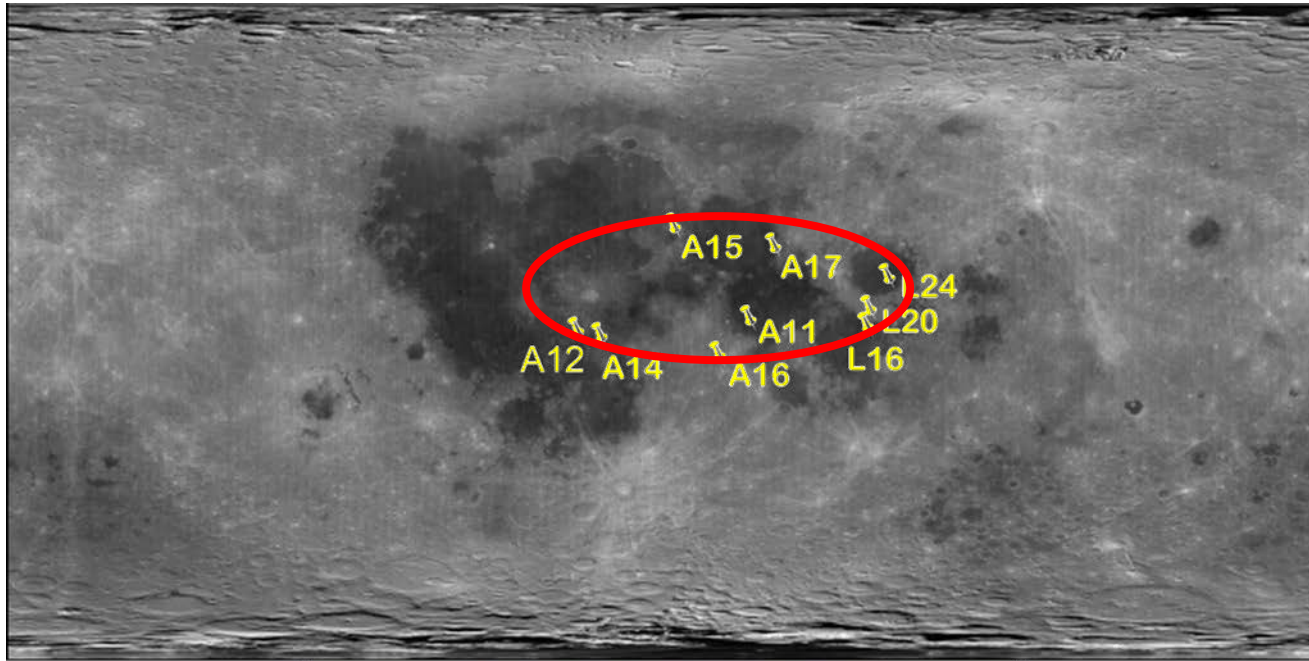


Haviland – Science Slides

Pass the Torch Panel Artemis
Space & Rocket Center 10/10/19

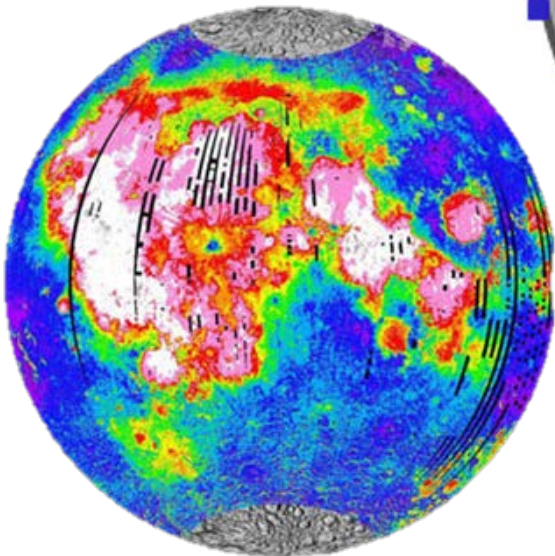
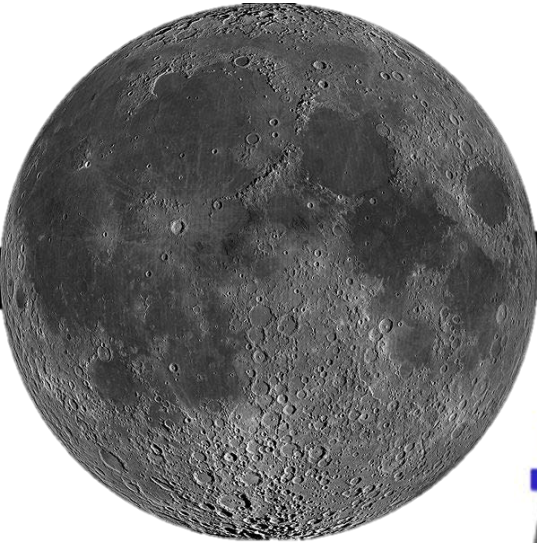


Apollo + Luna
sampling sites =
~6% of the total
lunar surface area

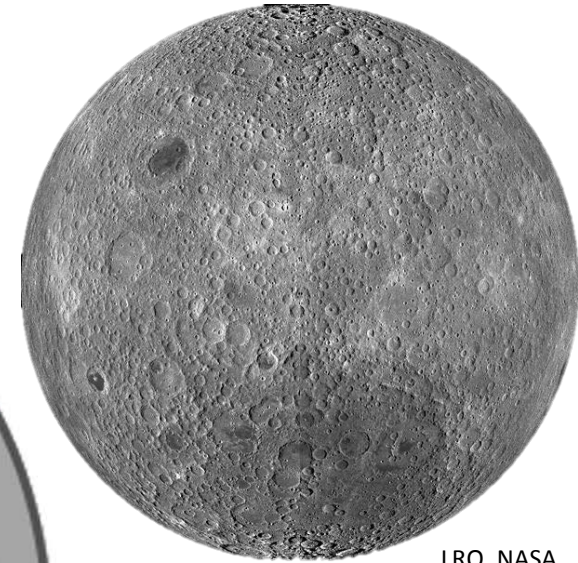


6% of the total
terrestrial surface
≈ North America

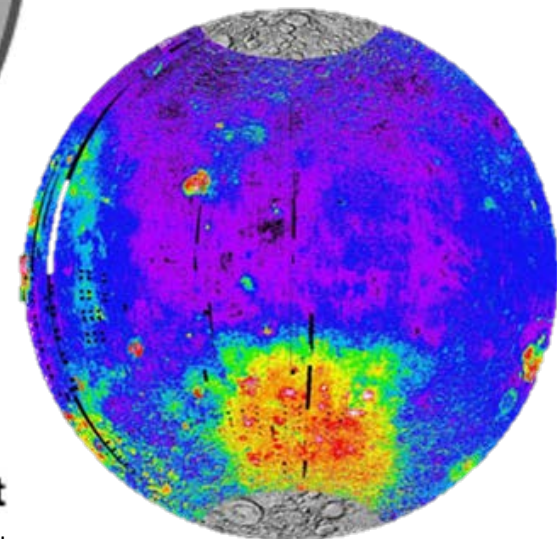
Near Side



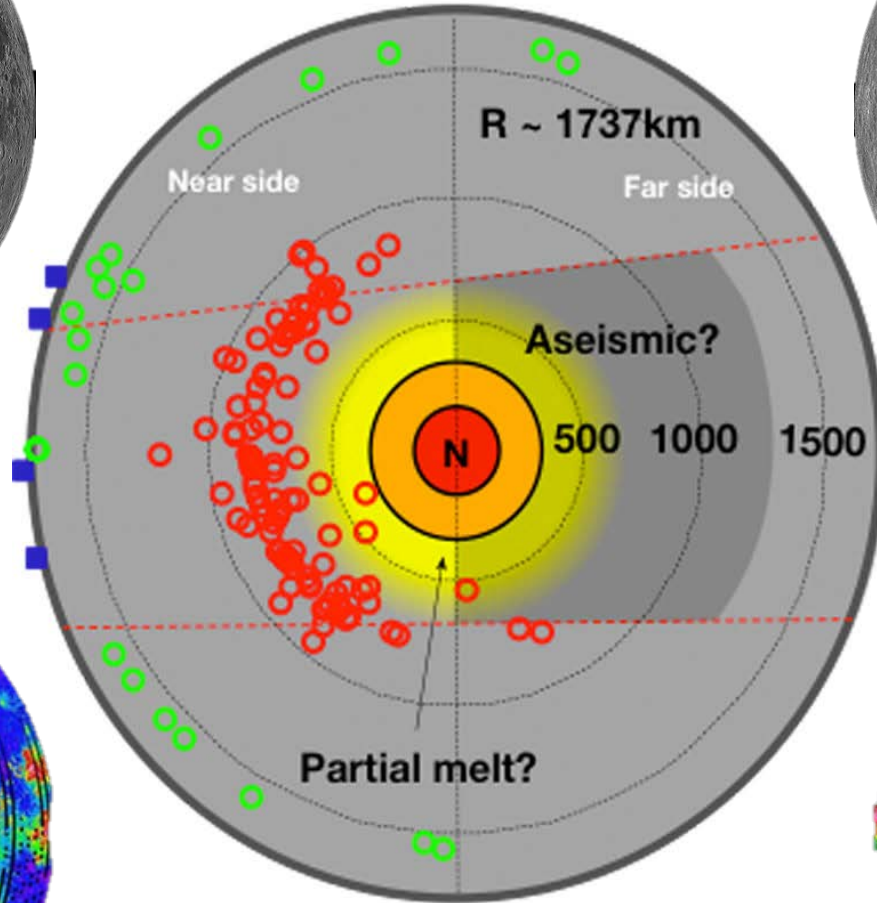
Far Side



LRO, NASA

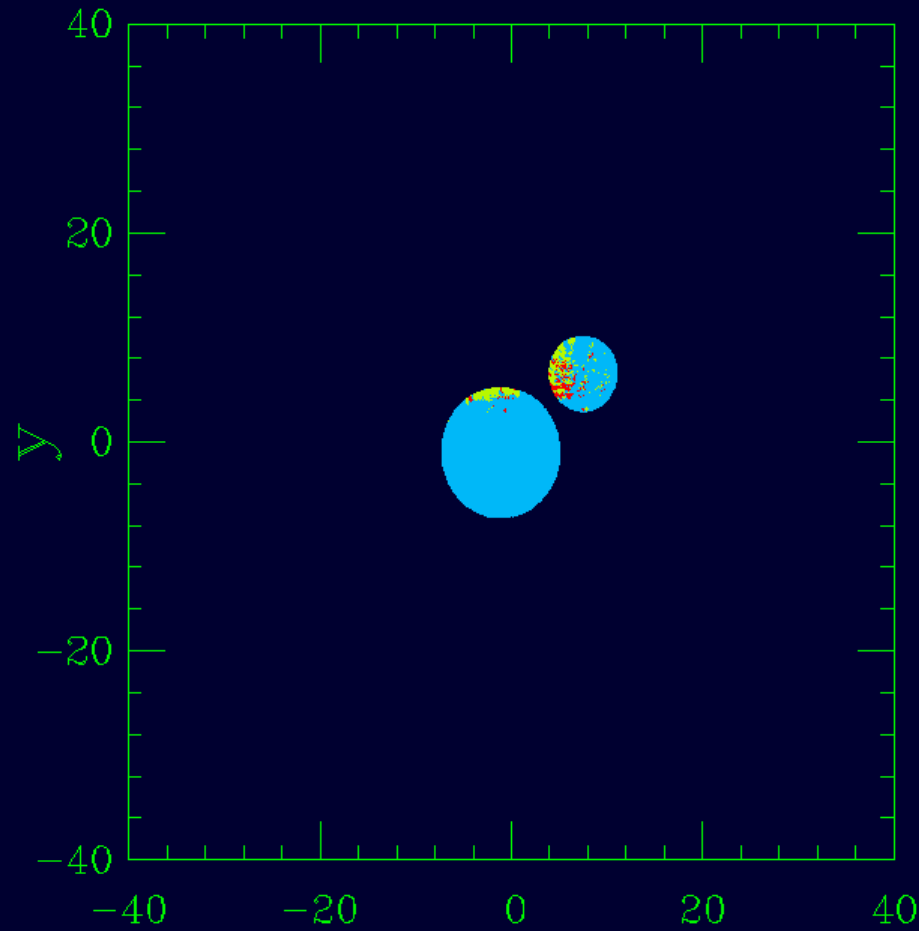


Equatorial Cross-section



- Apollo station
- Deep moonquake nest
- Shallow moonquake event

LPI

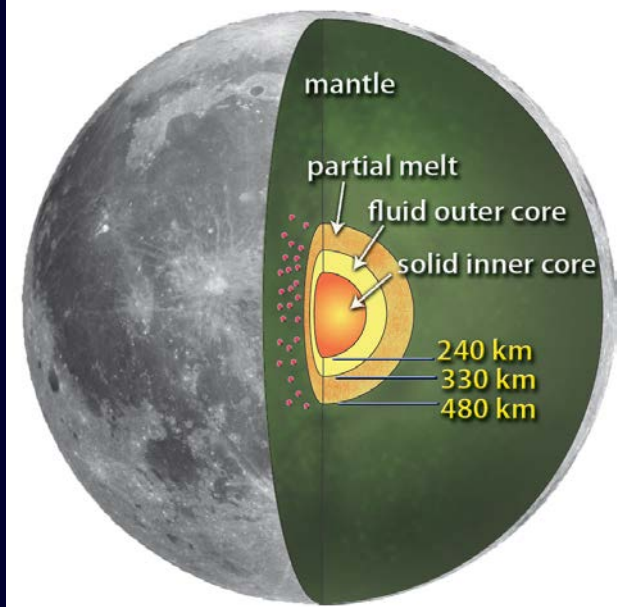


SPH

X

SwRI
xplot

Canup et al. 2016



Weber et al., 2011

The current state is key to constraining origin theories.

CLPS Supports the Artemis Program

Artemis Phase 1: To the Lunar Surface by 2024

ARTEMIS 1: FIRST HUMAN SPACECRAFT TO THE MOON IN THE 21st CENTURY

ARTEMIS 2: FIRST HUMANS TO THE MOON IN THE 21st CENTURY

FIRST HIGH POWER SOLAR ELECTRIC PROPULSION (SEP) SYSTEM

FIRST PRESSURIZED CREW MODULE DELIVERED TO GATEWAY

ARTEMIS 3: CREWED MISSION TO GATEWAY AND LUNAR SURFACE

Commercial Lunar Payload Services

- CLPS delivered science and technology payloads

Early South Pole Crater Rim Mission(s)

- First robotic landing on eventual human lunar return and ISRU site
- First ground truth of polar crater volatiles

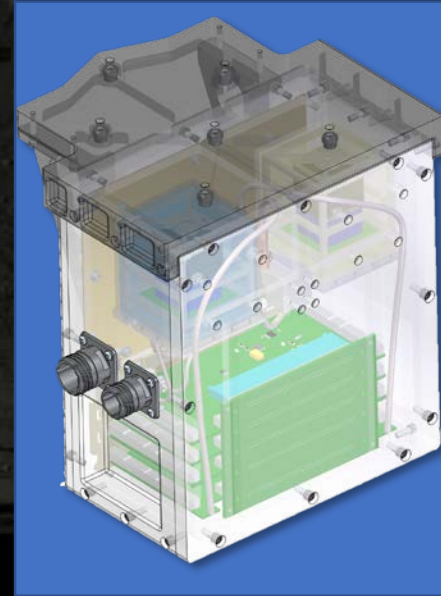
Large-Scale Cargo Lander

- Increased capabilities for science and technology payloads

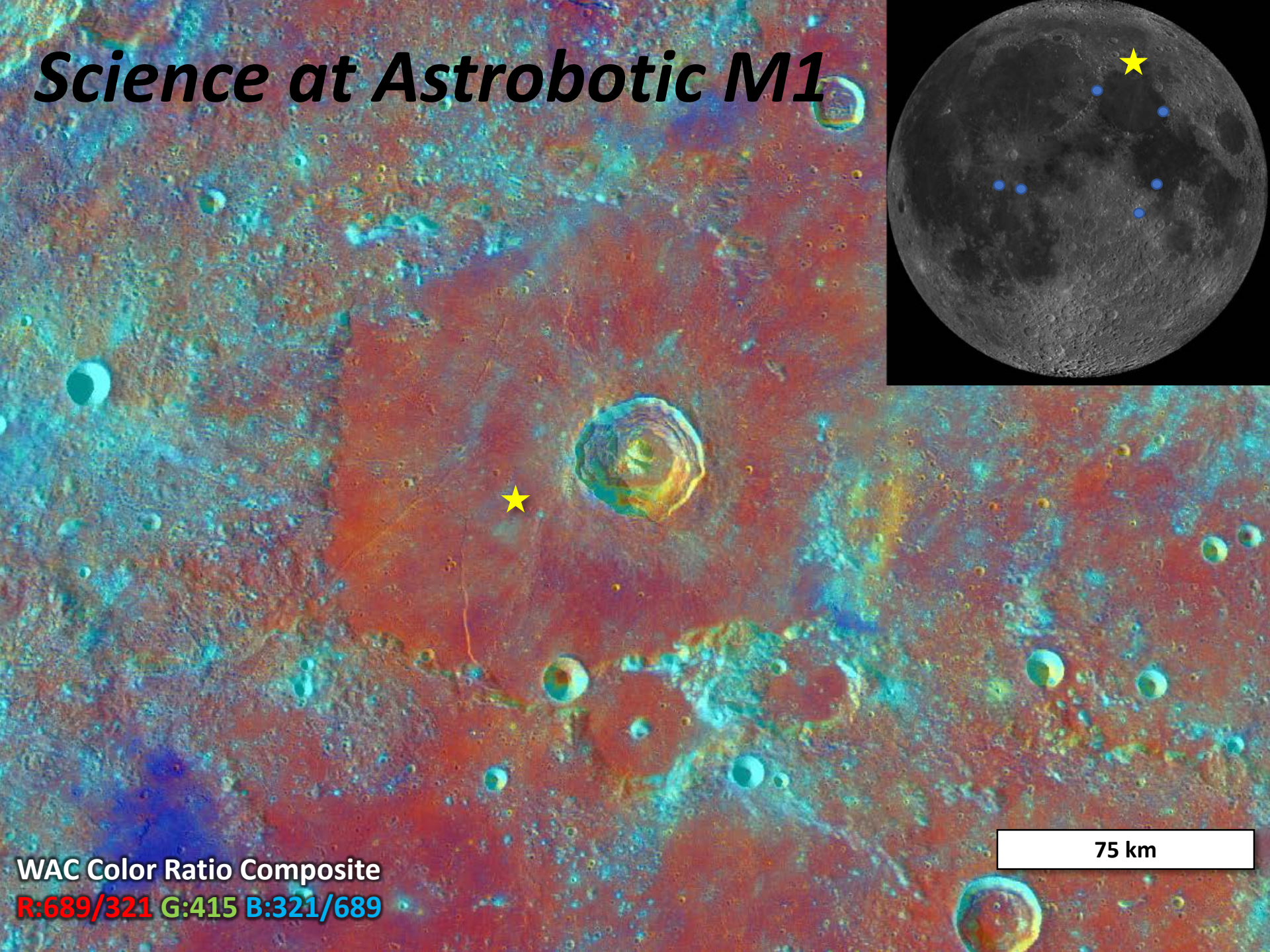
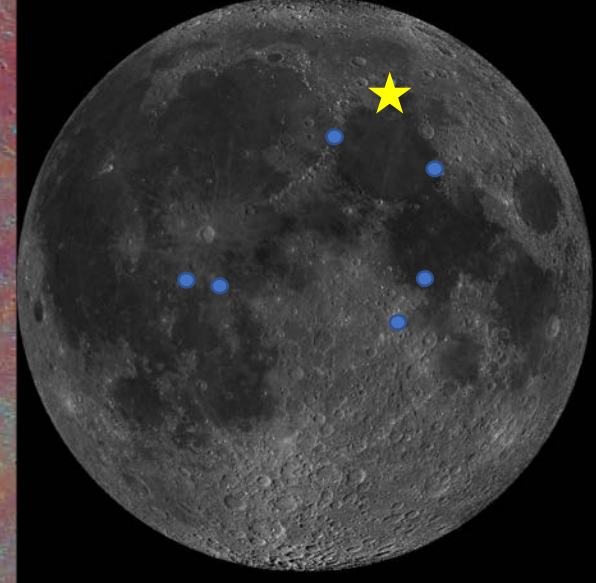
Humans on the Moon - 21st Century

First crew leverages infrastructure left behind by previous missions

Neutron Measurements at the Lunar Surface (NMS)

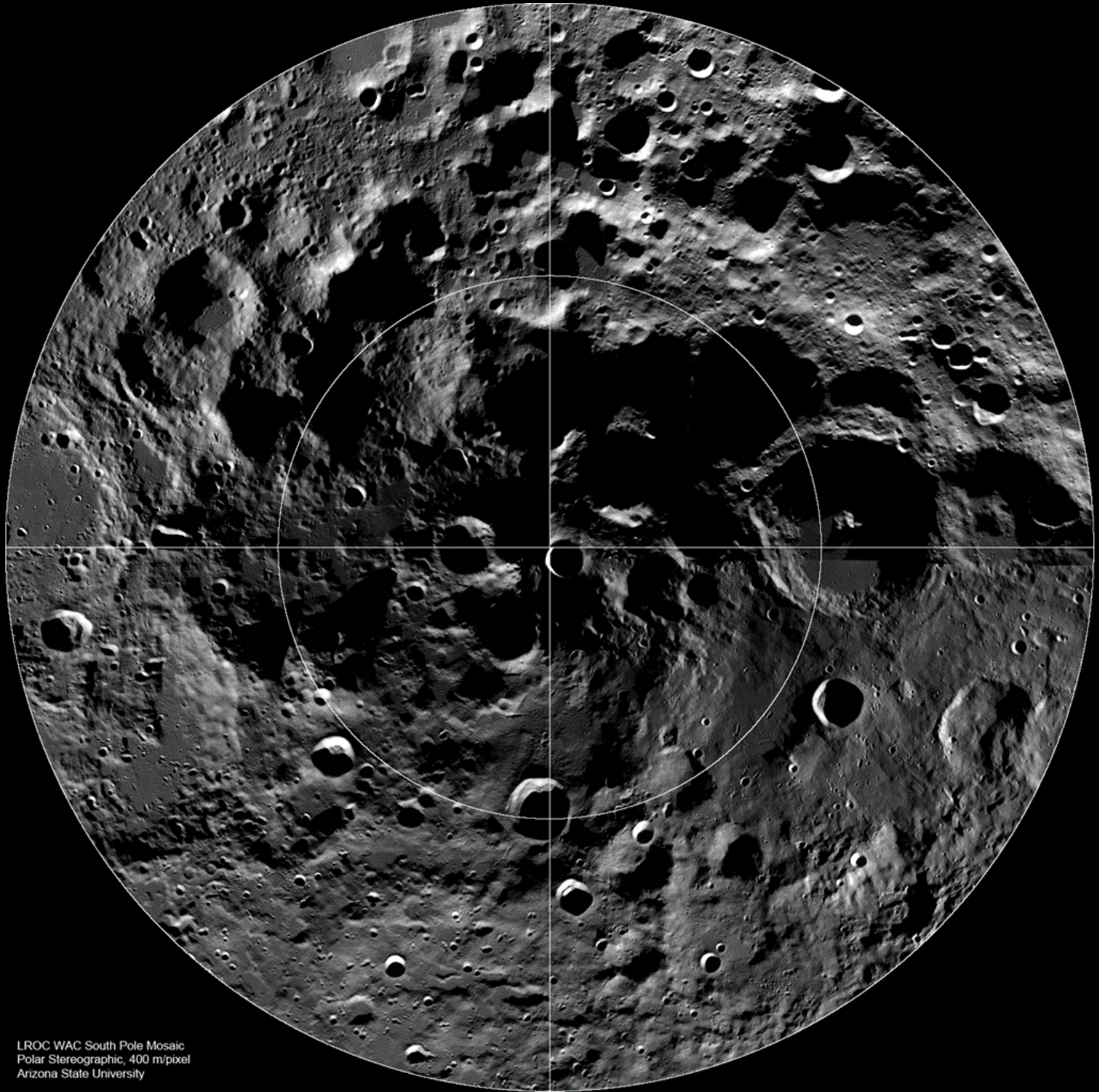


Science at Astrobotic M1

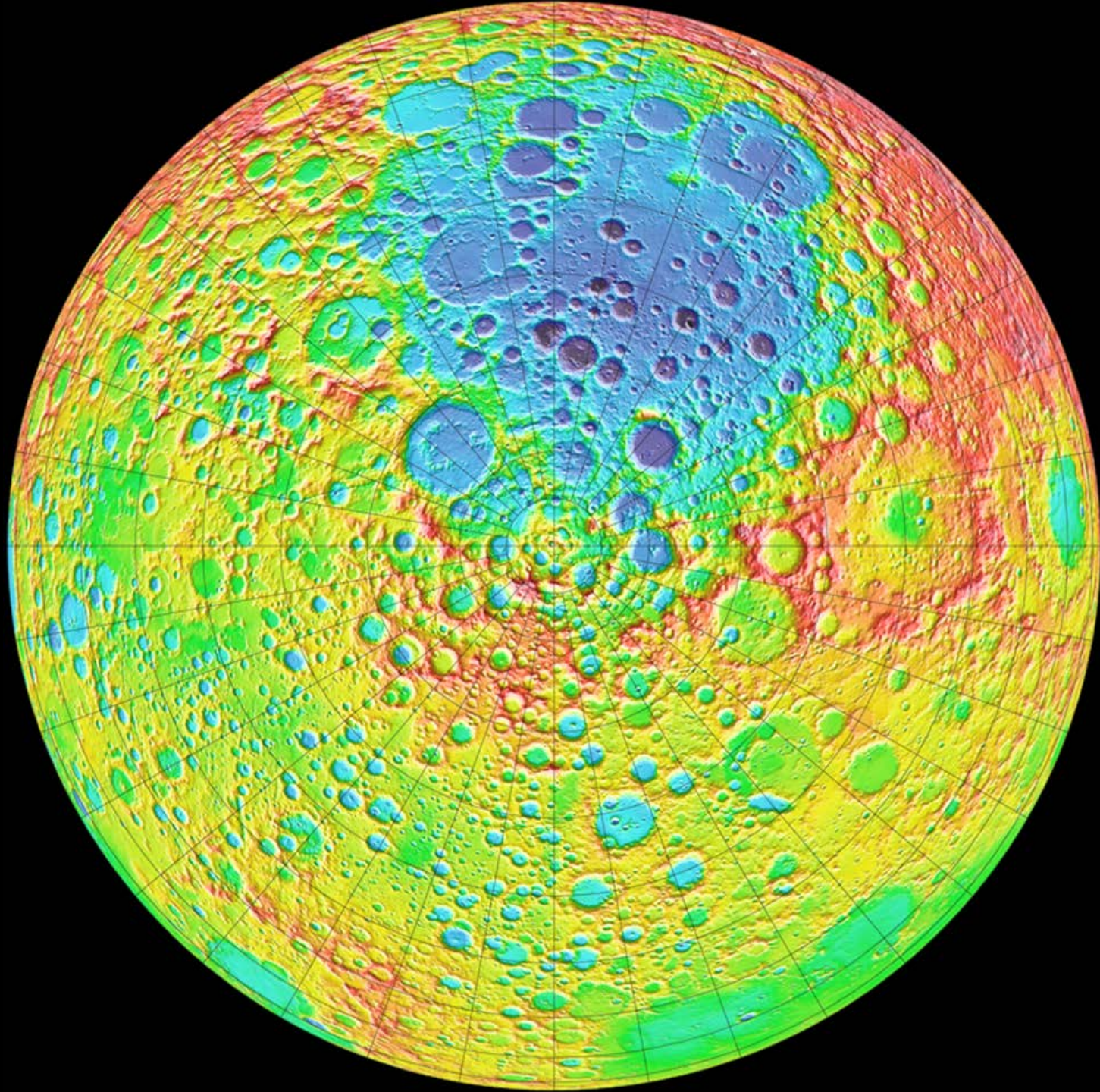


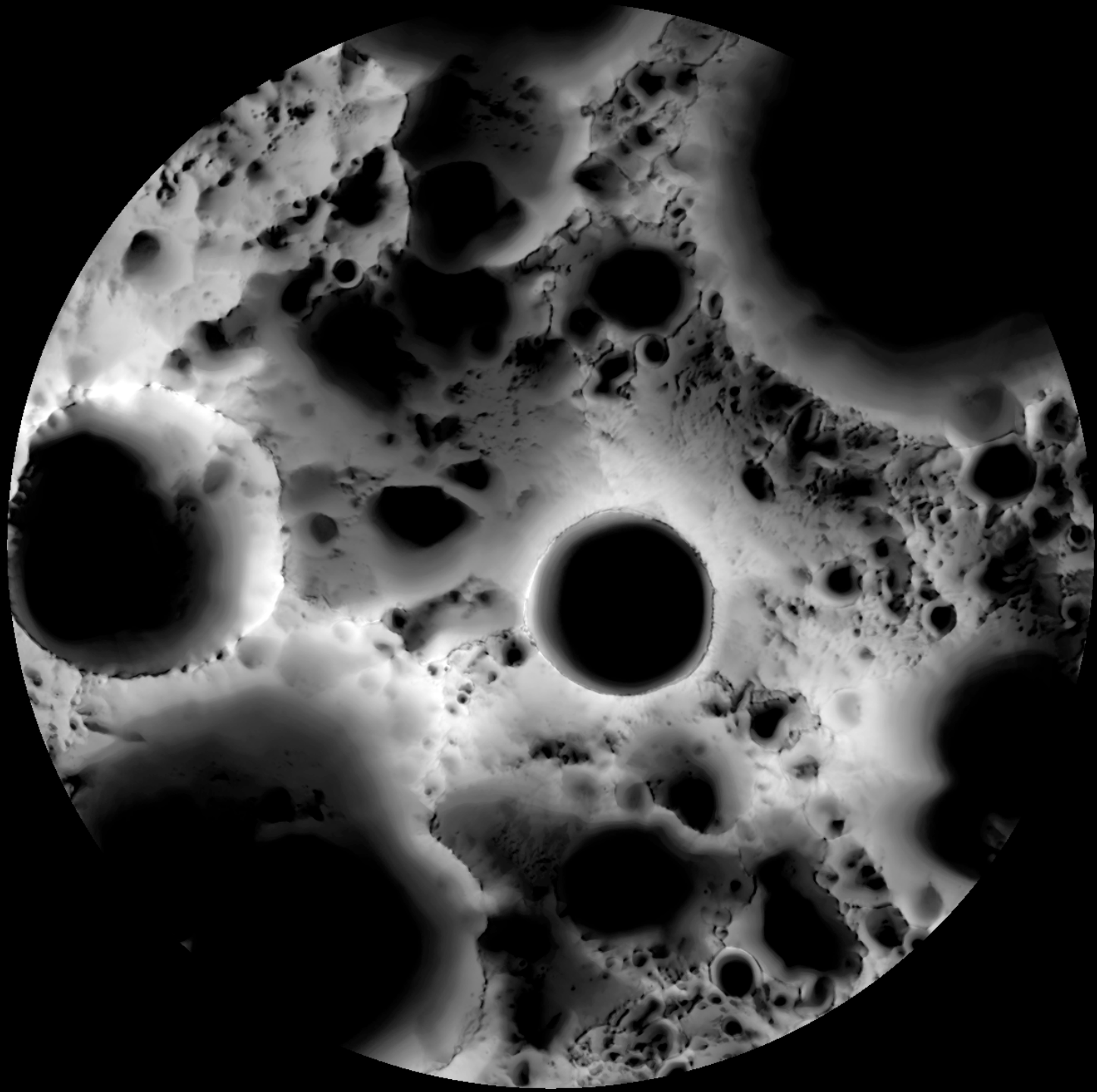
75 km

WAC Color Ratio Composite
R:689/321 G:415 B:321/689



LROC WAC South Pole Mosaic
Polar Stereographic, 400 m/pixel
Arizona State University

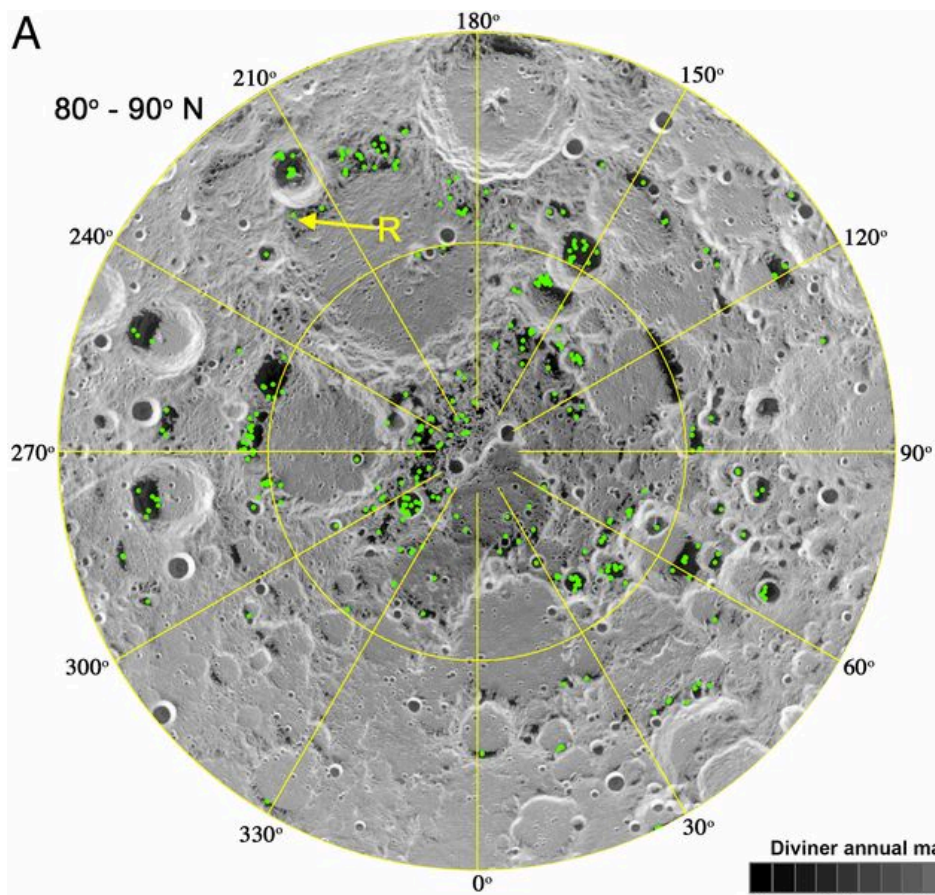




North Pole

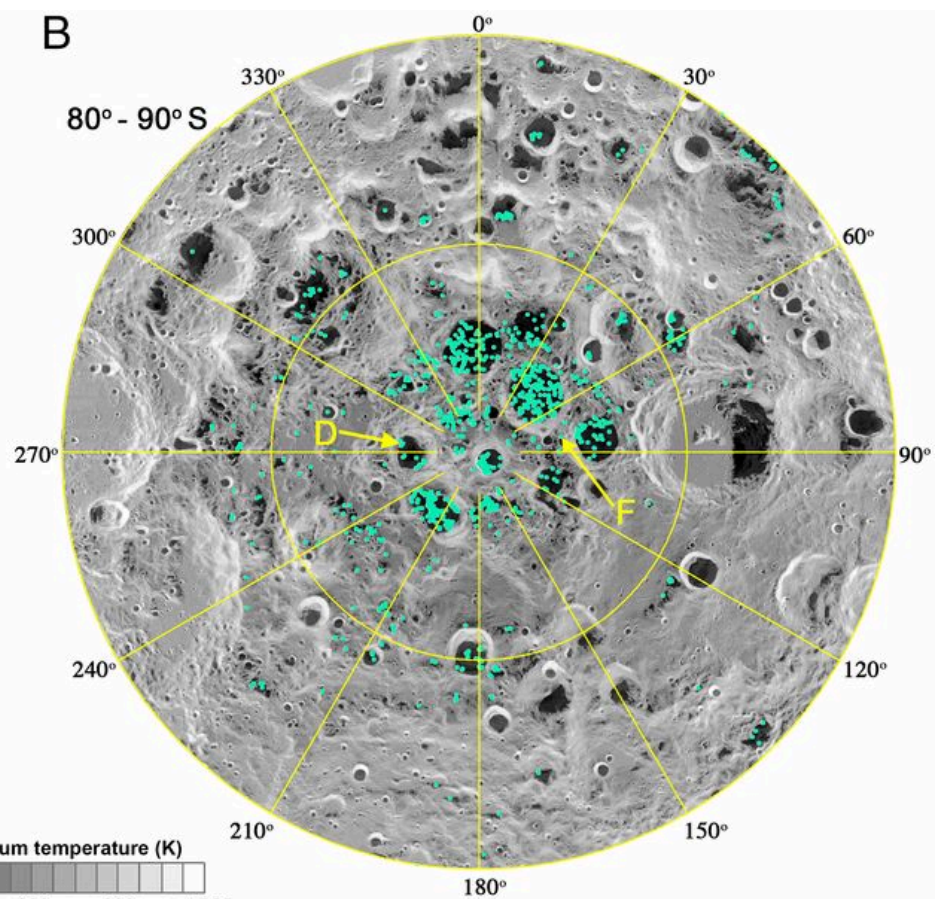
South Pole

A



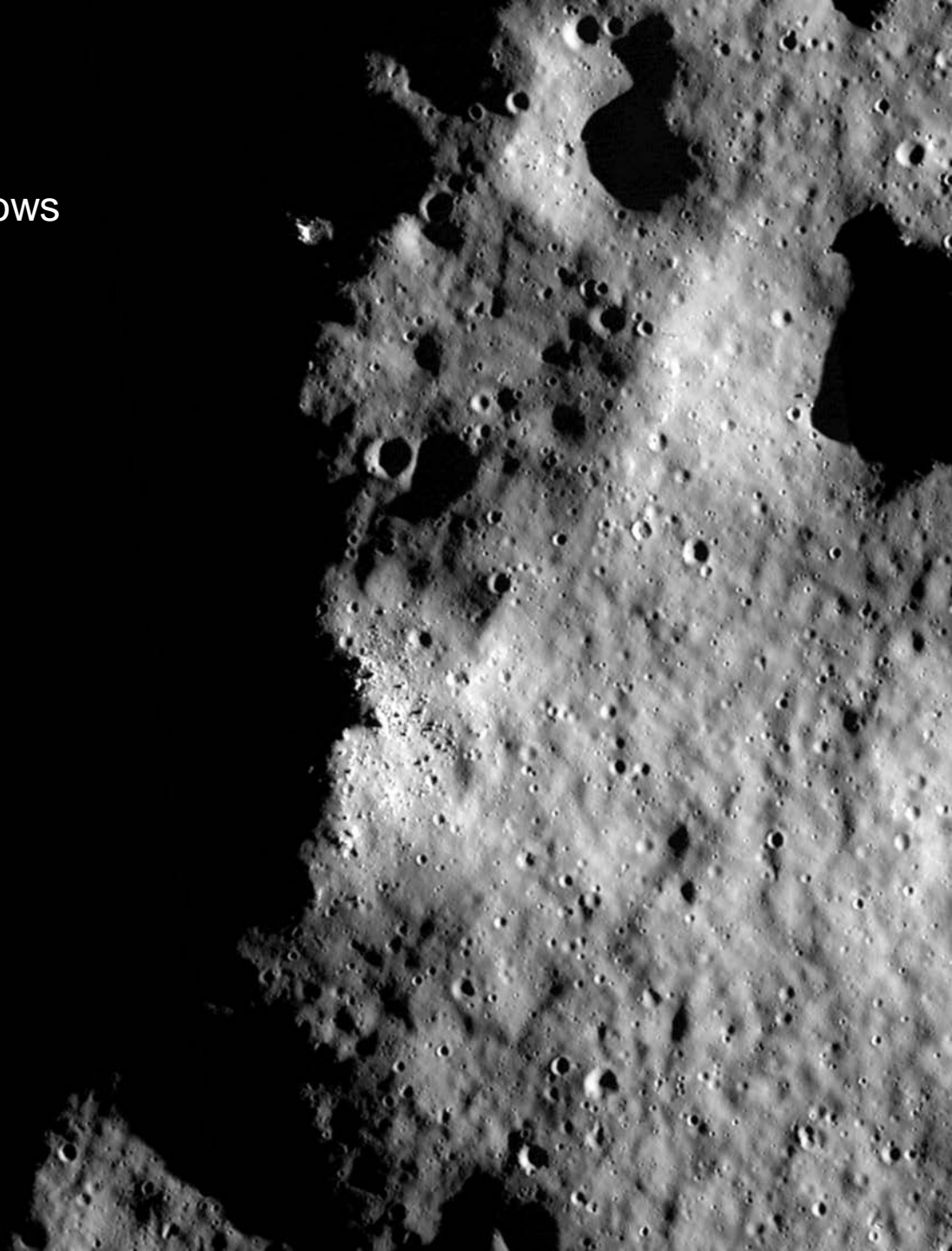
● Ice exposures constrained by M³, LOLA, and Diviner

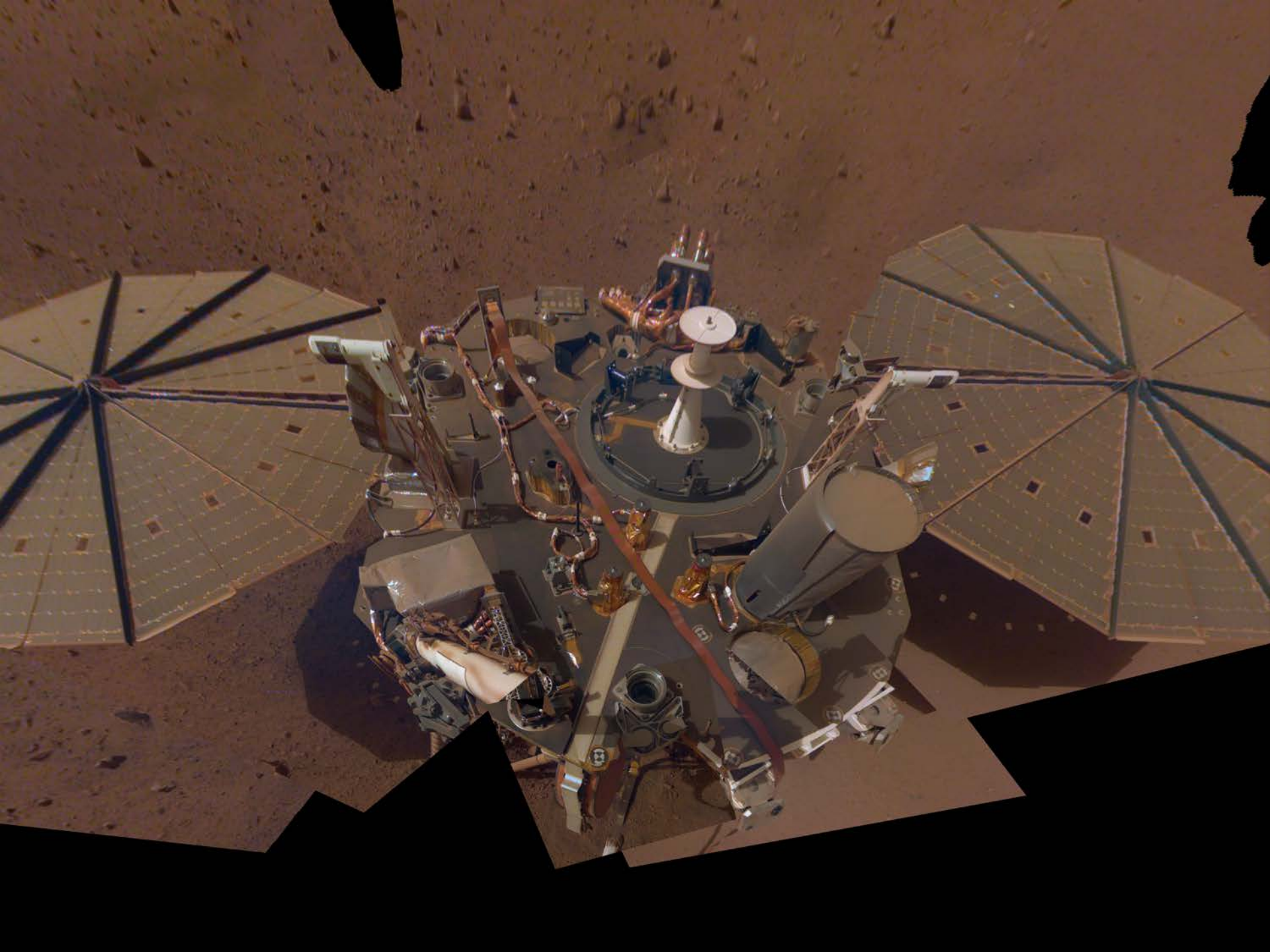
B

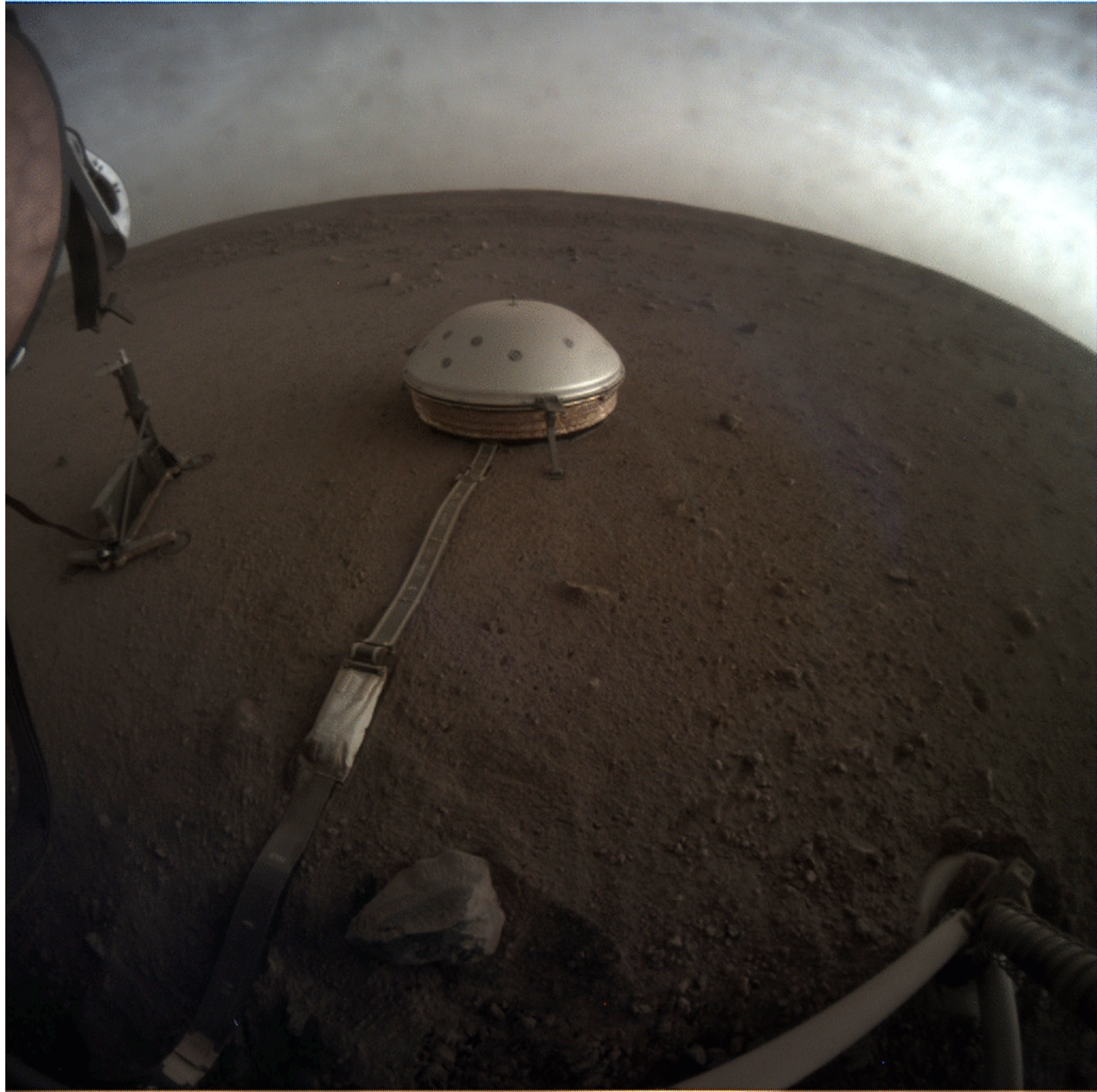


● Ice exposures constrained by M³, LOLA, Diviner, and LAMP

Low Sun angle means long shadows







Back up slides

Big Science Questions

- Where are the polar volatiles and how did they get there?
 - What are the chemical and isotopic compositions of volatile deposits?
- How did the Moon form/evolve?
 - Sampling of ancient crust/mantle material, and geophysical measurements (seismometer/heat flow probe) will provide new insight into the lunar interior structure and composition, and of the Moon's geologic evolution.
- Are there rock types that we didn't sample in Apollo, and what can they tell us about the Moon's evolution?
- Can we use the Moon to understand the distribution and timescale of impacts and volcanism on the inner planets?
- Can we explore craters to understand the physics of impact cratering, the most prevalent geologic process in the Solar System?

NMS Overview

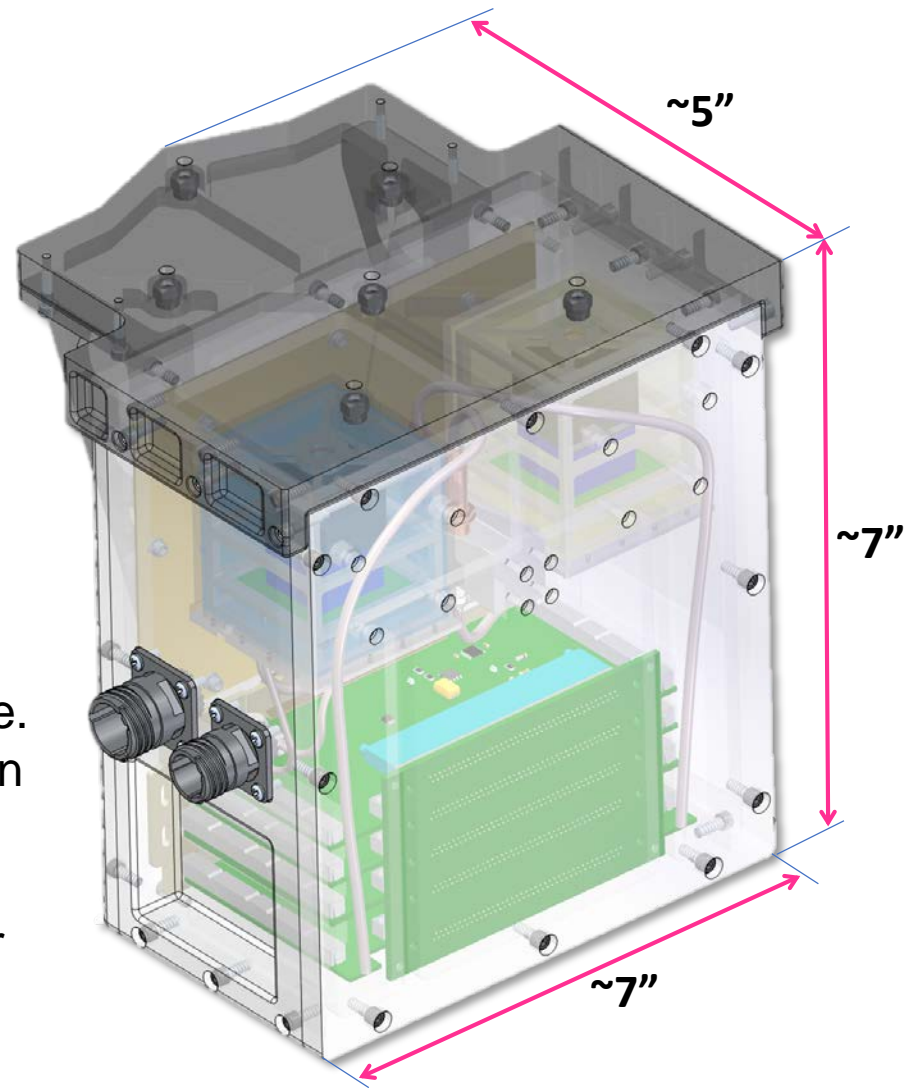
Mission Objectives:

1. Characterize the neutron radiation environment.
2. Provide in-situ ground truth for calibrating orbital data.
3. Provide constraints on composition (e.g., science & ISRU).
4. Monitor hydrogen cycle through lunar day.

Project Description:

- Provide neutron counts at the lunar surface.
 - Deliver thermal and epithermal neutron rate counters using ^6Li -doped scintillators.
 - Operate for ~7 Earth days, (~1/2 lunar day).
- Based on flight heritage (developed at MSFC), FNS instrument currently operating on the ISS, and in development for Gateway.

Funding: Lunar Discovery and Exploration Program (LDEP)

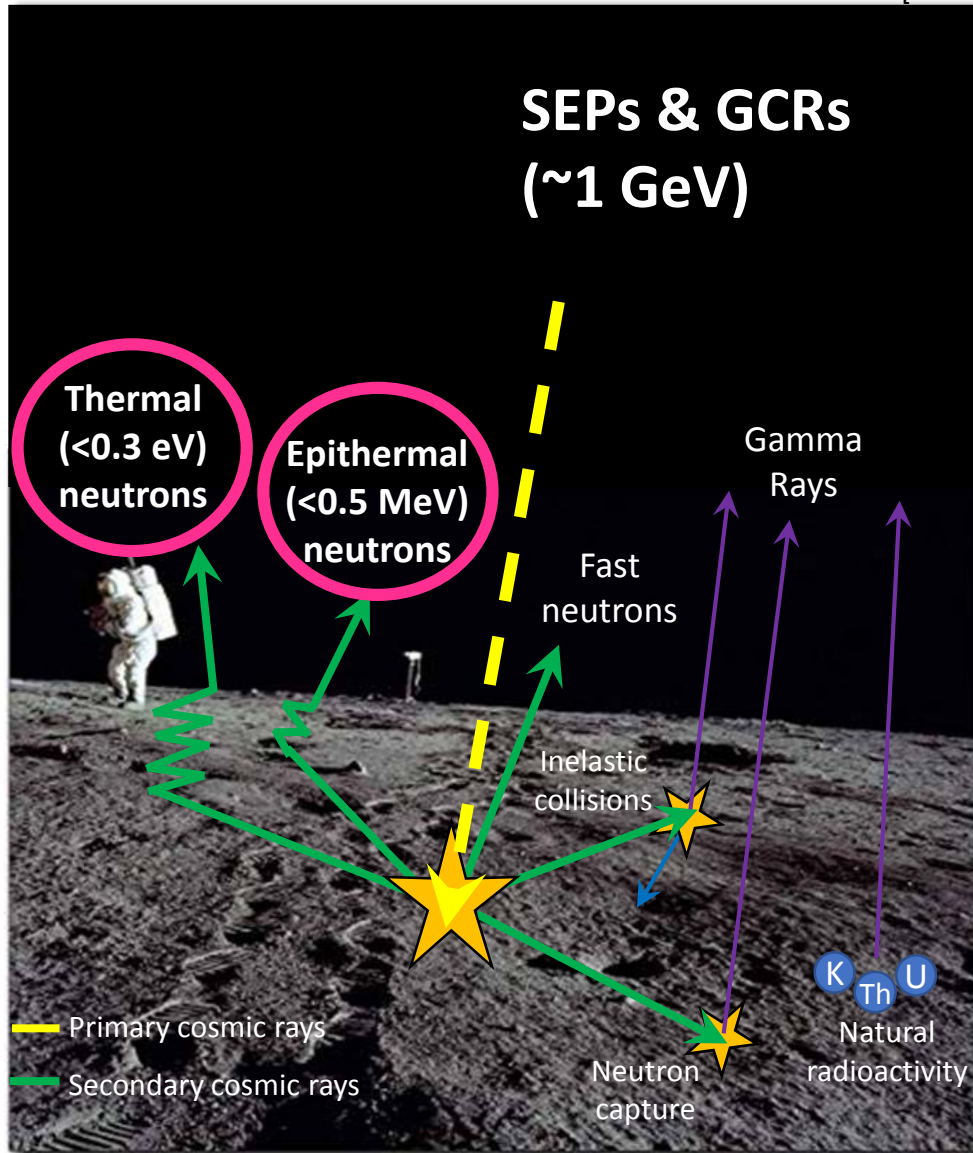


NMLS Mechanical Model

Mass: ~4 kg
Data rate: 10 bps
Ave Power: 4.8 W
Peak Power: 10 W

Neutron Spectroscopy

After Curran [2017]

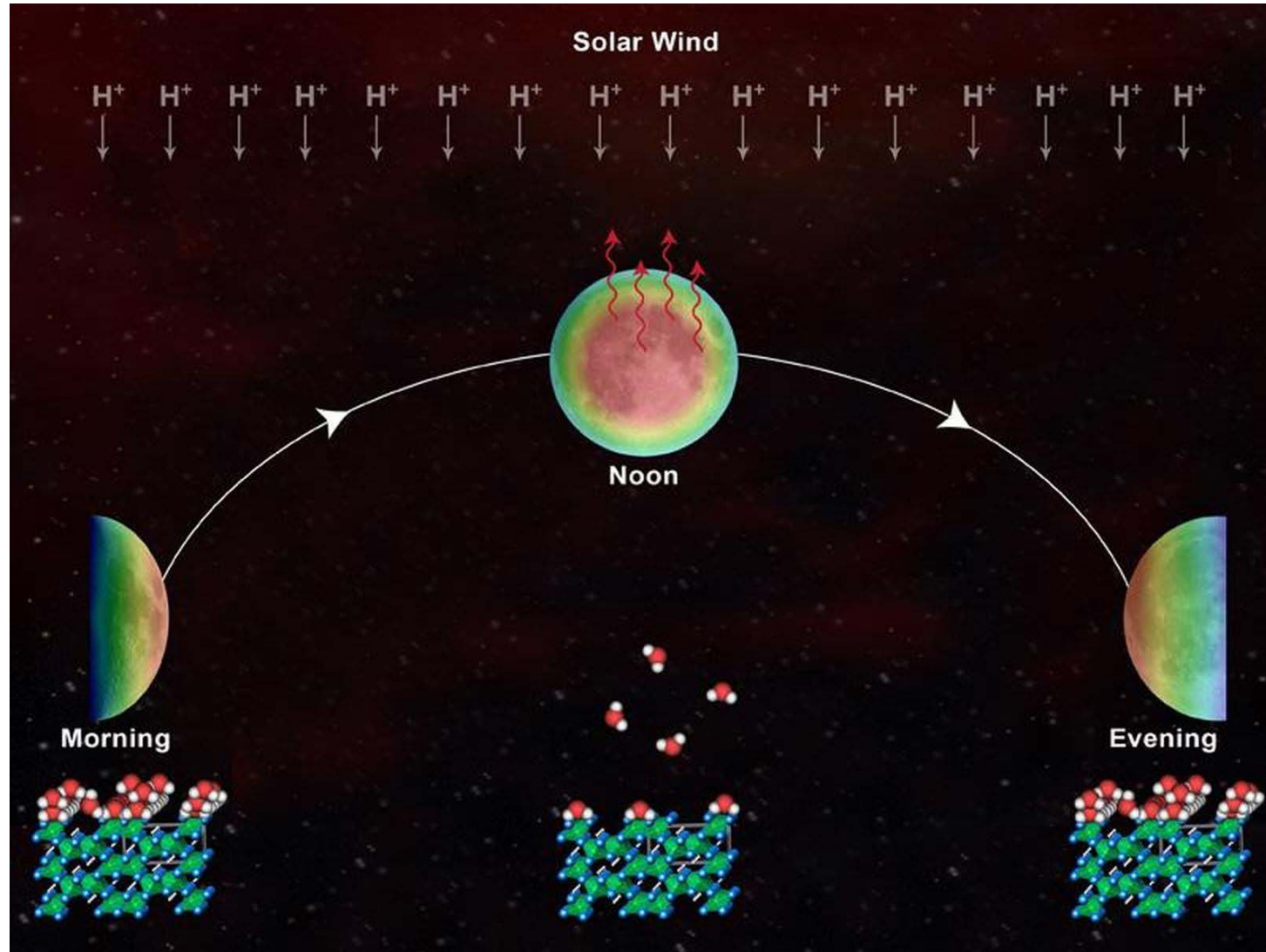


- “Epithermal neutrons”
 - medium energy
 - ~constant for most lunar compositions (except H).
- “Thermal neutrons”
 - low energy
 - absorption cross section increases by nuclei
 - is highly composition dependent (flux is large for Fe, Ti)
 - Flux is greater in mafic materials (mare basalts, Mg or Fe-rich, of igneous/volcanic origin, dark in color, olivine, pyroxene)
 - Flux is smaller in the Fe-poor highlands (farside).
- MSFC scintillator technology effectively discriminates between pulse shapes and distinguishes between neutron and gamma ray (as well as other false) triggers.

High value science opportunities exist for NMLS.

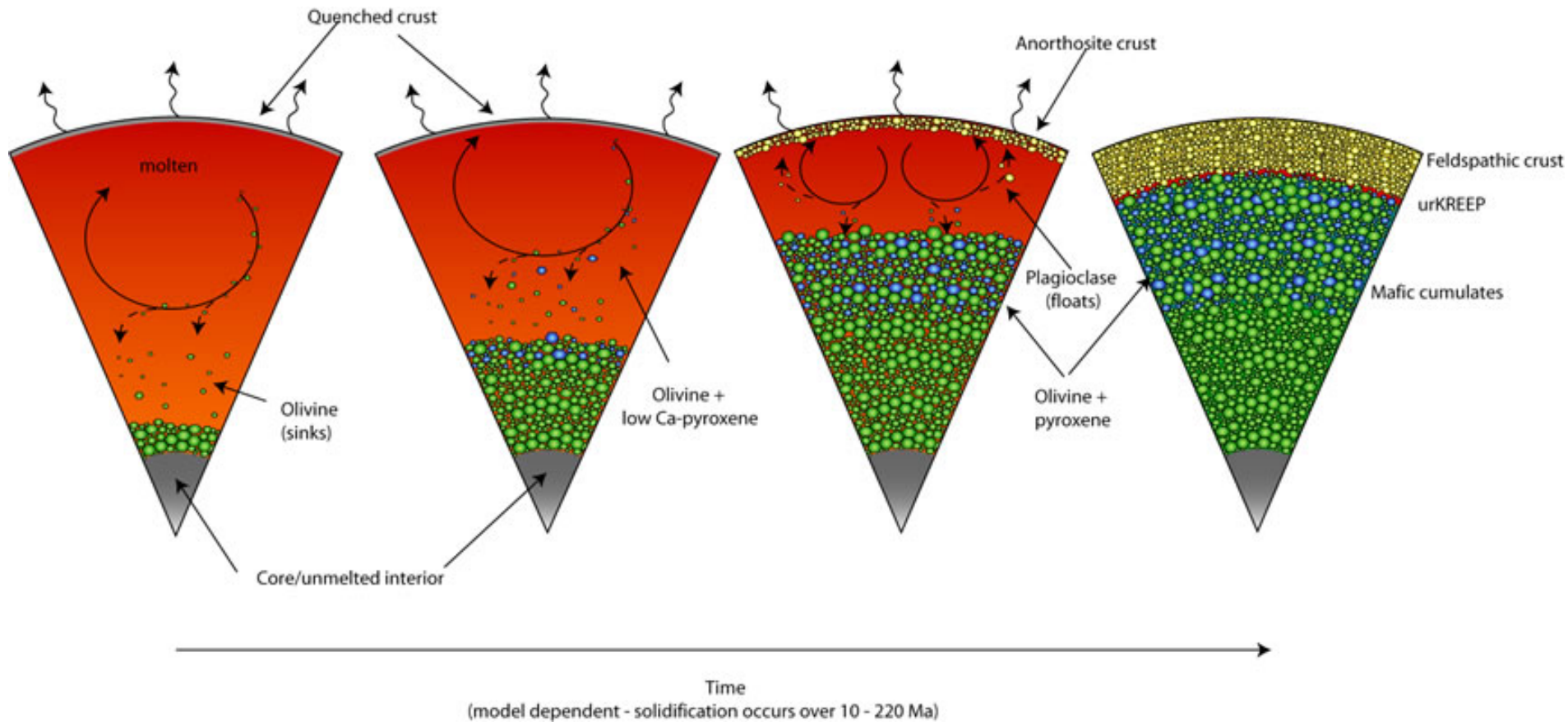
Monitor hydrogen cycle through lunar day

- The Moon's water cycle varies over the course of a lunar day.
- This change in hydrogen concentration as a function of time will be detected with NMS.
- Dependent on data and power availability during lunar evening.



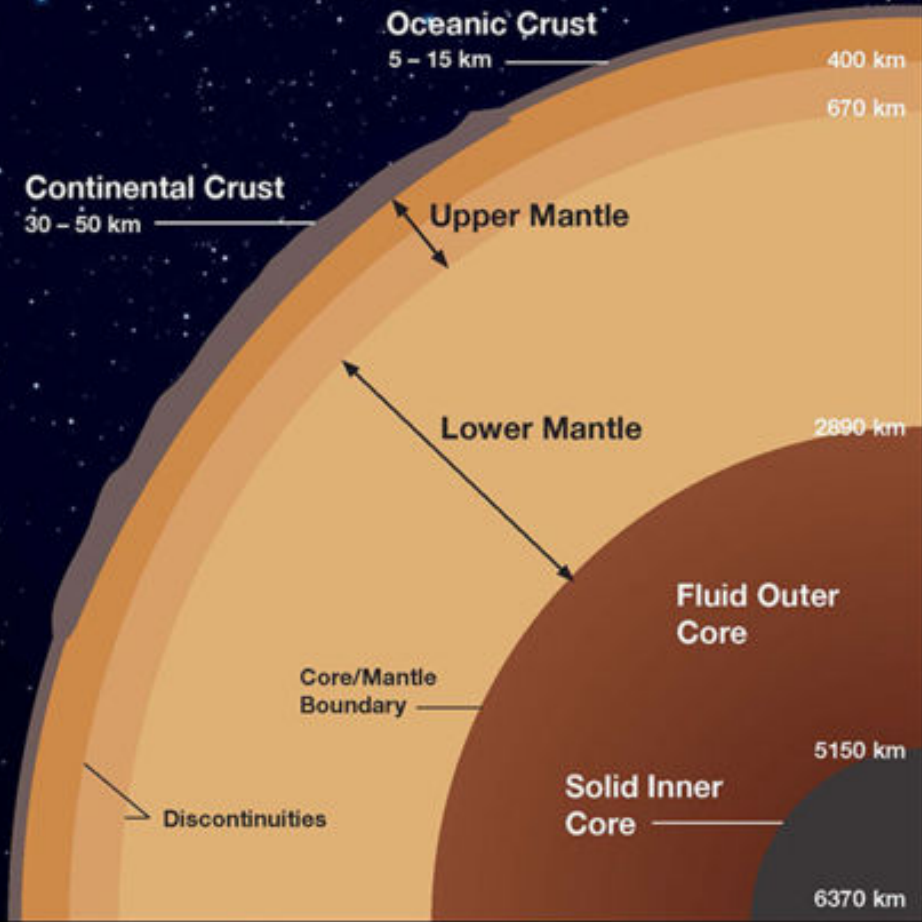
Atkinson [2010]

Magma Ocean Crystallization Models

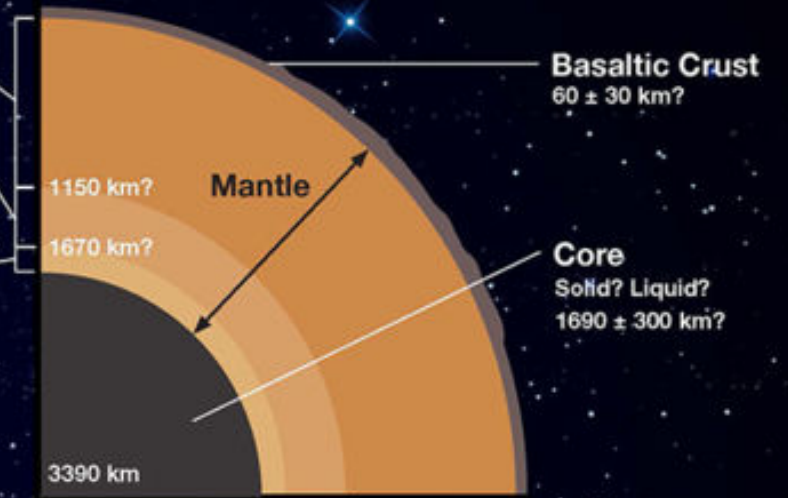


The current state of the lunar interior is the first step to constraining formation.

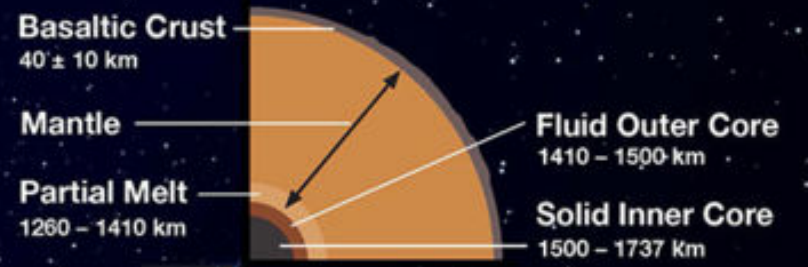
EARTH



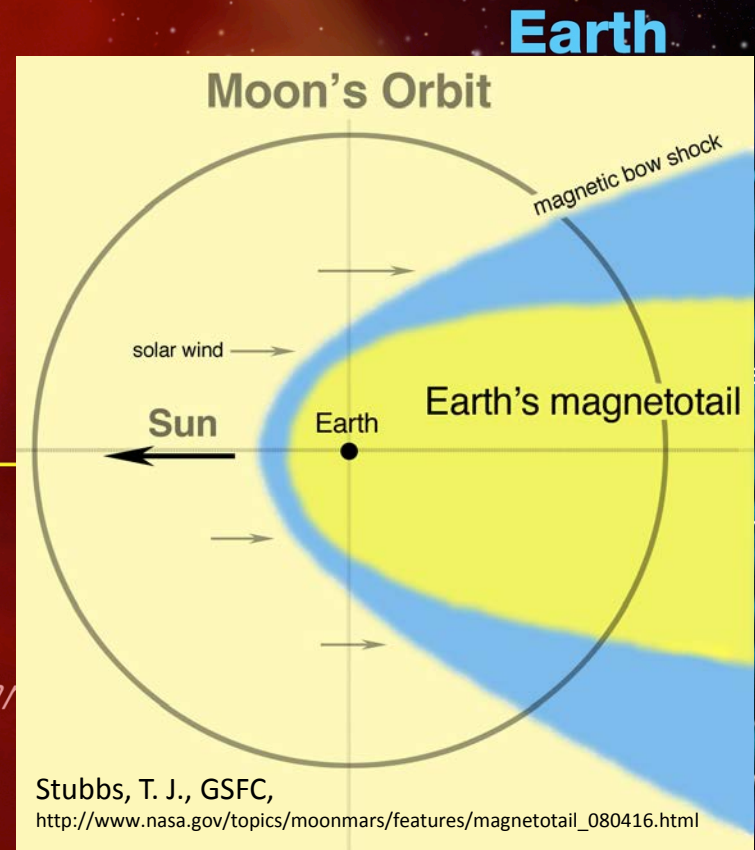
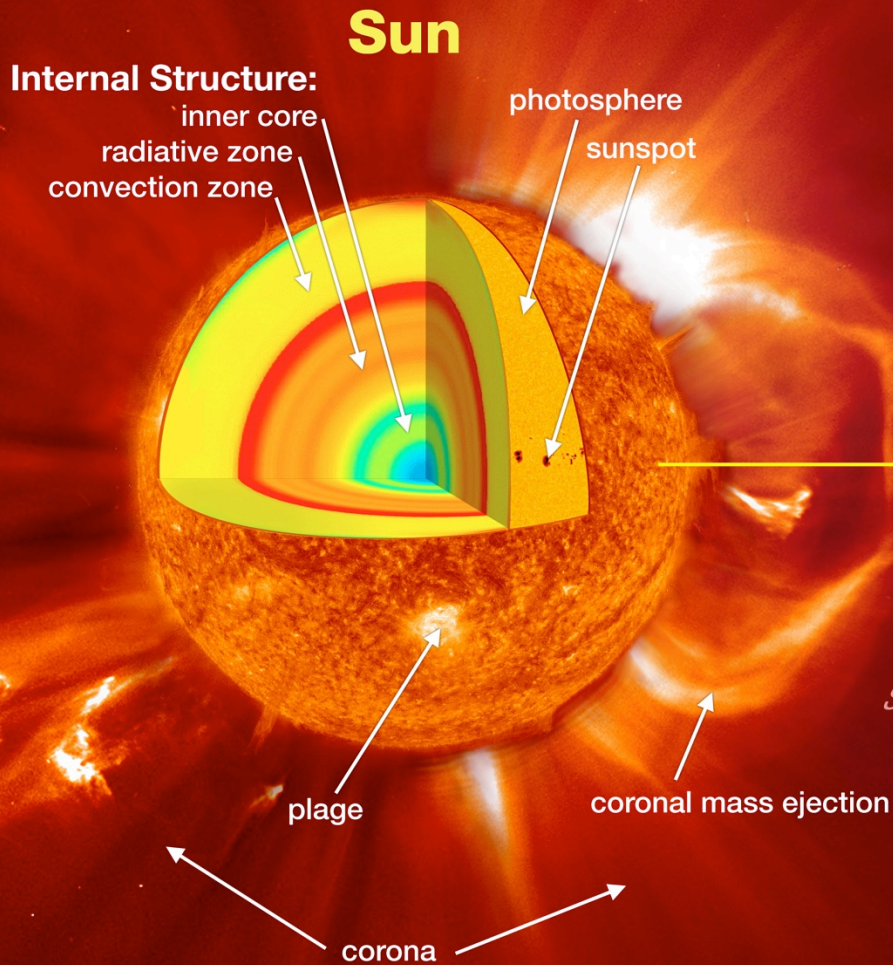
MARS



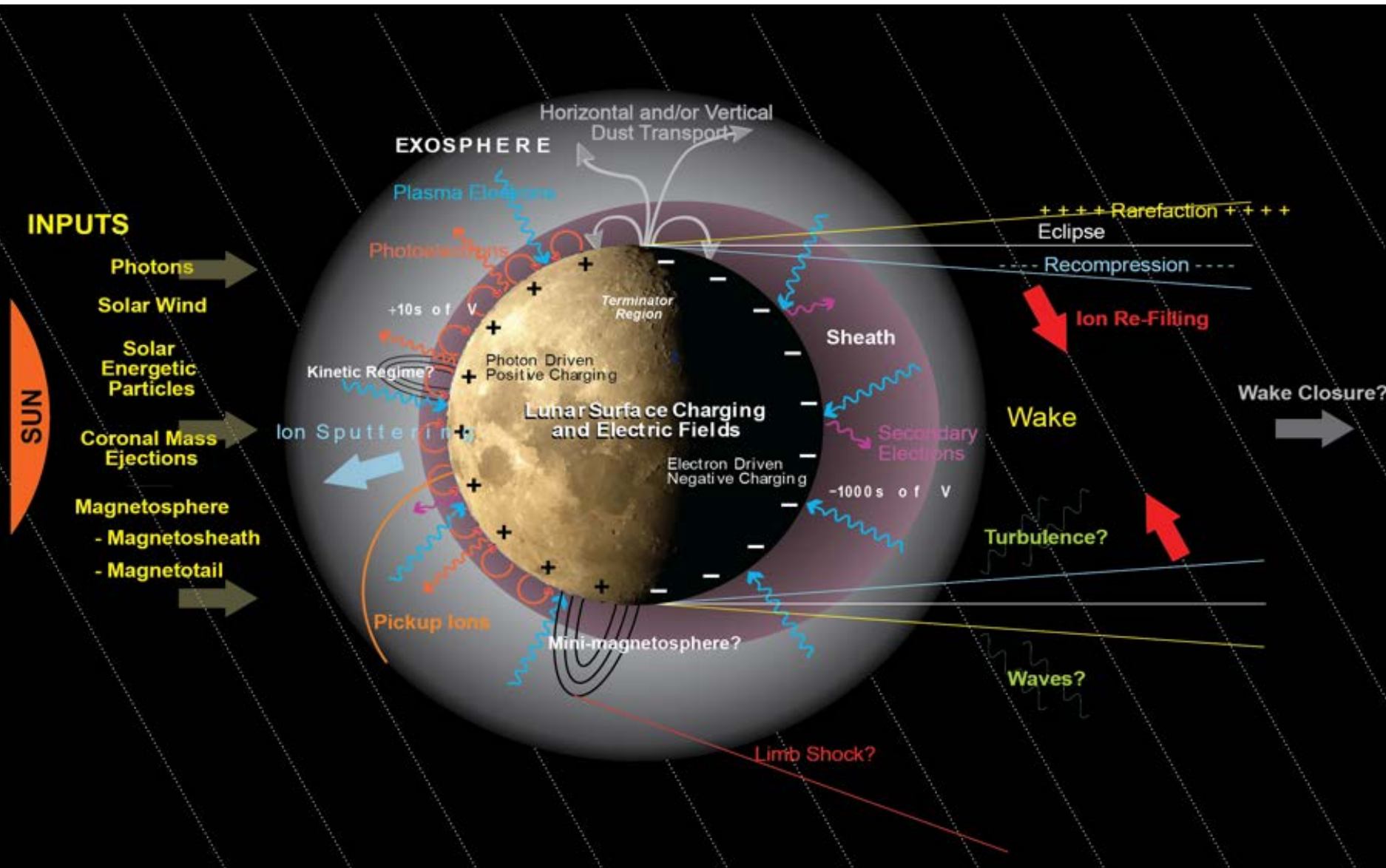
MOON



Earth-Sun-Moon Space Environment



Lunar Space Plasma Environment



Lunar Science by 2024



Polar Landers and Rovers

- First direct measurement of polar volatiles, improving understanding of lateral and vertical distribution, physical state, and chemical composition
- Provide geology of the South-Pole Aitken basin, largest impact in the solar system

Non-Polar Landers and Rovers

- Explore scientifically valuable terrains not investigated by Apollo, including landing at a lunar swirl and making first surface magnetic measurement
- Using PI-led instruments to generate Discovery-class science, like establishing a geophysical network and visiting a lunar volcanic region to understand volcanic evolution

Orbital Data

- Deploy multiple CubeSats with Artemis 1
- Potential to acquire new scientifically valuable datasets through CubeSats delivered by CLPS providers or comm/relay spacecraft
- Global mineral mapping, including resource identification, global elemental maps, and improved volatile mapping

In-Situ Resource Initial Research

- Answering questions on composition and ability to use lunar ice for sustainment and fuel

Science After 2024

Human and Robotic Missions Provide Unique Science Opportunities

On Gateway

- Deep space testing of Mars-forward systems
- Hosts groundbreaking science for space weather forecasting, full-disc Earth observation, astrophysics, heliophysics, lunar and planetary science
- Mars transit testbed for reducing risk to humans

Surface Exploration

- Understanding how to use in-situ resources for fuel and life
- Revolutionizing the understanding of the origin and evolution of the Moon and inner solar system by conducting geophysical measurements and returning carefully selected samples to Earth
- Studying lunar impact craters to understand physics of the most prevalent geologic process in the solar system, impact cratering
- Setting up complex surface instrumentation for astrophysics, heliophysics and Earth observation
- Informing and supporting sustained human presence through partial gravity research in physical and life sciences, from combustion to plant growth

Surface Telerobotics to Provide Constant Science

- Sending rovers into areas too difficult for humans to explore; rovers can be teleoperated from Earth to maximize the scientific return

