Skimming the Lunar Surface for Science: The LADEE Mission

Brian Lewis – Spacecraft Manager

Lunar Atmosphere and Dust Environment Explorer

Objective
- Measure Lunar Dust
- Examine the Lunar atmosphere

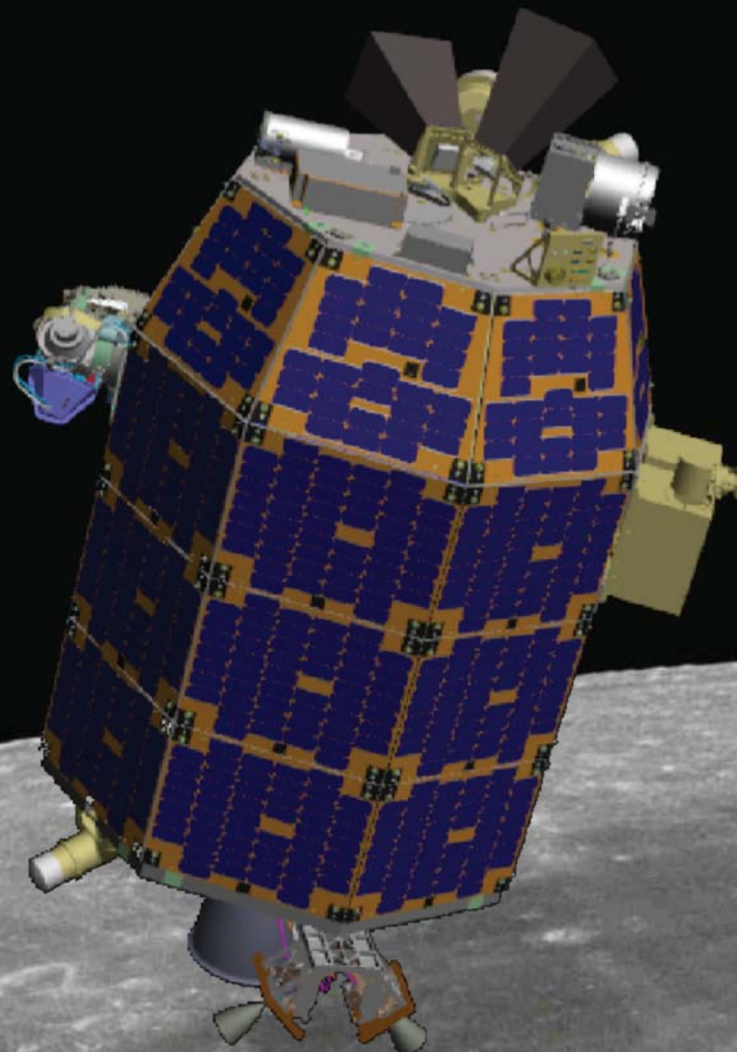
Key parameters
- Launched Sept 6, 2013
- Lunar Impact April 18, 2014

Spacecraft
- Type: Small Orbiter - Category II, Enhanced Class D
- Provider: NASA ARC and NASA GSFC

Instruments
- Science Instruments: NMS, UVS, and LDEX
- Technology Payload: Lunar Laser Communications Demo

Launch Vehicle: Minotaur V

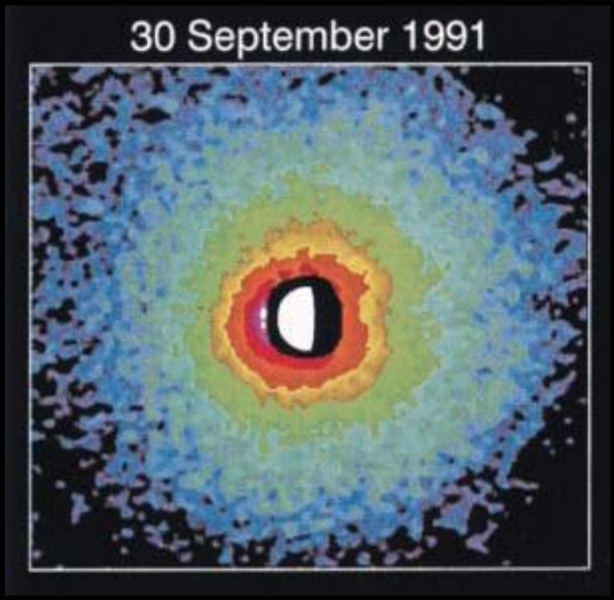
Launch Site: Wallops Flight Facility

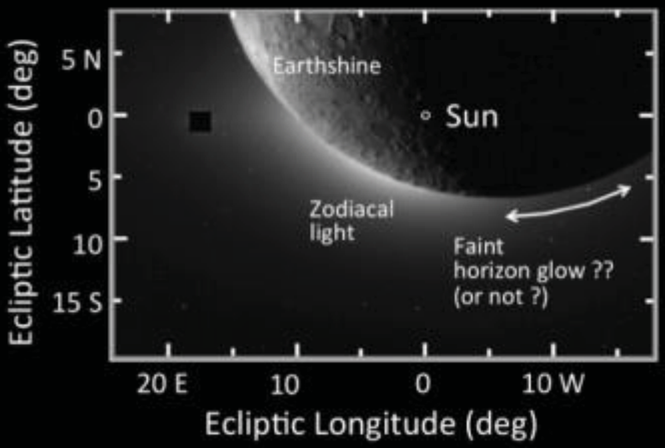


LADEE Science Objectives

- Determine **composition** of the lunar atmosphere, investigate processes controlling distribution and variability - sources, sinks, and surface interactions.

- Characterize lunar exospheric dust environment, measure spatial and temporal variability, and impacts on the lunar atmosphere.





Sample Star Tracker Image – Orbit 193

LADEE Science Payload

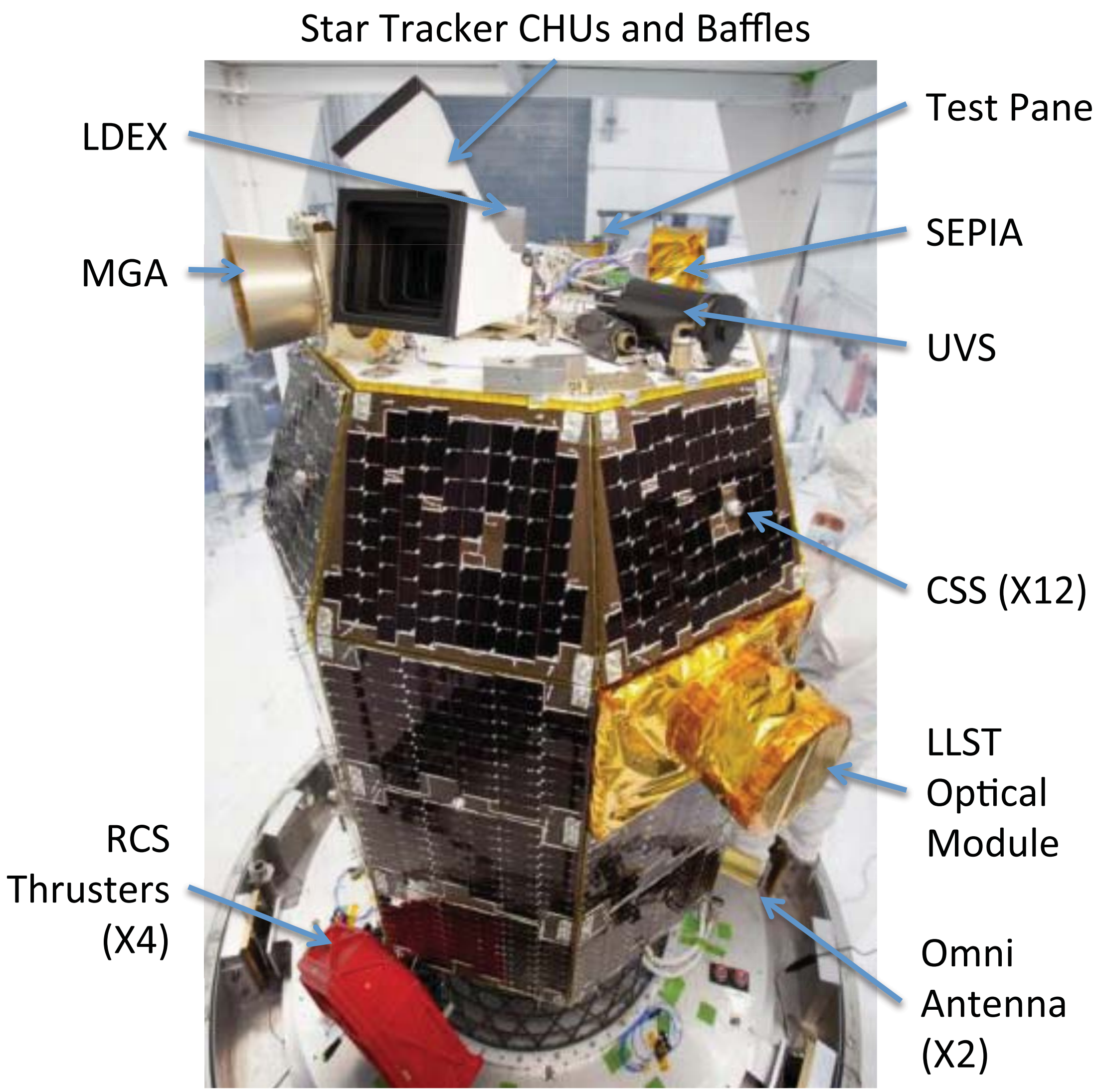
- Neutral Mass Spectrometer (NMS) measures in situ ambient lunar exospheric species (eg., Ar, He, Ne)
- Ultraviolet/Visible Spectrometer (UVS) measures emissions from exospheric species and scattered light from dust
- Lunar Dust Experiment (LDEX) measures in situ dust

LADEE Lasercomm Payload

LLCD/OM Integrated on the LADEE Spacecraft

- Achieved 622 Mbps downlink
- 20 Mbps uplink
- Achieved fully autonomous, fully optical two-way lockup.
- Streaming video!

Flight System Overview



- Composite facesheet / Al honeycomb structure
- Single stage biprop system
- Body mounted solar arrays
- 24 A-h Li-Ion battery
- S-Band STDN compatible comm system
- Broad Reach IAU with RAD750 PPC
- Passive thermal control with heaters
- 3-axis RWA based GNC for nominal ops
- RCS thrusters for control during burns and momentum management
- 240.7 kg dry mass with 134.8 kg prop mass
- ~1090 m/s Delta-V with ~100 Nms momentum unload capacity


CHESAPEAKE BAY BRIDGE - TUNNEL
NON-FLAMMABLE GAS
4BG1587

Spin Balancing LADEE

Fueling LADEE

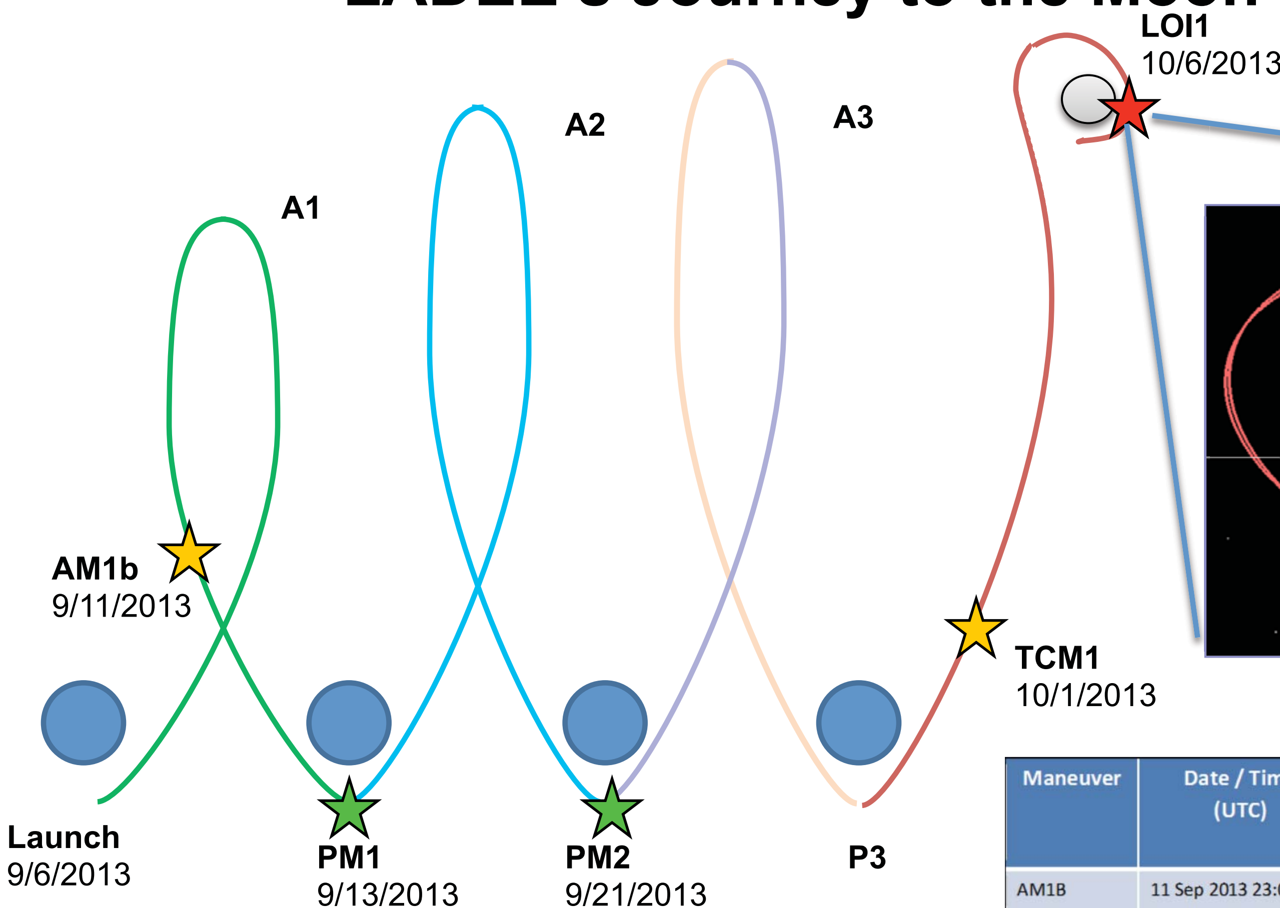
LADEE Launch 6 Sept 2013

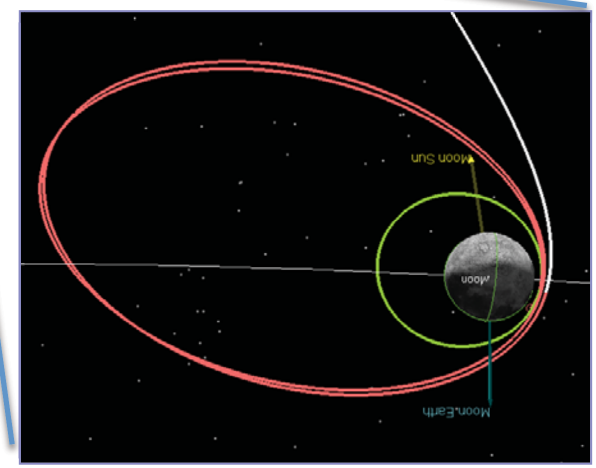

View from Big Apple
Photo: Ben Cooper

View from Suborbital Amphibian

Photo credit: Chris Perry of the WFF Optical Systems Group.

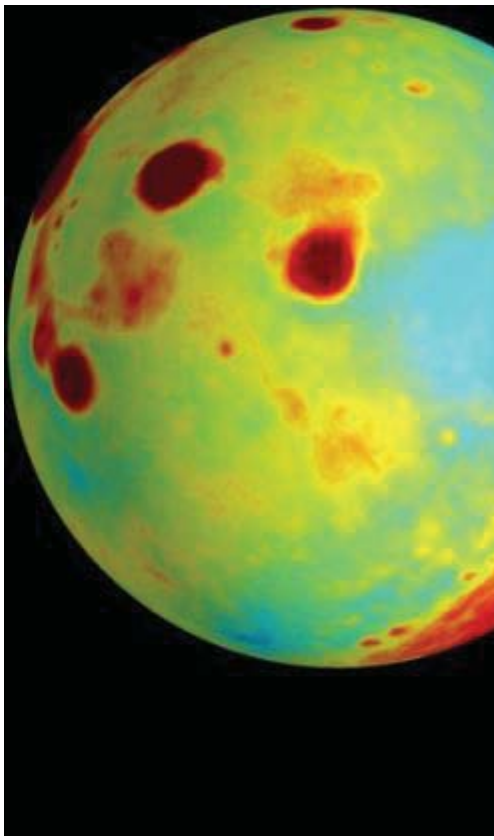
LADEE's Journey to the Moon

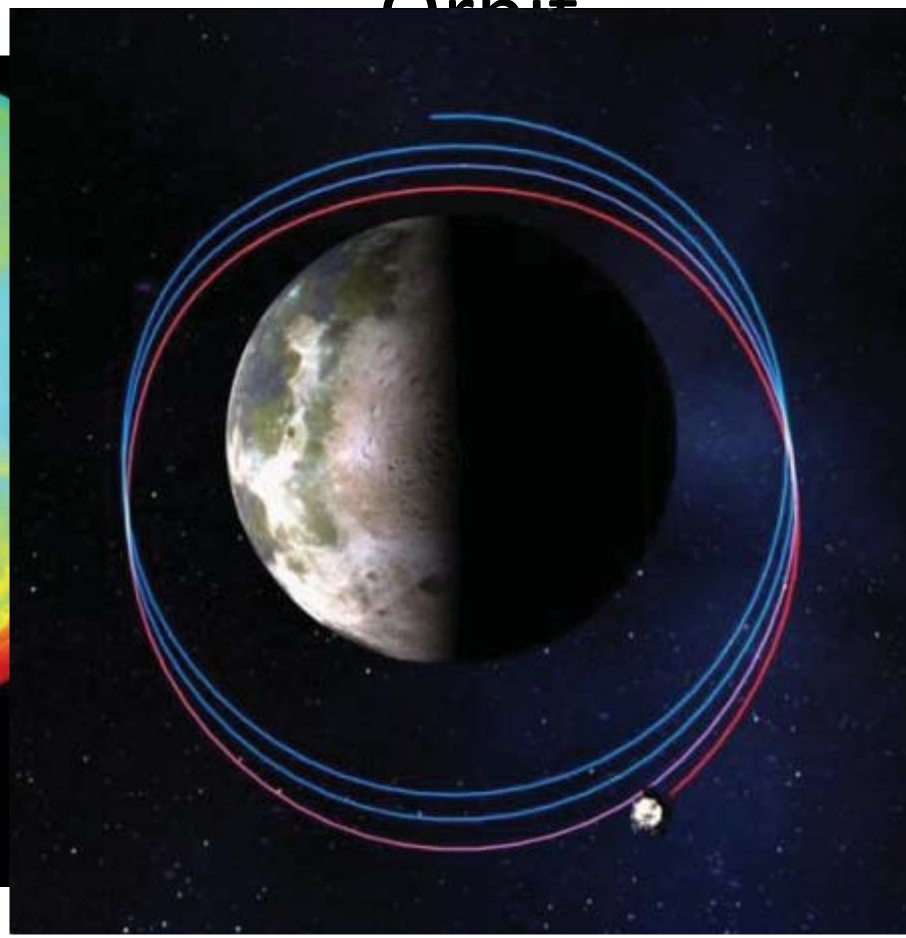


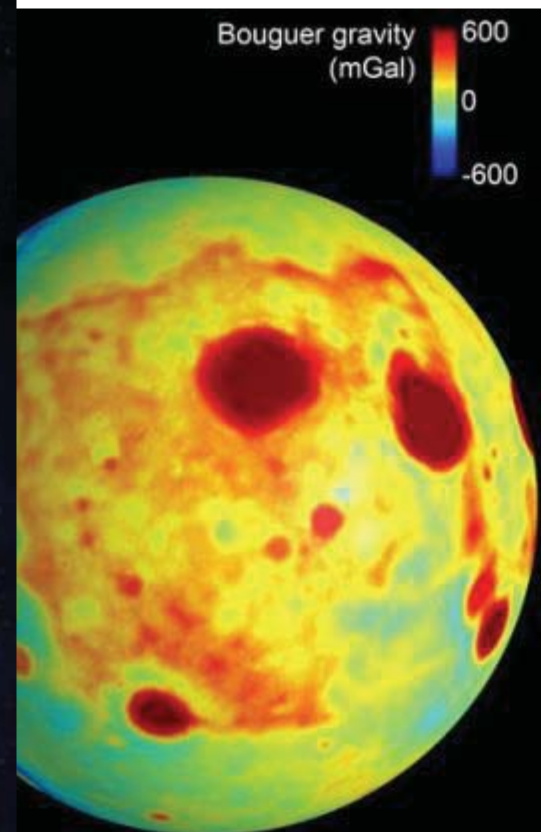


Maneuver	Date / Time (UTC)	Baseline Magnitude (m/s)	Ops Target Magnitude (m/s)	Perf. Error (m/s)	Perf. Error (%)
AM1B	11 Sep 2013 23:00	7.0	9.35	0.03	+1.0
PM1	13 Sep 2013 16:36	20.3	16.97	-0.21	-1.2
PM2	21 Sep 2013 11:53	16.0	17.49	0	0.0
TCM1	01 Oct 2013 22:00	N/A	0.88	0.04	+4.2
LOI1	6 Oct 2013 10:57	328.2	333.4	-2.9	-0.9
LOI2	09 Oct 2013 8:16	295.8	292.9	-1.8	-0.6
LOI3	13 Oct 2013 02:57	238.8	243.4	+0.8	+0.35

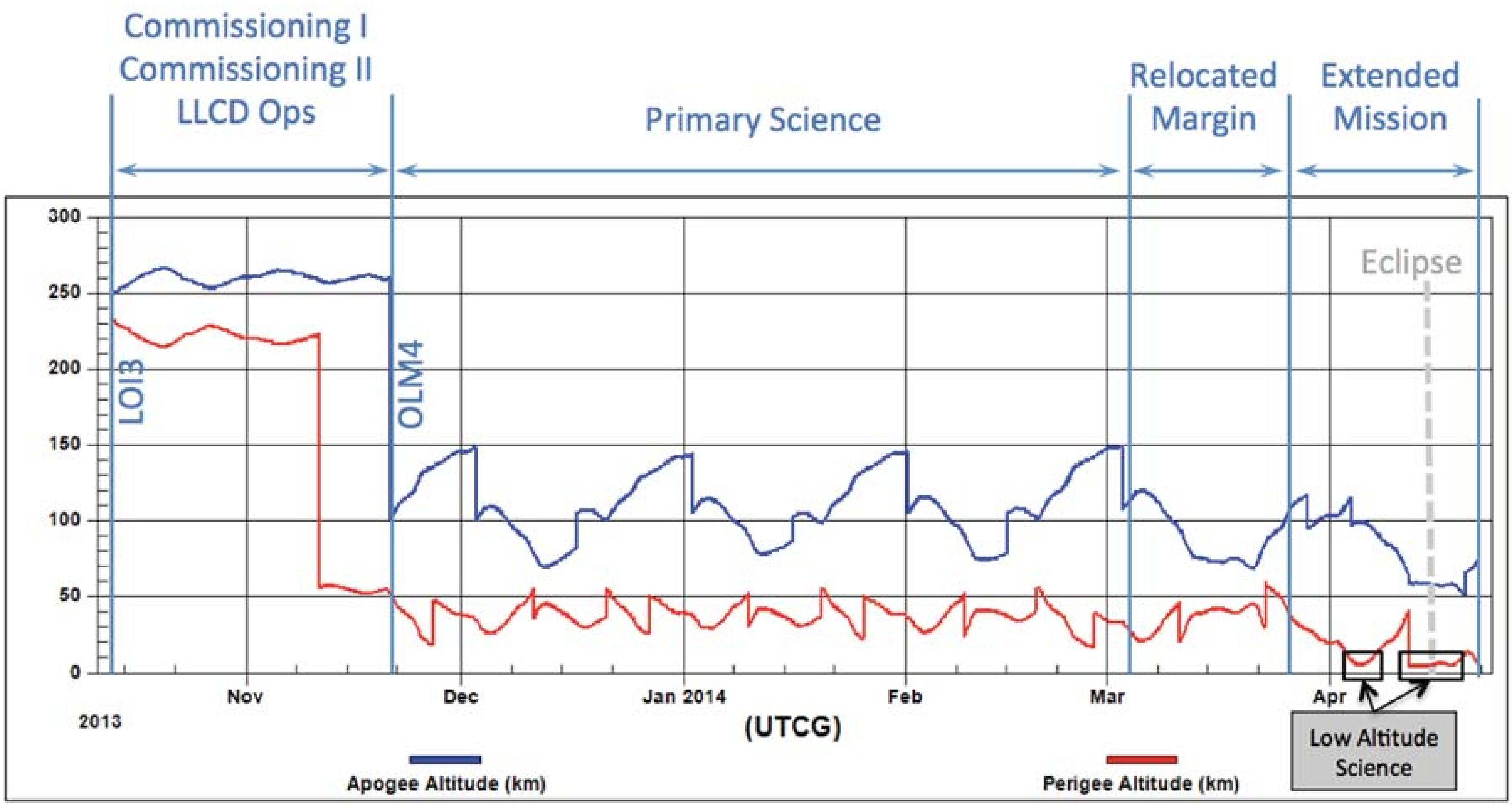
Lunar Gravity and Influence on LADEE Orbit





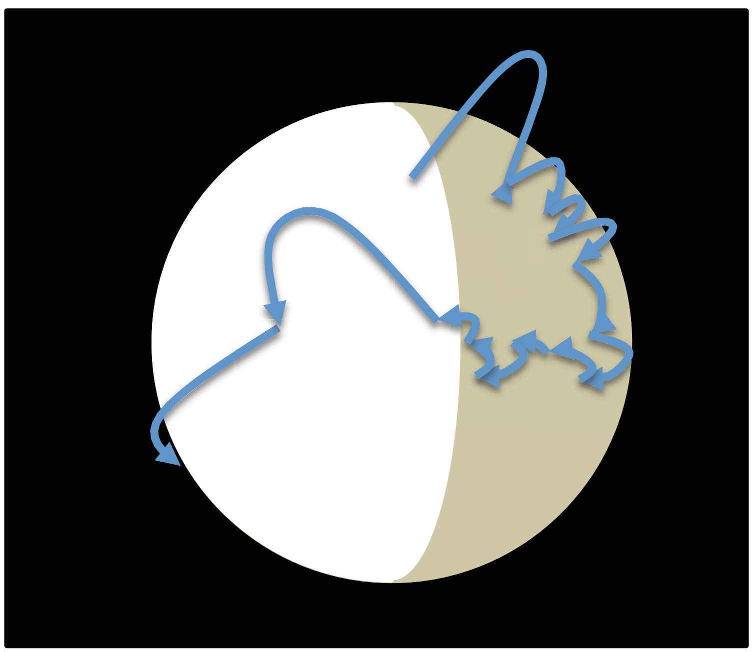


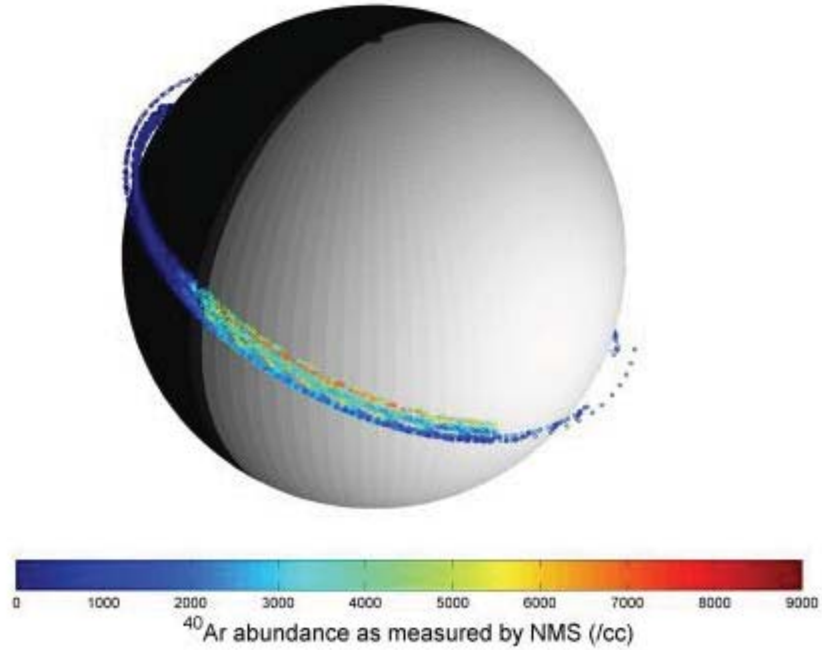
LADEE Lunar Trajectory Overview

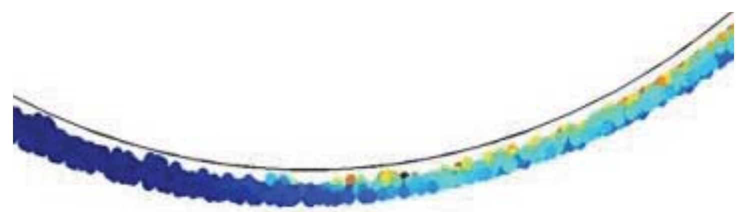


LADEE Argon measurements

- Apollo 17 detected argon
- Not detected by LRO
- NMS detected argon and mapped its movements
- Thin layer of Argon sticks to cold lunar surface (like frost) and is released by solar warming

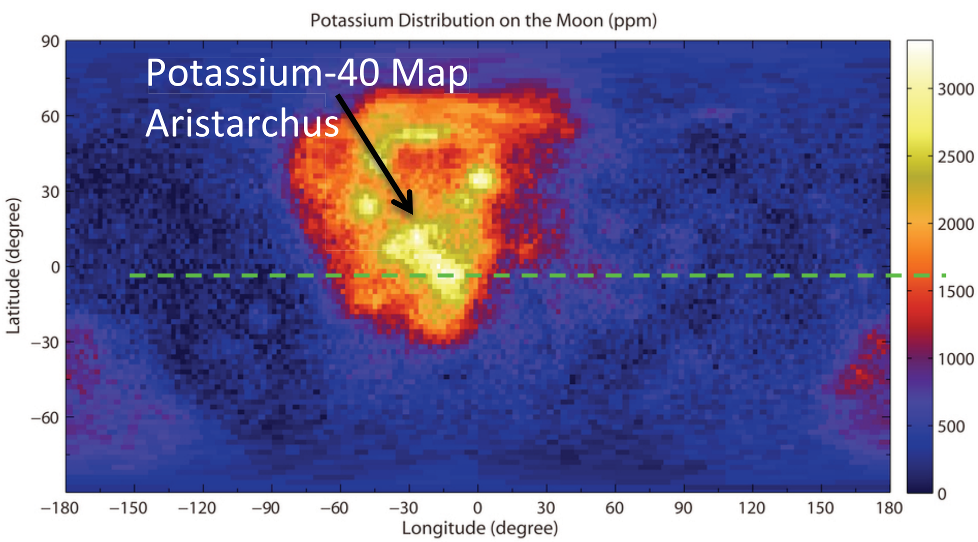


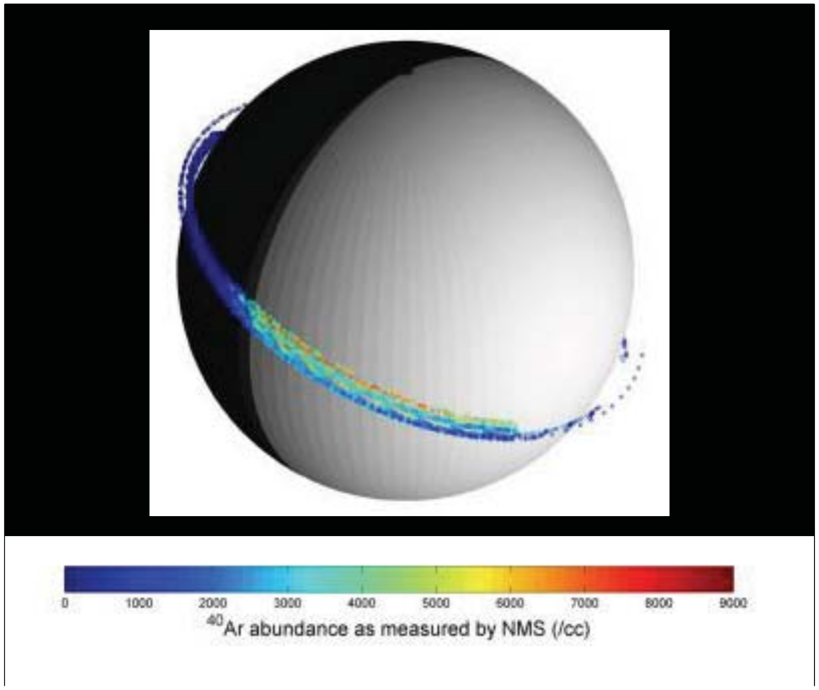




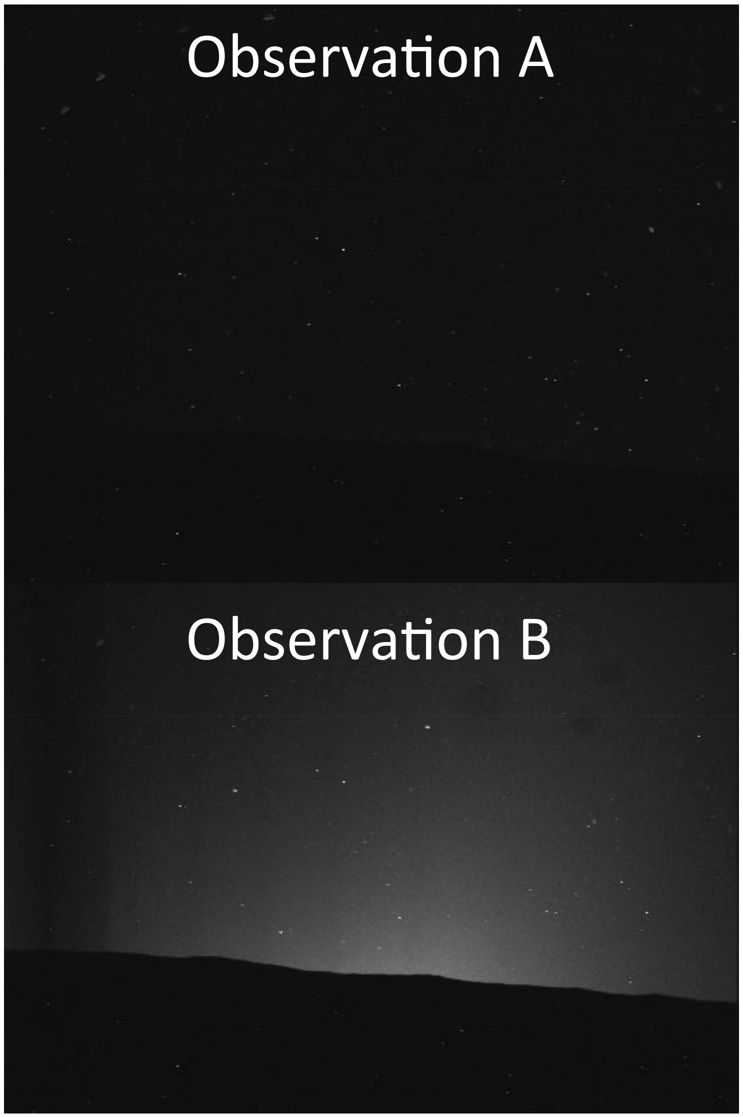
LADEE Argon measurements

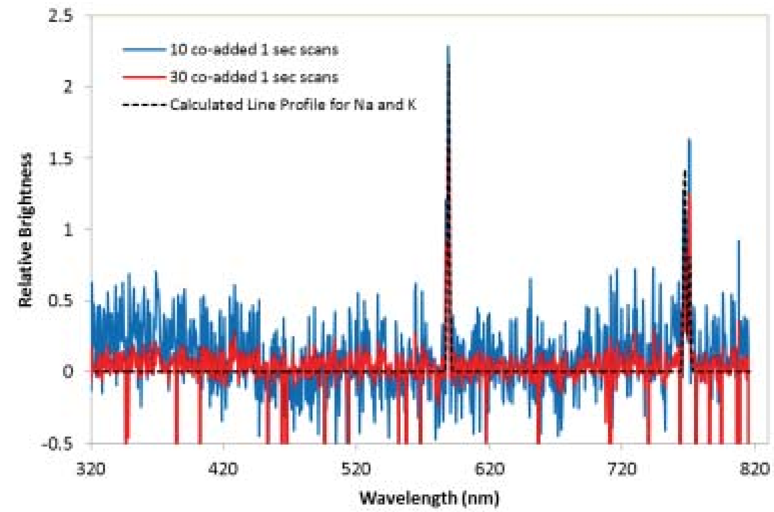
- Localized “bump” in ^{40}Ar density at ~-50° longitude
- Persists throughout dayside
- This location is special

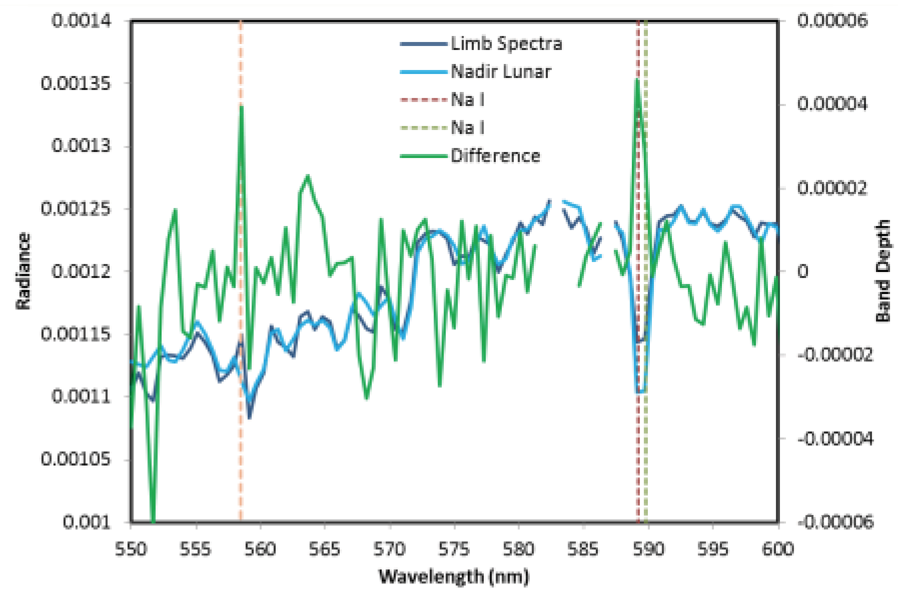




UVS Viewing Geometry and Data Products

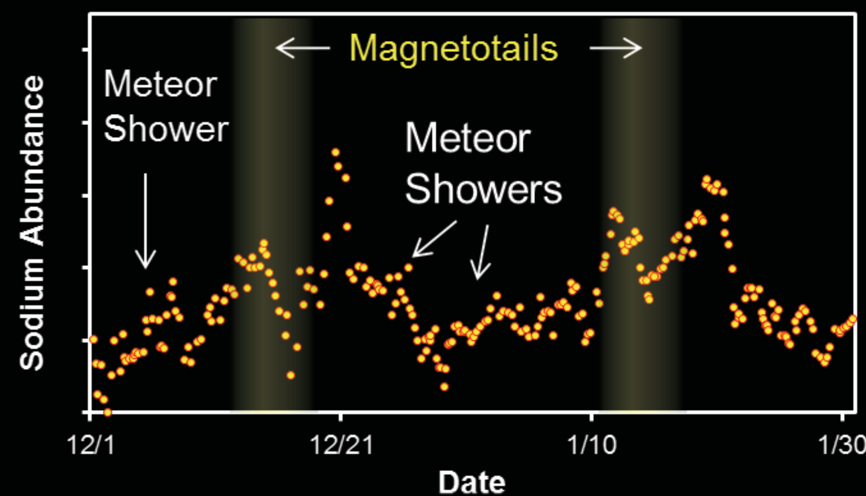


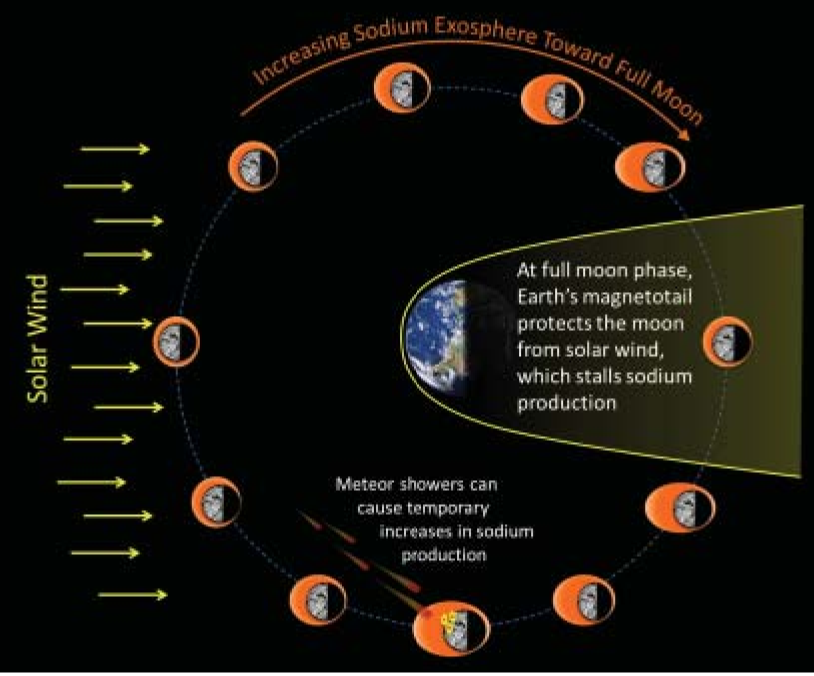




Characterizing the Lunar Atmosphere: First results from LADEE Sodium observations

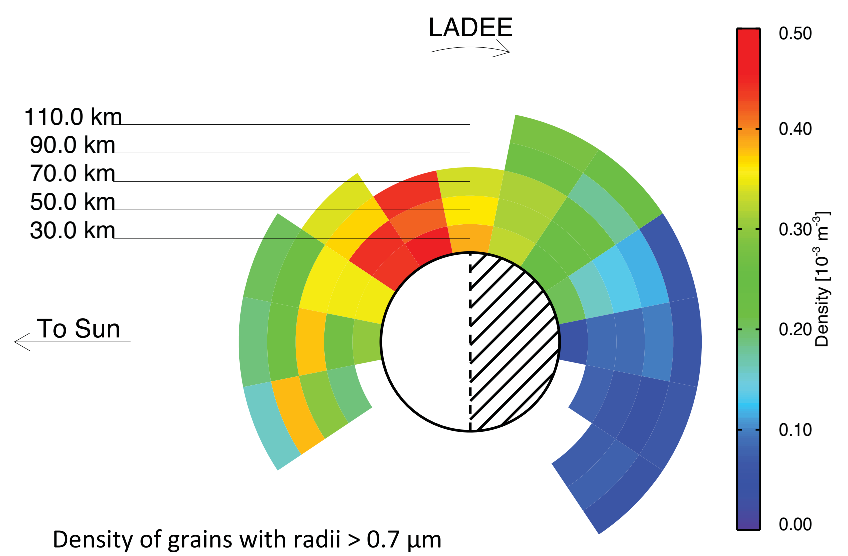
- UVS has constructed maps of sodium in the atmosphere
- Sodium varies with lunar phase, increasing toward full moon
- Sodium increases with meteoroid showers
- Decreases in the Earth's magnetotail
- Variations suggest multiple sources that constrain processes at other airless solar system bodies





Characterizing the Lunar Dust Environment: First results from LADEE Dust measurements

- Over 11,000 impacts recorded
- Dust cloud sustained by bombardment from interplanetary particles
- Occasional particle bursts detected
- Likely generated from impacts close to LADEE's path



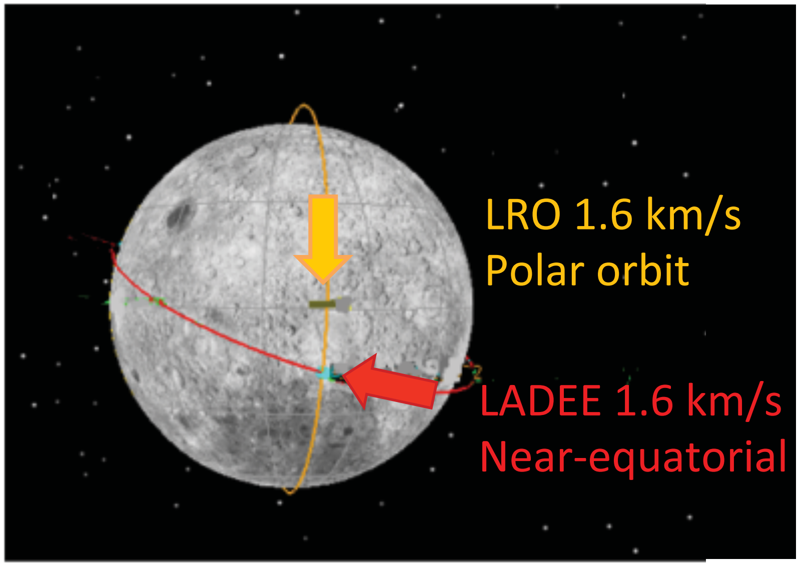
Density of grains with radii > 0.7 μm

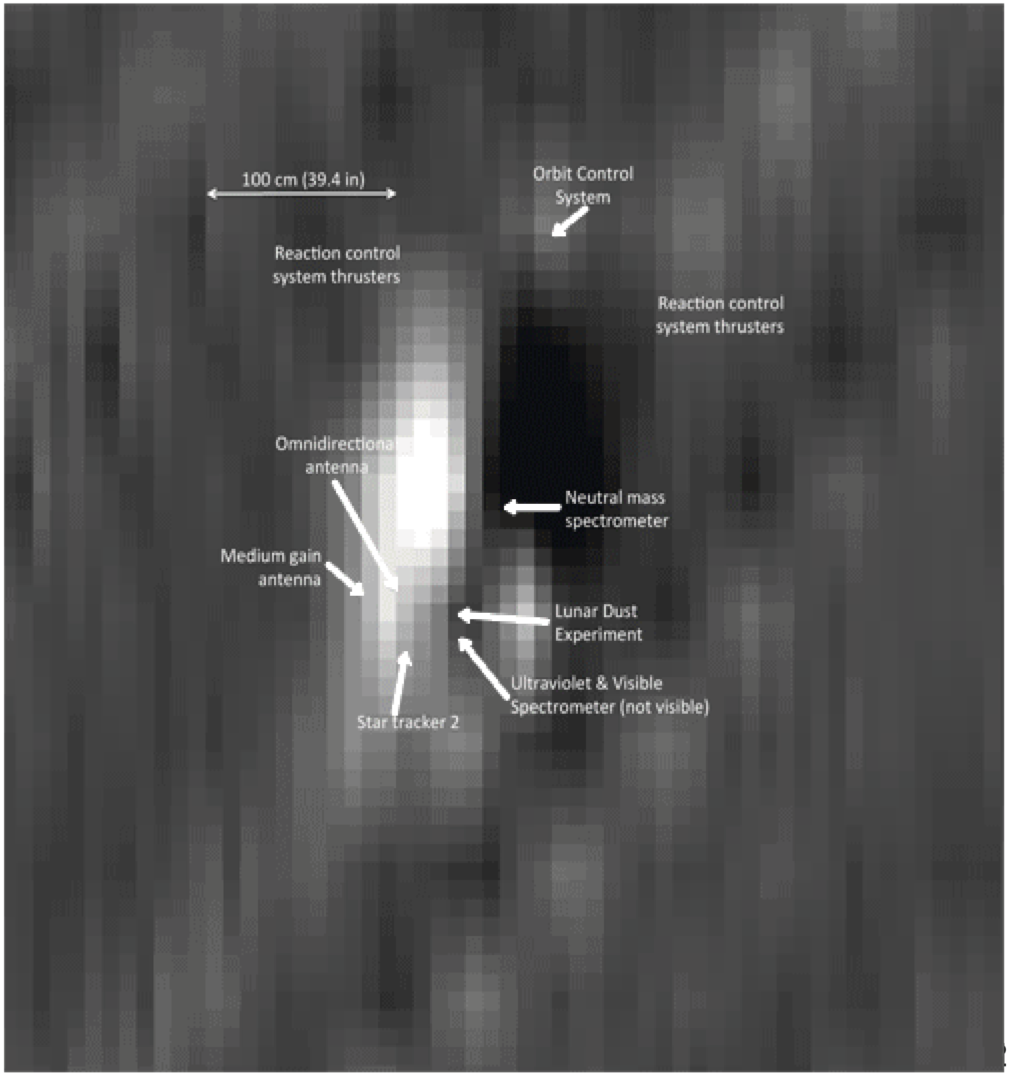
This figure shows the variation in density of impacts seen by LADEE at different heights above the surface and at different times of the lunar day.

The discovery of the lunar dust exosphere opens the door to new approaches to surface composition studies and will improve our hazard estimates of large (> 100 μm) dust impacts.

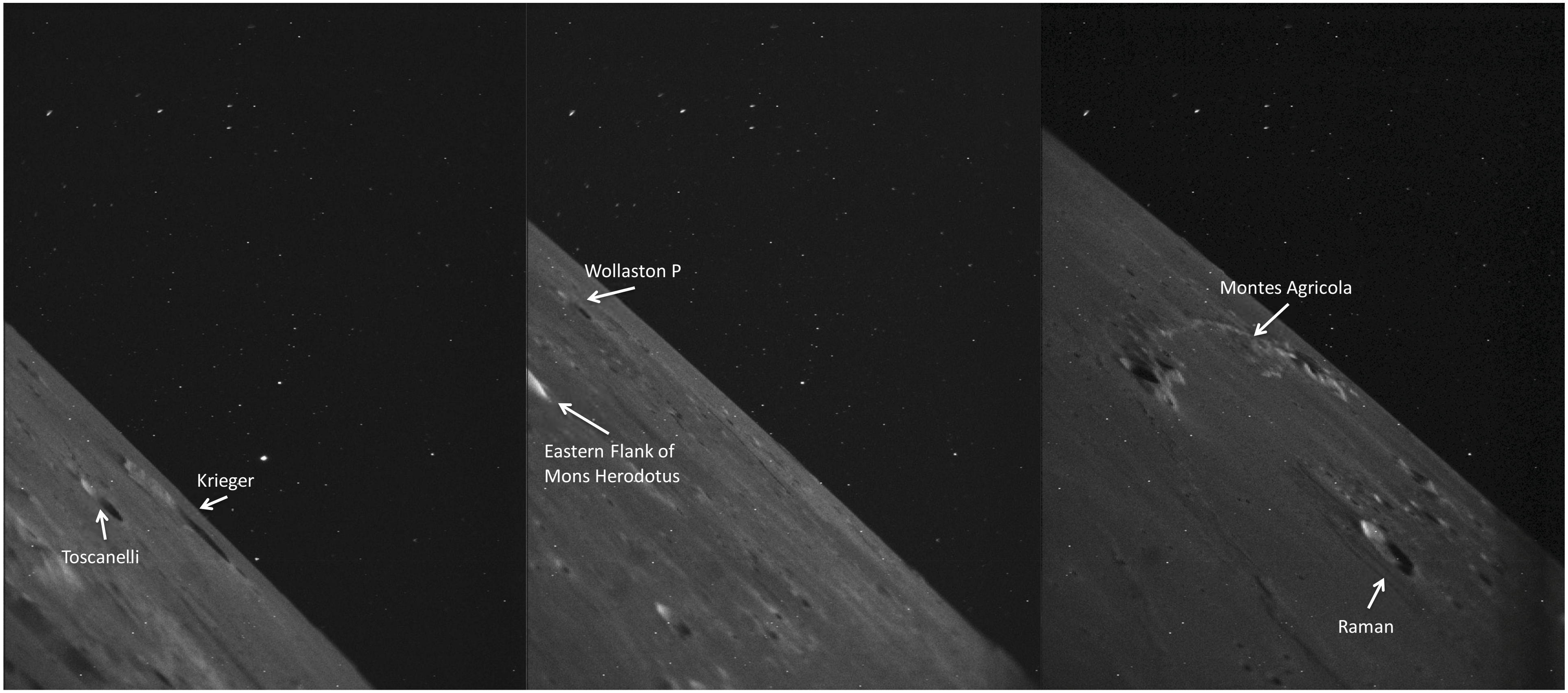
High Precision in Predicted Position

- LADEE Orbit Determination team predicted the location of the spacecraft precisely enough for an LROC photo at a high velocity fly-by
  - Two spacecraft at a nearly perpendicular orbit crossing
  - Both travelling at 1.6 km/sec

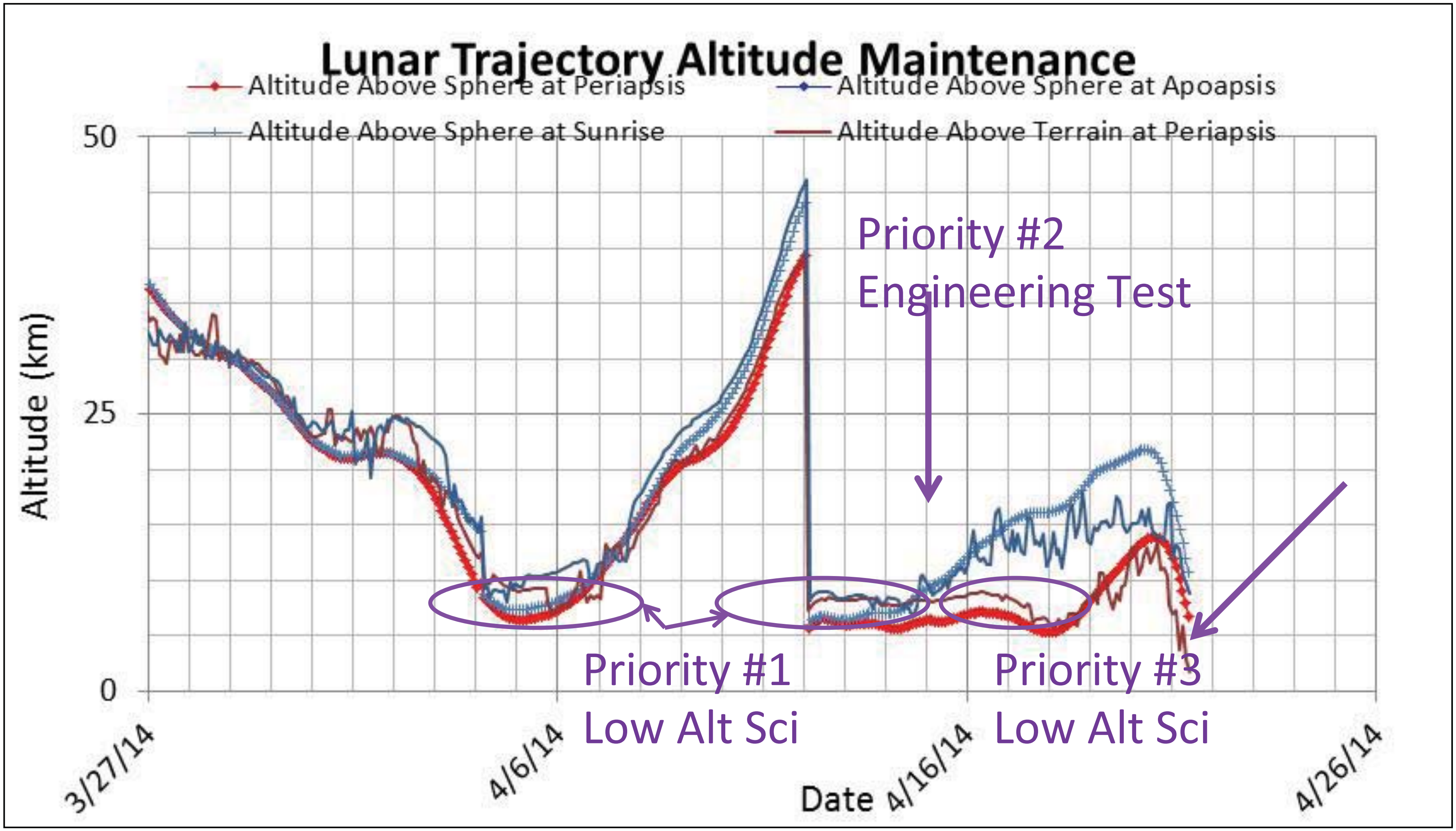




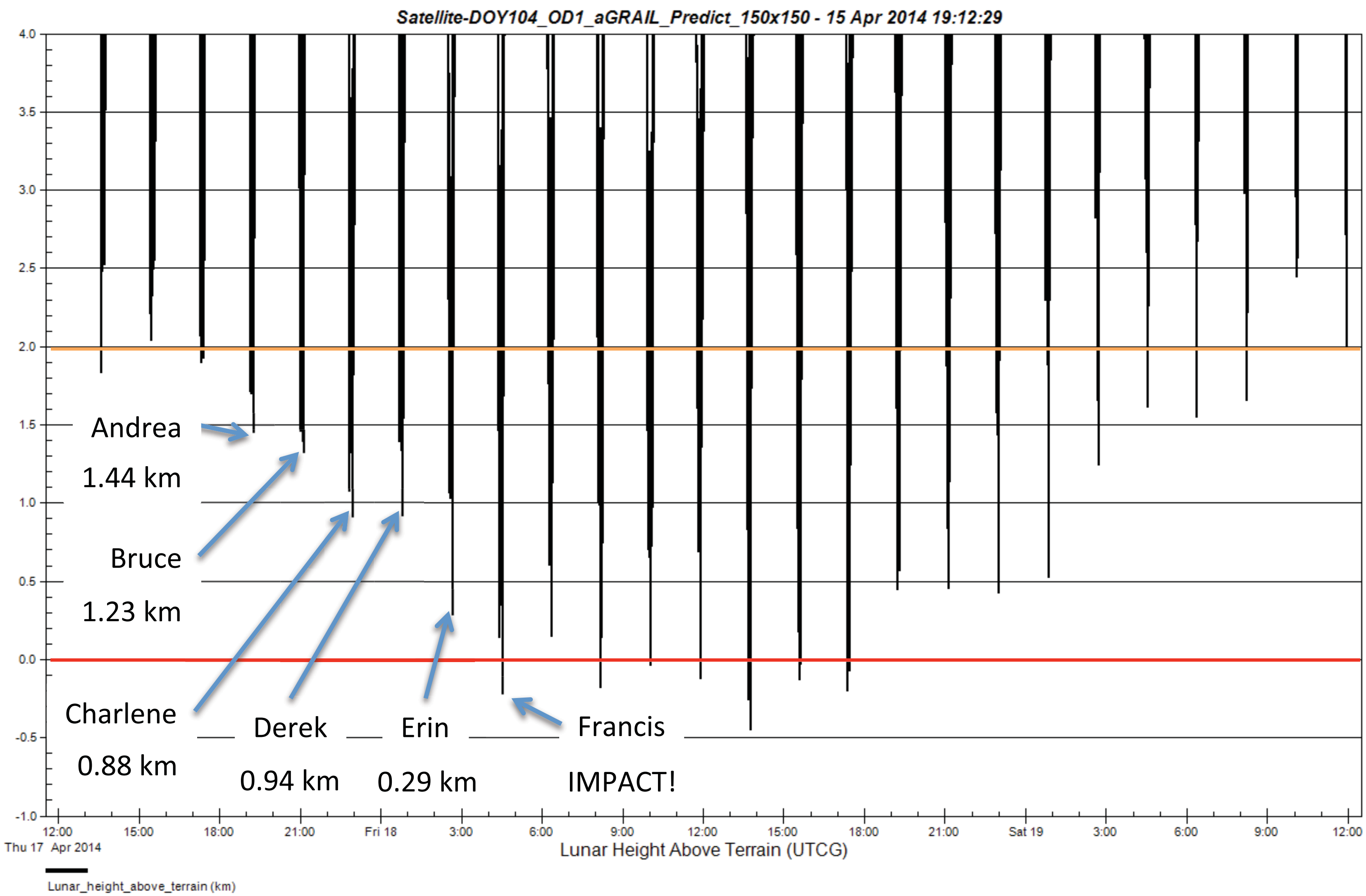
Star Tracker Images



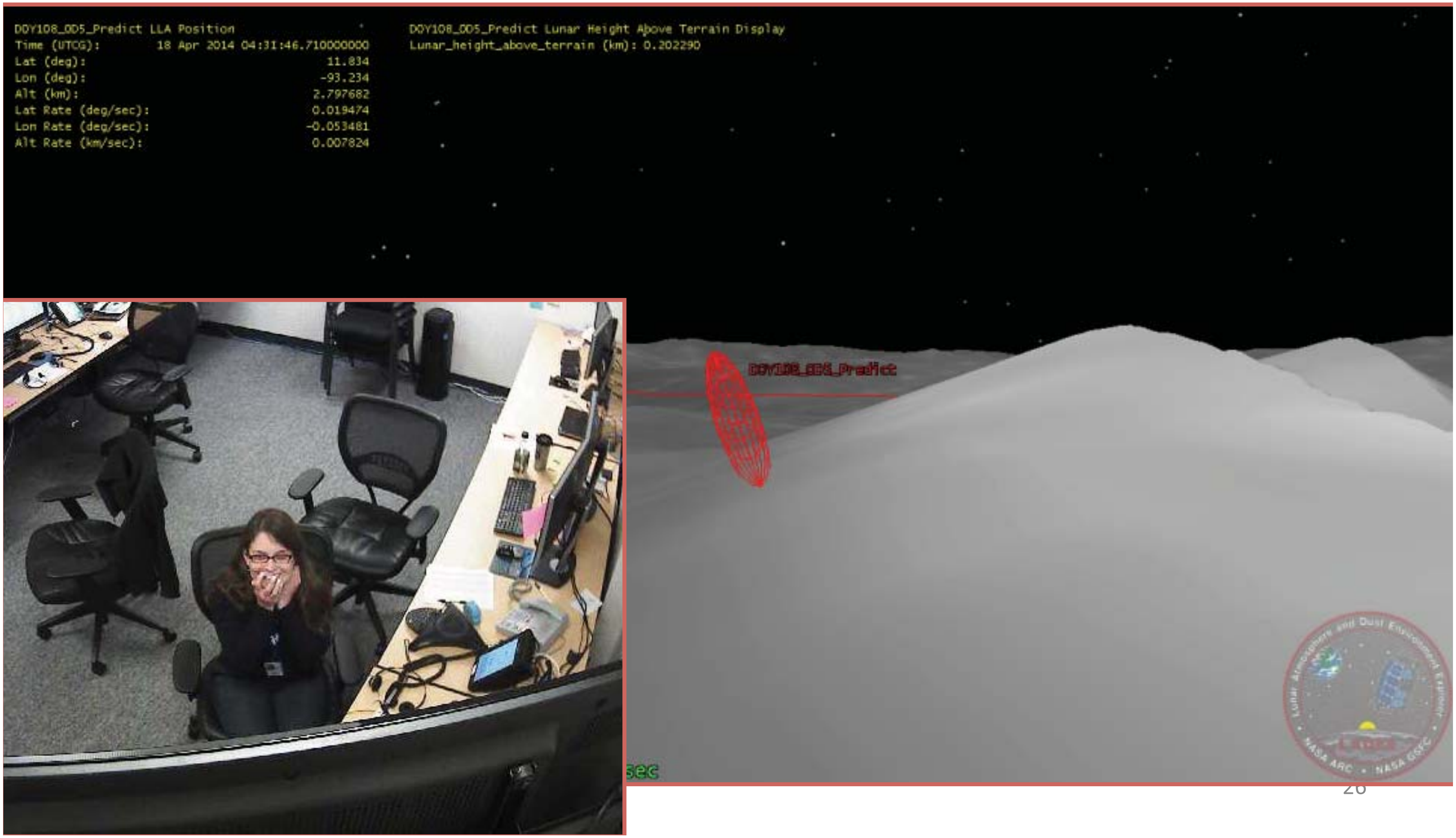
LADEE's Final Days



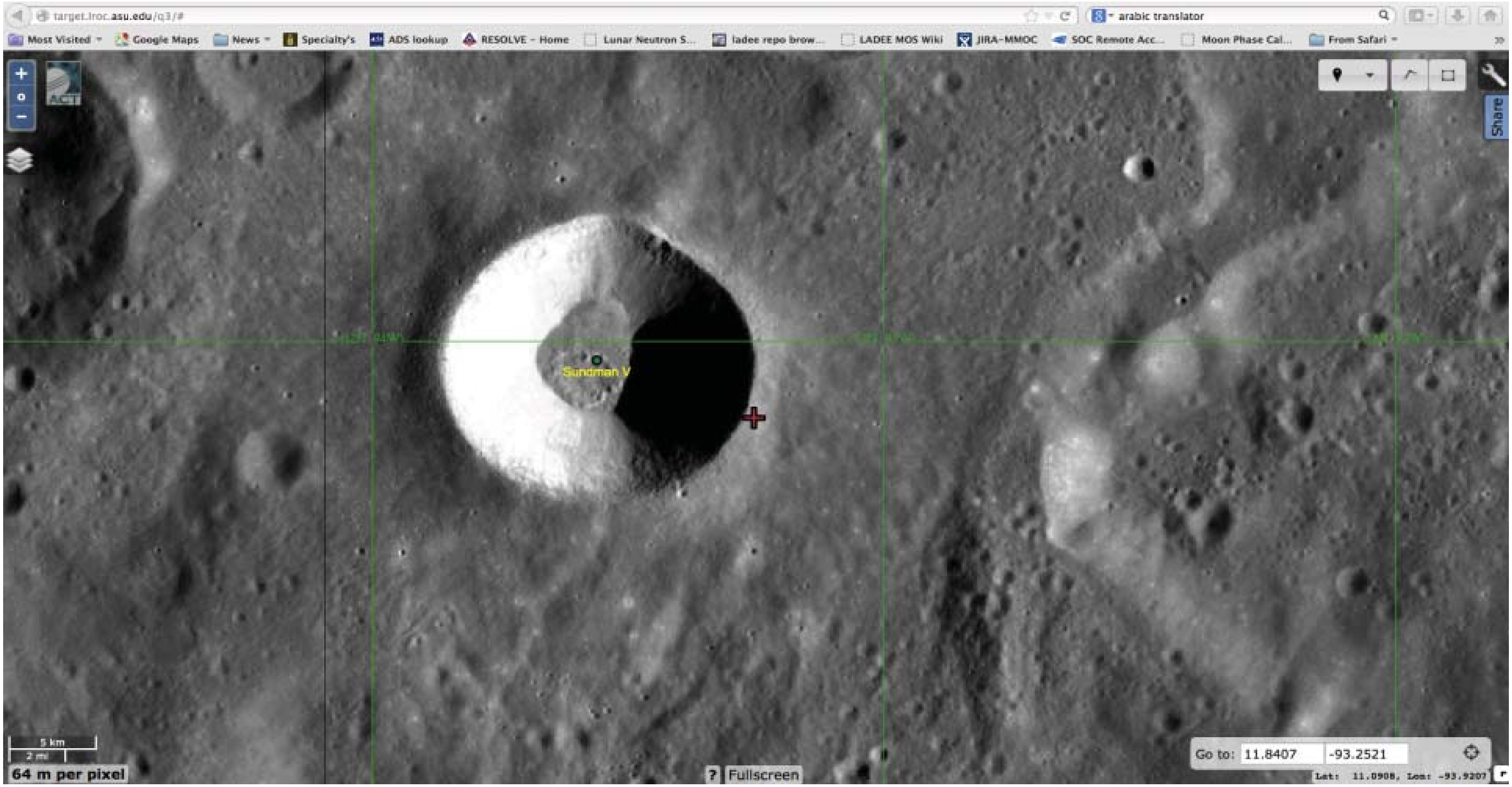
Predicted Height Above Lunar Terrain



And then.....


DOY108_OD5_Predict LLA Position
Time (UTCG): 18 Apr 2014 04:31:46.710000000
Lat (deg): 11.834
Lon (deg): -93.234
Alt (km): 2.797682
Lat Rate (deg/sec): 0.019474
Lon Rate (deg/sec): -0.053481
Alt Rate (km/sec): 0.007824
DOY108_OD5_Predict Lunar Height Above Terrain Display
Lunar_height_above_terrain (km): 0.202290

LADEE Impact Site

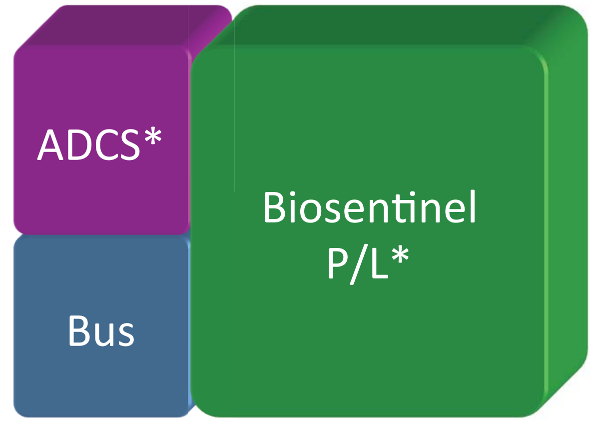


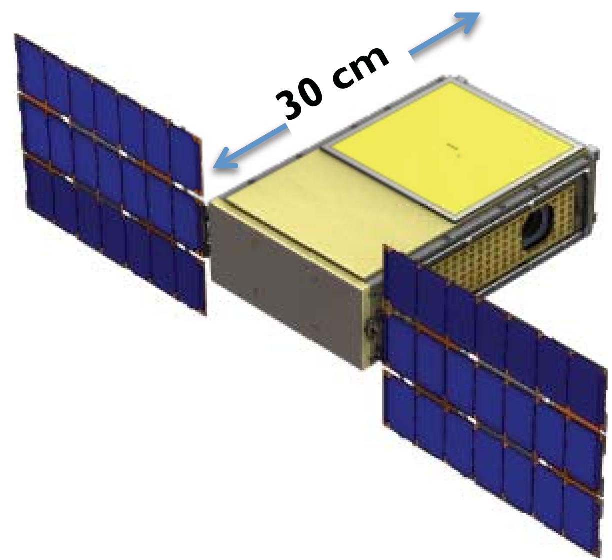
Location is eastern outer rim of Sundman V crater

BioSentinel – Mission Description

- 6U autonomous nanosatellite
  - 4U microfluidic biology payload
    - Microwells with yeast
    - Tailored to detect radiation based DNA damage
    - Includes silica based LET spectrometer
  - ~2U for bus, ADCS, and propulsion
  - 14 kg mass, 23 W power
  - 18 month duration

- Identical payload developed for ISS
- Identical payload for delayed-synchronous ground control
- Identical payload for radiation exposure ground control





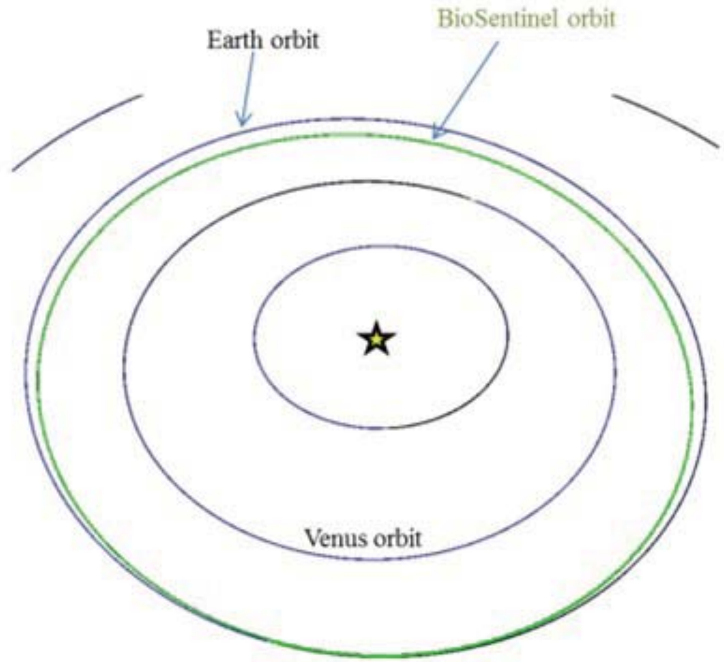
Launch

Artist's rendering of the Space Launch System

- Launched as a secondary payload on **EM**-1
  - **E**xploration **M**ission 1: 1st flight of NASA's Space Launch System
- Exact deployment orbit of 2° payloads still being determined
- Will likely be Earth-leading, heliocentric orbit
- Ranges of up to 70m km from Earth
- Far outside the LEOs typically occupied by CubeSats

  … and far outside the protective shield of Earth's magnetosphere

Orbit



A representative orbit that BioSentinel might occupy

Who am I