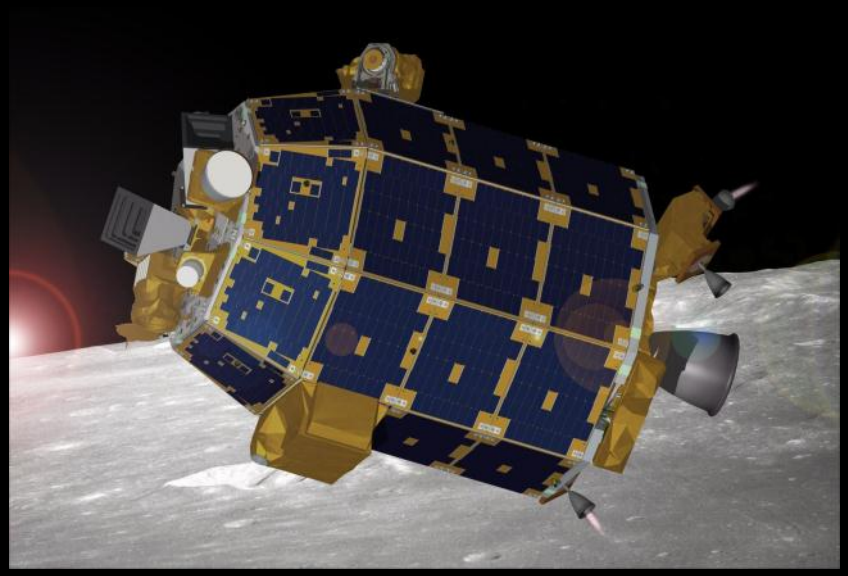
Exploring the Moon with LADEE

The Lunar Atmosphere and Dust Environment Explorer

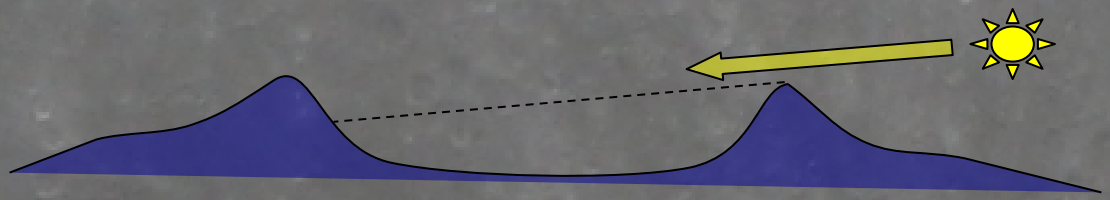
NASA Night Sky Network
November 12, 2013

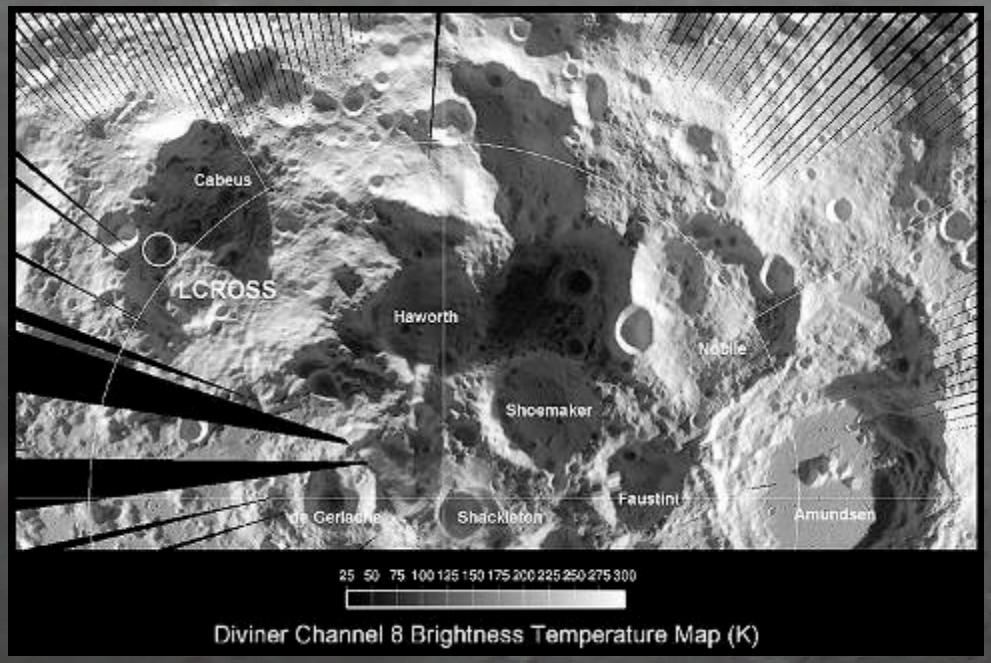
Brian Day
NASA Ames Research Center
LADEE Mission
NASA Solar System Exploration Research Virtual Institute
Brian.H.Day@nasa.gov



Some Craters Near the Moon's Poles are Permanently Shadowed

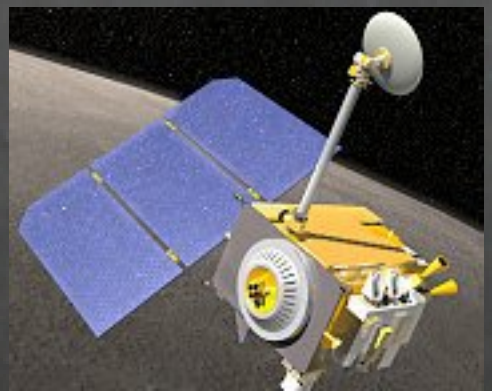
- The Sun never rises more than a few degrees above the polar horizon so some crater floors have been dark for billions of years.

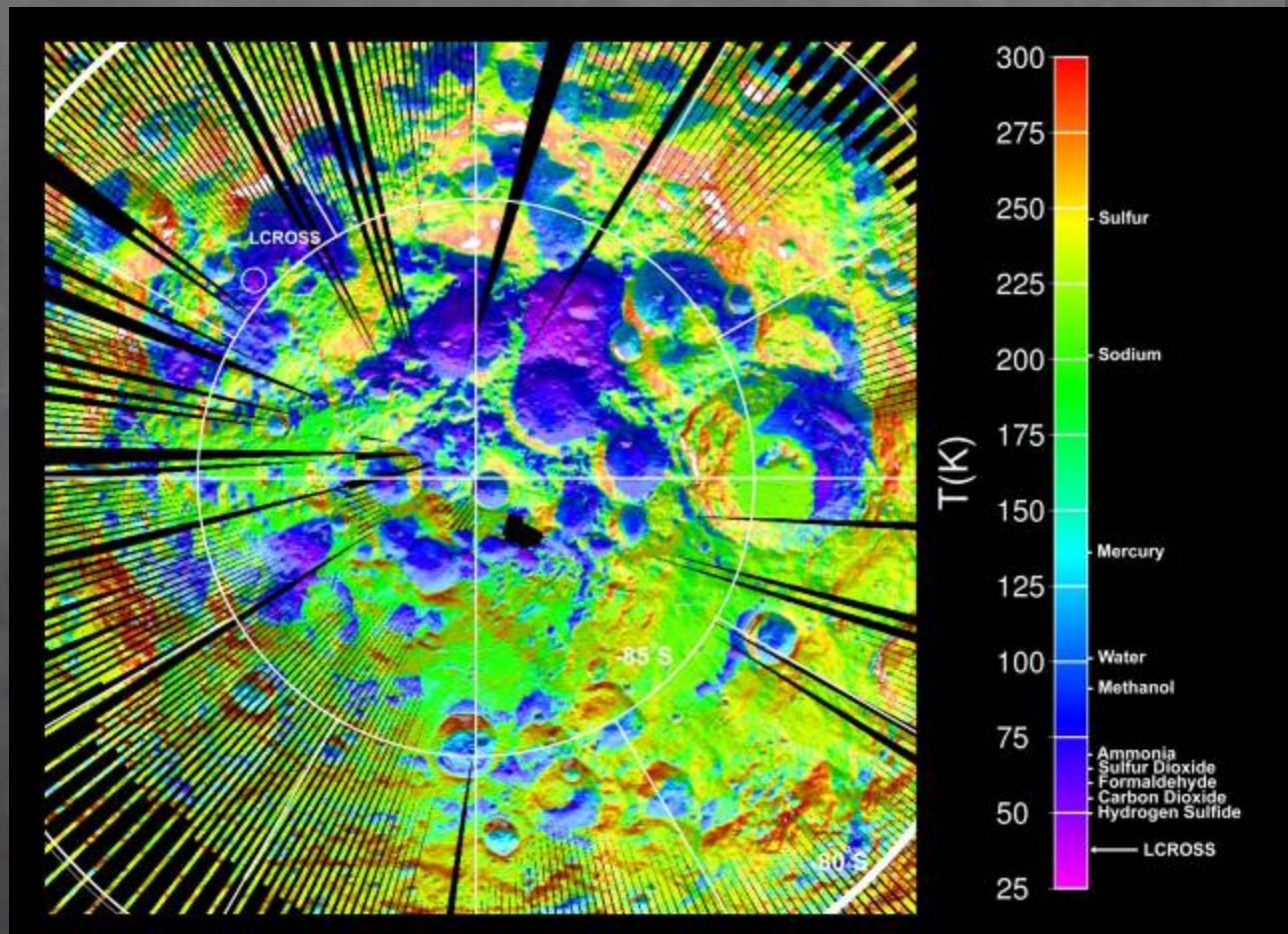




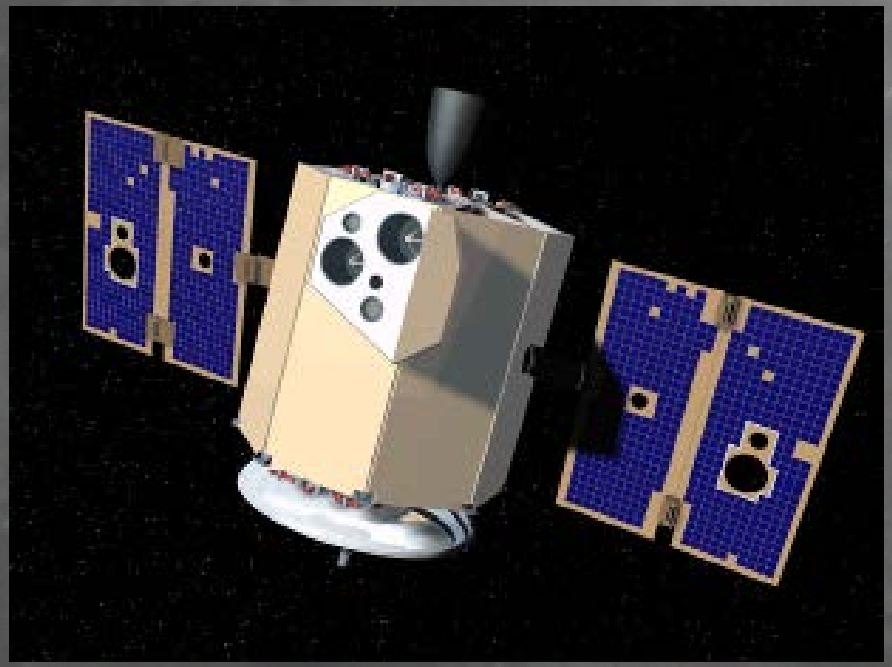
The Moon's Permanently Shadowed Craters are the Coldest Places We have Found in the Solar System

- LRO has measured temperatures as low as -248 degrees Celsius, or -415 degrees Fahrenheit
- This is colder than the daytime surface of Pluto! (-230 Celsius)





Early Evidence for Water

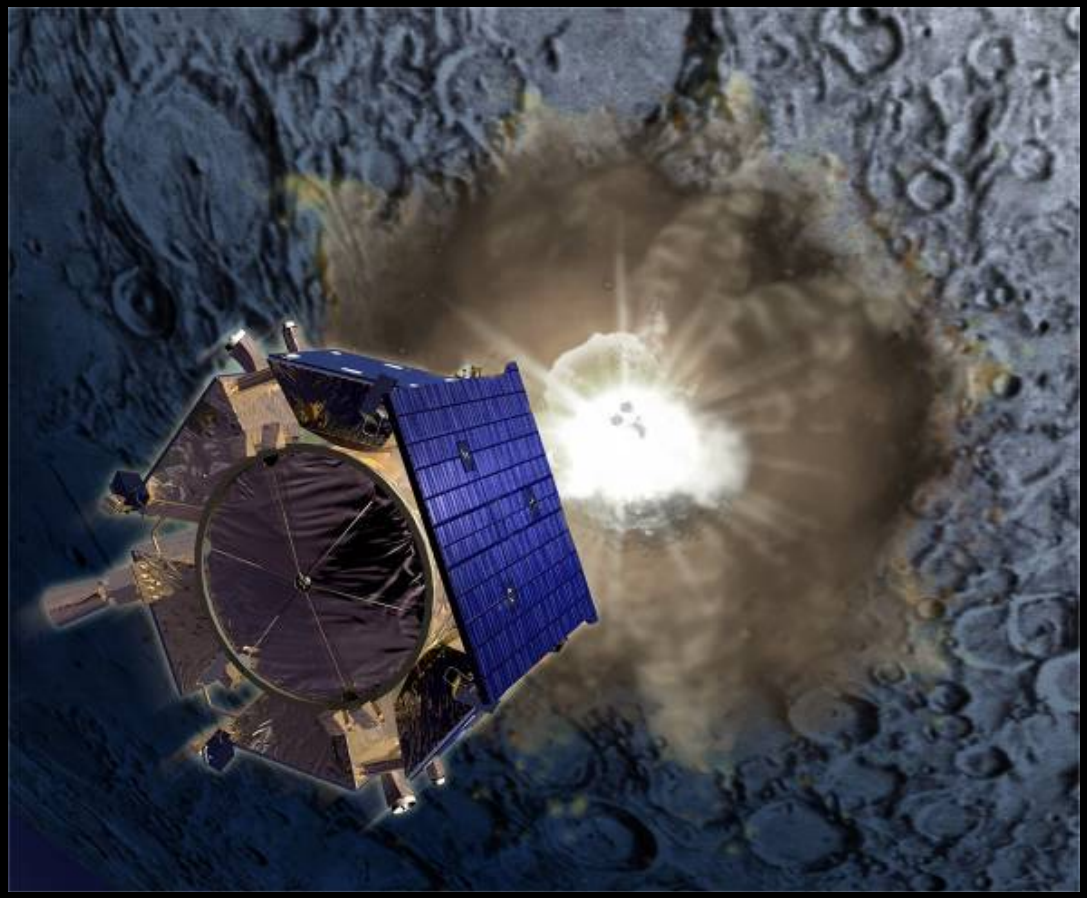


Clementine

Lunar Prospector

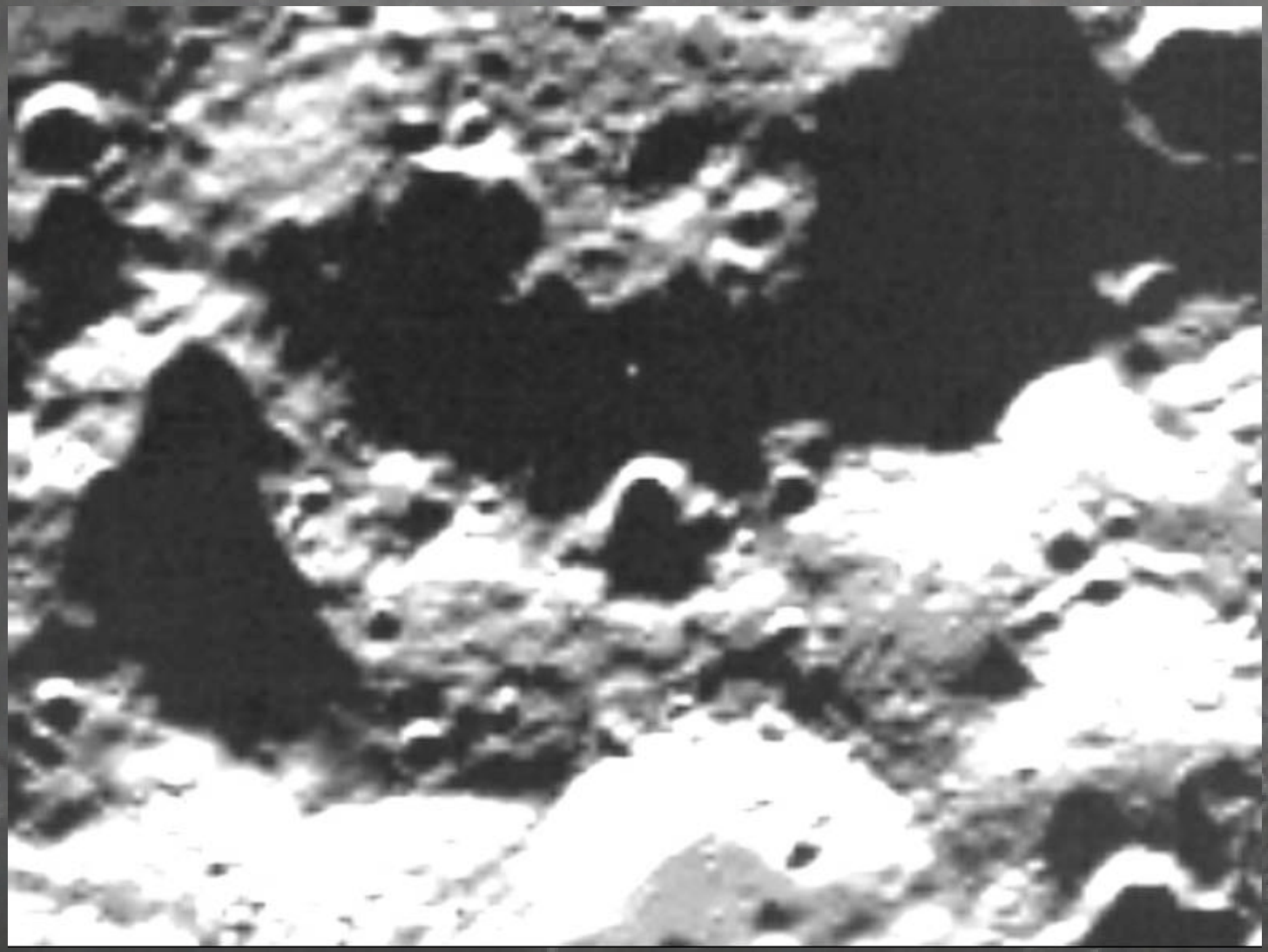
Two missions, Clementine (1994) and Lunar Prospector (1999) gave us preliminary evidence that there <u>may</u> be deposits of water ice at the lunar poles.

LCROSS Mission Concept

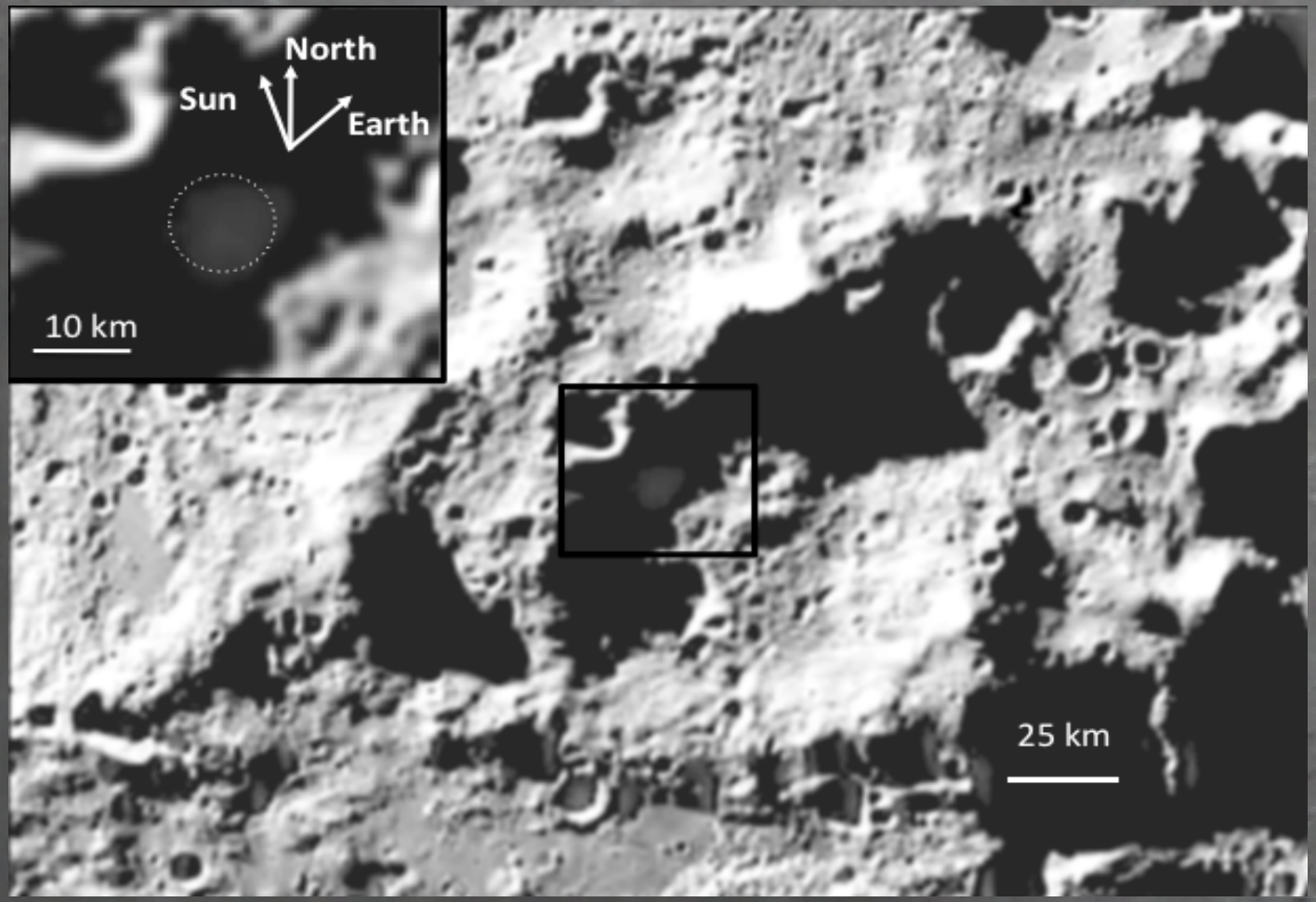


- Impact the Moon at 2.5 km/sec with a Centaur upper stage and create an ejecta cloud that reaching over 10 km above the surface
- Observe the impact and ejecta with instruments that can detect water

What did we see?



What did we see?



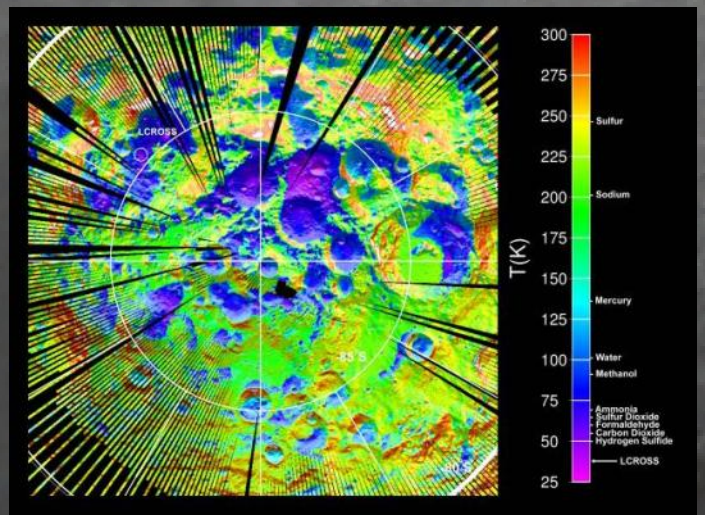
Cam1_W0000_T3460421m473

Schultz, et al (2010)

(Observed expanded ejecta cloud 10-12 km in diameter at 20s after impact. Visible camera imaged curtain at t+8s through t+42s, before cloud dropped below sensitivity range).

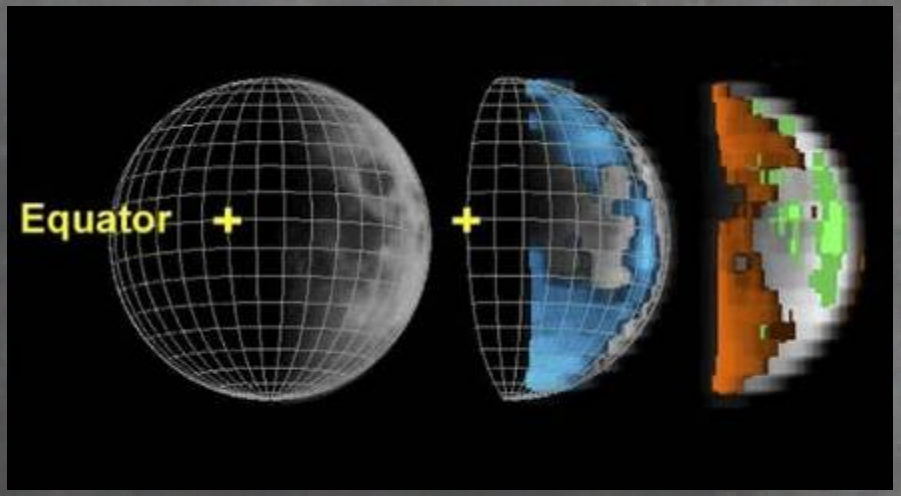
LRO's DIVINER Indicates Widespread Ice at Lunar Poles

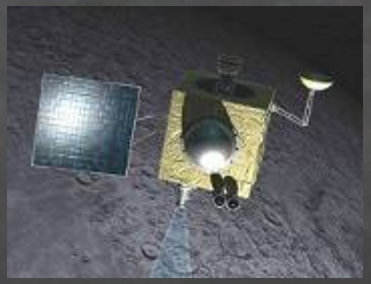
- In permanently-shadowed craters at the Moon's poles, surface deposits of water ice have been found.
- These areas are surrounded by much larger permafrost regions where ice exists just beneath the surface.



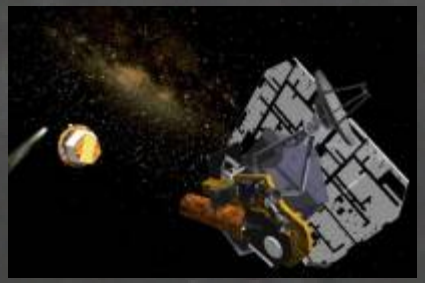
Water in the Soil

- Chandrayann-1 and two other robot explorers found small amounts of water away from the poles.

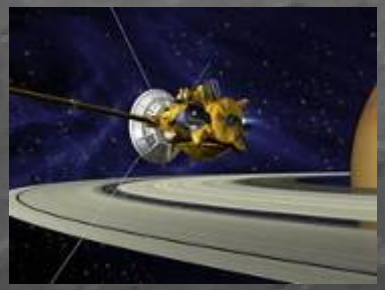




Chandrayaan-1



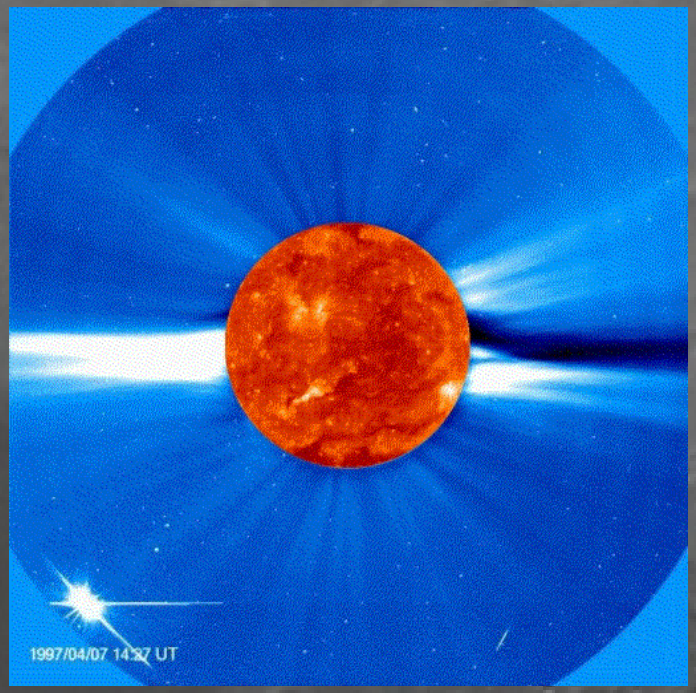
Deep Impact



Cassini

Where Did the Water Come From?

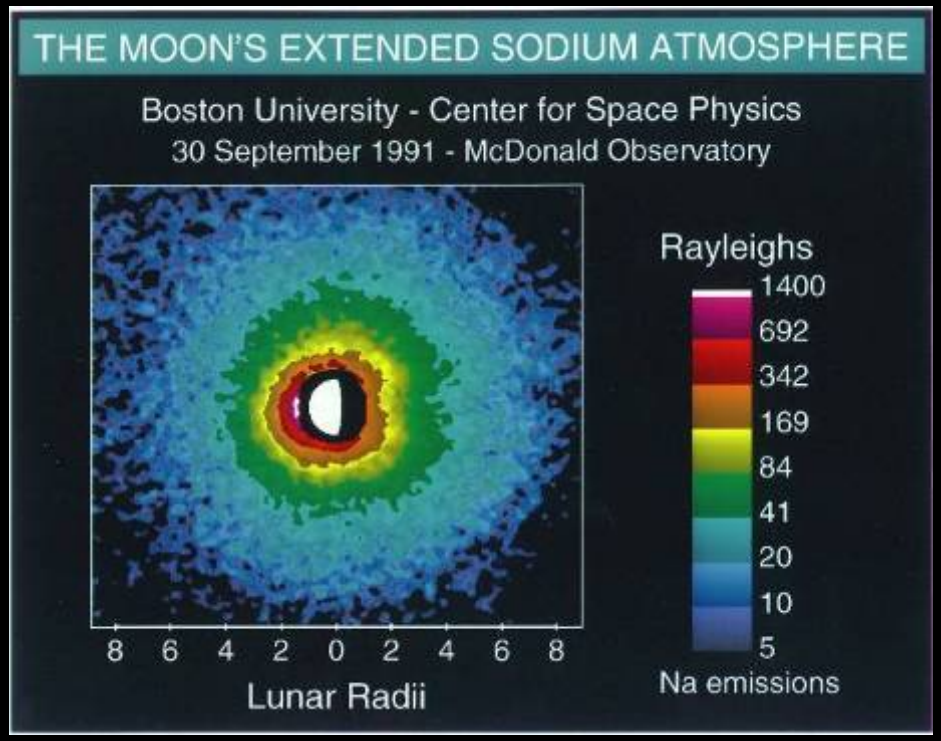
- We're not sure, but we have some clues.



Lunar Atmosphere?

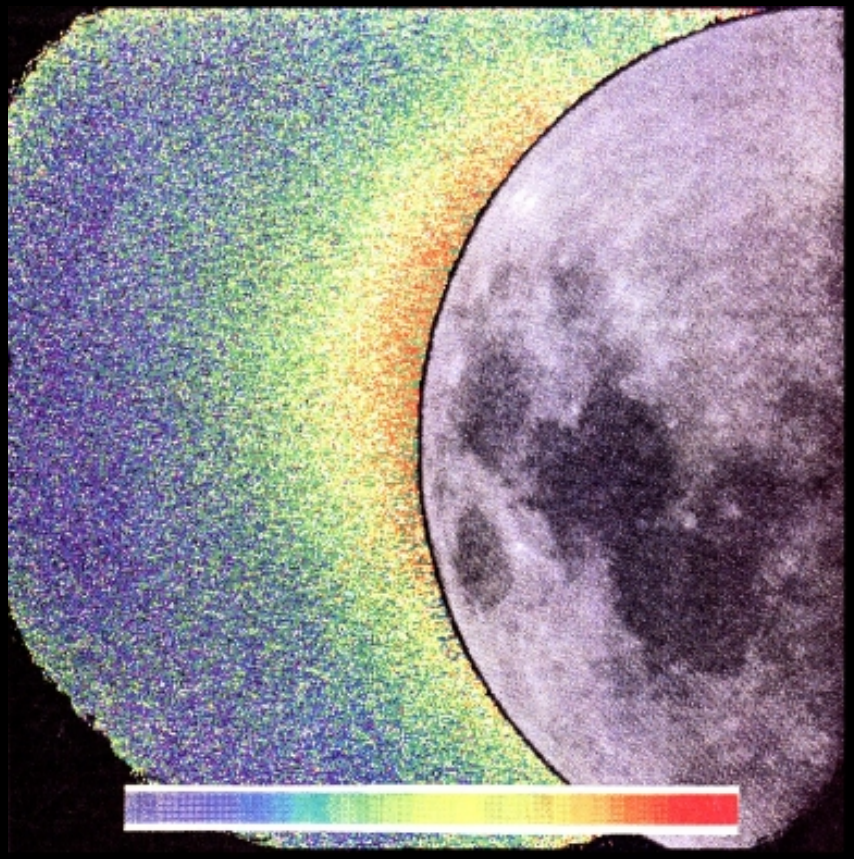
- Yes, but very thin! A cubic centimeter of Earth's atmosphere at sea level contains about 10^{19} molecules. That same volume just above the Moon's surface contains only about 100,000 to a few million molecules.

- It glows most strongly from atoms of sodium. However, that is probably a minor constituent. We still do not know its composition.



Lunar Exosphere

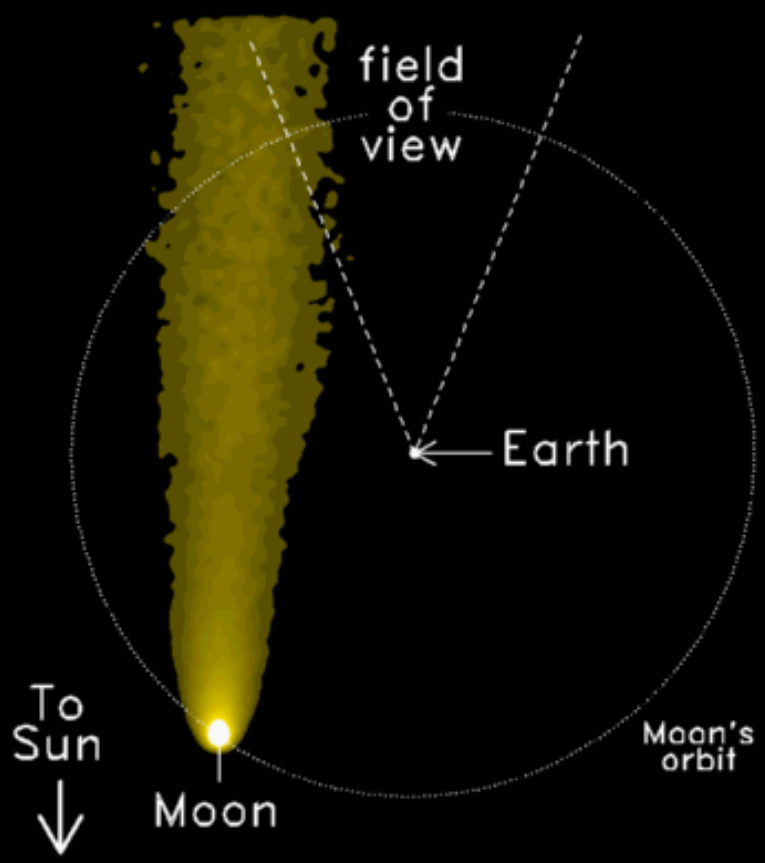
- An exosphere is a tenuous, collisionless atmosphere.
- The lunar exosphere is bounded by the lunar surface – a *surface boundary exosphere*.
- Consists of a variety of atomic and molecular species – indicative of conditions at the Moon (surface, subsurface).
- Wide variety of processes contribute to sources, variability, losses.



Sodium exosphere of the Moon imaged by the Evans coronagraph, National Solar Observatory, New Mexico (Potter et al., 1998)

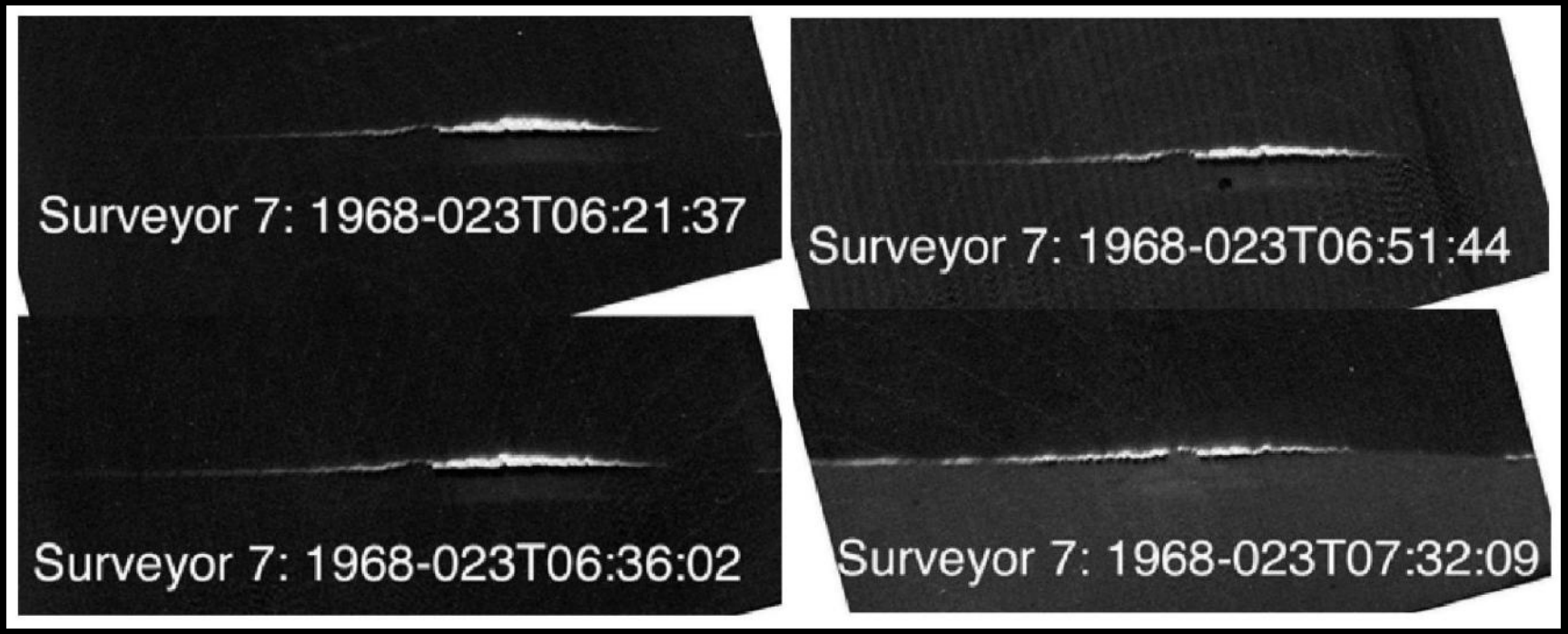
Center for Space Physics, Boston University

Lunar Sodium Tail



Nov. 16, 1998
00:00 UT

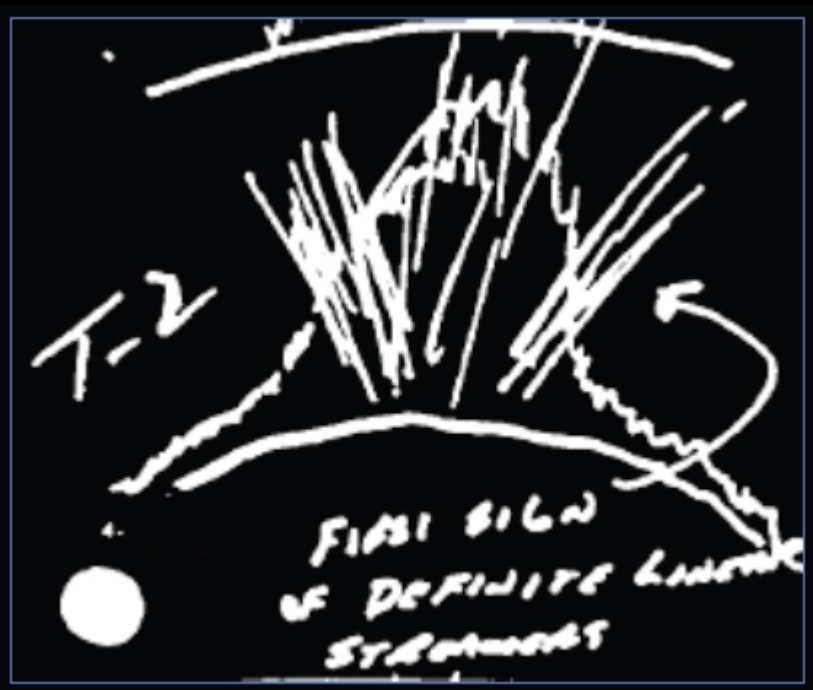
A Dusty Lunar Sky?



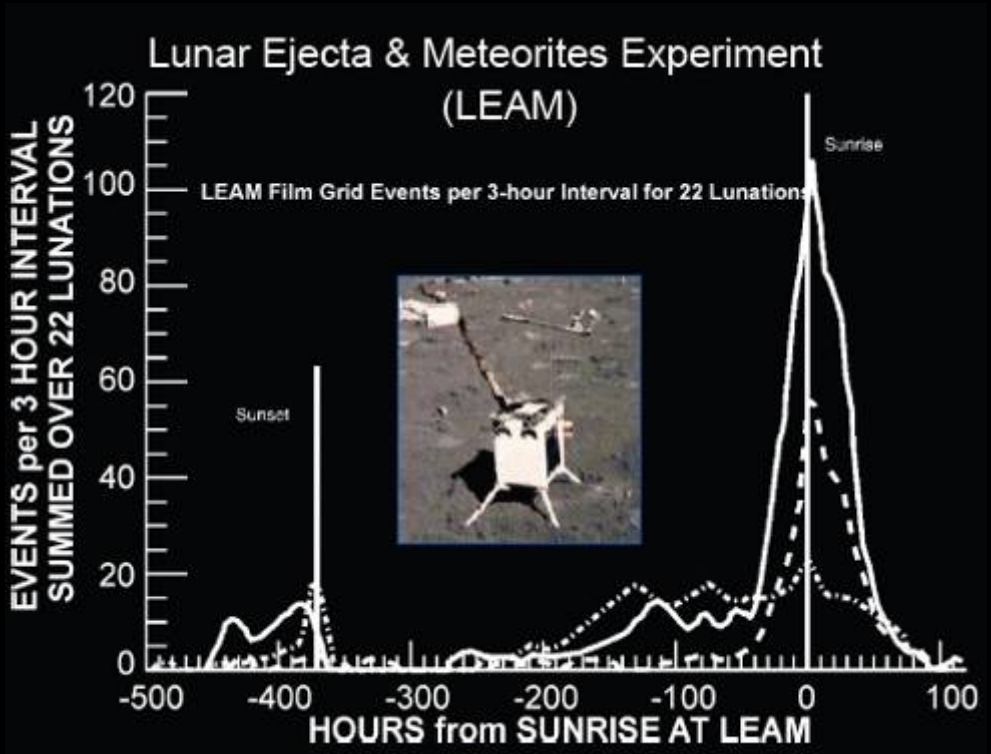
In 1968, NASA's Surveyor 7 moon lander photographed a strange "horizon glow" looking toward the daylight terminator. Observations are consistent with sunlight scattered from electrically-charged moondust floating just above the lunar surface.

A Dusty Lunar Sky?

More possible evidence for dust came from the Apollo missions.



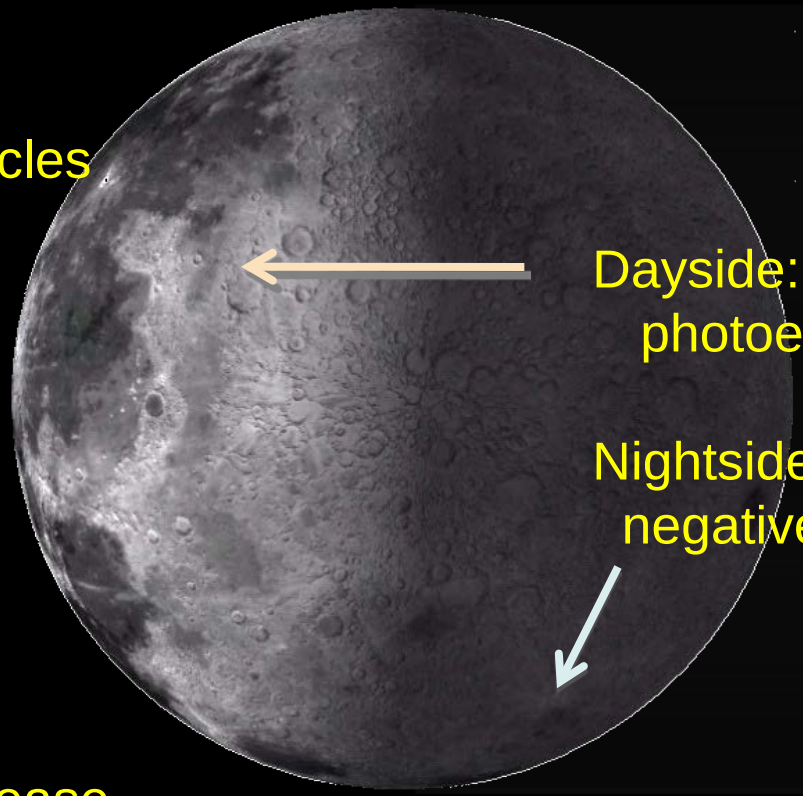
Apollo Astronaut sketch (G. Cernan)



Berg et al., 1976

The Lunar Exosphere and Dust: Sources & Sinks

Inputs:
- Solar photons
- Solar Energetic Particles
- Solar wind
- Meteoric influx
- Large impacts

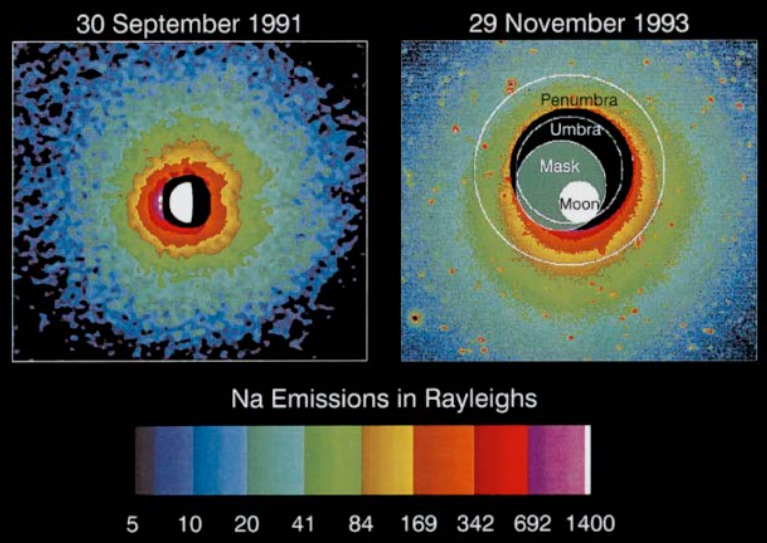


Dayside: UV-driven photoemission, +10s V

Nightside: electron-driven negative charging -1000s V

Processes:
- Impact vaporization
- Interior outgassing
- Chemical/thermal release
- Photon-stimulated desorption
- Sputtering

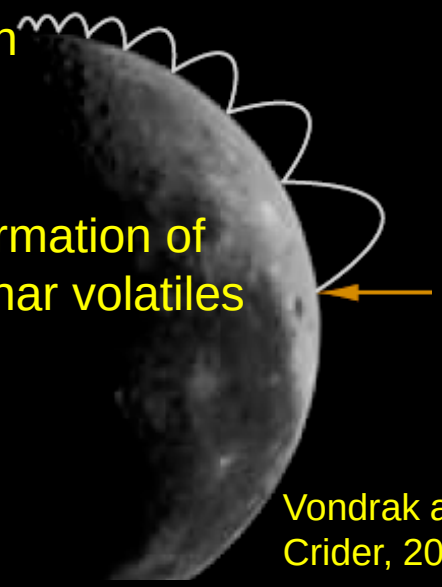
Lunar Exosphere



Mendillo et al, 1997

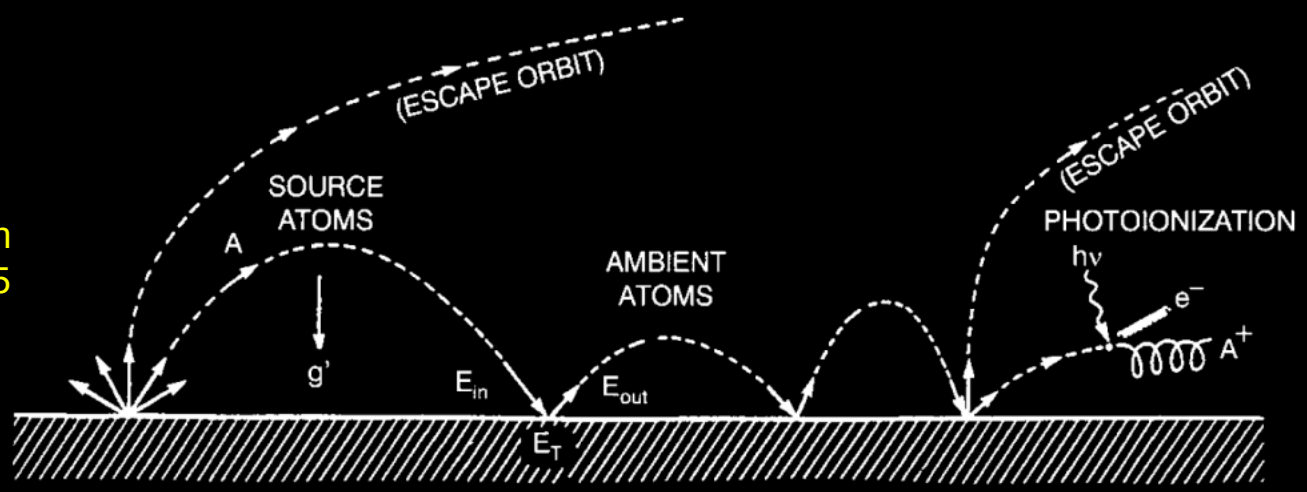
Cold-trapping in Polar regions

Formation of Lunar volatiles



Vondrak and Crider, 2003

Stern, 1999;Smyth and Marconi, 1995



Exospheres and Dust

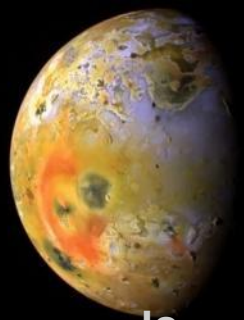
Surface Boundary Exospheres (SBEs) may be the most common type of atmosphere in the solar system…

Mercury

Moon

Large Asteroids & KBOs

Europa & other Icy satellites



Io

Evidence of dust motion on Eros and the Moon....

Eros

LADEE

The Lunar Atmosphere and Dust Environment Explorer

- Determine the global density, composition, and time variability of the fragile lunar atmosphere before it is perturbed by further human activity.

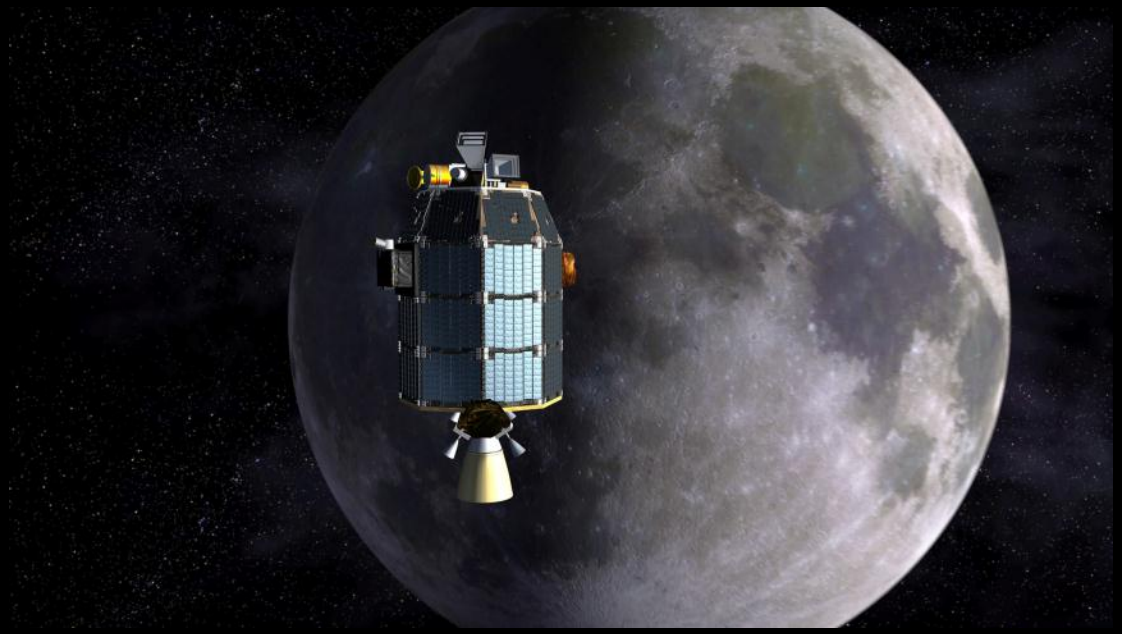
- Determine the size, charge, and spatial distribution of electrostatically transported dust grains.

- Test laser communication capabilities.

- Demonstrate a low-cost lunar mission:
  - Simple multi-mission modular bus design
  - Low-cost launch vehicle

LADEE

The Lunar Atmosphere and Dust Environment Explorer



ARC:

- Project Management
- Project Scientist
- Spacecraft Bus
- Environmental Testing
- Mission Operations and GDS
- S&MA Lead

GSFC:

- Payload Management
- Payload Integration
- Science Operations Center
- Spacecraft subsystem support
- Launch Vehicle
- Launch Range
- S&MA Support

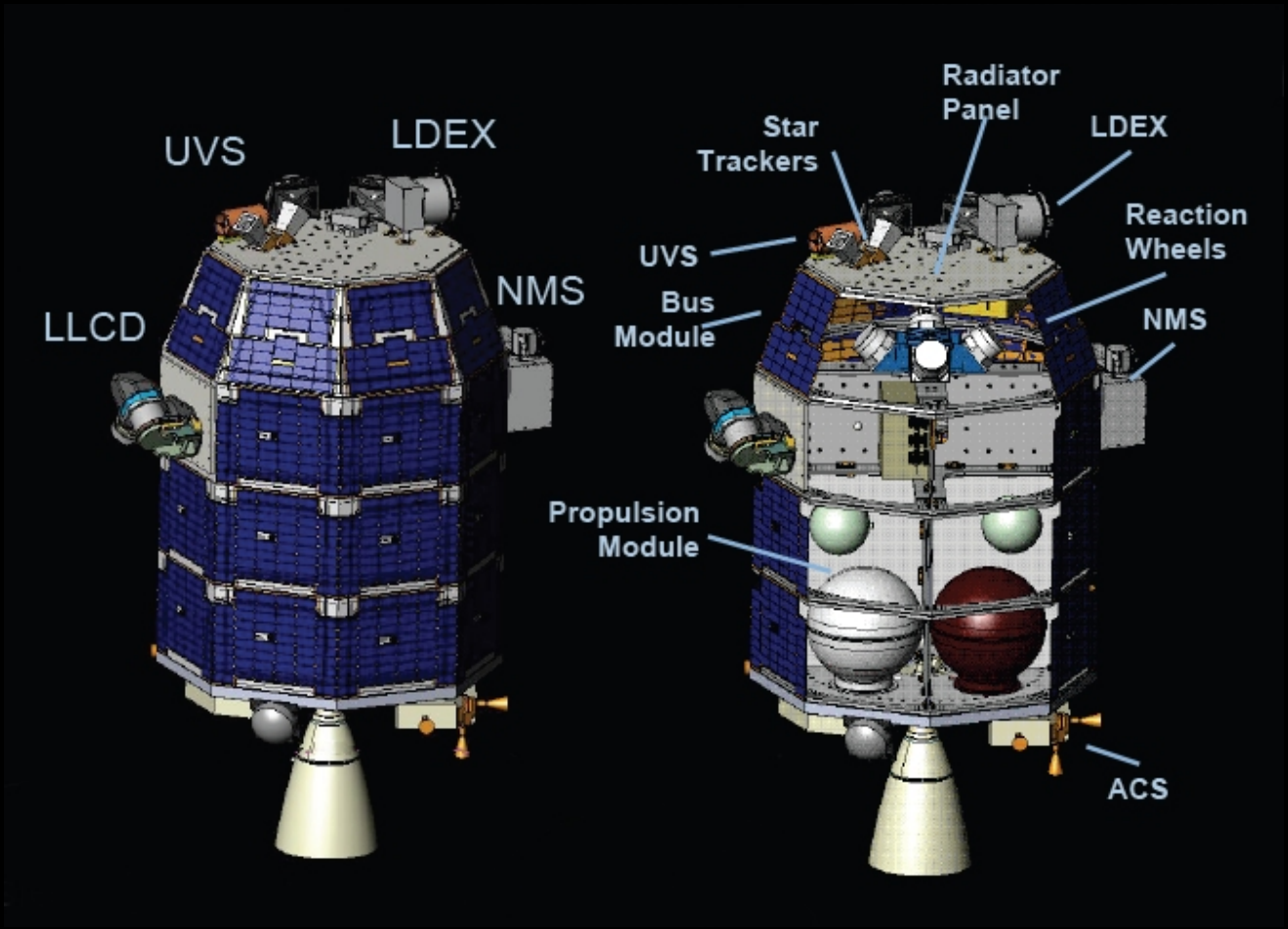
Payloads:

- NMS – NASA/GSFC
- UVS – NASA/ARC
- LDEX – LASP
- LLCD – MIT/LL

MSFC:

- Program Office

Spacecraft Configuration



- 330 kg spacecraft mass
- 53 kg payload mass

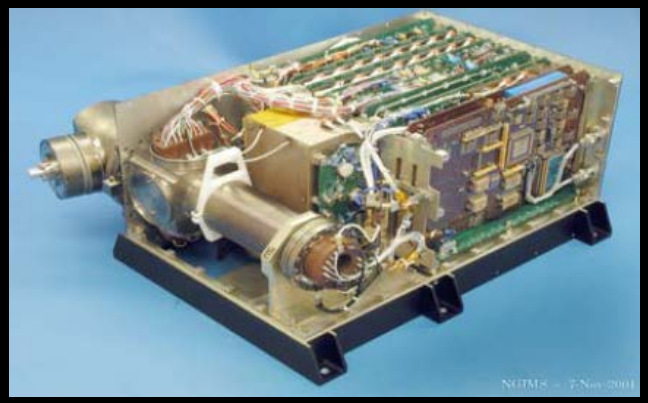
Neutral Mass Spectrometer (NMS)

MSL/SAM Heritage

SMD - directed instrument

In situ measurement of exospheric species

P. Mahaffy
NASA GSFC

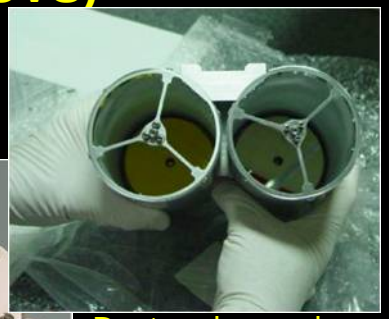


150 Dalton range/unit mass resolution

UV Spectrometer (UVS)

LCROSS heritage

SMD - directed instrument



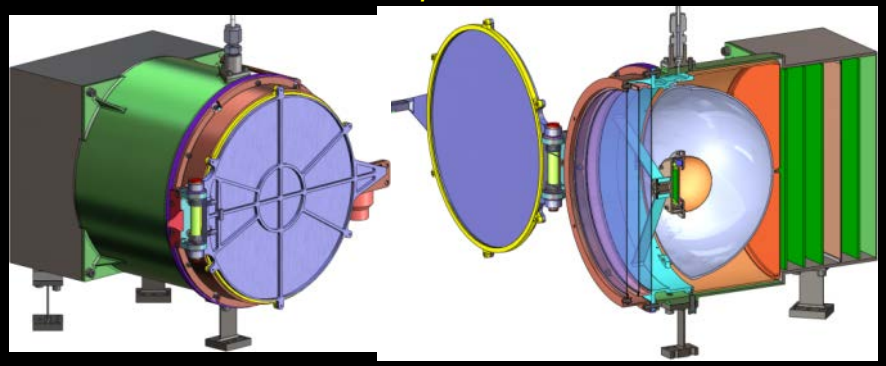
Dust and exosphere measurements

A. Colaprete
NASA ARC

Lunar Dust EXperiment (LDEX)

HEOS 2, Galileo, Ulysses and Cassini Heritage

SMD - Competed instrument



M. Horányi, LASP

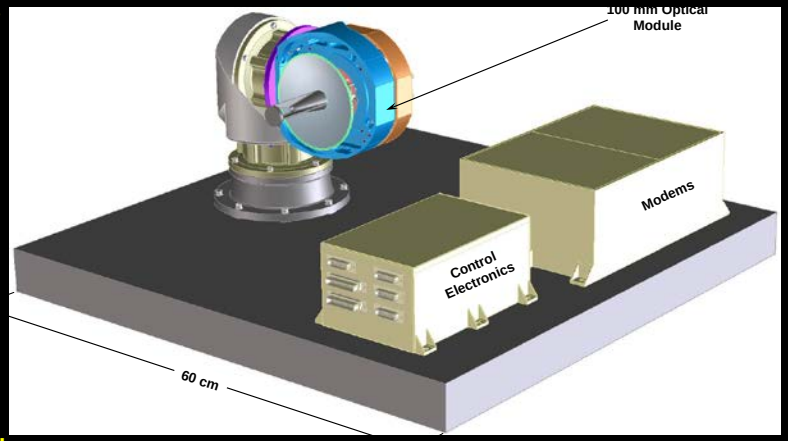
Lunar Laser Com Demo (LLCD)

Technology demonstration

SOMD - directed instrument

High Data Rate Optical Comm

D. Boroson
MIT-LL



51-622 Mbps

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OVERSIZE LOAD
DIGGING & RIGGING

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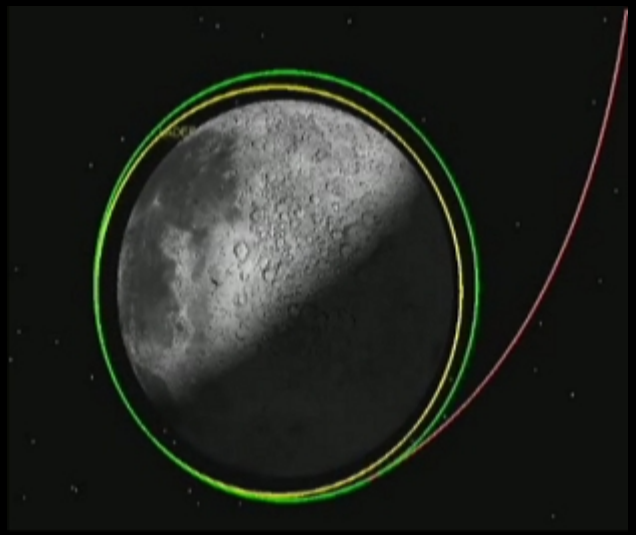
Exploring the Moon with LADEE

Ben Cooper, LaunchPhotography.com

LADEE Mission Profile

- Launched Sept 6, 2013 11:27 EDT as first deep space launch from Wallops Flight Facility.
- First space probe designed and built at NASA Ames.
- First payload to fly on the new Minotaur V launch vehicle.
- 3 phasing orbits to get to Moon.
- Insertion into retrograde orbit around Moon.
- Checkout orbit (initially 250km) for 30 days.
- 100-day science mission at ~20-75km.
- Measurements at <50 km altitude over the sunrise terminator are of high priority
- Low altitude measurements desired throughout the orbit
- Retrograde orbit (avoid sunlight into FOVs over sunrise terminator)



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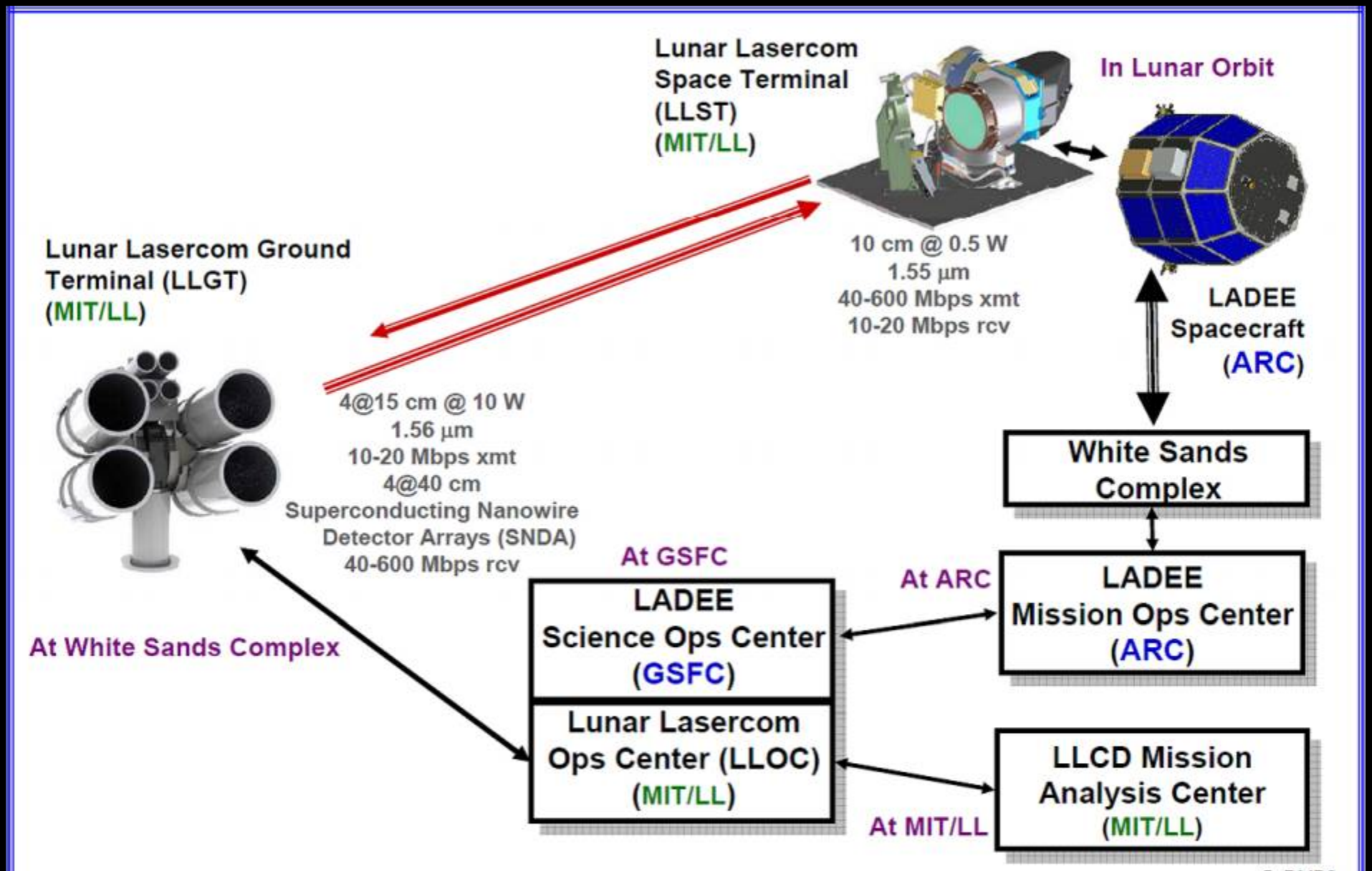
Exploring the Moon with LADEE

- Launch Sept 6
- Phasing loop perigee maneuver burns of main engine on Sept 13, Sept 21, and Oct 1.
- Lunar Orbit insertion burns on Oct 6, Oct 9, and Oct 12
- Instrument checks during 30-day commissioning orbit.
- Laser communications successfully demonstrated during commissioning orbit, reaching 622 Mbps download rate.
- Lower periapsis ~Nov 14; begin routine science observations
- Lower apoapsis ~Nov 24; begin full science mission

NASA's Lunar Laser Communication Demonstration

Exploring the Moon with LADEE

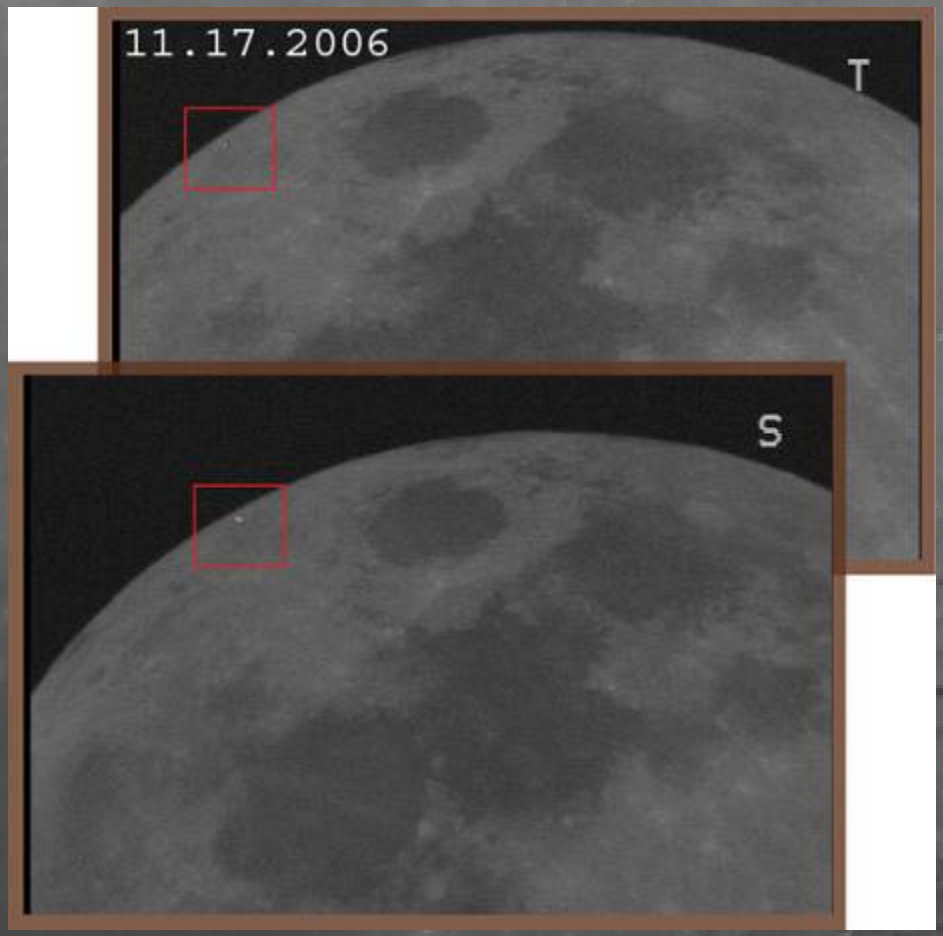


Citizen Science Opportunities: LADEE and Lunar Impacts

NASA Meteoroid Environment Office/ ALPO Lunar Impact Monitoring Program

- Help lunar scientists determine the rate of meteoroid impacts on the Moon.
- Meteoroid impacts are an important source for the lunar exosphere and dust.
- Can be done with a telescope as small as 8 inches of aperture.

Working with ALPO Lunar Meteoritic Impact Search Section.



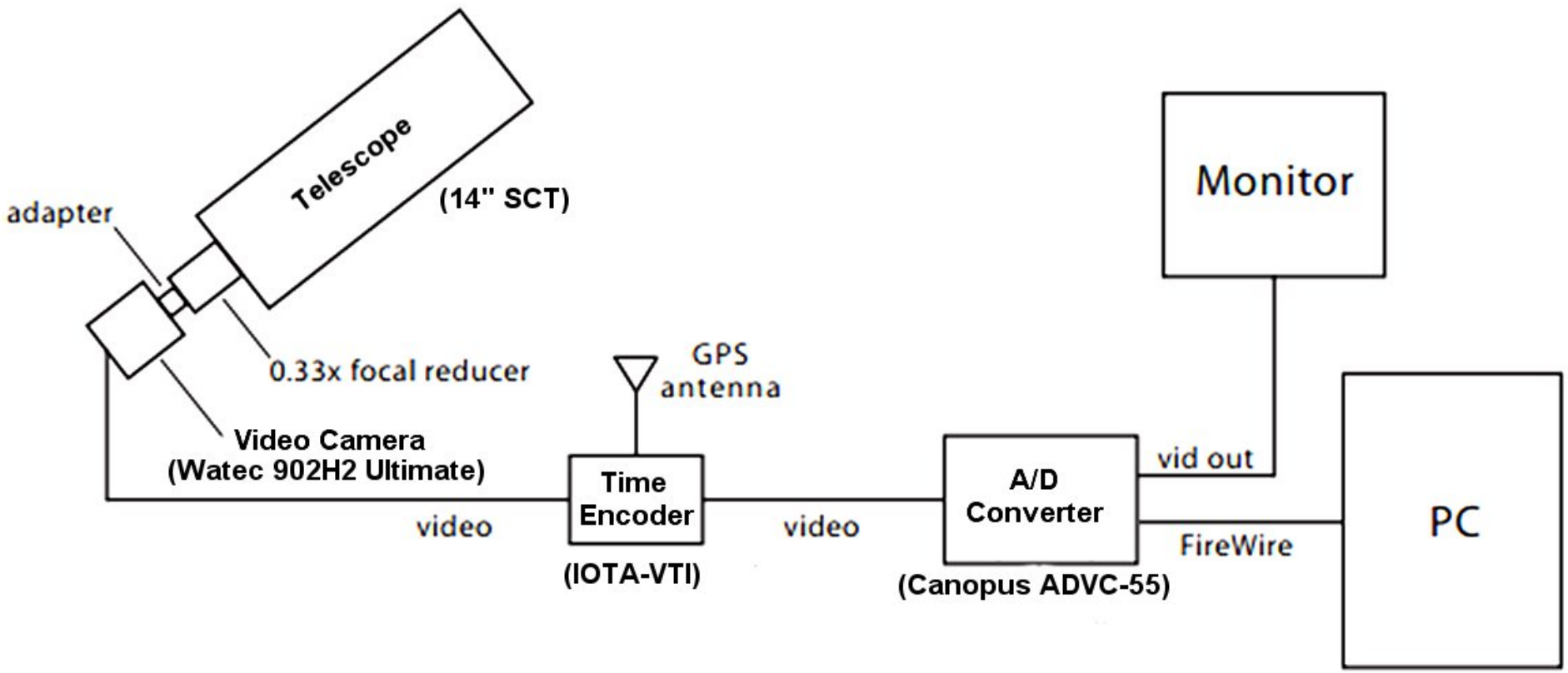
http://www.nasa.gov/mission_pages/LADEE/main/get-involved.html

Lunar Meteoroid Impact Monitoring

Minimum System Requirements

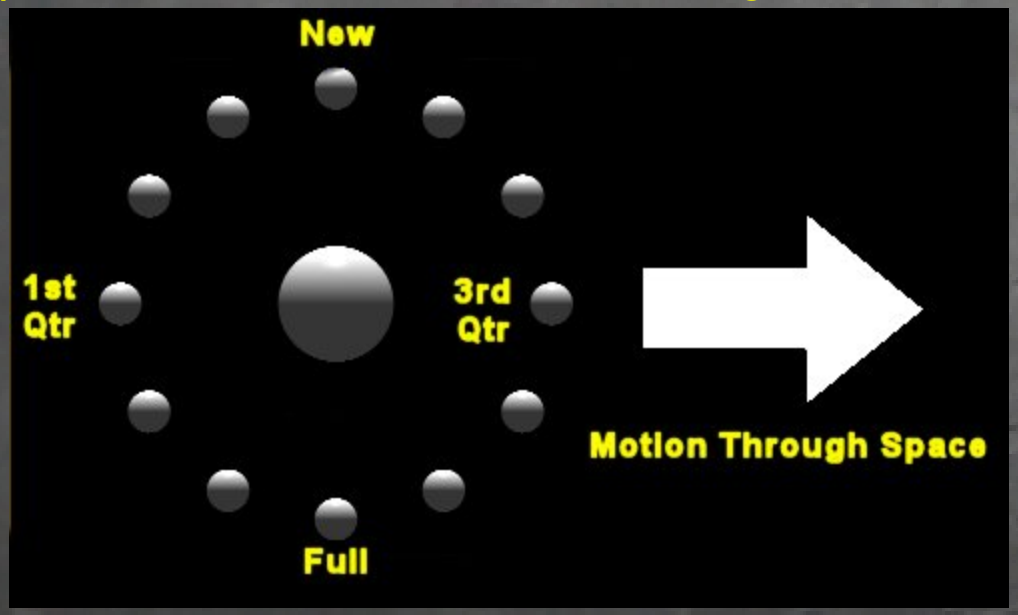
- 8" telescope
  - ~1m effective focal length
  - Equatorial mount or derotator
  - Tracking at lunar rate
- Astronomical video camera with adapter to fit telescope
  - NTSC or PAL
  - 1/2" detector
- Digitizer - for digitizing video and creating a 720x480 .avi
  - Segment .avi to files less than 1GB (8000 frames)
- Time encoder/signal
  - GPS timestamp or WWV audio
- PC compatible computer
  - ~500GB free disk space
- Software for detecting flashes
  - LunarScan software available as a free download

Example of a Lunar Impact Monitoring System Configuration



Phase Matters

- Impact flashes are observed in the unilluminated area of the Moon.
- Near 1st Qtr, the Moon's leading hemisphere faces Earth – generally best for observing impact flashes.
- Near 3rd Qtr, the Moon's trailing hemisphere faces Earth – generally less favorable for observing impact flashes.
- A large gibbous phase results in lots of glare from illuminated lunar surface, small unilluminated area for observing flashes, and diminished Earth shine on unilluminated area making localizing impacts difficult.
- Thin crescent phase results in restricted observing time in dark sky.



Provide Background Science Data: LADEE and Lunar Impacts

Confirmed Lunar Impact March 13, 2008 02:04:21UT by George Varos

Meteor Counting

- Even if you don't have a telescope, you can still participate in the science of the LADEE mission!
- The vast majority of meteoroids impacting the Moon are too small to be observable from Earth.
- Small meteoroids encountering the Earth's atmosphere can result in easily-observable meteors.
- Conducting counts of meteors during the LADEE mission will allow us to estimate what is happening on the Moon at that time.
- http://www.nasa.gov/mission_pages/LADEE/main/get-involved.html

Image credit:NASA/ISAS/Shinsuke Abe and Hajime Yano

Solar System Exploration Research

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Exploring the Moon with LADEE

Meteor Counter

For iPhone, iPad & iPod Touch

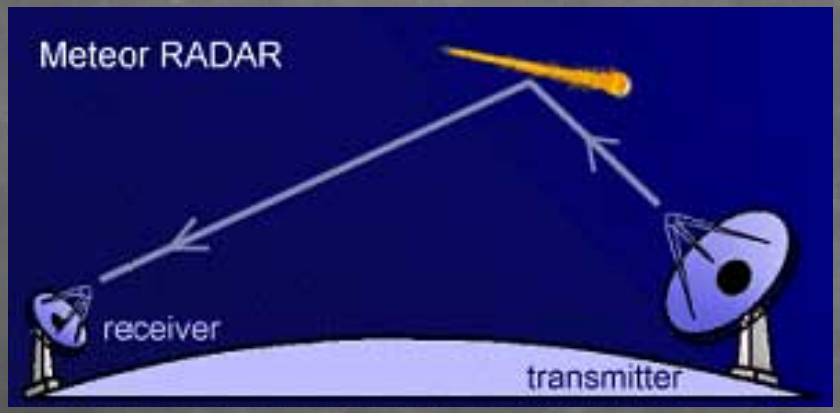
Available on the App Store

Now available for Android too!

Lunar Phases for Major Meteor Showers During Projected LADEE Mission Timeframe

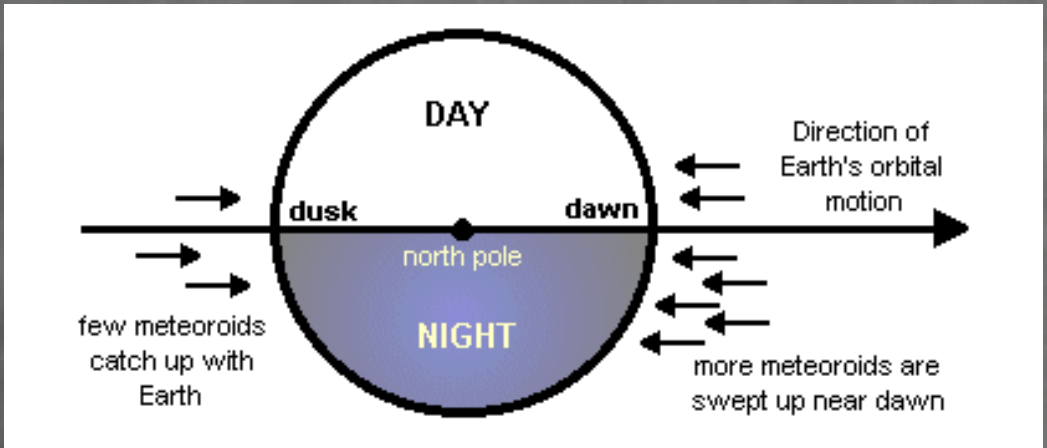
Nov 19 2013	Leonids	Waning Gibbous	94%
Dec 14 2013	Geminids	Waxing Gibbous	95%
Dec 22 2013	Ursids	Waning Gibbous	73%
Jan 4 2014	Quadrantids	Waxing Crescent	13%

Radio Observations of Meteors



- Meteors produce a column of ionized gas as they pass through the atmosphere.
- This column reflects radio waves from transmitters on Earth's surface.
- The columns of ionized gas created by meteors usually last for only a fraction of a second.
- Brighter meteors can produce columns that last for several seconds.
- Traditionally, VHF frequencies between 40-60 MHz have been used.
- Frequencies at low end of the FM band between 88-104 MHz are also useful.
- Most radio systems used for meteor detection are of the forward scatter type.

Radio Observations of Meteors

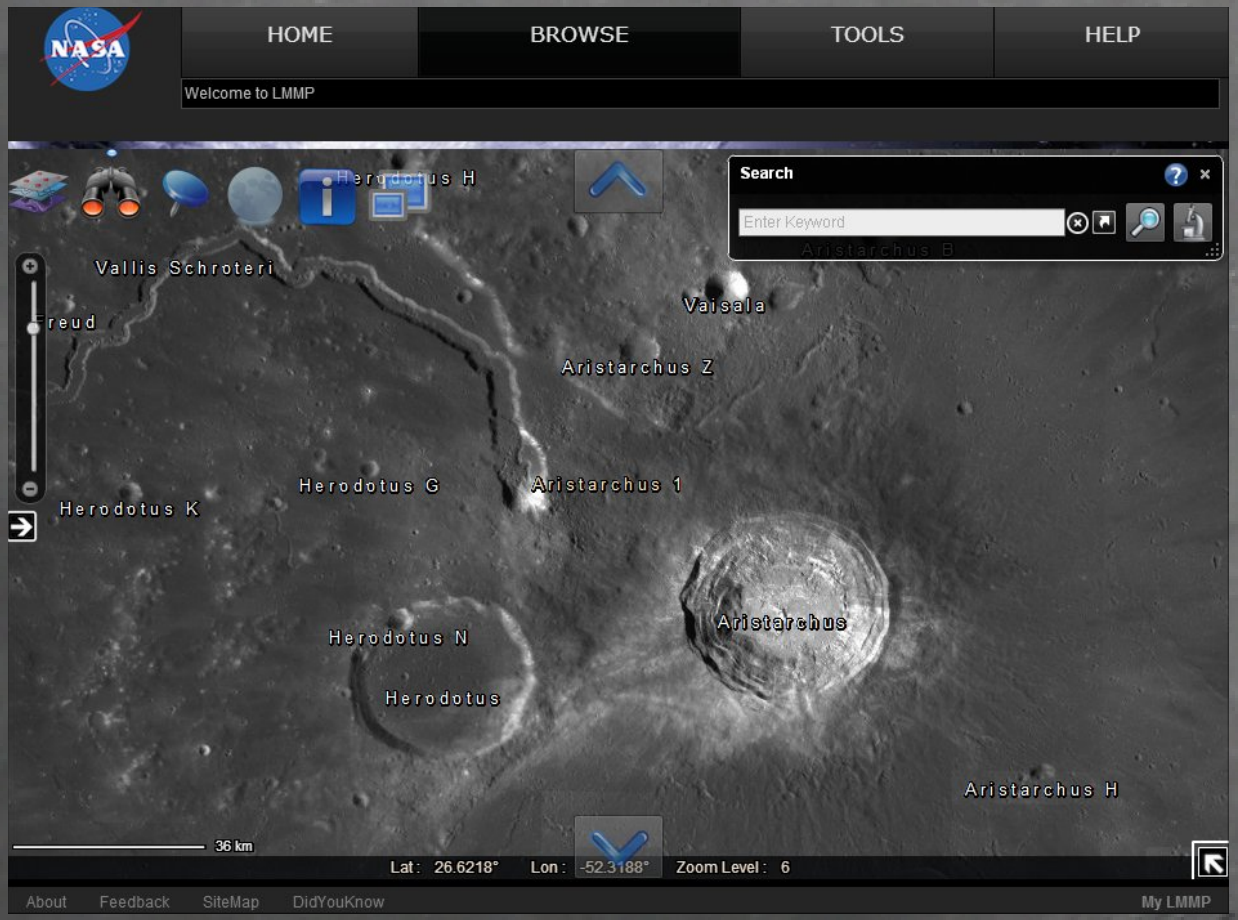


- Radio observations provide the only way to measure activity from daytime meteor showers.
- Radio observations have fewer constraints imposed by clouds and light pollution (both man-made and arising from fuller lunar phases).
- Observations are preferentially made in the hours proceeding from midnight to noon.

Daytime Meteor Showers

Shower	Activity Period	Maximum
Capricornids/Sagittariids	1/15-2/4	2-Feb
Chi Capricornids	1/29-2/28	14-Feb
April Piscids	4/8/-4/29	20-Apr
Delta Piscids	4/24-4/24	24-Apr
Epsilon Arietids	4/24-5/27	9-May
May Arietids	5/4-6/6	16-May
Omicron Cetids	5/5-6/2	20-May
Arietids	5/22-7/02	7-Jun
Zeta Persieds	5/20-7/5	9-Jun
Beta Taurids	6/5-7/17	28-Jun
Gamma Leonids	8/14-9/12	25-Aug
Sextantids	9/9-10/9	27-Sep

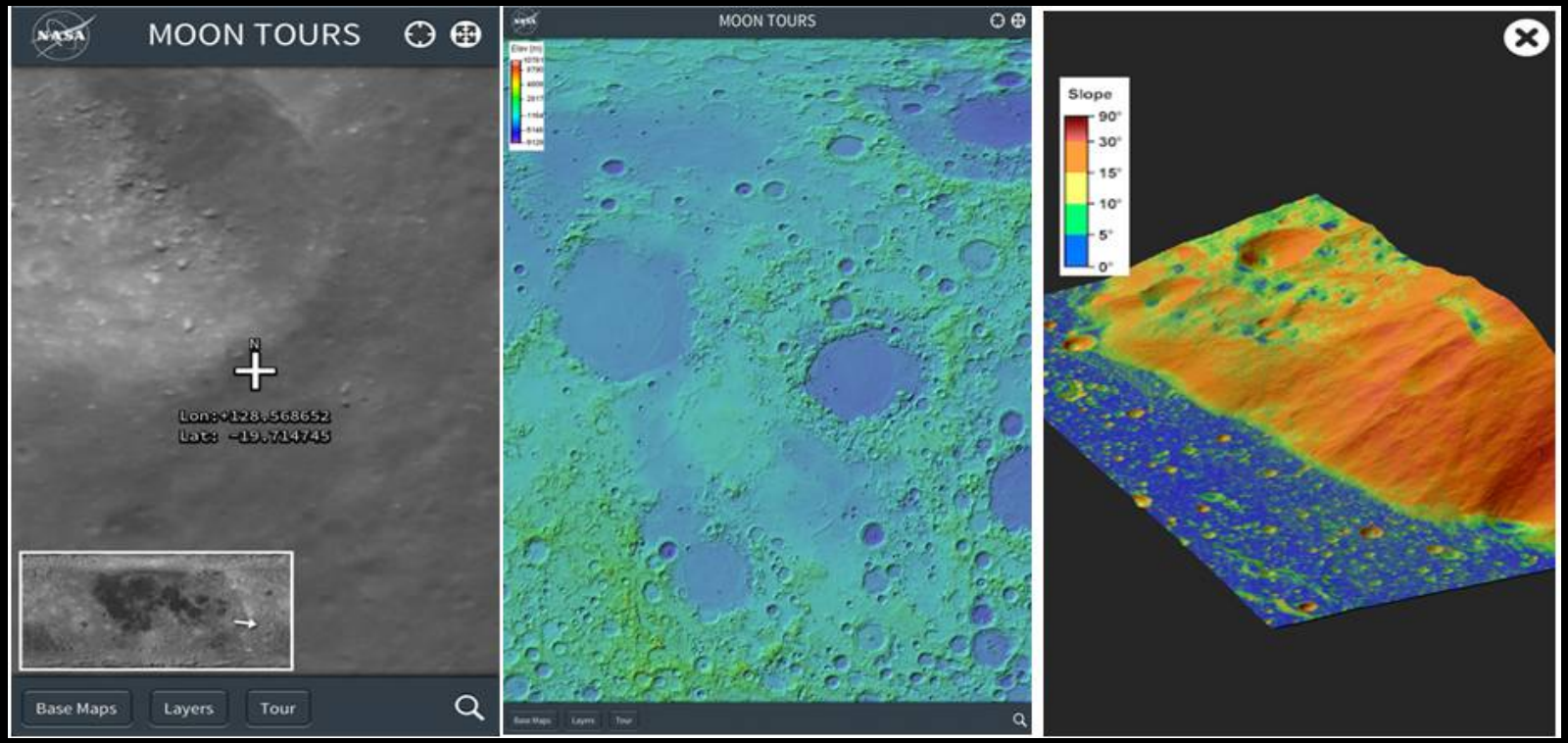
You Can Help Explore the Moon!



The Lunar Mapping and Modeling Portal (LMMP) gives you access to a wide range of images and data from current and past lunar missions. Soon you will be able to explore the Moon with LMMP on your smart phone or tablet. http://pub.lmmp.nasa.gov

Moon Tours

The mobile version of the NASA's Lunar Mapping and Modeling Portal. Moon Tours is currently available for free download for iPhone and iPad . An Android version is currently in development and will be available shortly.




Questions