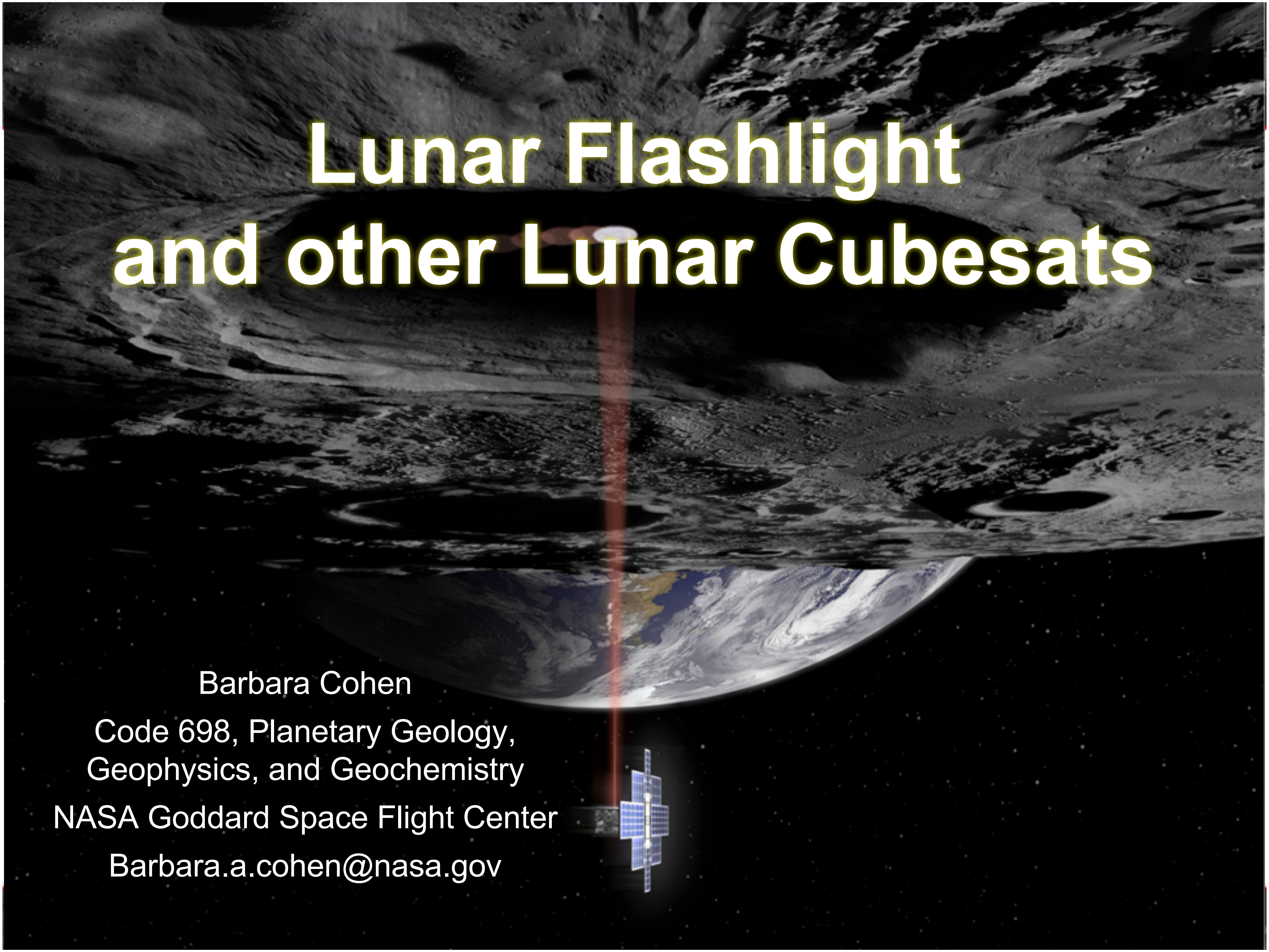
# Lunar Flashlight and other Lunar Cubesats



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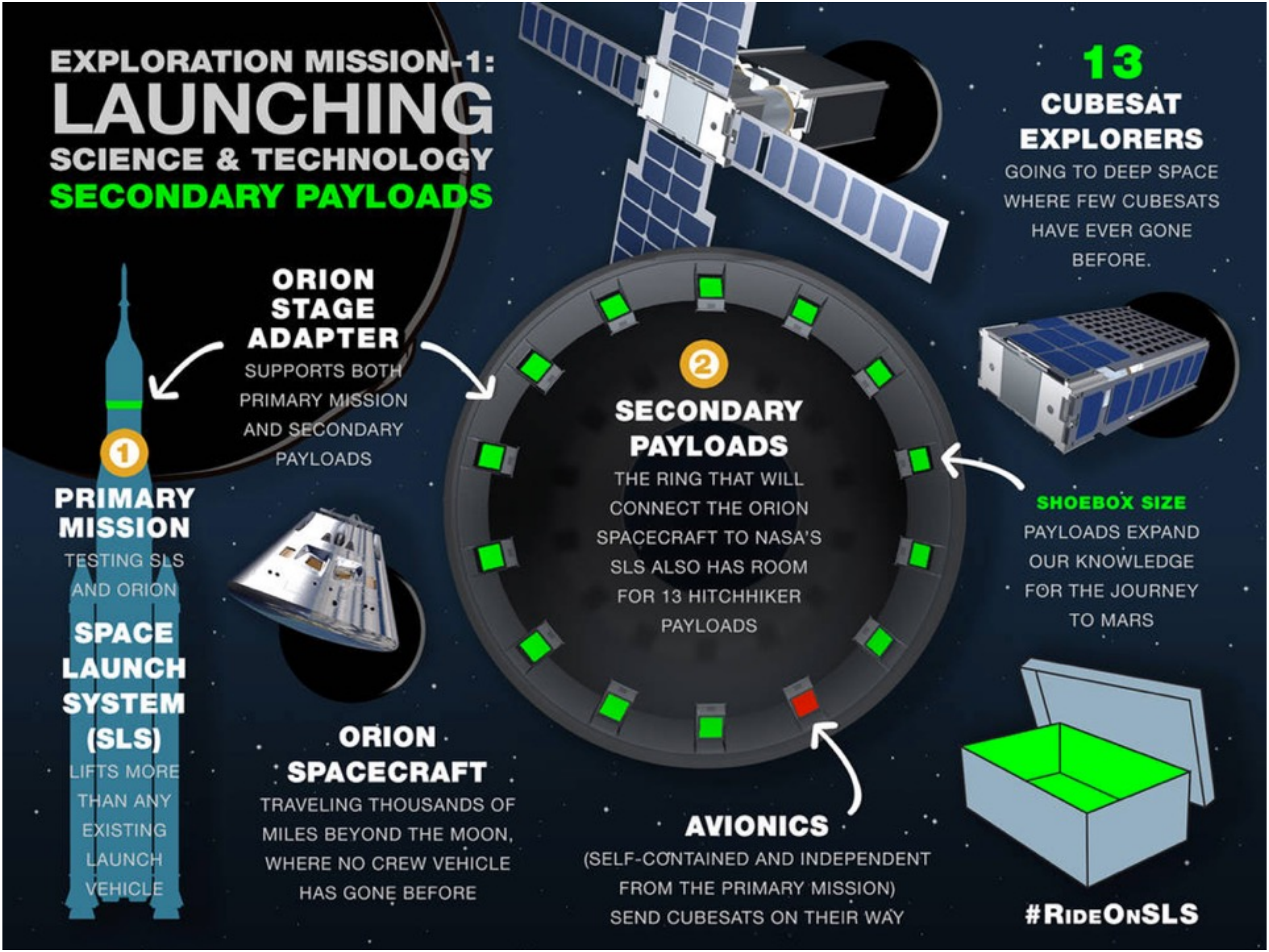
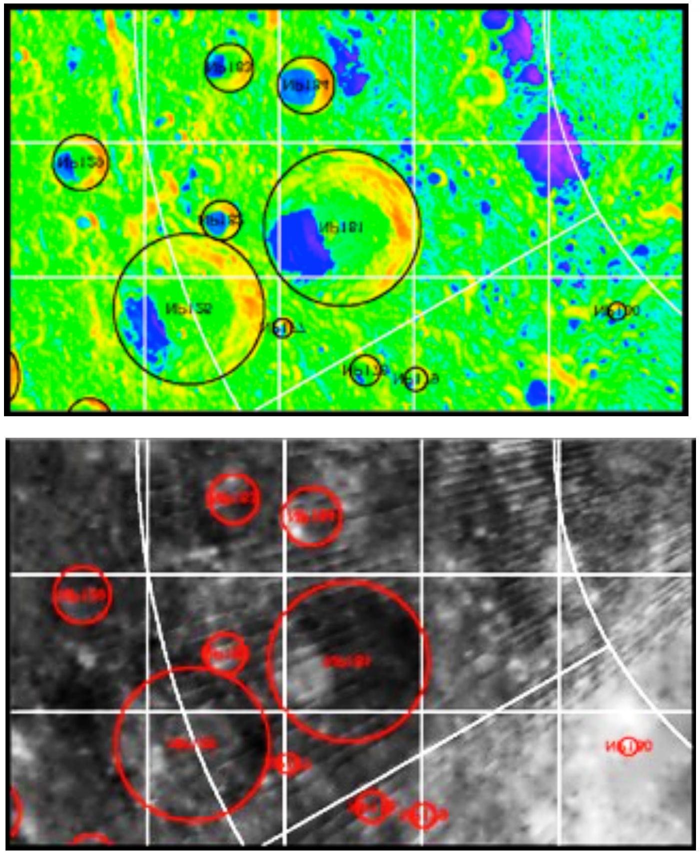
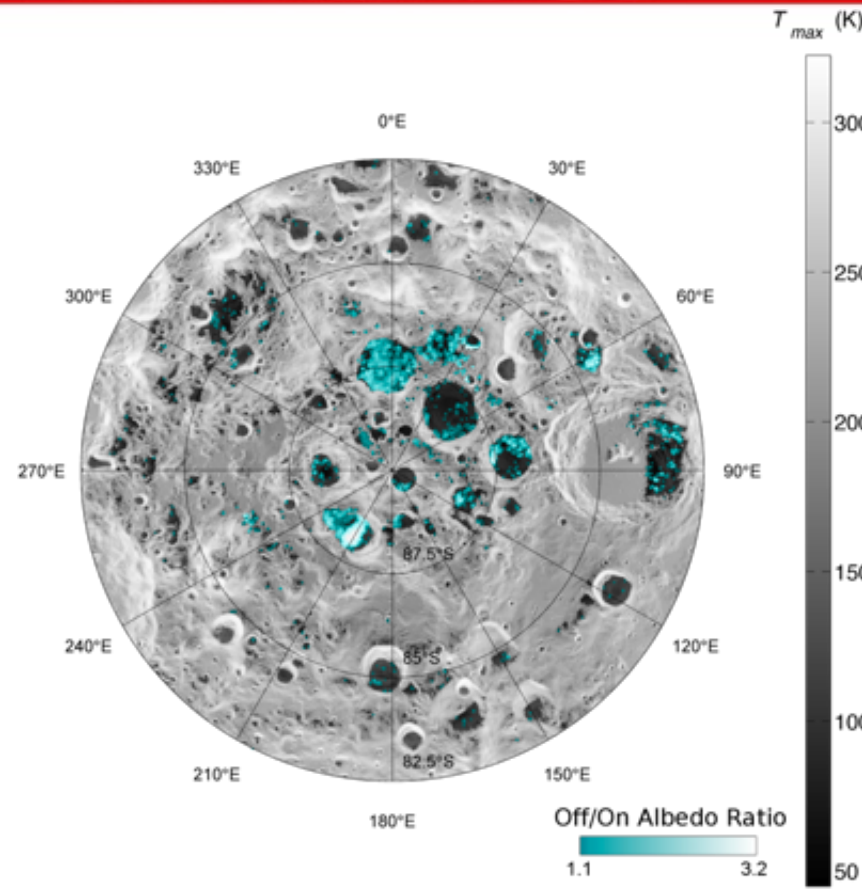

EXPLORATION MISSION-1:
LAUNCHING
SCIENCE & TECHNOLOGY
SECONDARY PAYLOADS
13
CUBESAT EXPLORERS
GOING TO DEEP SPACE WHERE FEW CUBESATS HAVE EVER GONE BEFORE.
ORION STAGE ADAPTER
SUPPORTS BOTH PRIMARY MISSION AND SECONDARY PAYLOADS
1
PRIMARY MISSION
TESTING SLS AND ORION
2
SECONDARY PAYLOADS
THE RING THAT WILL CONNECT THE ORION SPACECRAFT TO NASA'S SLS ALSO HAS ROOM FOR 13 HITCHHIKER PAYLOADS
SHOEBOX SIZE
PAYLOADS EXPAND OUR KNOWLEDGE FOR THE JOURNEY TO MARS
SPACE LAUNCH SYSTEM (SLS)
LIFTS MORE THAN ANY EXISTING LAUNCH VEHICLE
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
#RIDEONSLS

# Resources for human exploration

- Humans exploring the Moon will need water:
  - Option 1: Carry it there. ↲ expensive (at $10K/lb, 1 gal $H_2O$=$80K)
  - Option 2: Use water that may be there already. ↲ “live off the land”
- Can mine $O_2$ 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 $H_2O$ from the Moon
- **At the surface or near surface**
- **In “operationally useful” quantities**

# Water ice frost on the lunar surface?

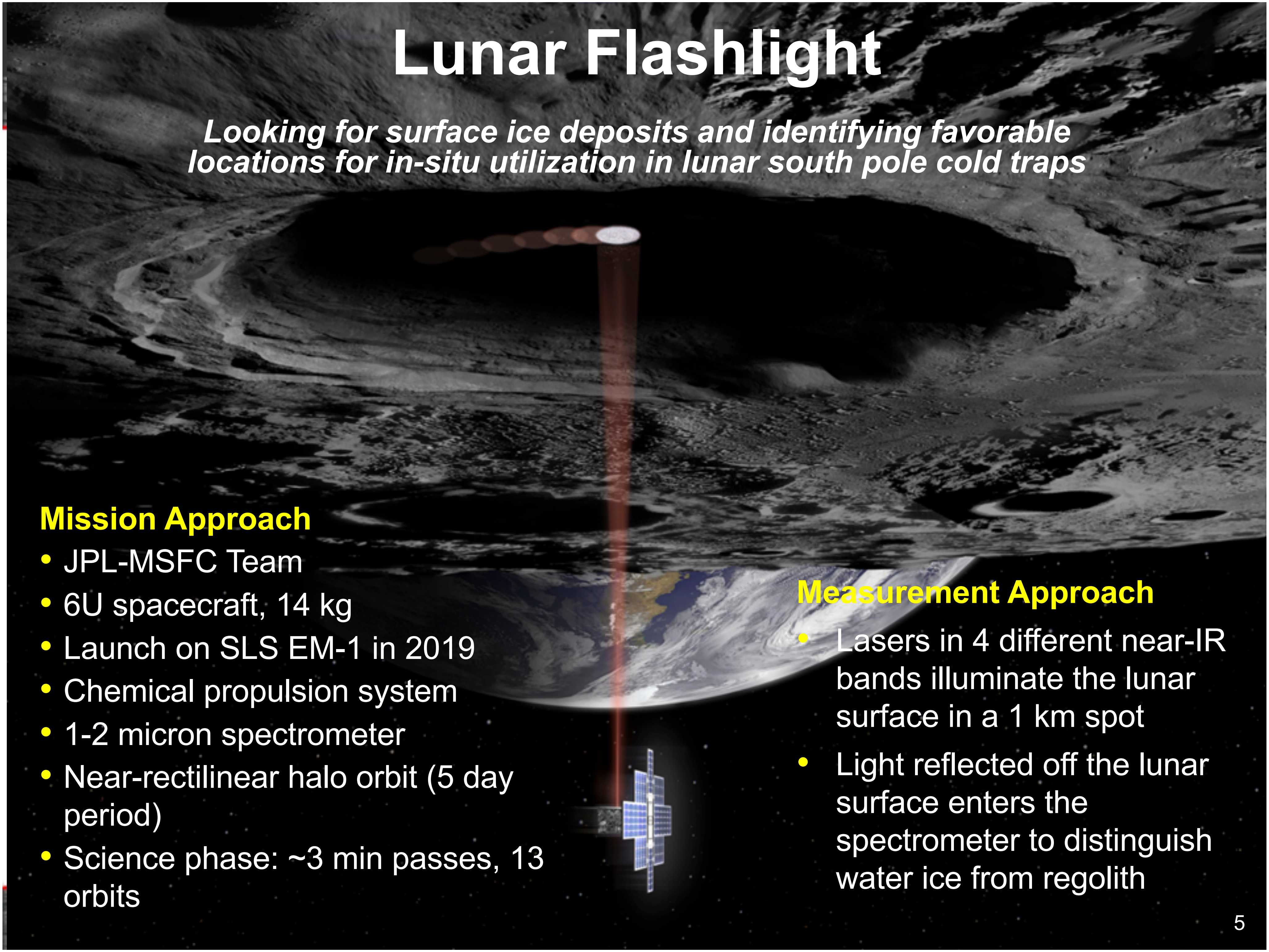





- Cold temperatures (Diviner) correlate with high albedo at 1.064 μm (LOLA) (Zuber et al. 2012, Lucey et al. 2014, Haruyama et al. 2013, Fisher et al. 2017)
- Also correlated with high ultraviolet albedo data from LAMP (Hayne et al. 2014)

# Lunar Flashlight

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



## Mission Approach

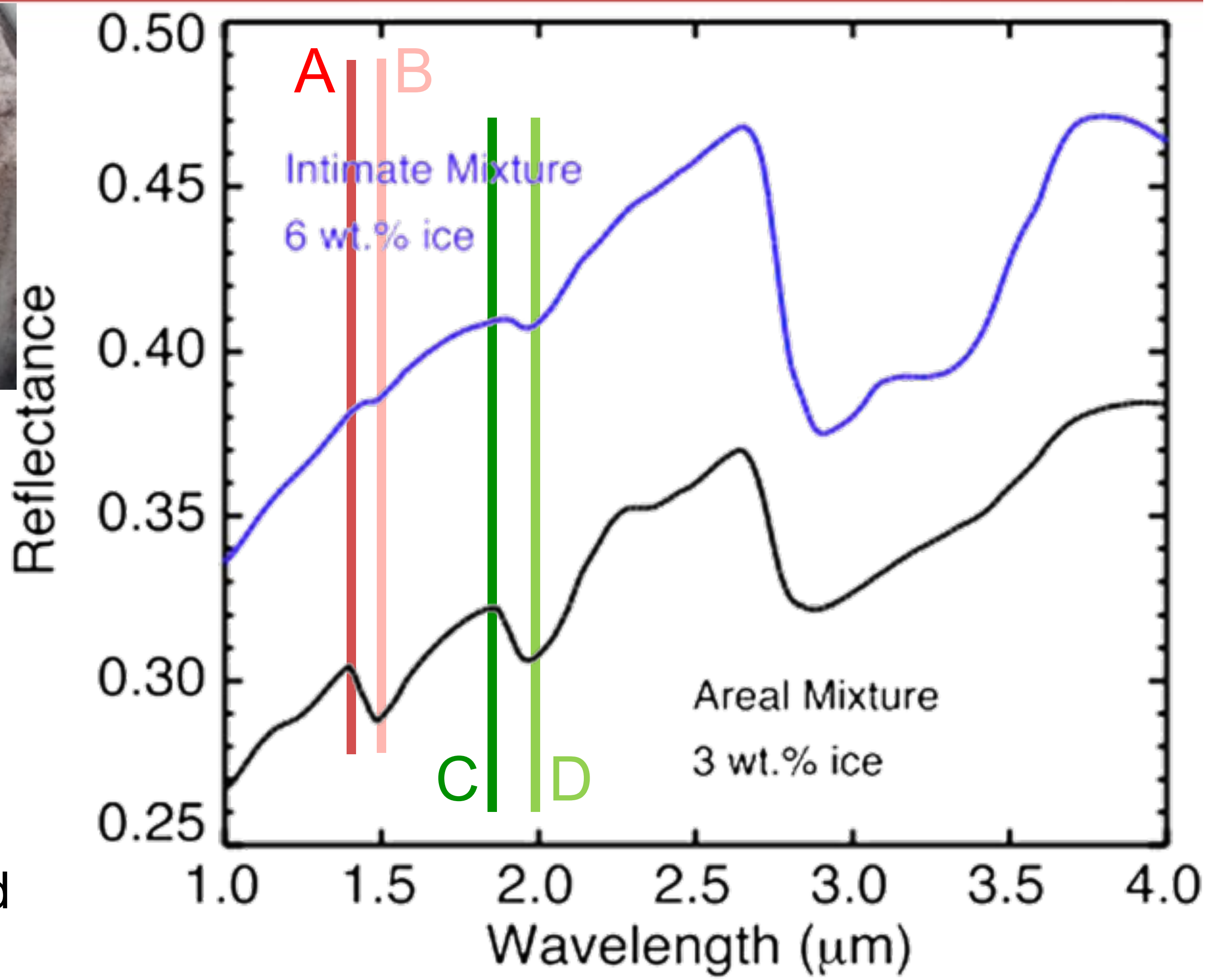
- JPL-MSFC Team
- 6U spacecraft, 14 kg
- Launch on SLS EM-1 in 2019
- Chemical propulsion system
- 1-2 micron spectrometer
- Near-rectilinear halo orbit (5 day period)
- Science phase: ~3 min passes, 13 orbits

## 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

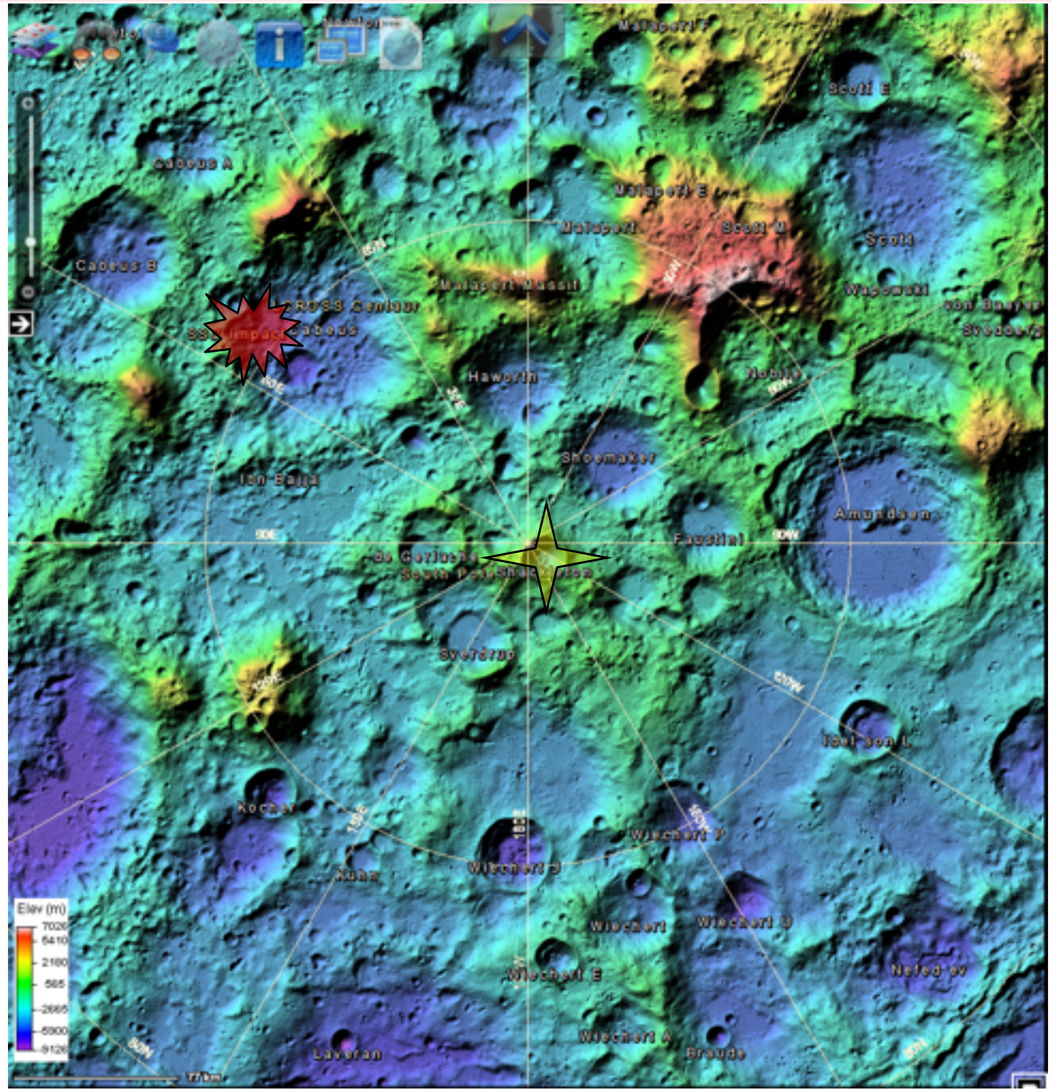
# Measurement Goal

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



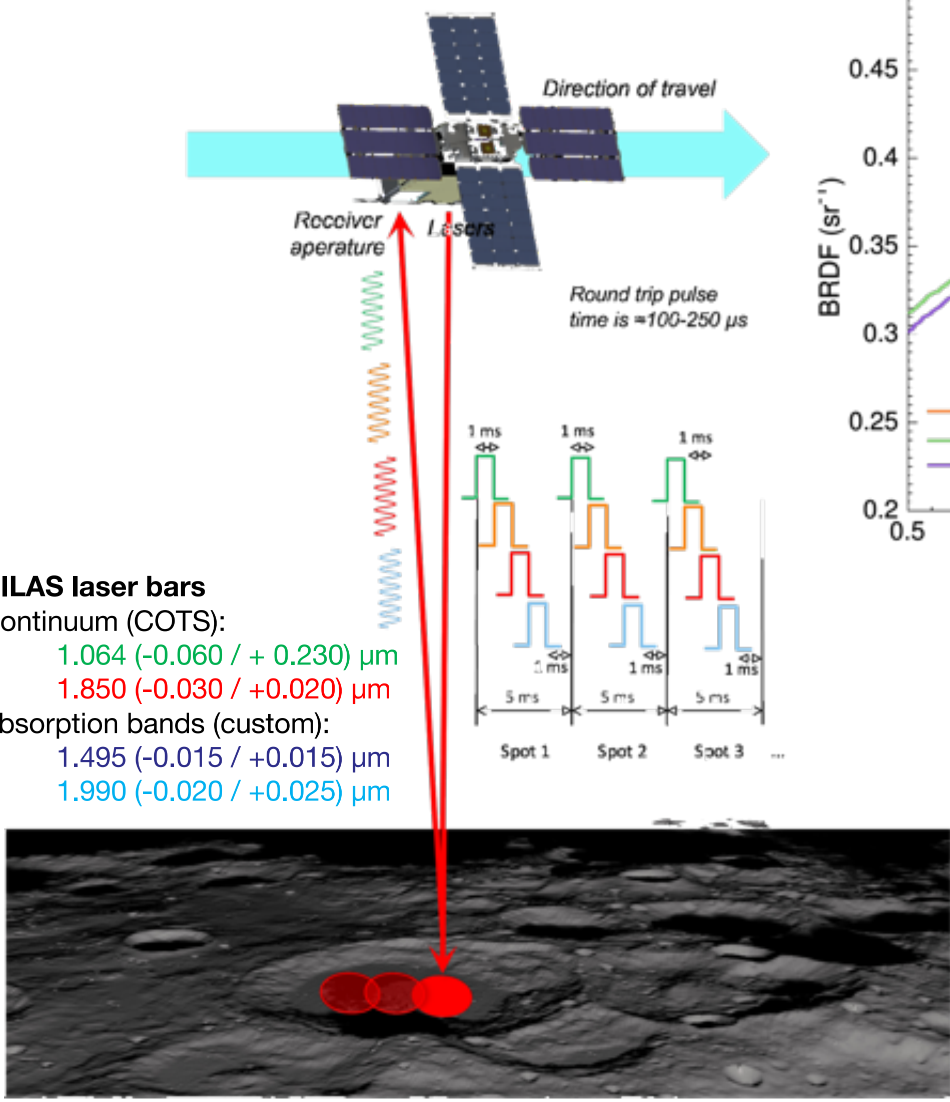
# Mapping Goal

- 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*

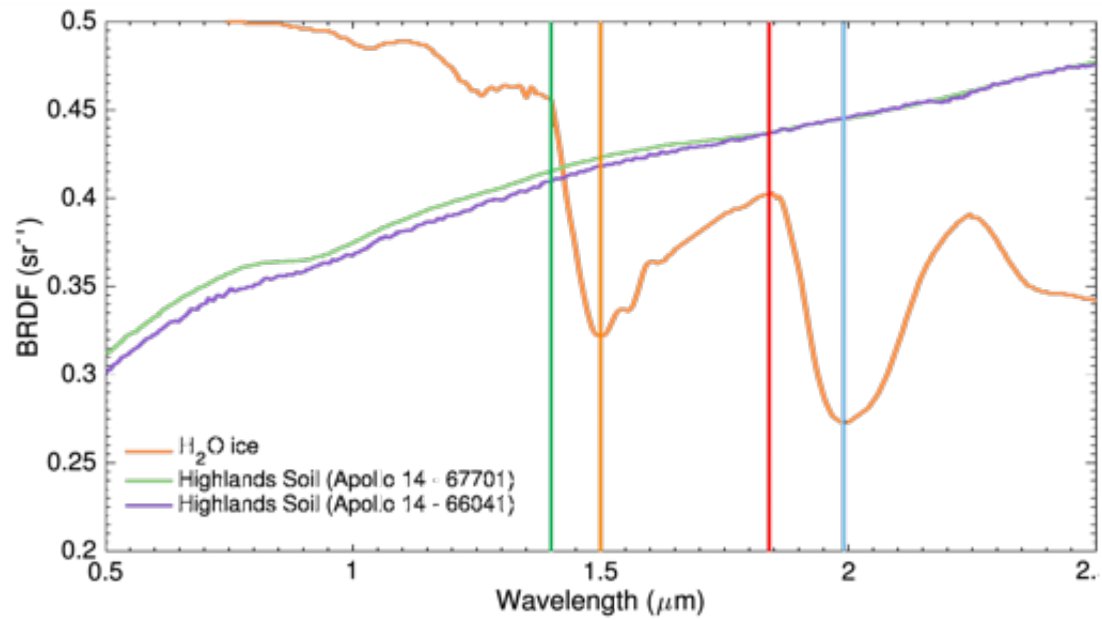
# Lunar Flashlight Measurement




**DILAS laser bars**

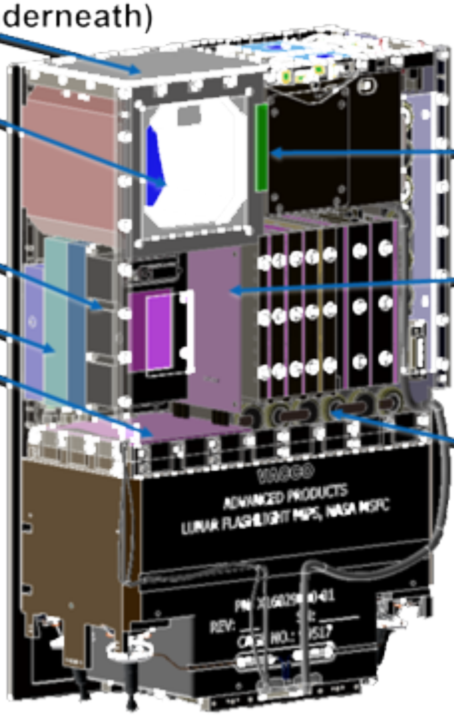
Continuum (COTS):
- 1.064 (-0.060 / + 0.230) µm
- 1.850 (-0.030 / +0.020) µm

Absorption bands (custom):
- 1.495 (-0.015 / +0.015) µm
- 1.990 (-0.020 / +0.025) µm



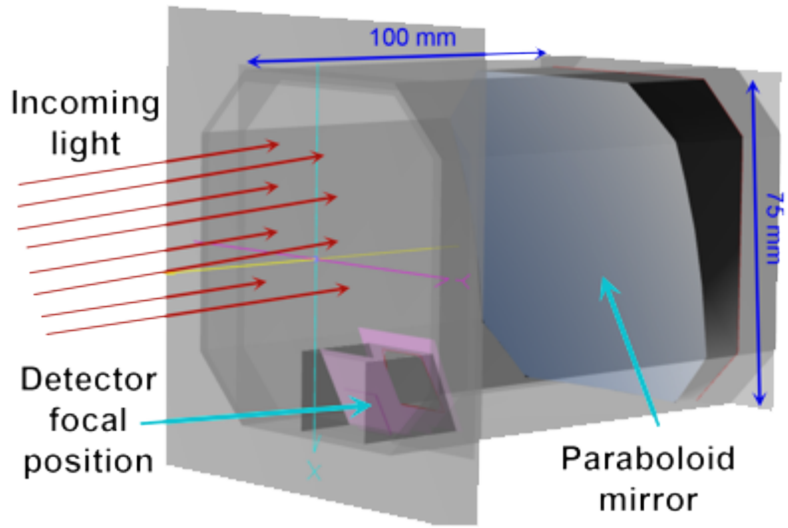

- ***Lunar Flashlight will be the first planetary mission to use an active multi-band reflectometer***
- Observe permanently shadowed and eclipsed ground within 80° S
- 1ms time pulsing of 4 lasers, plus one dark ms
- Independent laser power subsystem and power monitoring
- 1 pixel detector reflectometer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



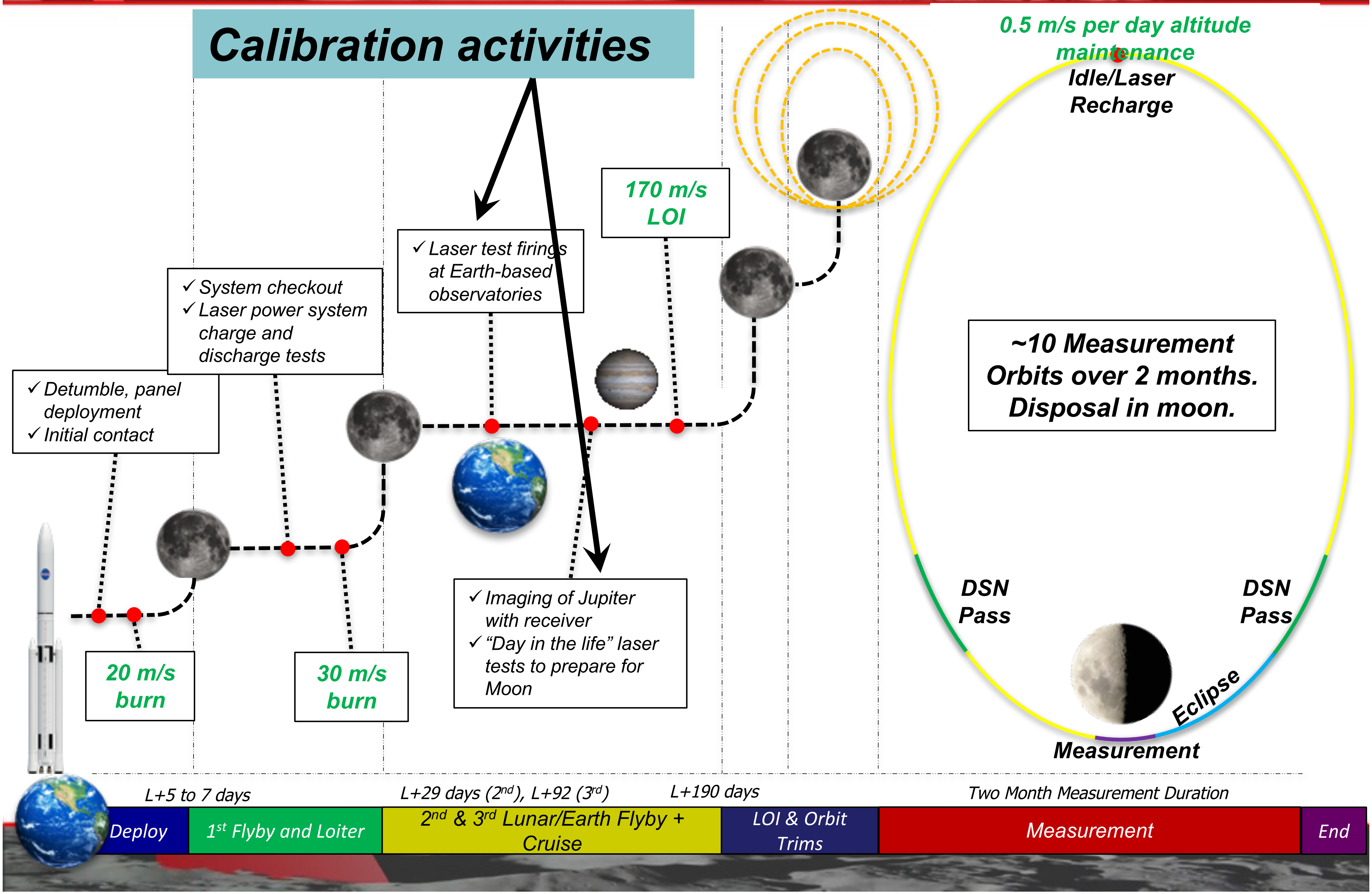

**Detector**

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

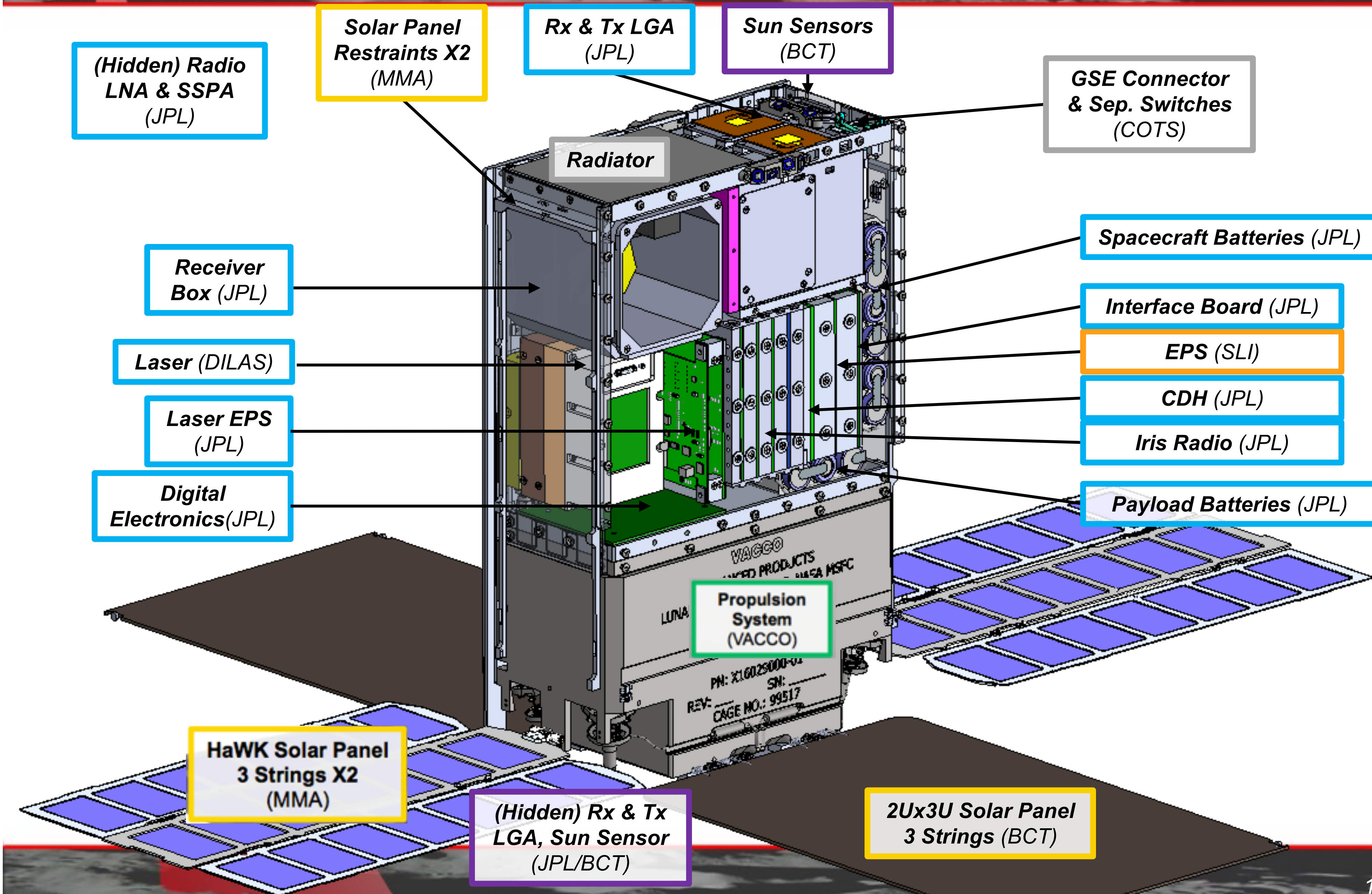
**Mirror Surface:**

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

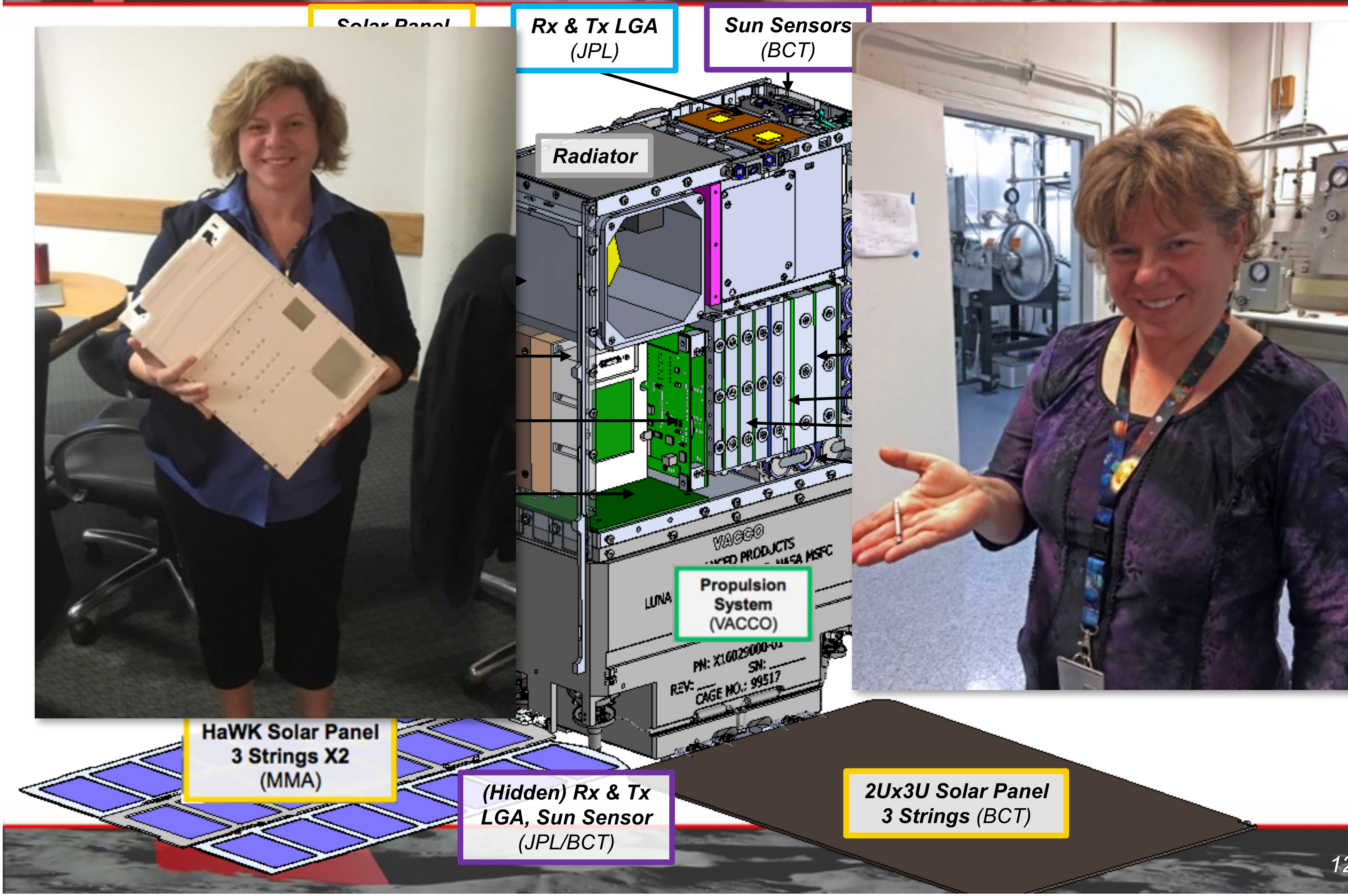
# Lunar Flashlight ConOps



# LF System Overview

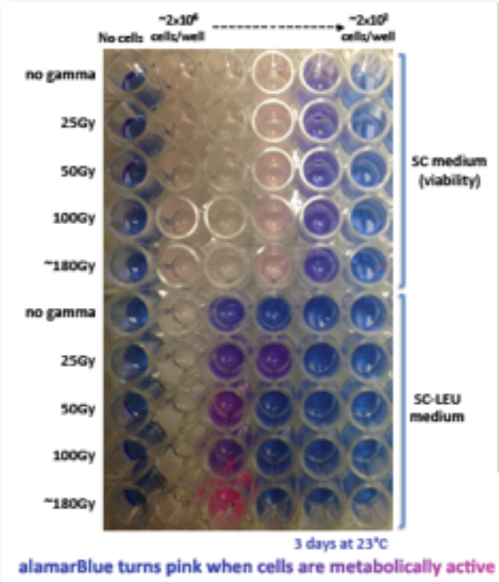


# LF System Overview



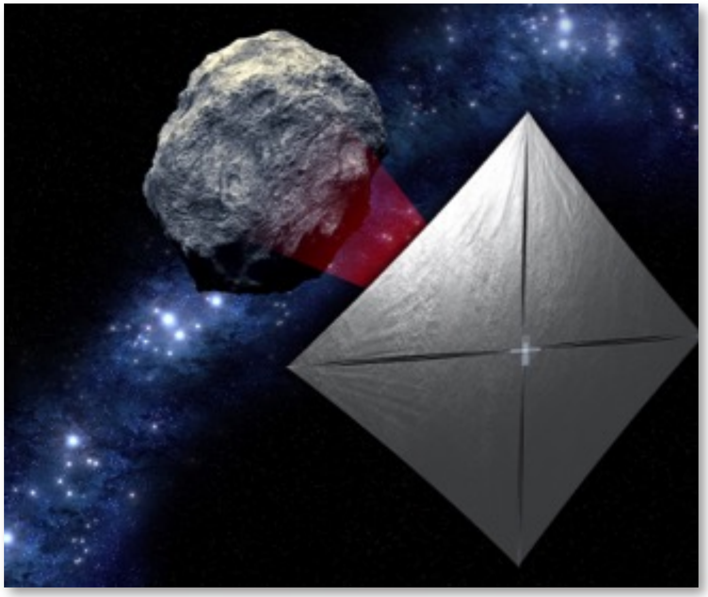
# Other EM-1 cubesats

**Biosentinel**: DNA damage-and-repair experiment using microfluidics

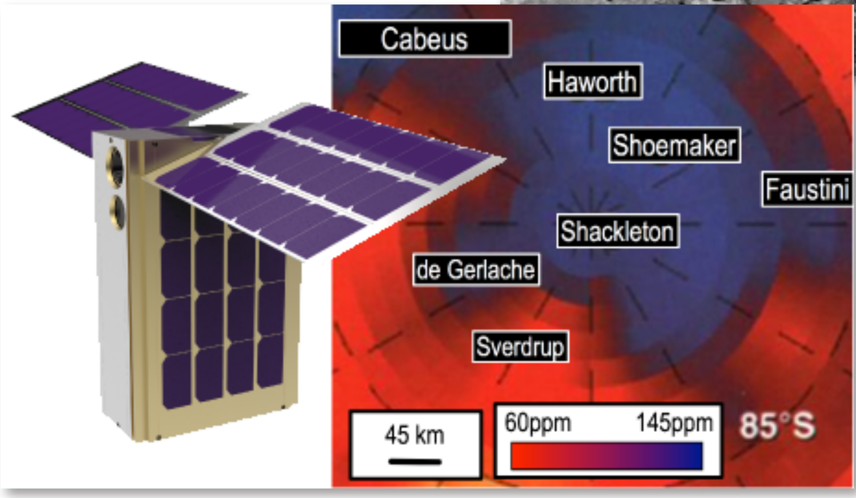



**Lunar IceCube**: Characterize surfical water and its variability using a passive IR spectrometer (1-4 μm)

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

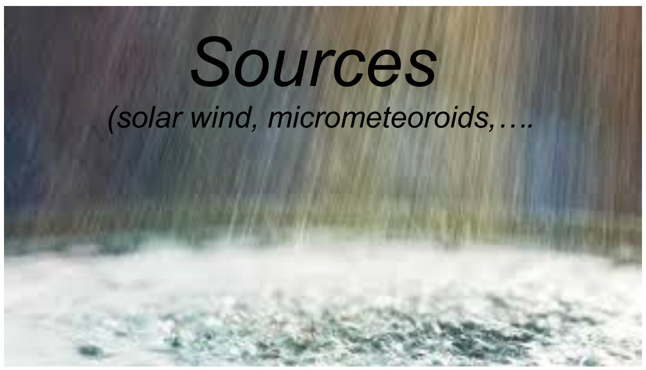


**NEA Scout**: Characterize a near-earth asteroid's volume, spectral type, spin and orbital properties



# 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

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- Solid Iodine Solar Electric Propulsion (SEP)
- Wet mass: 200kg (GTO), 160kg (ride to LEO)
- Trade among flight-heritage instruments
  - 3-µm spectral imager -- MidIR Laser
  - UV spectral imager -- Neutron Spectrom
  - Neutral Atom Imager -- Faraday cup
  - Electrostatic Analyzer -- 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