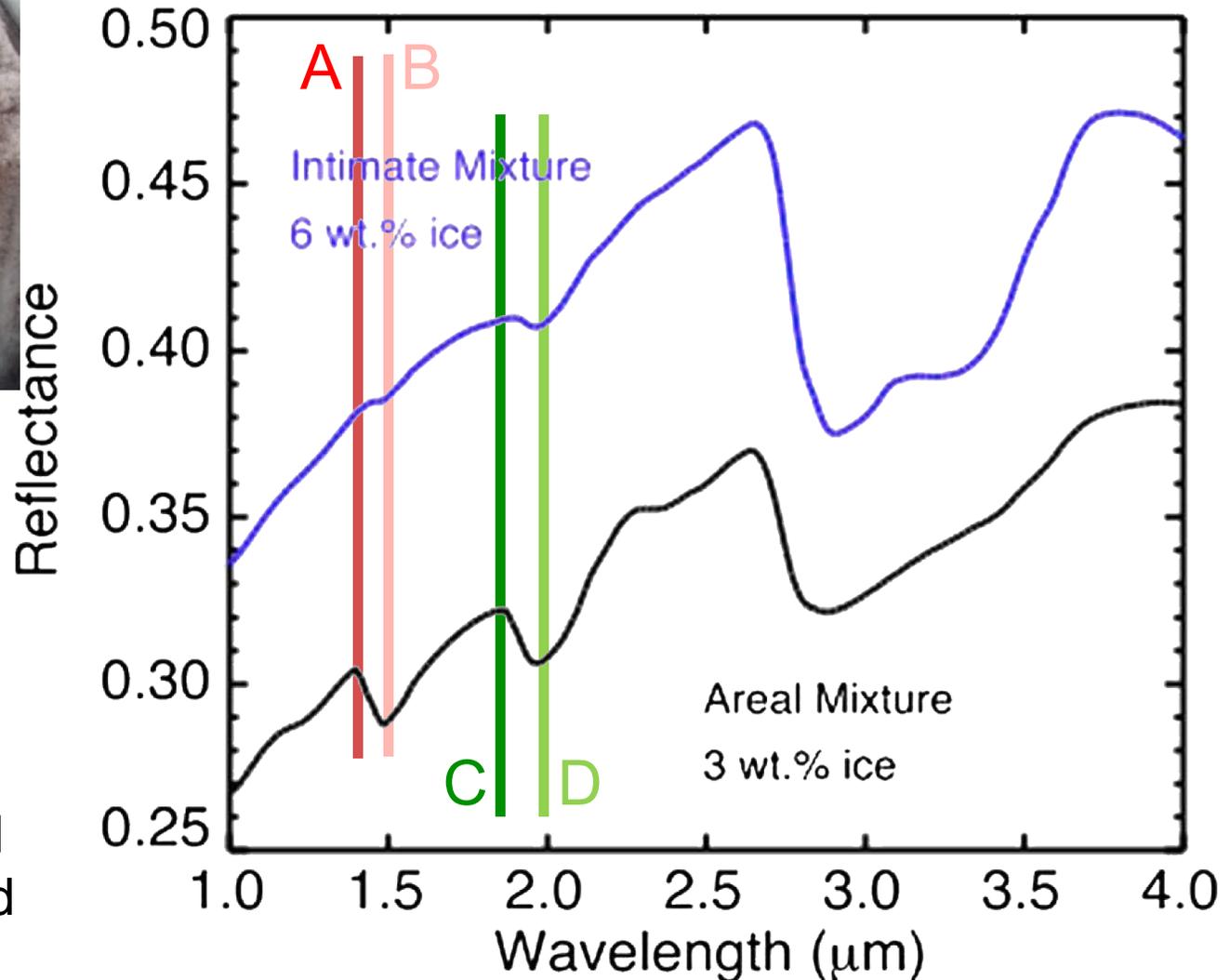
Measurement Approach

- Lasers in 4 different near-IR bands illuminate the lunar surface in a 1 km spot
- Light reflected off the lunar surface enters the spectrometer to distinguish water ice from regolith

Measurement Goal



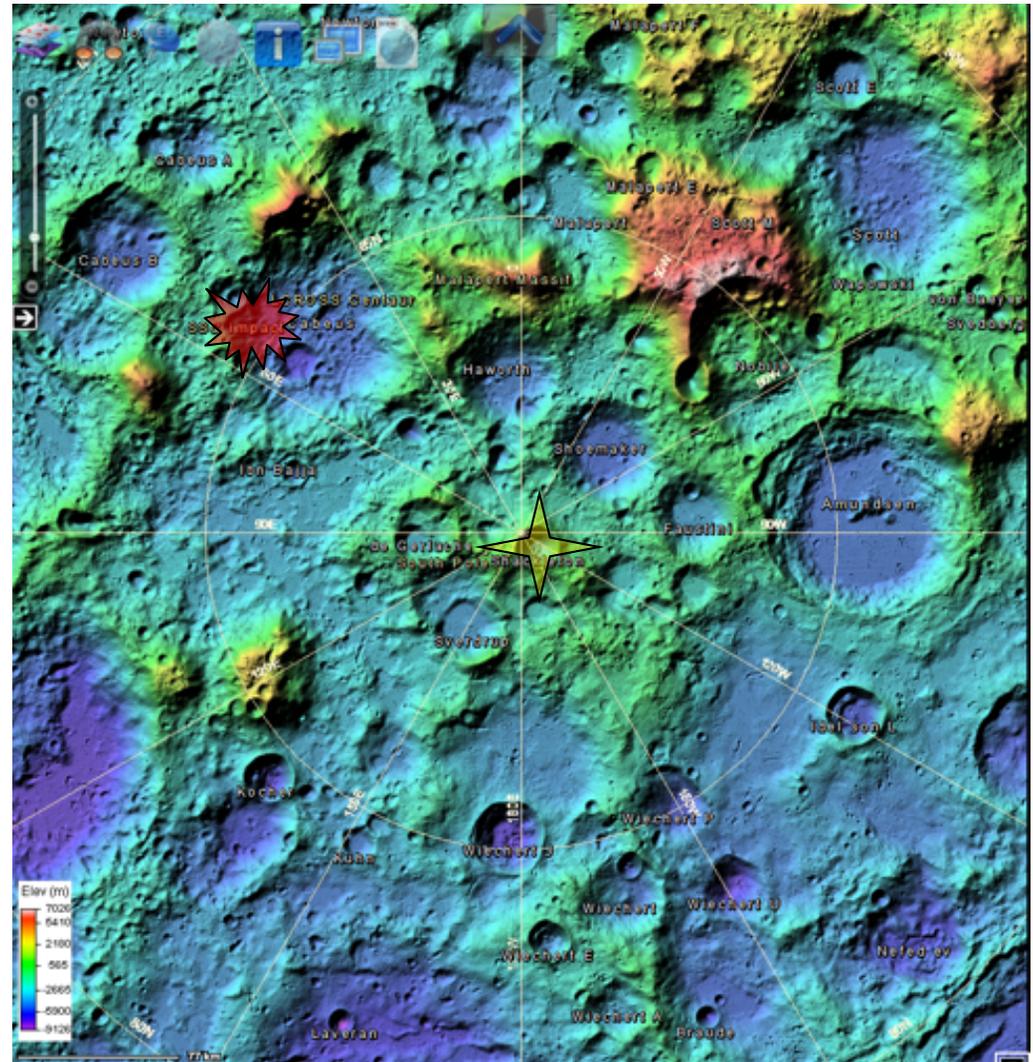
- Reflectance spectroscopy is the standard technique for identifying molecular “fingerprints” from a distance
- Measure absorption and continuum to understand ice abundance



Mapping Goal

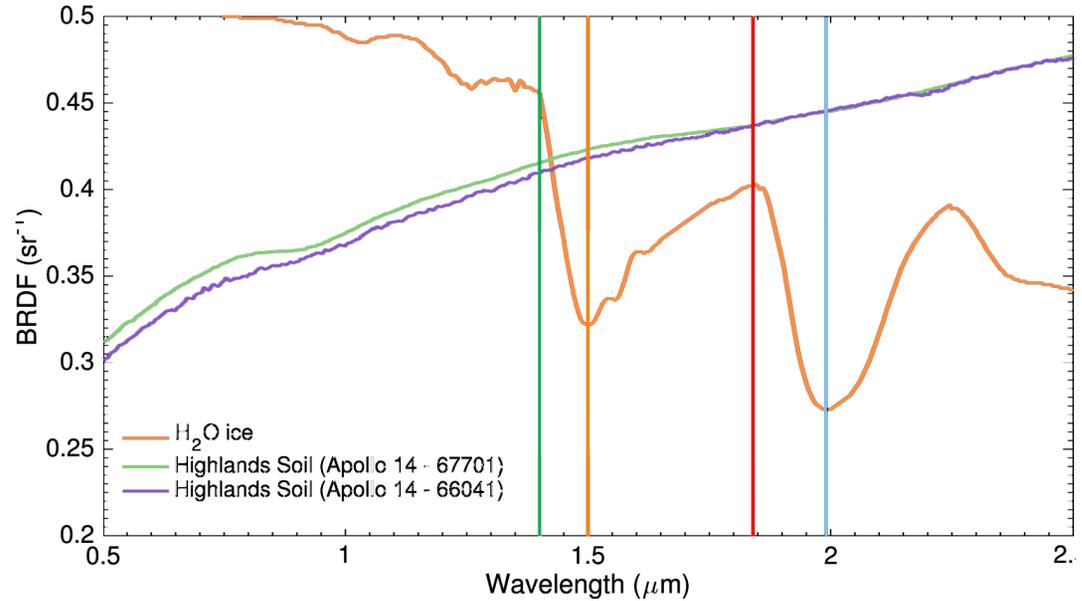
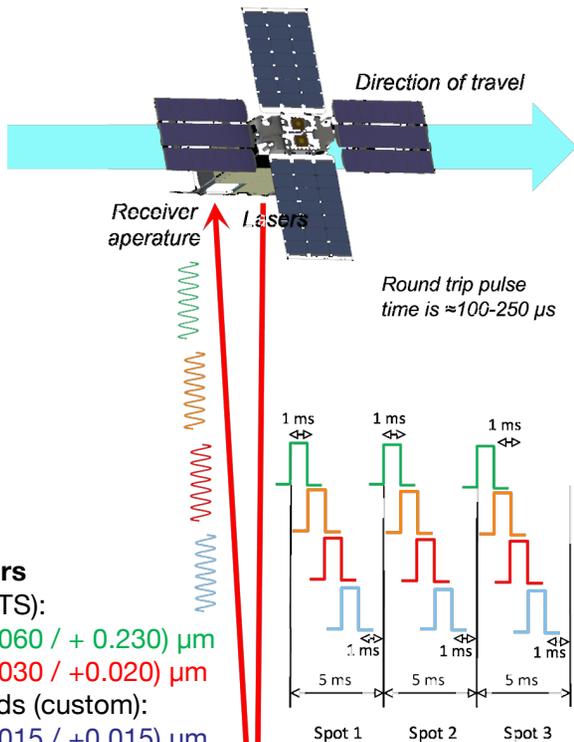


- Measure water ice at multiple locations within PSRs at one pole at ~1-2 km footprint per spot
- This is an *operationally useful* scale for future landers and rovers
- Enables prediction of other ice deposits by correlating data with other mapped geologic characteristics, including latitude, temperature, topography, lighting, proximity to young fresh craters, etc.



LOLA topographic map for the South Polar region from 80S showing large craters and PSRs

Lunar Flashlight Measurement



DILAS laser bars

Continuum (COTS):

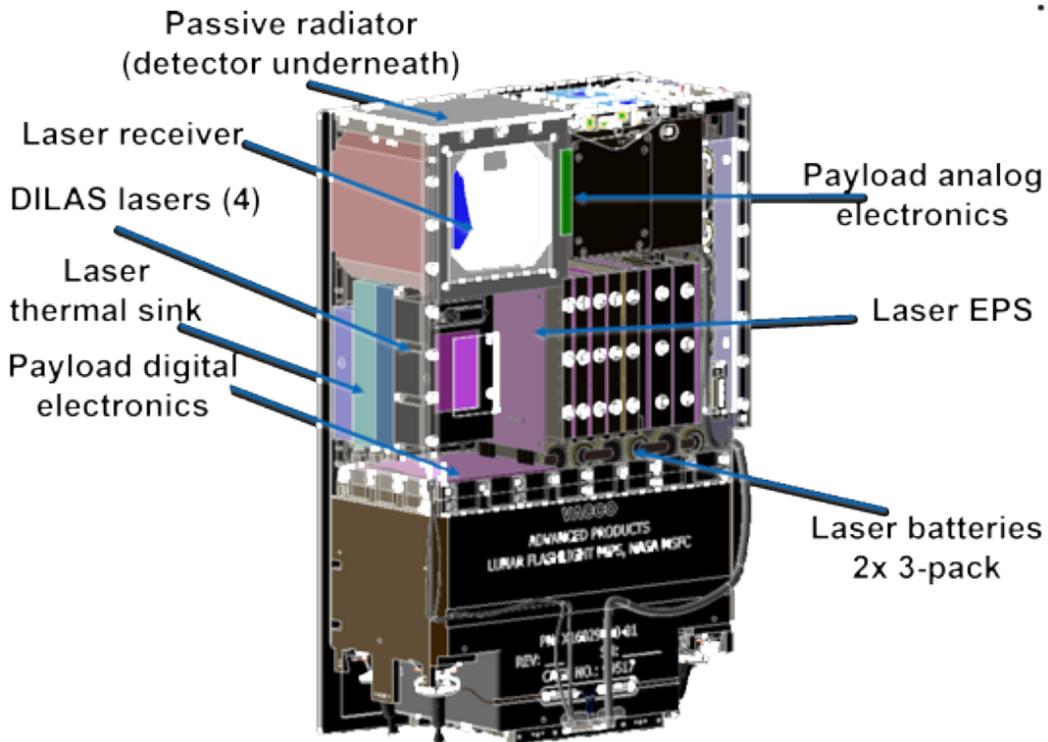
- 1.064 (-0.060 / + 0.230) μm
- 1.850 (-0.030 / +0.020) μm

Absorption bands (custom):

- 1.495 (-0.015 / +0.015) μm
- 1.990 (-0.020 / +0.025) μm

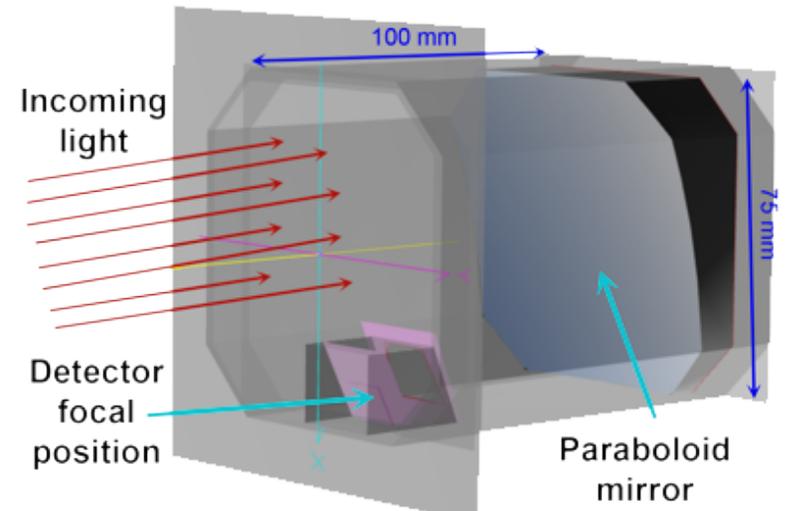
- **Lunar Flashlight will be the first planetary mission to use an active multi-band reflectometer**
- Observe permanently shadowed and eclipsed ground within 80° S
- 1ms time pulsing of 4 lasers, plus one dark ms
- Independent laser power subsystem and power monitoring
- 1 pixel detector reflectometer sensitive over 1-2 μm
- Raw data collection and transfer from SC to ground

Lunar Flashlight Payload



Receiver:

- Field-of-view: 14 mrad
- Volume 88.9 x 99.06 x 88.9 mm
- Passively cooled by external radiator



Detector

- 1mm diameter Teledyne Judson InGaAs detector
- 2.2 μ m cutoff
- 1.1A/W responsivity
- Detector operational T: 208 K

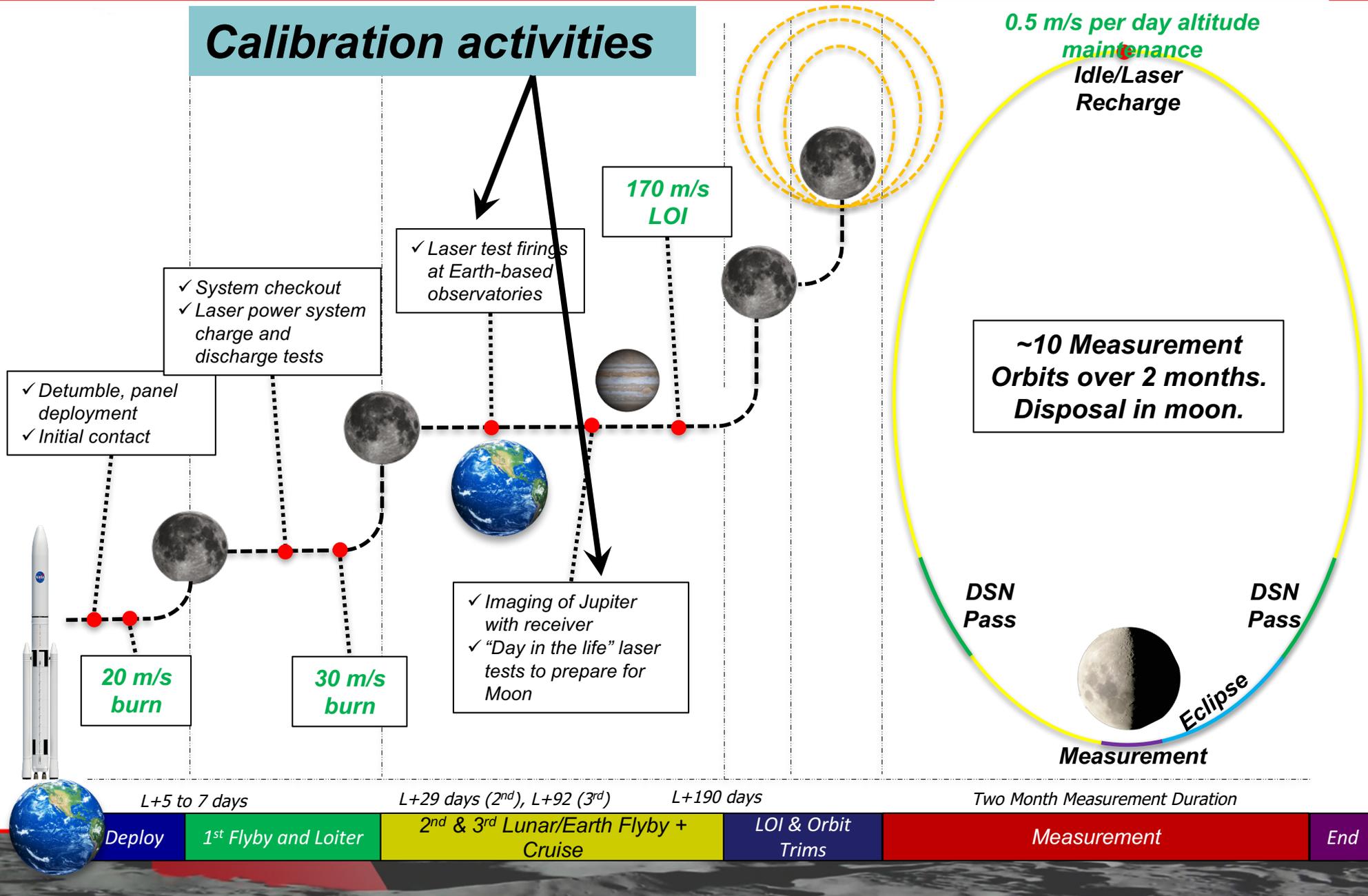
Mirror Surface:

- AR-coated aluminum bare mirror for 1- 2 μ m
- Radius of curvature: 140mm
- Conic constant: -1
- Figure 2λ @ 632.8 nm
- RMS roughness: <30Å

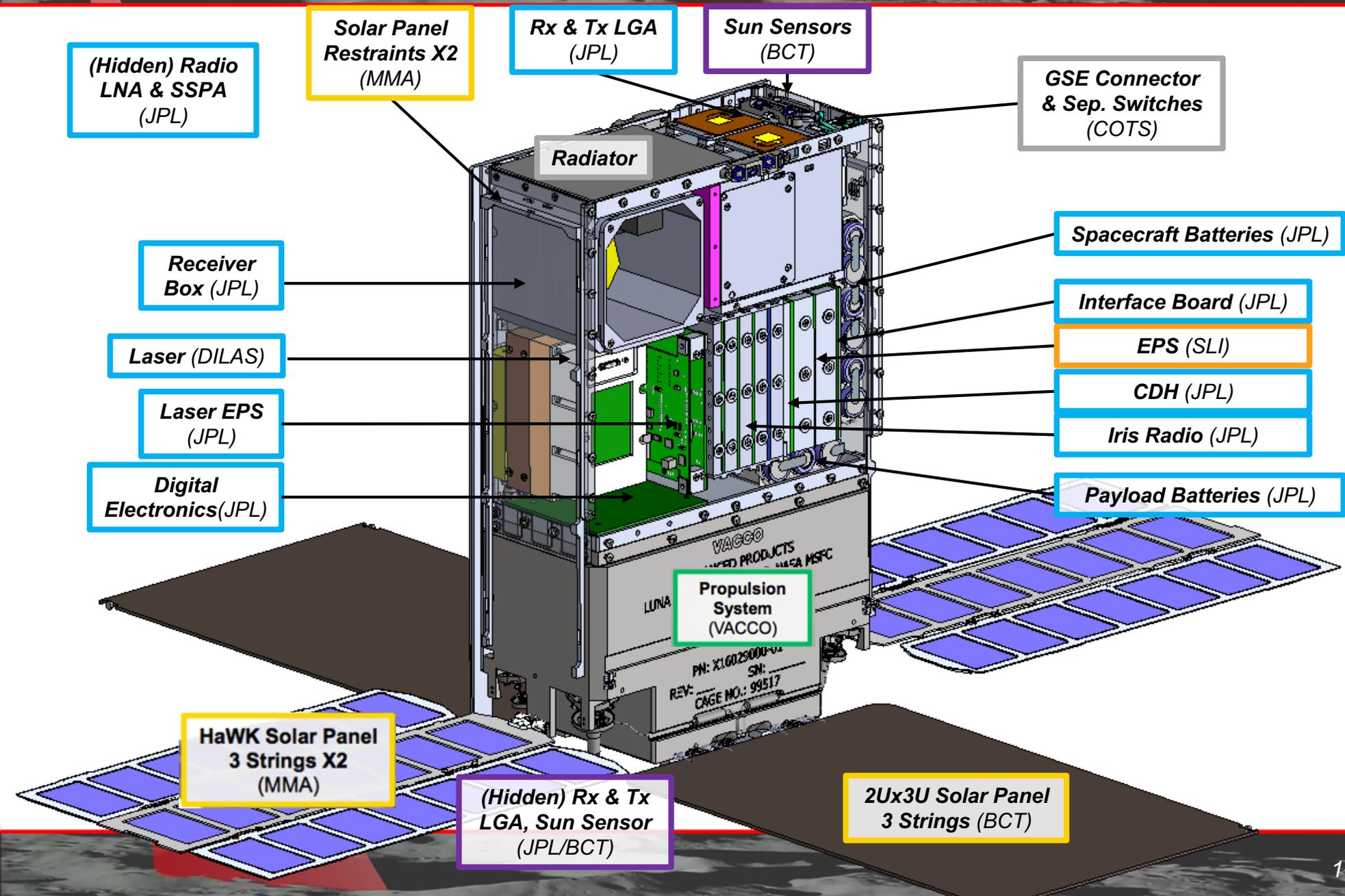
Lunar Flashlight ConOps



Calibration activities



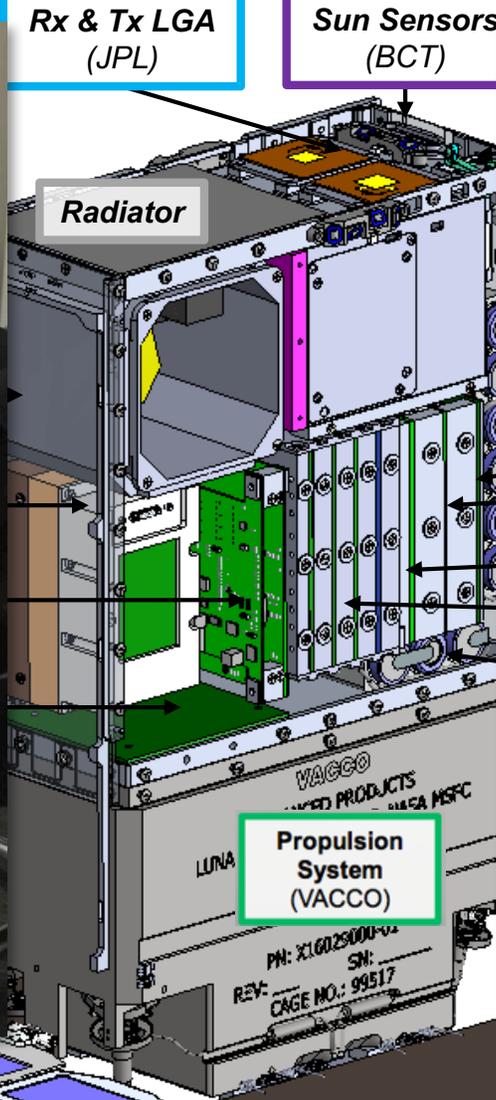
LF System Overview



LF System Overview



Solar Panel



Rx & Tx LGA (JPL)

Sun Sensors (BCT)

Radiator

Propulsion System (VACCO)



HaWK Solar Panel
3 Strings X2
(MMA)

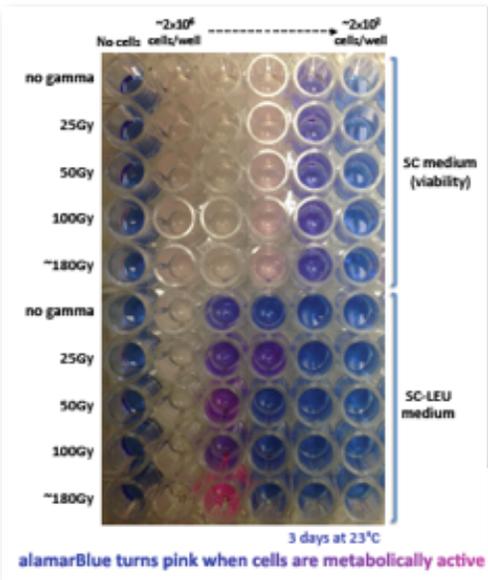
(Hidden) Rx & Tx
LGA, Sun Sensor
(JPL/BCT)

2Ux3U Solar Panel
3 Strings (BCT)

Other EM-1 cubesats



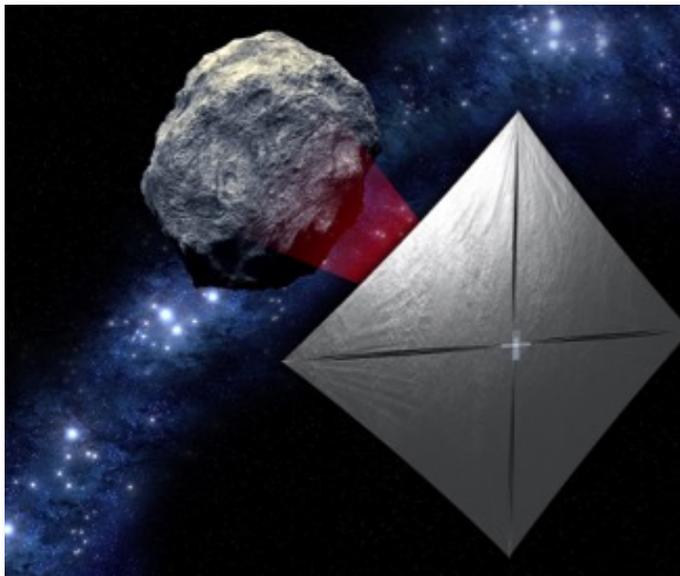
Biosentinel:
DNA damage-
and-repair
experiment
using
microfluidics



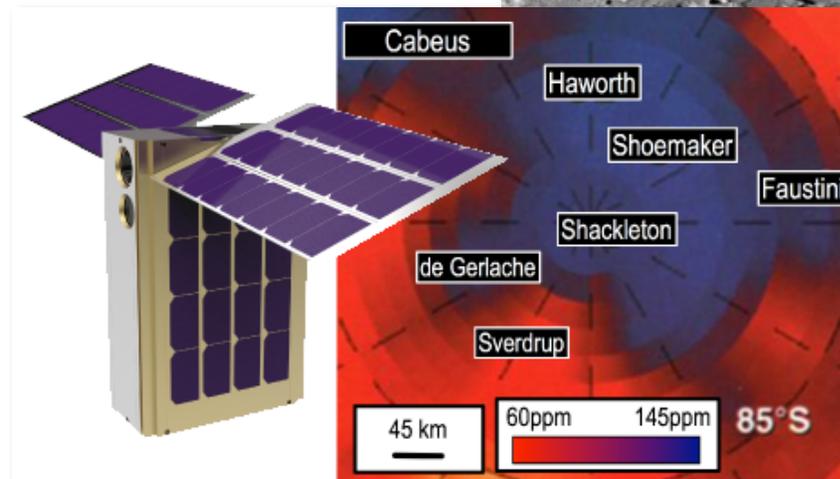
Lunar IceCube: Characterize
surficial water and its variability
using a passive IR
spectrometer (1-4 μm)



LunaH-map: Deep polar H
deposits at the lunar south
pole with low-altitude
neutron spectroscopy



NEA Scout:
Characterize
a near-earth
asteroid's
volume,
spectral type,
spin and
orbital
properties



Lunar WATER PSDS study



- The Lunar Water Assessment, Transport, Evolution, and Resource (WATER) Small Satellite Mission Concept, PI C.A. Hibbitts (APL)
- Evaluate a payload and CONOPS for a small lunar orbiter to achieve concurrent measurements of water sources and sinks
- Earth Geosynchronous transfer to eccentric lunar orbit



&



- Solid Iodine Solar Electric Propulsion (SEP)
- Wet mass: 200kg (GTO), 160kg (ride to LEO)
- Trade among flight-heritage instruments
 - 3- μ m spectral imager
 - UV spectral imager
 - Neutral Atom Imager
 - Electrostatic Analyzer
 - MidIR Laser
 - Neutron Spectrom
 - Faraday cup
 - Radar Sounder
- Results will be reported at a special session at the 2018 Lunar & Planetary Science Conference

Summary



- **Water is a human-exploitable resource**
- Lunar Flashlight is a Cubesat mission to **detect and map lunar surface ice** in permanently-shadowed regions of the lunar south pole
- **EM-1 will carry 13 Cubesat**-class missions to further smallsat science & exploration capabilities; much room to infuse LEO cubesat methodology, models, and technology
- Exploring the value of **concurrent measurements** to measure dynamical processes of water sources and sinks

