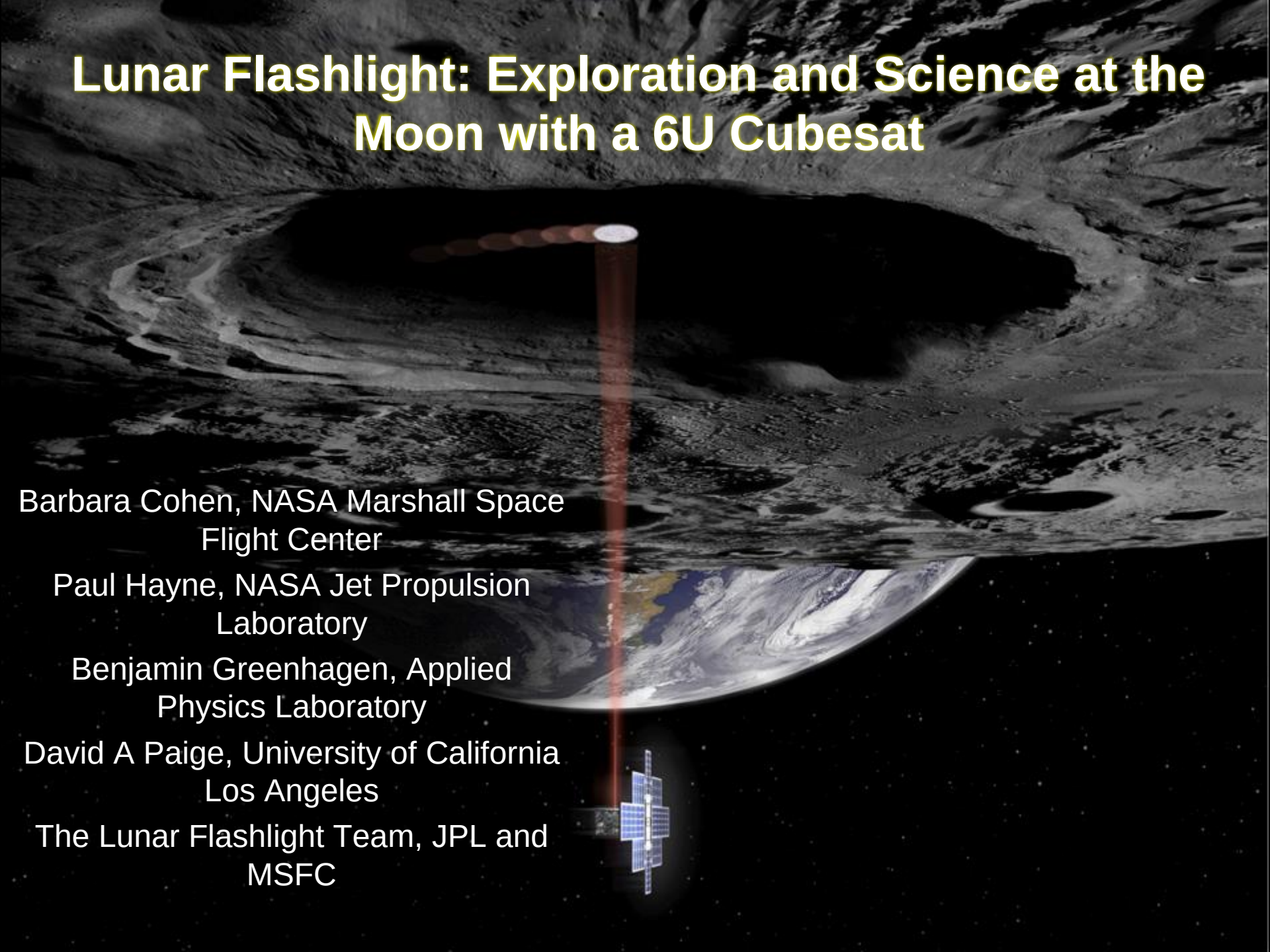
Lunar Flashlight: Exploration and Science at the Moon with a 6U Cubesat



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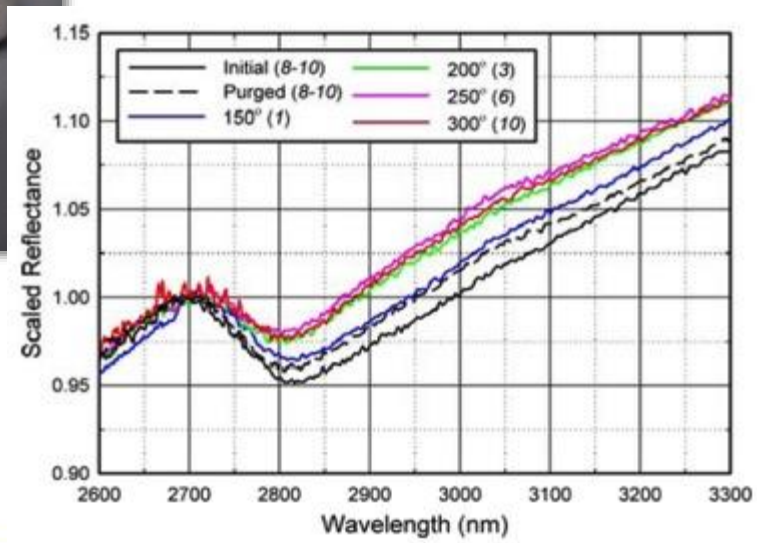
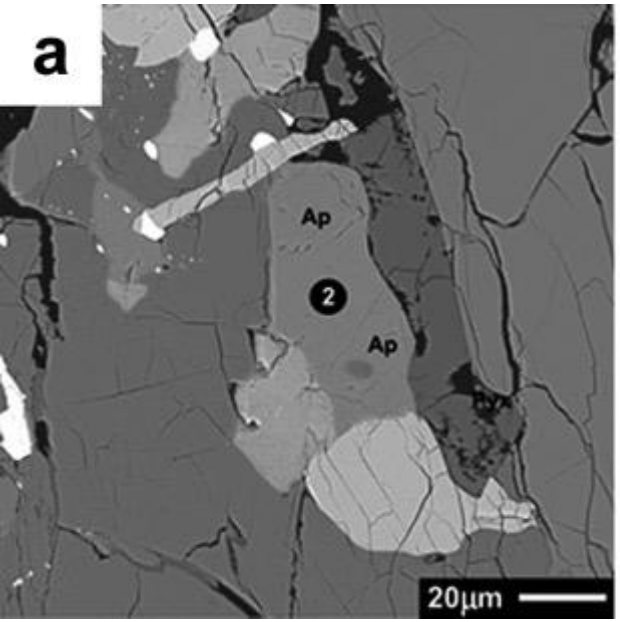
Water on the Moon

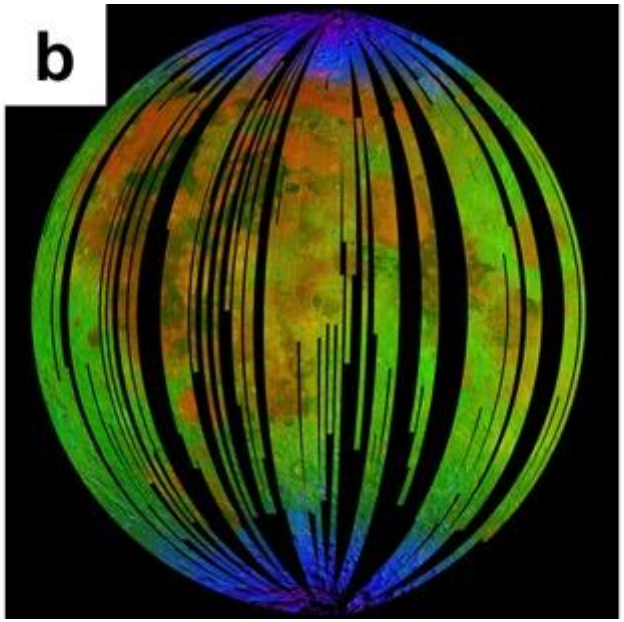


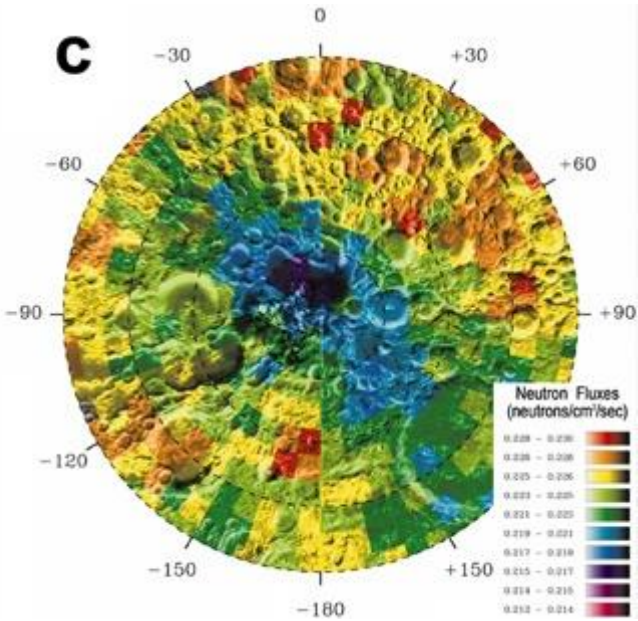
- Moon rocks are drier than any known terrestrial rock – no hydrous minerals like mica, amphibole, clay minerals, hydrous iron oxides
- All returned lunar samples have adsorbed water on their surfaces – thought to be terrestrial contamination (and probably most of it actually is)

When we looked harder….

- Updated techniques (in the lab and on spacecraft) show the Moon actually does have indigenous water, though in very small amounts
  a) Interior (magmatic) – in deep mantle rocks
  b) Surficial (in upper mm of grains)
  c) Polar deposits



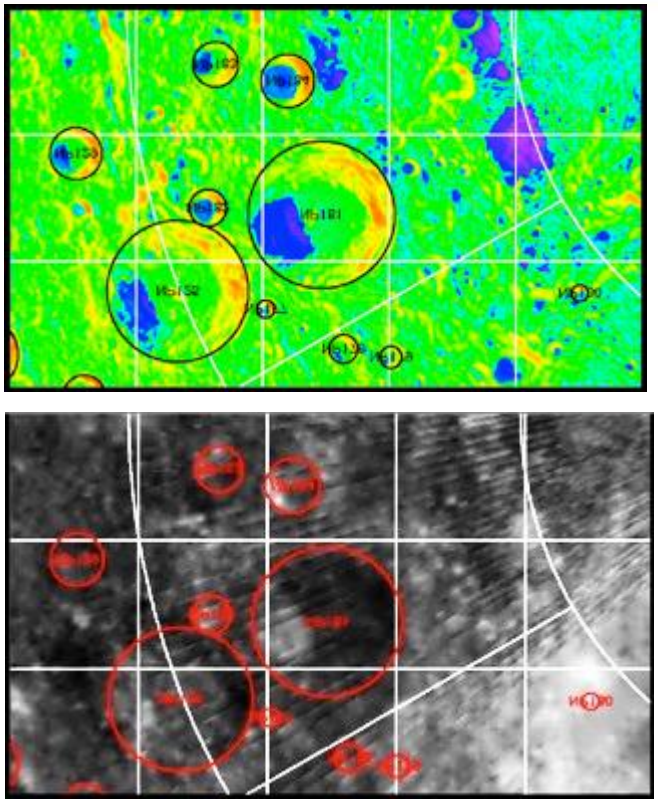


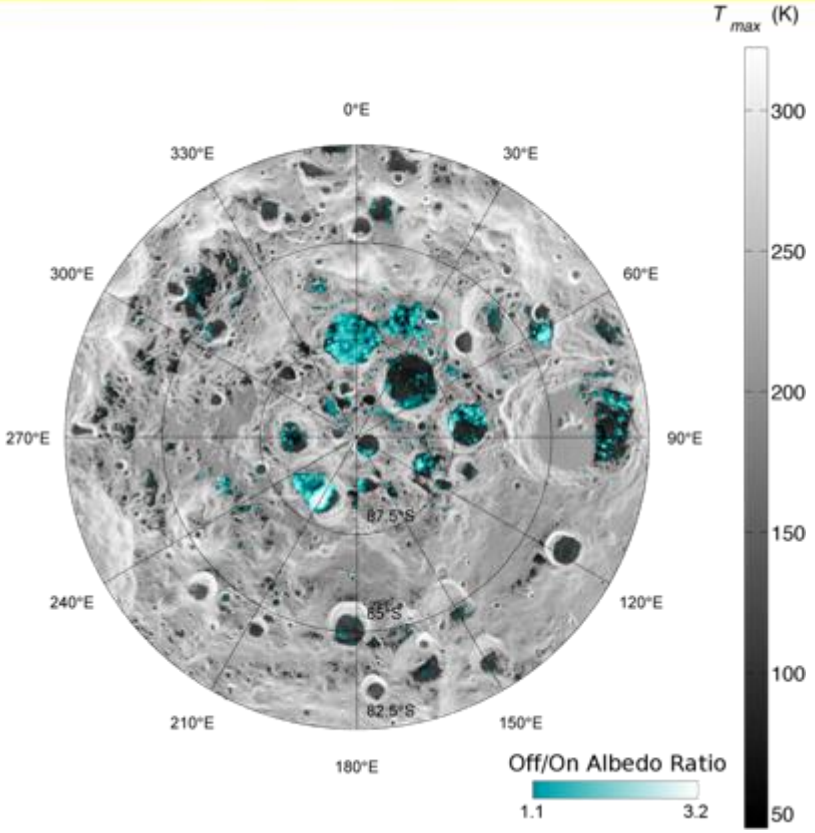


Water is a resource

- 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

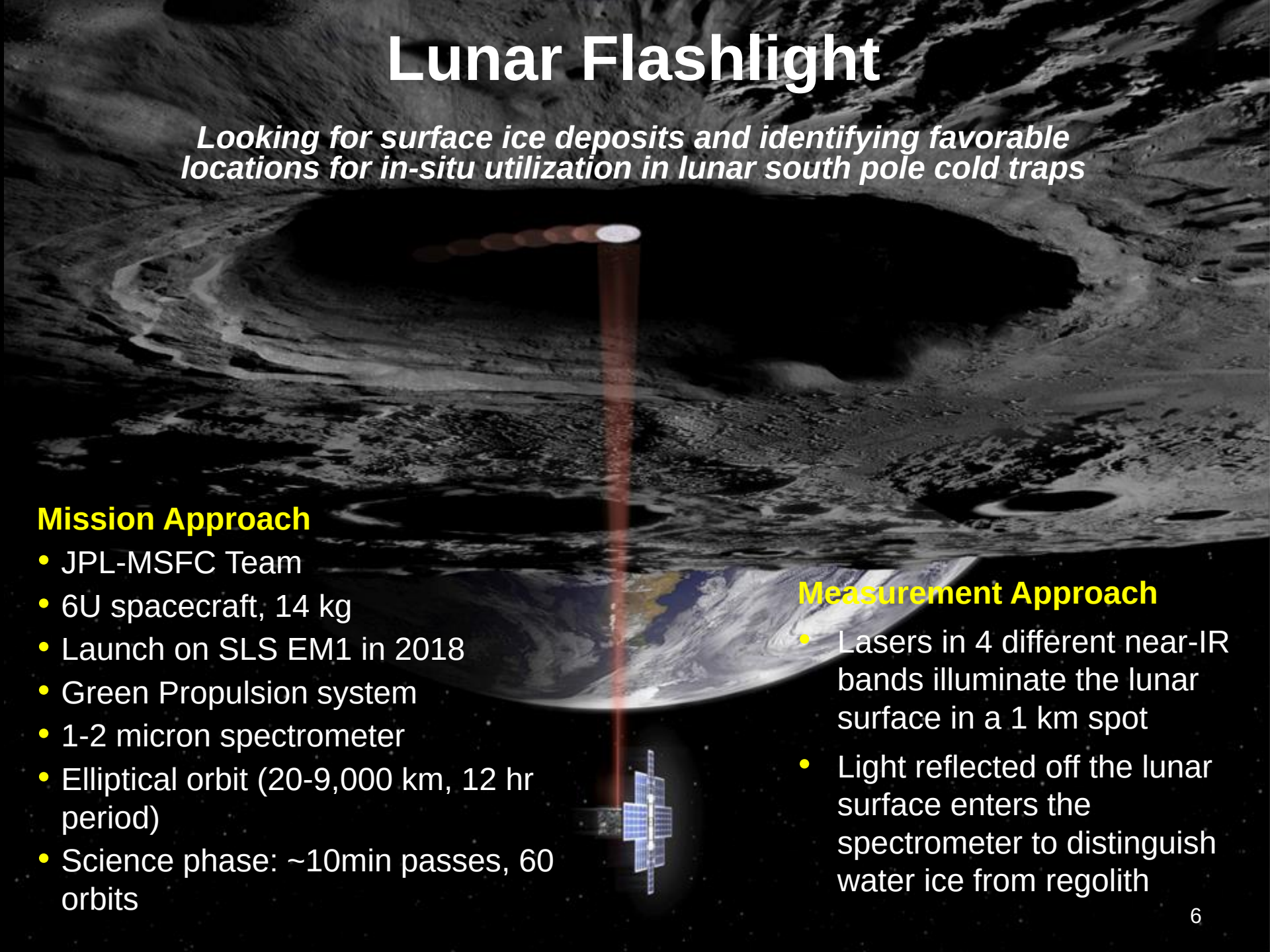




- Cold temperatures (Diviner) correlate with high albedo at 1.064 μm (LOLA) (Zuber et al. 2012, Lucey et al. 2014, Haruyama et al. 2013)
- Also correlated with high ultraviolet albedo data from LAMP (Hayne et al. 2014)

Lunar Flashlight

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



Mission Approach

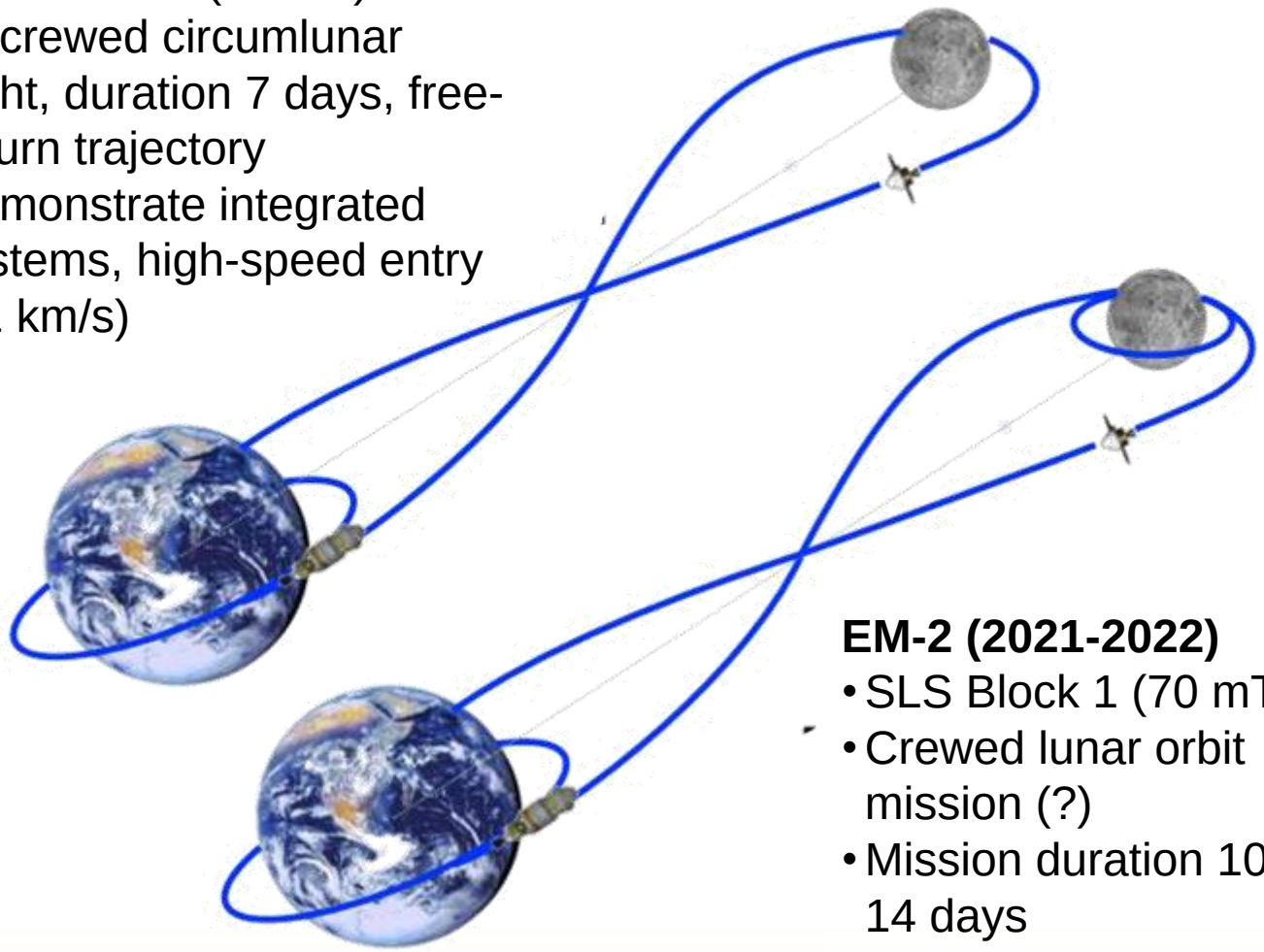
- JPL-MSFC Team
- 6U spacecraft, 14 kg
- Launch on SLS EM1 in 2018
- Green Propulsion system
- 1-2 micron spectrometer
- Elliptical orbit (20-9,000 km, 12 hr period)
- Science phase: ~10min passes, 60 orbits

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

Space Launch System (SLS)

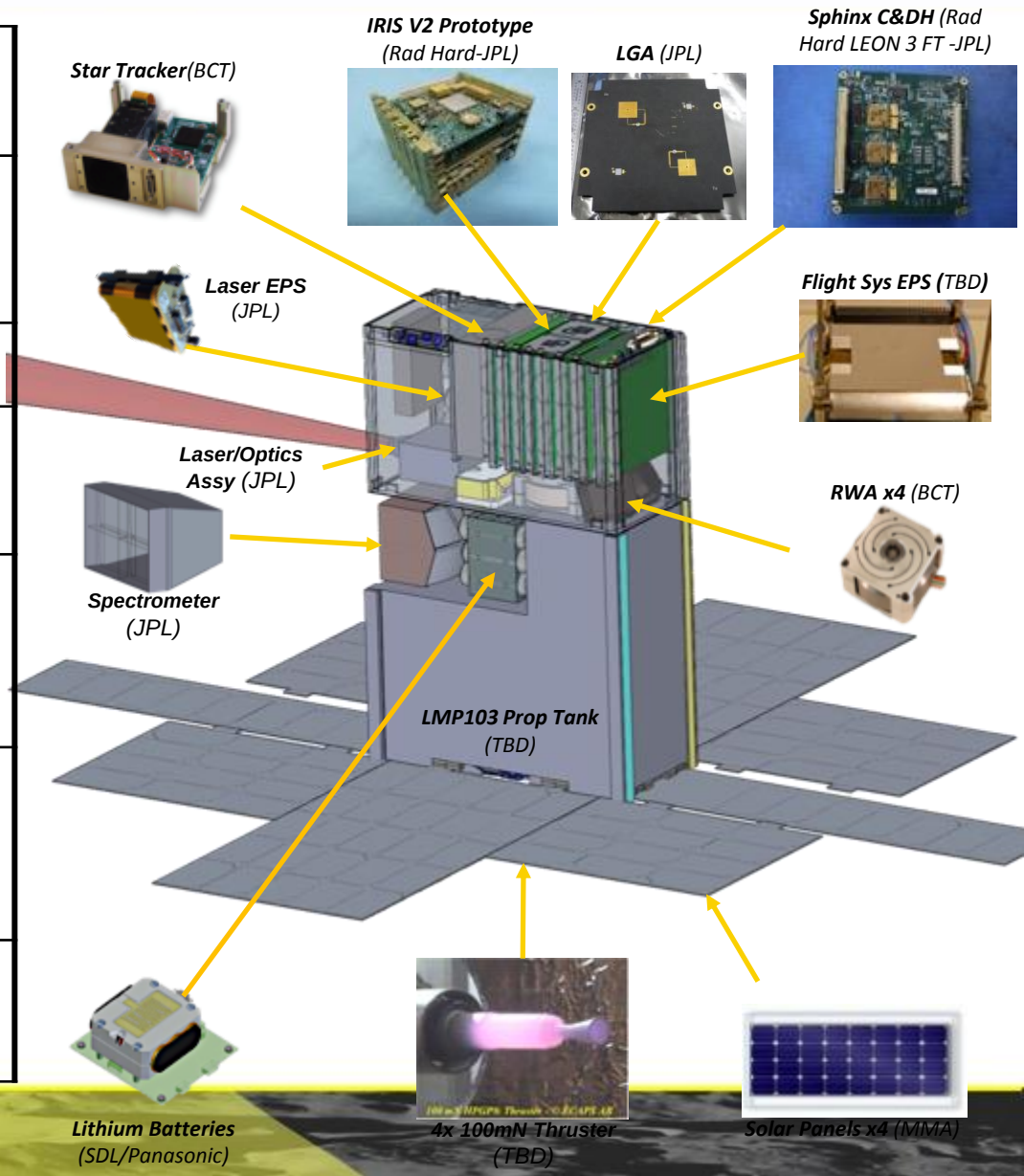
EM-1 (2018)
- SLS Block 1 (70 mT)
- Uncrewed circumlunar flight, duration 7 days, free-return trajectory
- Demonstrate integrated systems, high-speed entry (11 km/s)

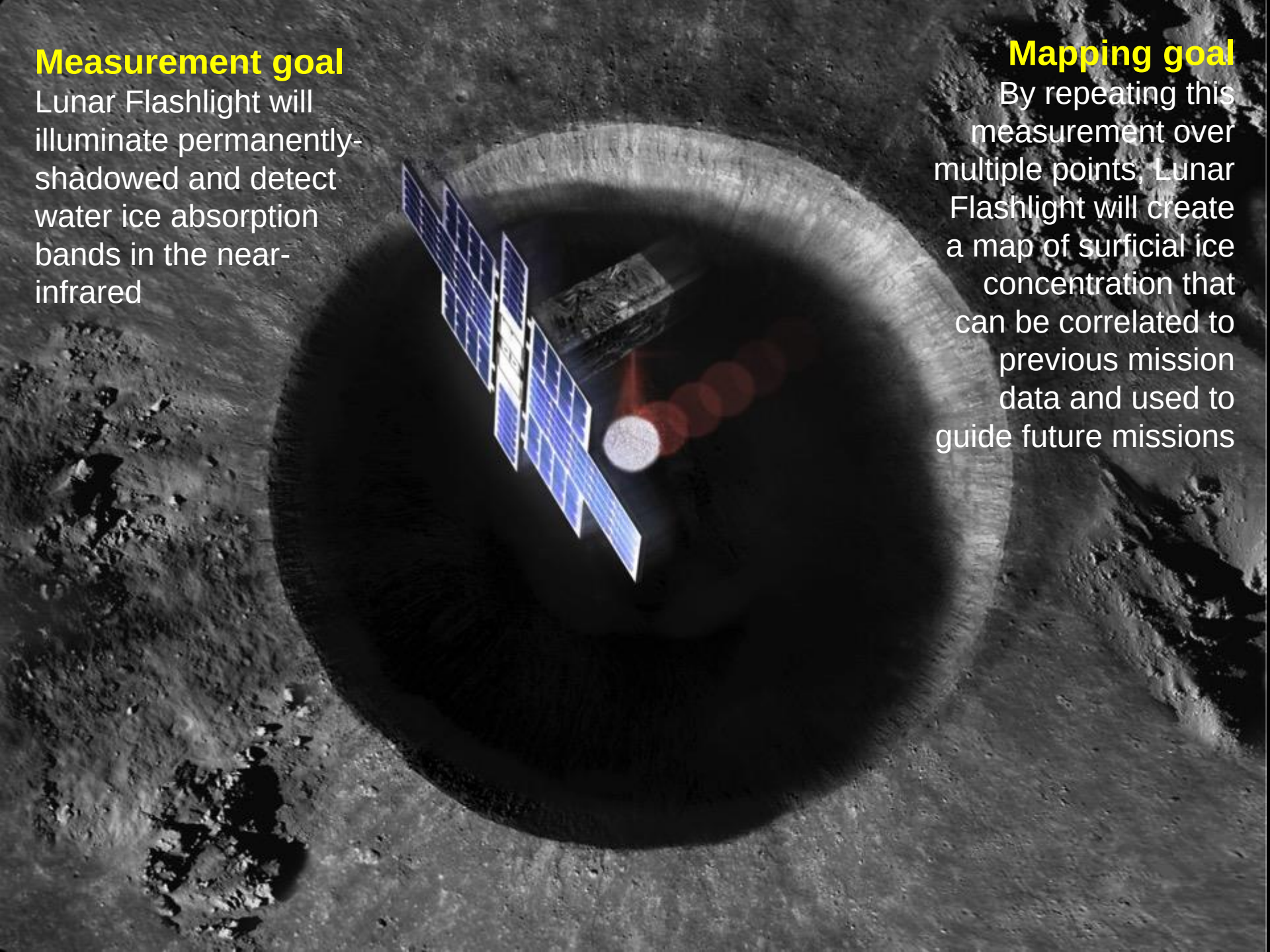


EM-2 (2021-2022)
- SLS Block 1 (70 mT)
- Crewed lunar orbit mission (?)
- Mission duration 10-14 days

Flight System Overview

Payload	• Lunar Flashlight: Custom spectrometer • Four separate 25-50 watt pulsed Lasers define the 4 spectral bands between 1-2µ
Mechanical & Structure	• “6U” CubeSat form factor (116x239x366 mm) • <14 kg total launch mass • Modular flight system concept
Propulsion	• LMP 103S low toxicity propellant with 290m/s ΔV and 4, 100mN thrusters.
C&DH	• Rad-hard LEON 3 FT Dual core CPU, 268MIPS@100MHz, 8GB NAND, 6 digital interfaces (RS422,I2C,SPI,SpW, GPIO, UART)
Electrical Power System	• Simple deployable solar arrays with UTJ GaAs cells (~35 W at 1 AU solar distance) • 6.8 Ah Battery (3s2p 18650 Lithium Cells) • Separate Laser EPS – 800w with Super capacitors coupled with Li-ion batteries
Telecom	• JPL Iris 2.0 X-Band Transponder; 1 W RF, supports doppler, ranging, and D-DOR • 2 pairs of LGAs (RX/TX) • Lunar Flashlight: >500 bps to 34m DSN at all times.
Attitude Control System	• 15 mNm-s (x3) & 100 mNm-s RWAs • Nano StarTracker, Coarse Sun Sensors & MEMS IMU for attitude determination.





Measurement goal

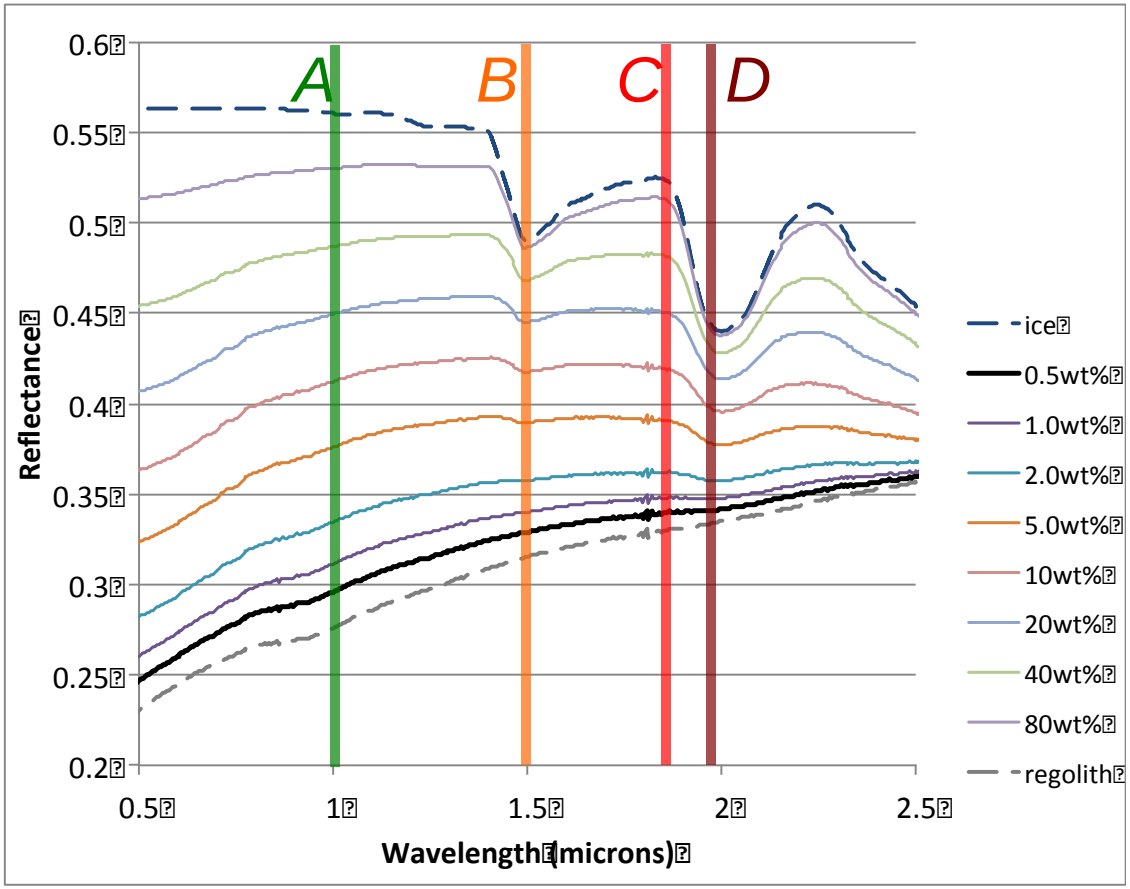
Lunar Flashlight will illuminate permanently-shadowed and detect water ice absorption bands in the near-infrared

Mapping goal

By repeating this measurement over multiple points, Lunar Flashlight will create a map of surficial ice concentration that can be correlated to previous mission data and used to guide future missions

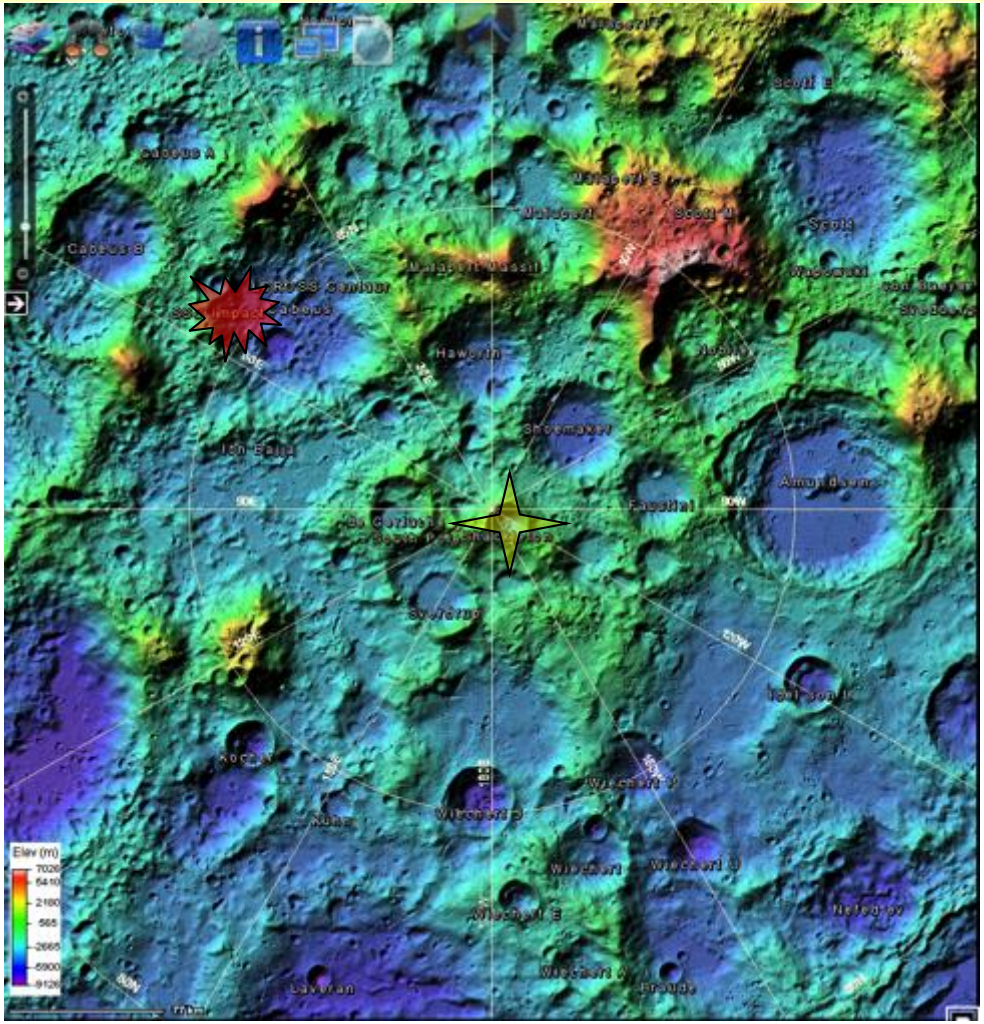
Measurement Goal

- 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.

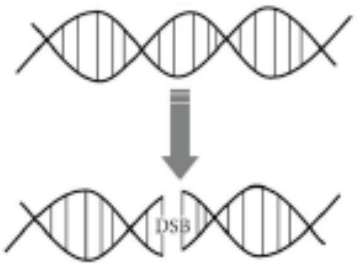


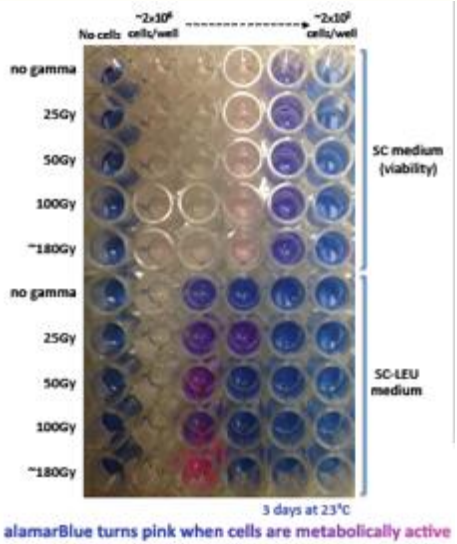
LOLA topographic map for the South Polar region from 80S showing large craters and PSRs

Other cubesats on EM-1

AES:

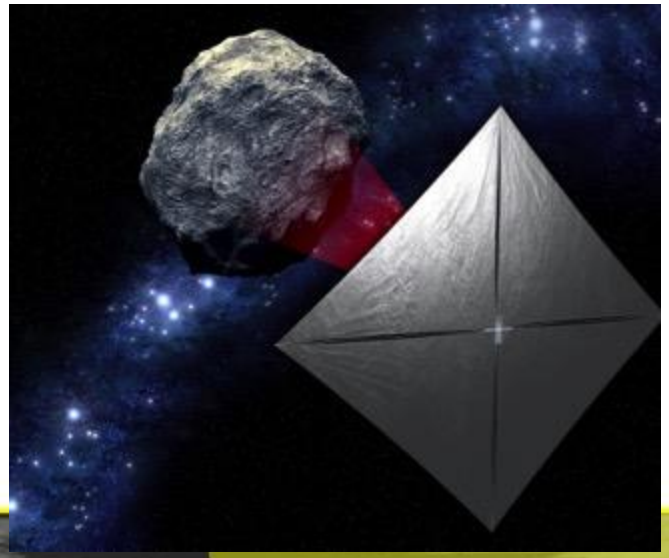
Biosentinel: DNA Damage-and-Repair Experiment Beyond Low Earth Orbit





Lunar IceCube

NEA Scout: Characterize a candidate NEA (volume, spectral type, spin and orbital properties, address key physical and regolith mechanical SKGs)



SMD: LunaH-map

Summary

- Water on the Moon is a complex topic that traces origin and evolution of the Earth-Moon system, solar wind interaction, and dynamics of impacts
- Water is a human-exploitable resource
- Lunar Flashlight is a cost-constrained Cubesat+ (nanosat) 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