



Lunar CRater Observation and Sensing Satellite Project

LCROSS



NORTHROP GRUMMAN

Anthony Colaprete

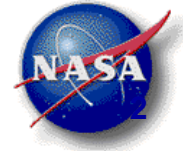
**Principle Investigator
Payload Manager**



presented by
Gwen Bart



LCROSS Science Background



Lunar Prospector detected an increase in hydrogen concentration over the lunar poles.

The debate over the form, concentration and distribution has continued ever since.

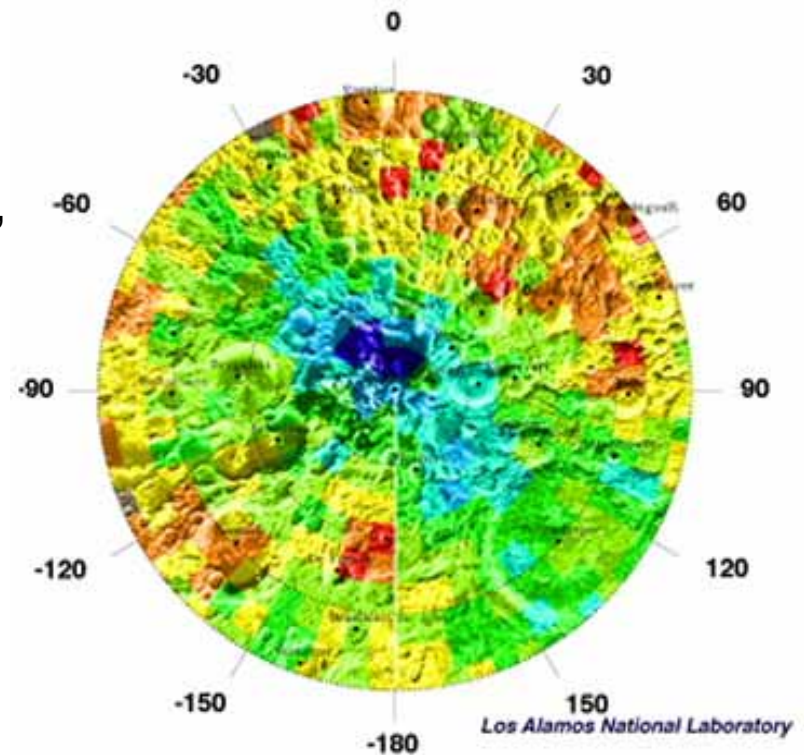
If the hydrogen is in an accessible and usable form, it could be a potential resource

Form, distribution and concentration of [H] relevant to inner solar system asteroid/comet fluxes, lunar volatiles and planetary evolution.

Several key questions:

- Is the hydrogen in the form of water?
- Is the hydrogen diffuse and uniform, or concentrated and distributed in pockets?
- Is the lunar regolith in a permanently shadowed crater the same as that characterized at the Apollo landing sites?

SP Hydrogen Abundance

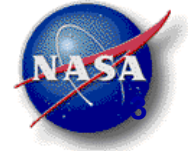


Feldman et al., 1998

LCROSS will provide the most unambiguous data set to address these questions.



LCROSS ESMD Mission Objectives



The LCROSS mission rationale:

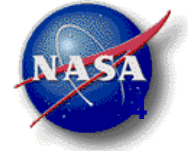
- The nature of lunar polar hydrogen is one of the most important drivers to the long term lunar exploration architecture
- Need to understand **Quantity**, **Form**, and **Distribution** of the hydrogen
- The lunar water resource can be estimated from a minimal number of “ground-truths”
- Early and decisive information will aid future ESMD missions

The LCROSS mission science goals:

- Confirm the presence or absence of water ice in a permanently shadowed region on the Moon
- Identify the form/state of hydrogen observed by at the lunar poles
- Quantify, if present, the amount of water in the lunar regolith, with respect to hydrogen concentrations
- Characterize the lunar regolith within a permanently shadowed crater on the Moon



LCROSS Science



Nature and form of the hydrogen?

- Water, hydrated minerals, hydrocarbons?
- Grain size?
- Distribution within regolith?

Nature of PSR regolith?

- Strength? Depth?
- Grain size?
- Composition?
- Is it similar to Apollo sites?

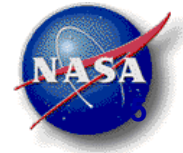
The Lunar Atmosphere / Volatile Processes?

- How does the Lunar atmosphere respond?
- What are the times scales for recovery?
- How do volatiles/dust migrate?





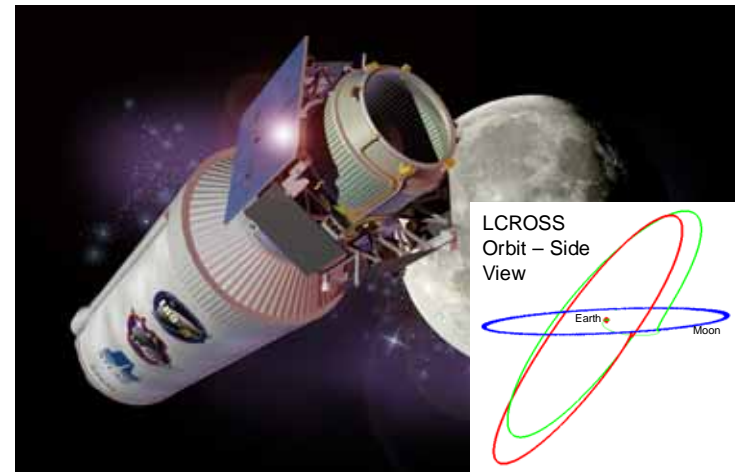
The LCROSS Mission



1. Launch stacked with LRO in Spring (April?) 2009



2. After Lunar swing-by, enter a 3-4 month cruise around Earth



3. Target the Centaur Upper Stage and Position S-S/C to fly four minutes behind



4. S-S/C observes impact, ejecta cloud and resulting crater, making measurements until impacting itself

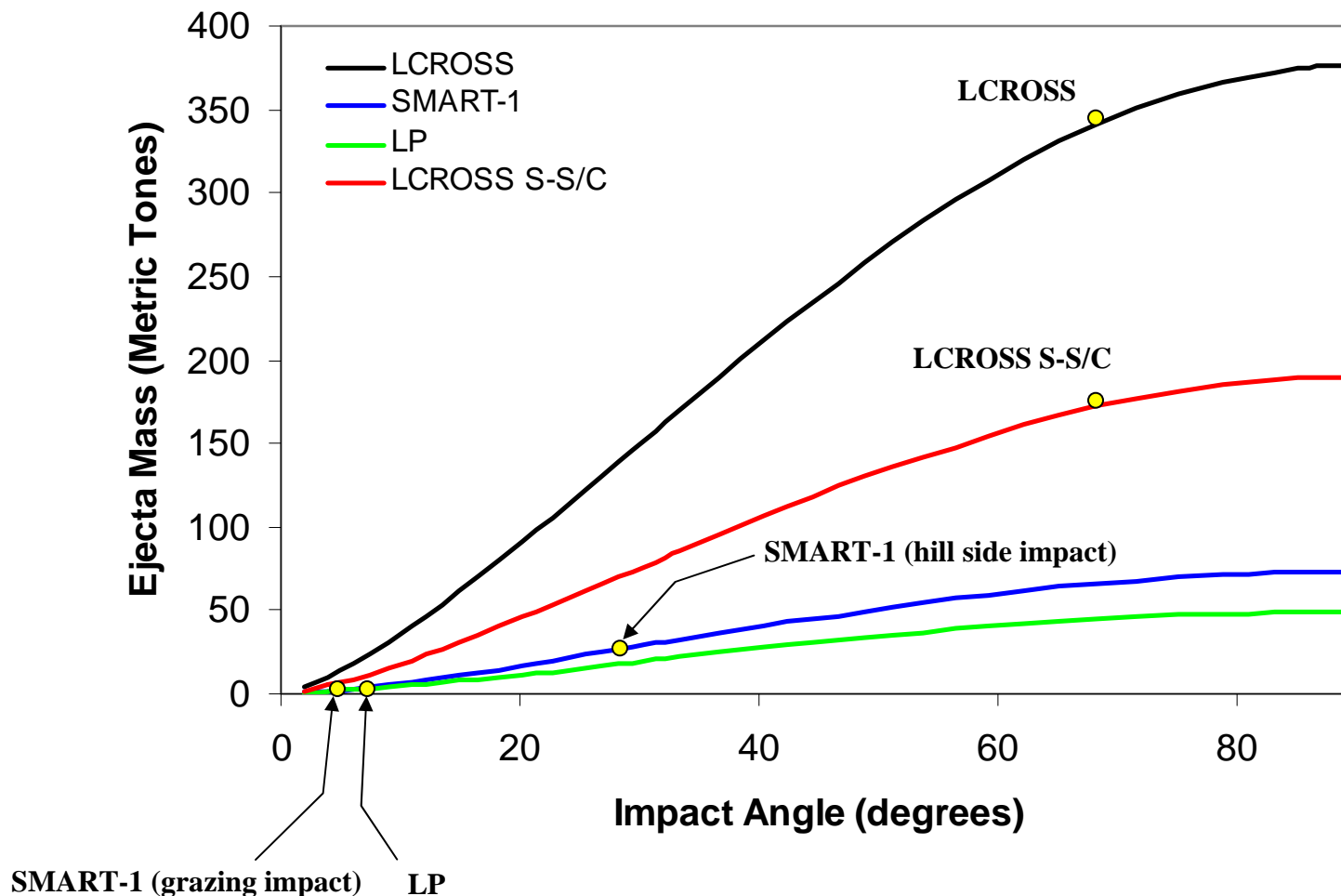




The Mission – How LCROSS is Different

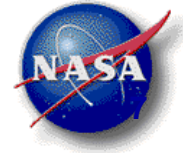


Estimates of the total ejecta mass as a function of impact angle for four impactors: LCROSS, LCROSS S-S/C, Lunar Prospector (LP), and SMART-1



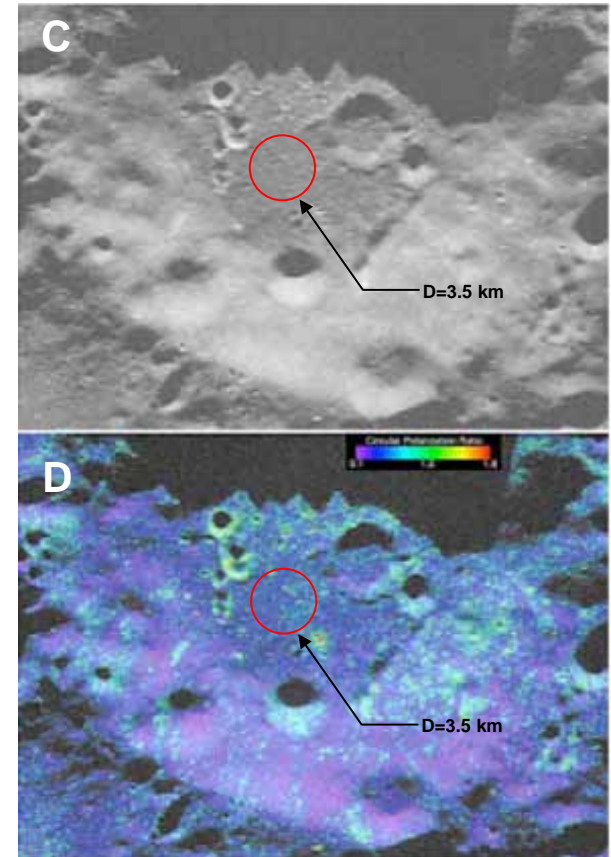
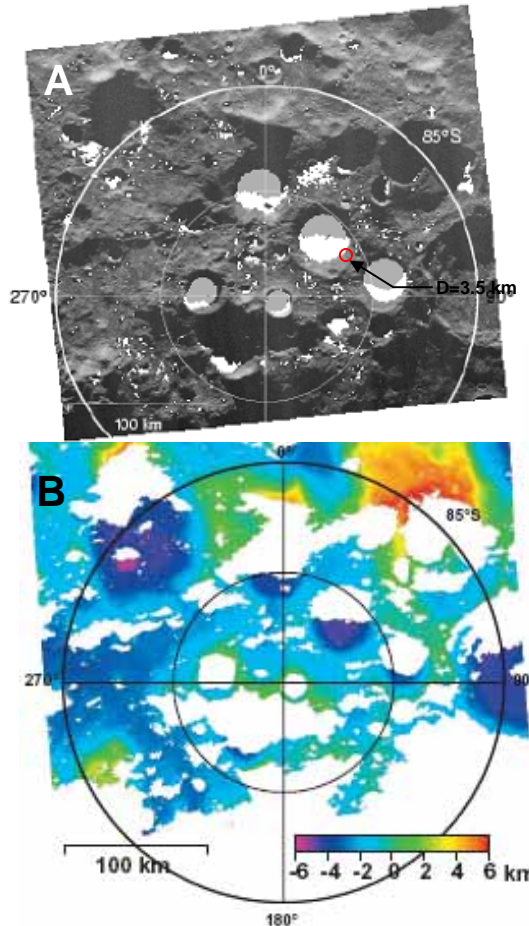


Impact Target Selection Criteria

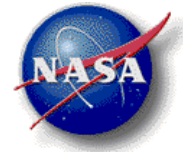


The four primary criteria for selection:

- Terrestrial Observations
- Illumination of ejecta by sunlight
- Target properties (e.g., surface roughness, slopes, and regolith depth)
- Observed concentration of increased hydrogen



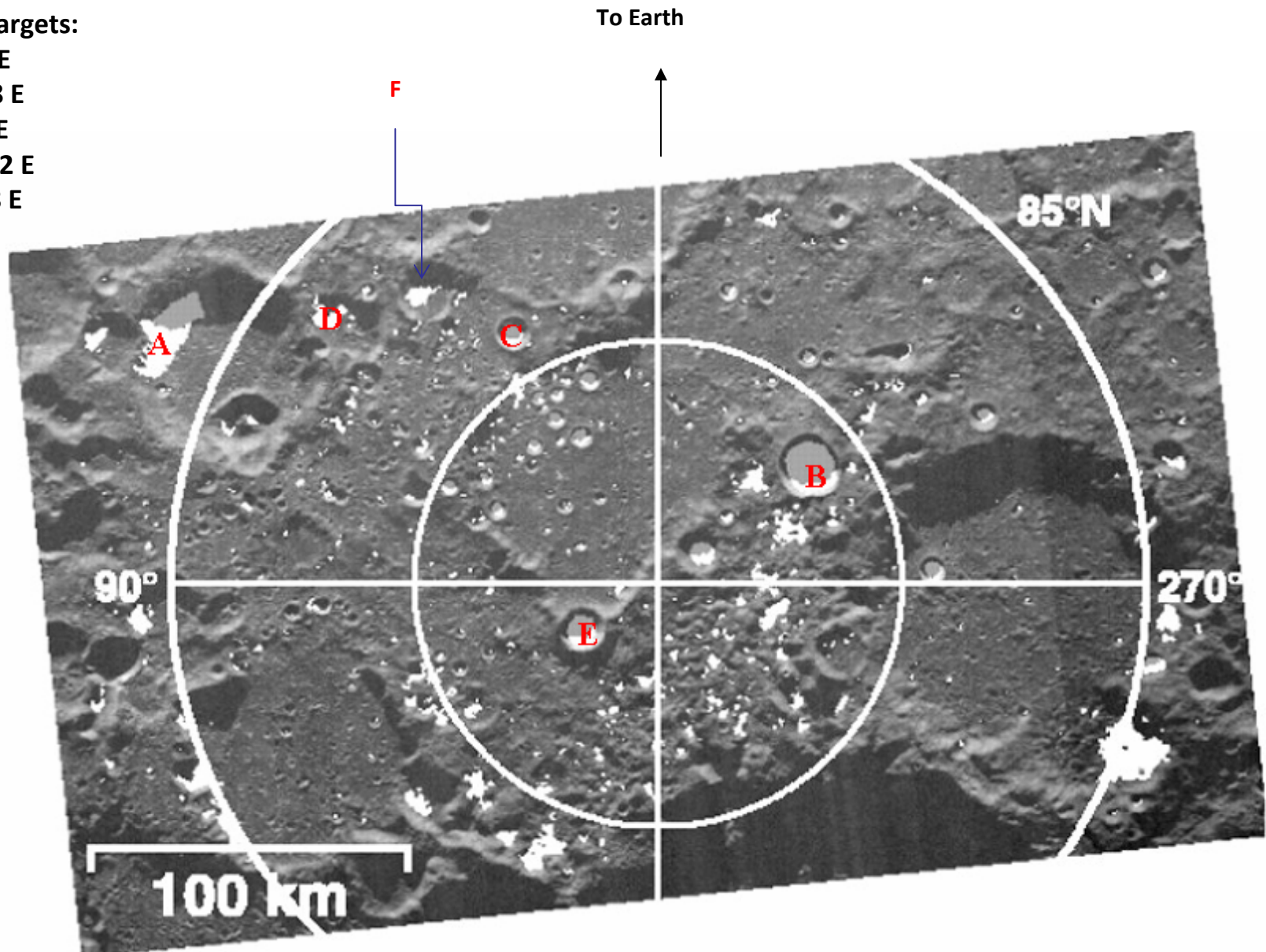
Selection process ongoing until 30 days prior to impact



Candidate North Pole Craters

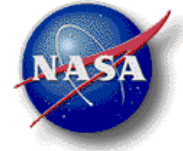
North Pole Targets:

- A: 84.5 N 55 E
- B: 88.0 N 318 E
- C: 87.1 N 24 E
- D: 85.5 N 45.2 E
- E: 89.2 N 128 E

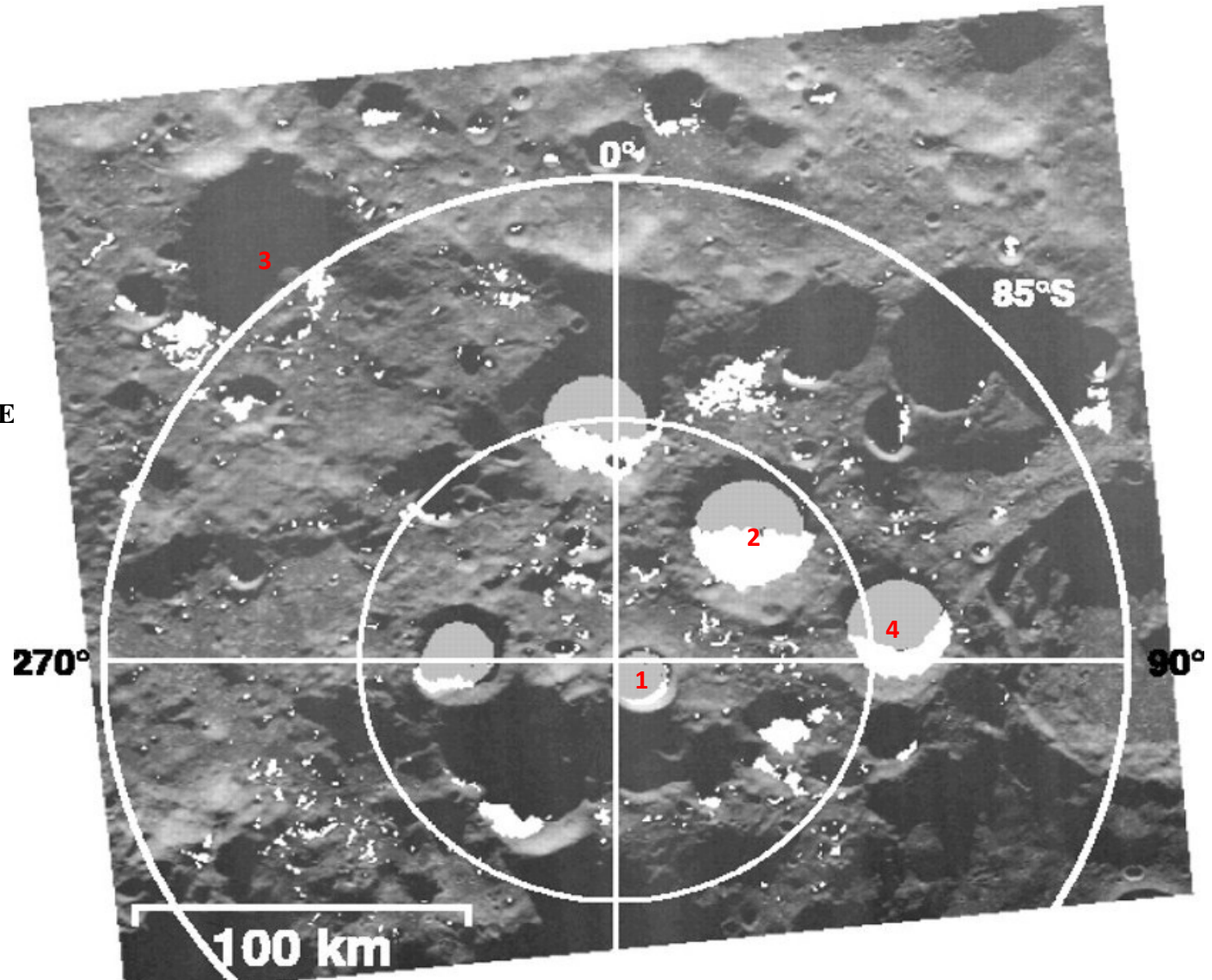




Candidate South Pole Craters

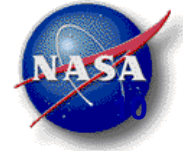


- 1 = Shackleton [89.5 S, 0 E]
- 2 = Shoemaker [88.1 S, 44.9 E]
- 3 = Cabeus [84.9 S, 324.5 E]
- 4 = Faustini [87.3 S, 77 E]

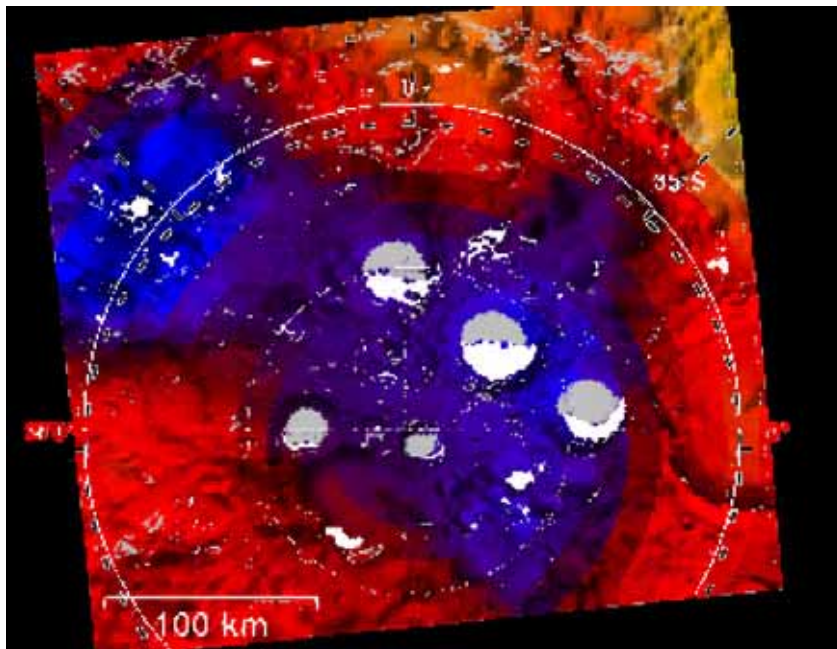




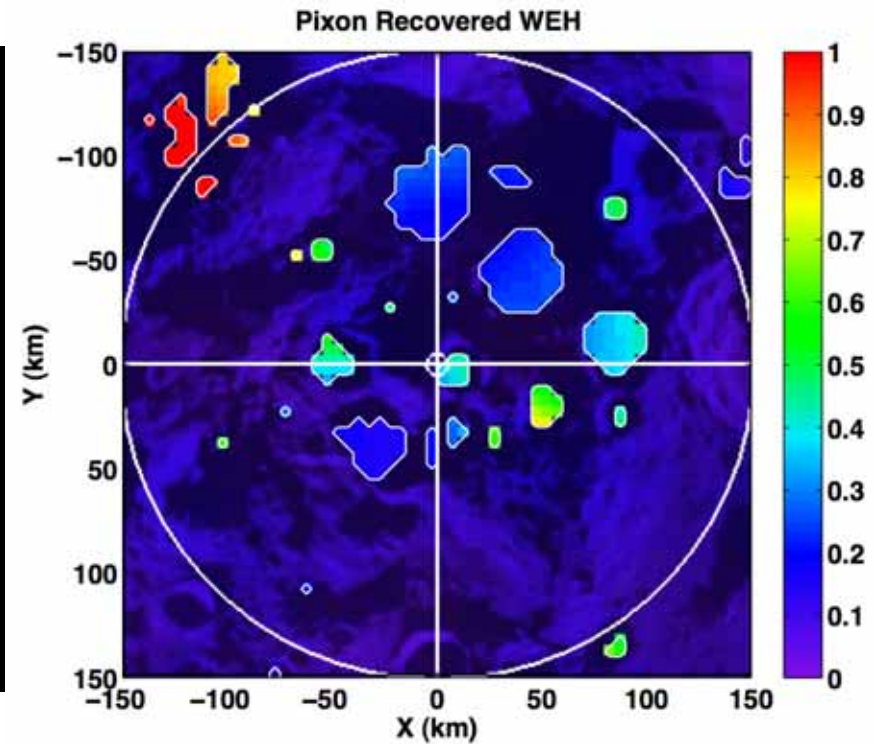
Lunar Polar Hydrogen



Original Lunar Prospector Hydrogen Map (Maurice et al., 2003)



Deconvolved Hydrogen Maps (Elphic et al., 2007)

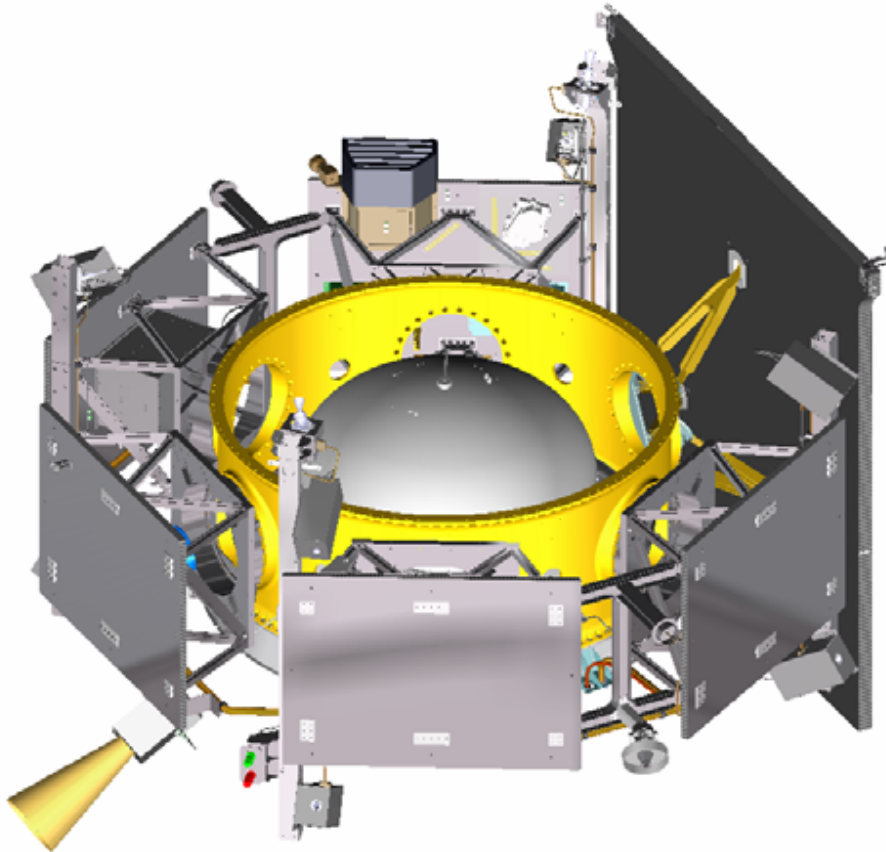


Water is heterogeneous from one crater to another

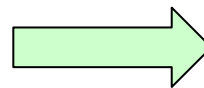
- Accumulation/retention processes differ at crater scales of ~50-100 km?
- Possibly different at smaller scales.



The Spacecraft and Payload

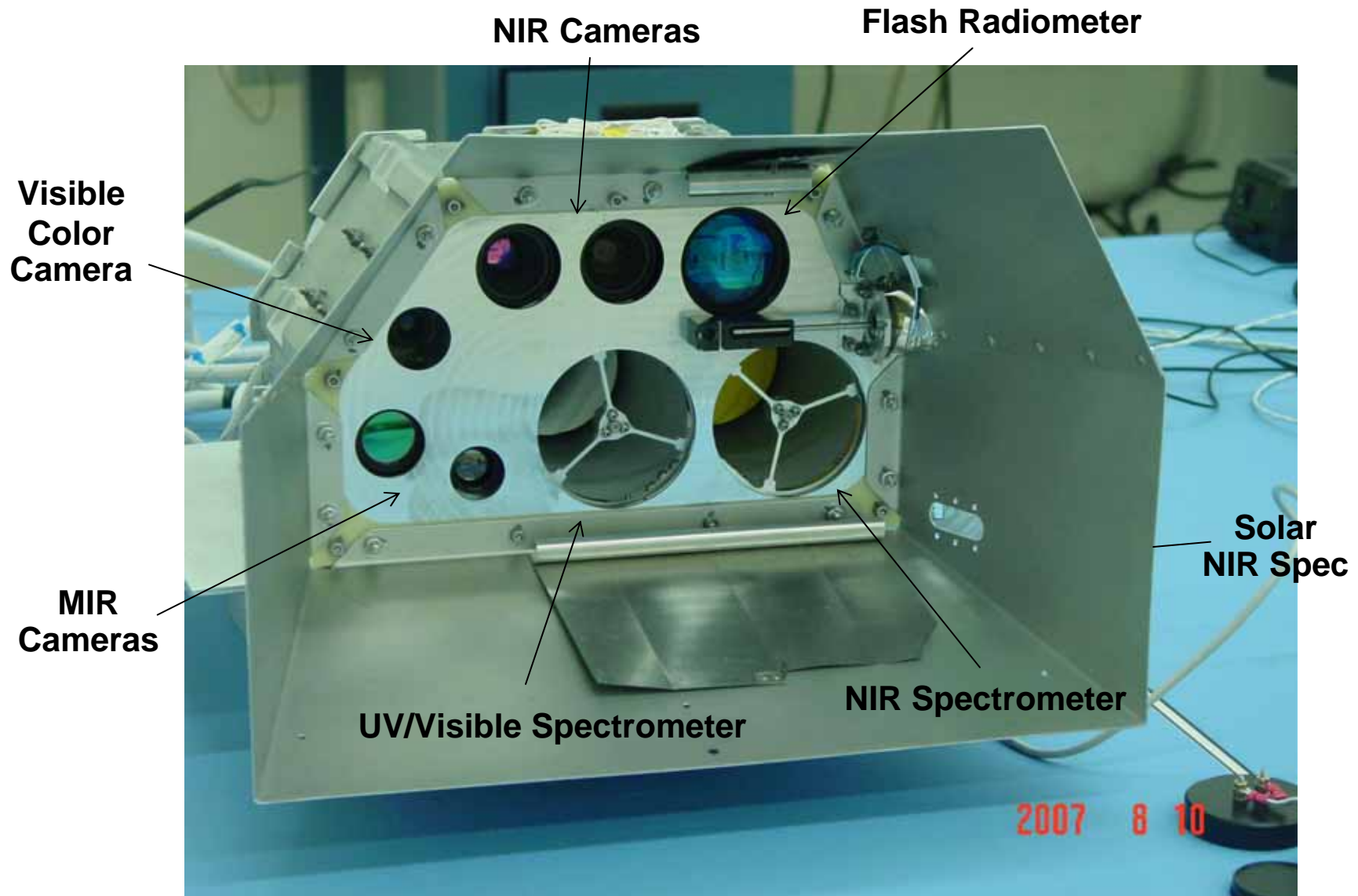


Spacecraft entering Northrop Grumman Thermal Vacuum Chamber



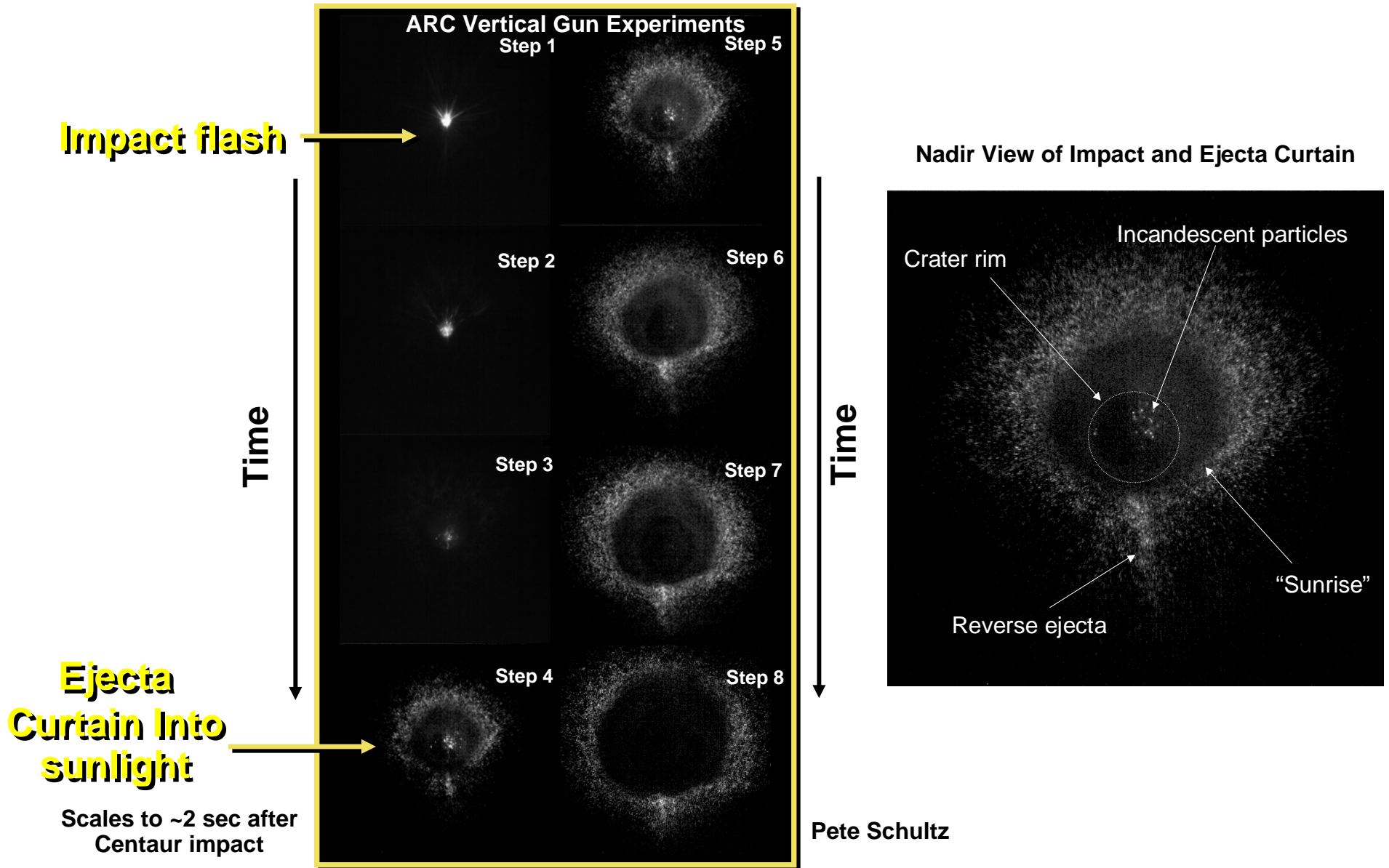
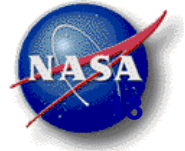


Payload Hardware





The Anatomy of the Impact: Flash, Curtain, Crater

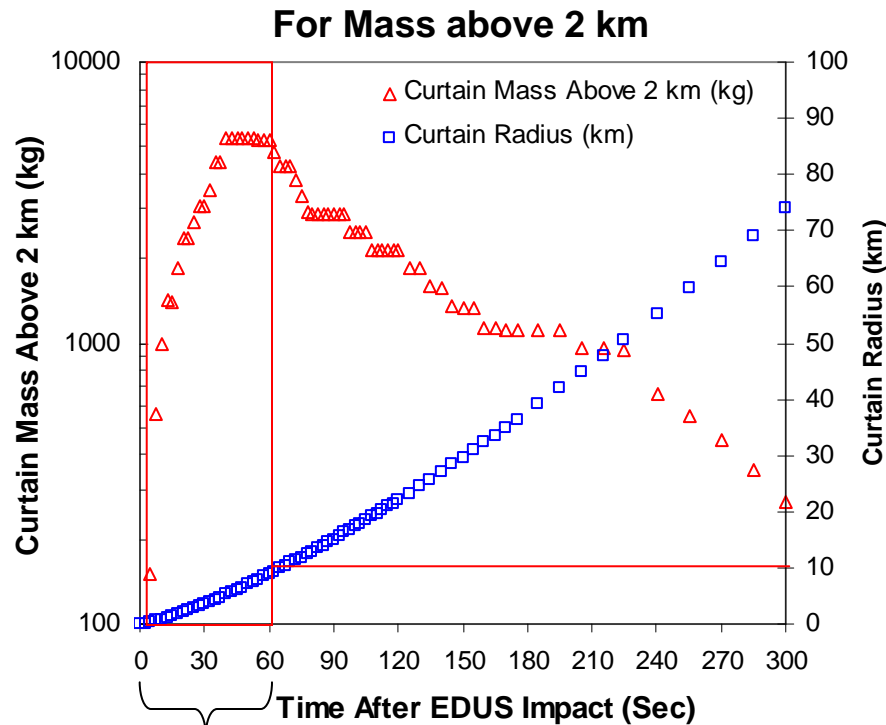




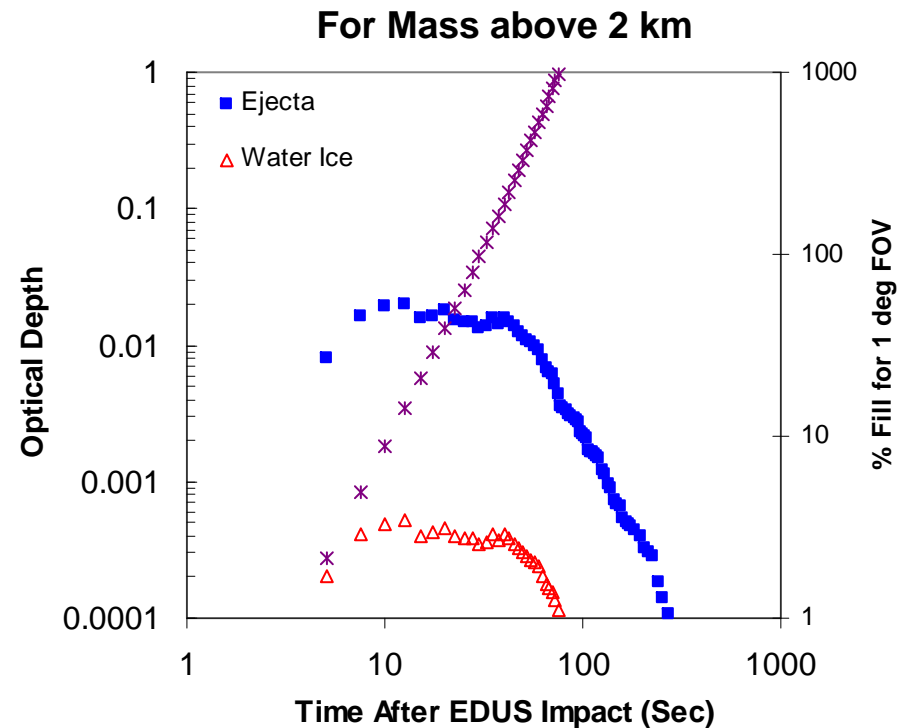
Impact Expectations: Curtain Properties



Curtain Mass and Radius



Curtain Dust and Water Ice Optical Depth



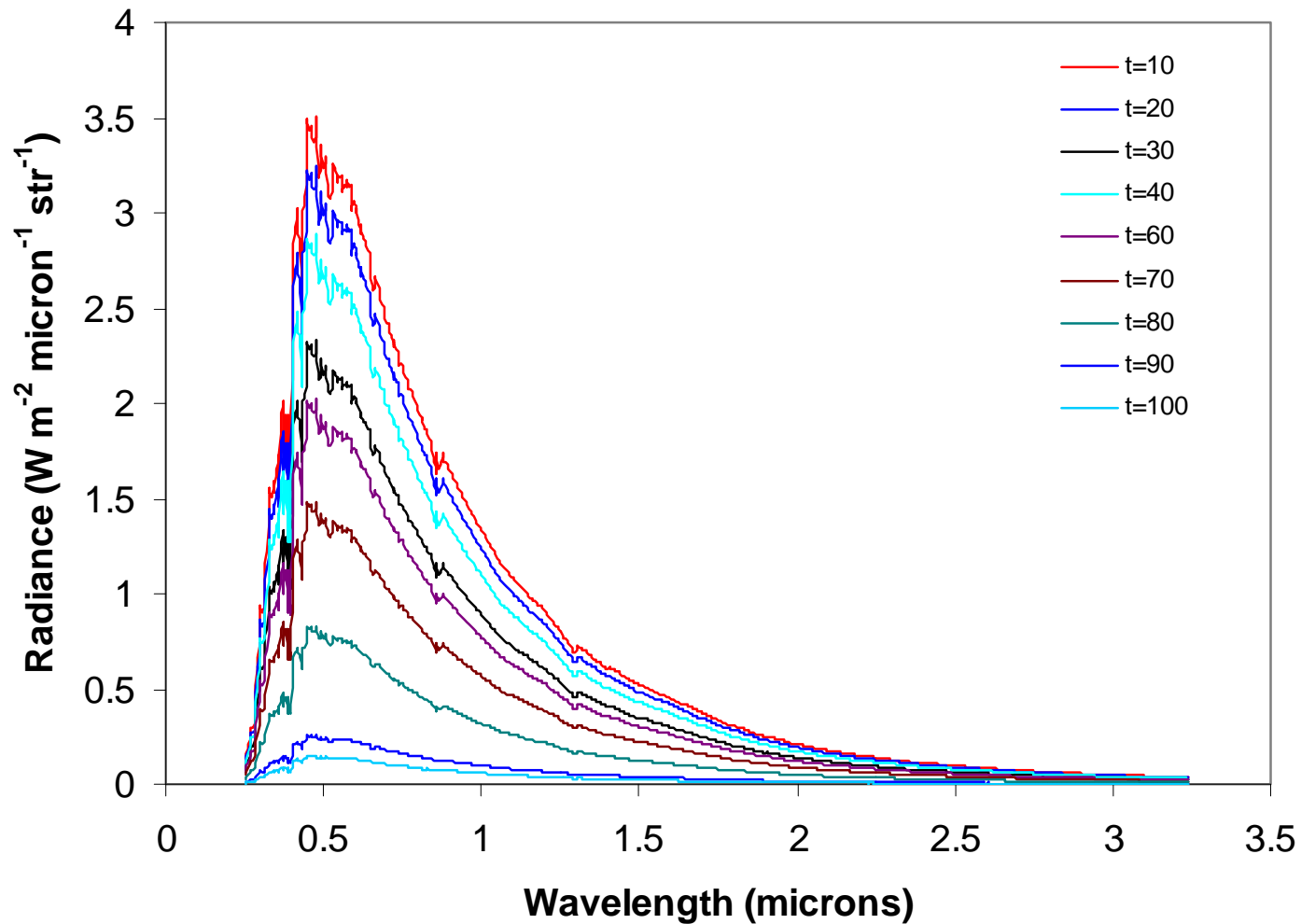
The most observable portion of the ejecta curtain will be between 10 and 60 seconds after impact, corresponding to a curtain radius of between 1 and 10 km.



Expectations: Curtain Brightness

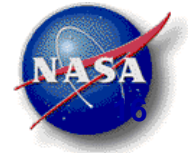


The radiance for the ejecta cloud only (derived by subtracting off the spectra from the lunar surface) for several times after Centaur impact.

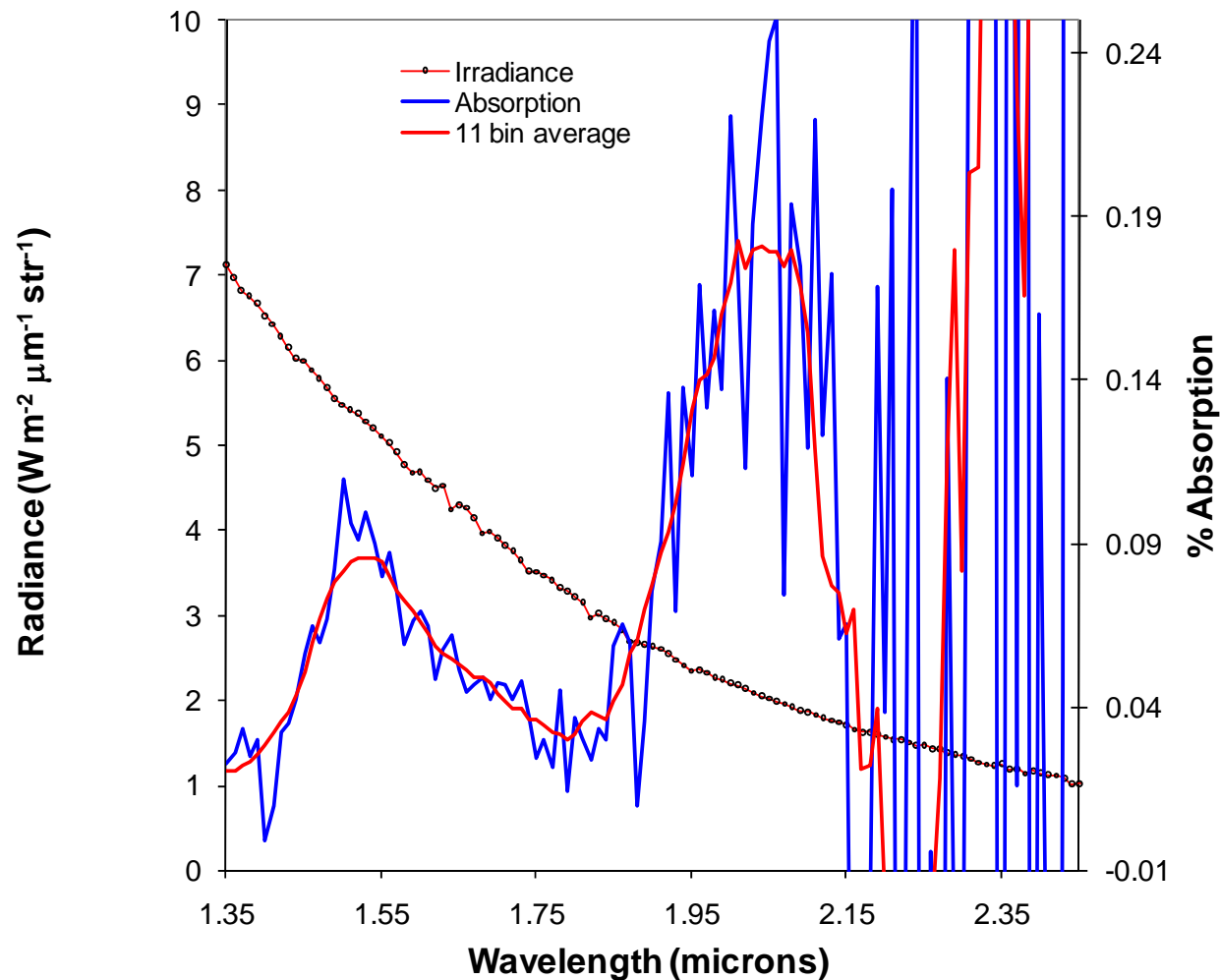




Expectations: LCROSS Water Detection

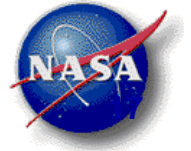


Calculated ejecta cloud radiance (left axis) and synthetic NIR spectrometer data for 1% water content





Conclusions

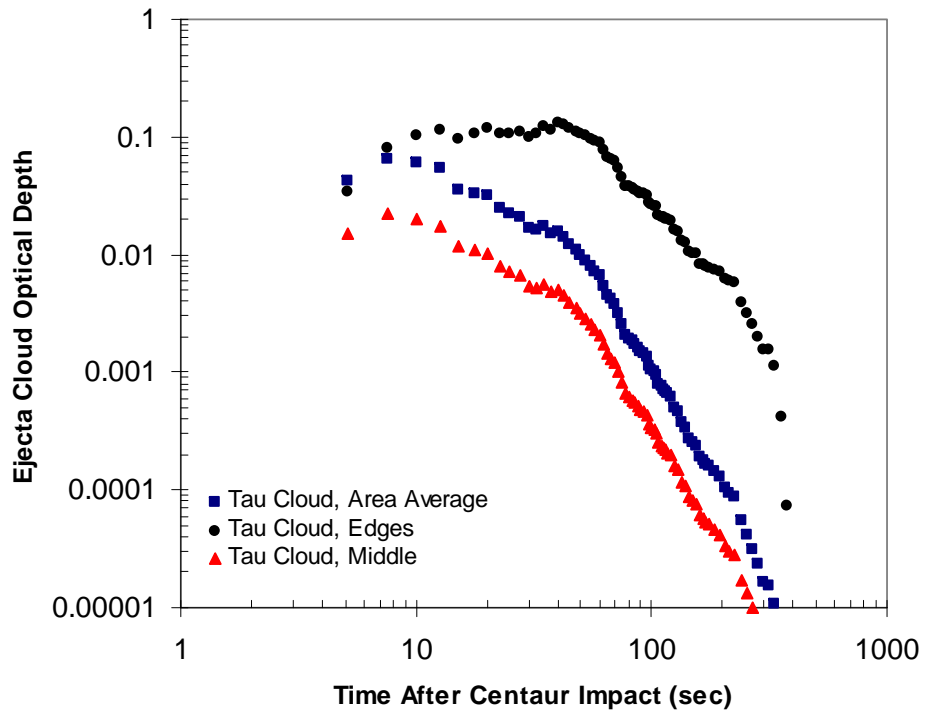
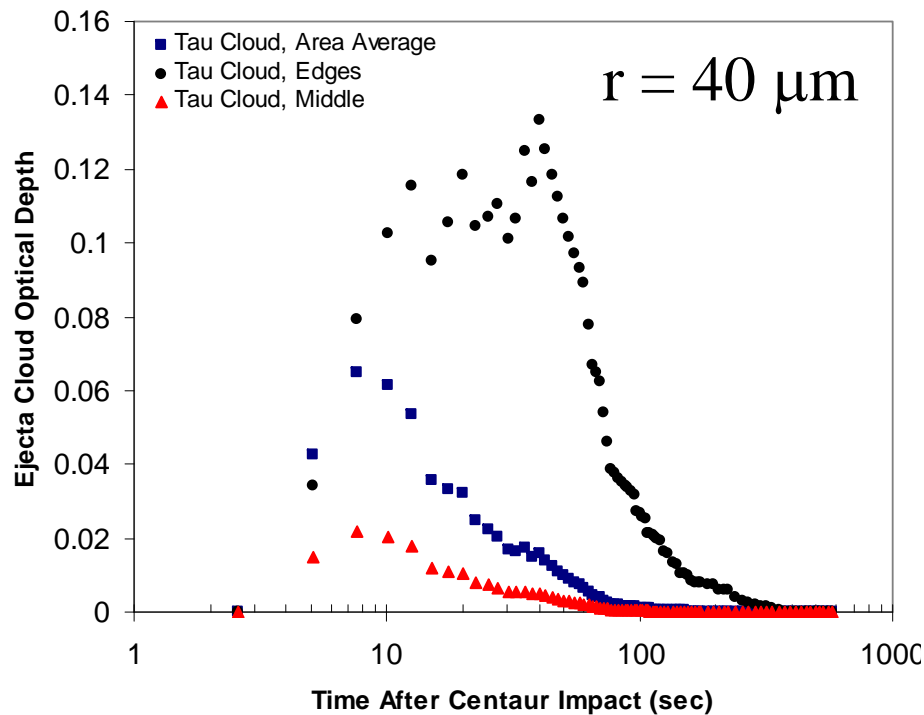
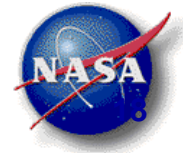


We'll know next year!

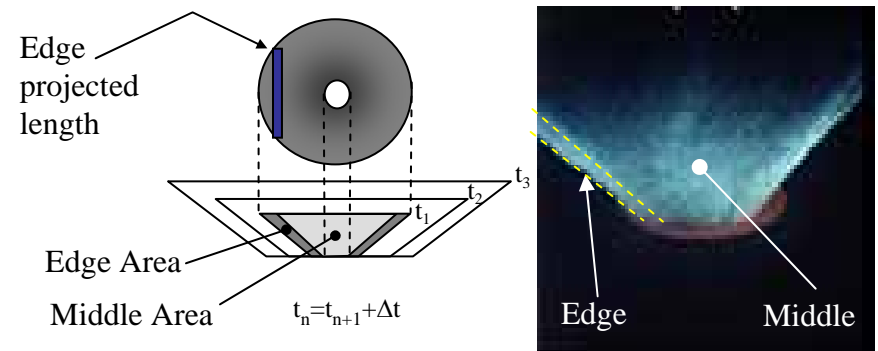
- Earliest likely impact date May 10, 2009
- Should be quite visible (Mag 9-10 per half arcsec) from Earth in the Pacific (including west coast) ([See Jennifer Heldmann's poster](#)).
- Impact target selection an on-going process ([See Gwen Bart's poster](#))
- LCROSS SC and Instrument development demonstrated a novel approach ([See Kim Ennico's poster](#))



Impact Expectations: Side View

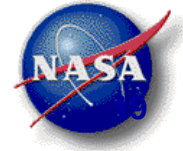


For the Edge/Middle Model the ejecta mass fills a volume described by two conic sections. The projected area is estimated along the edges and in the middle portion of the cloud. The edge area is estimated using an average projected edge length (calculated from curtain radius and ejecta angle). The middle area is estimated from the difference between conic sections, separated by the curtain wall thickness (assumed here to be 100 meters).





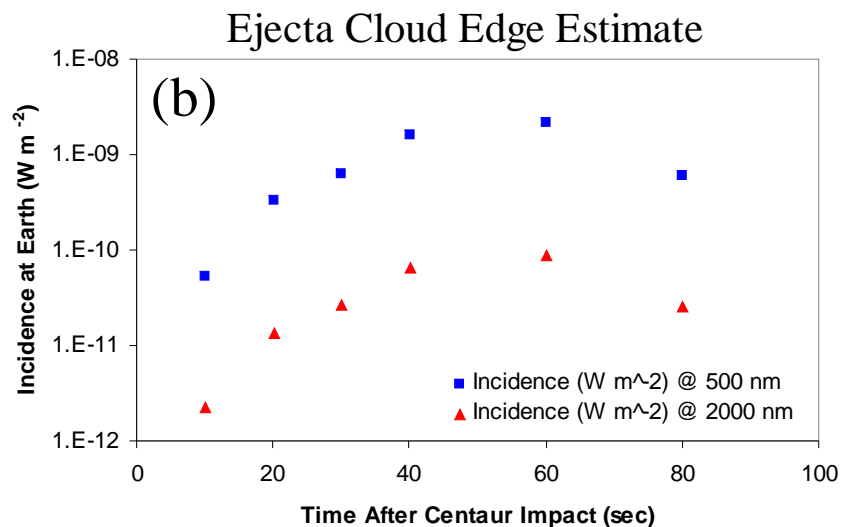
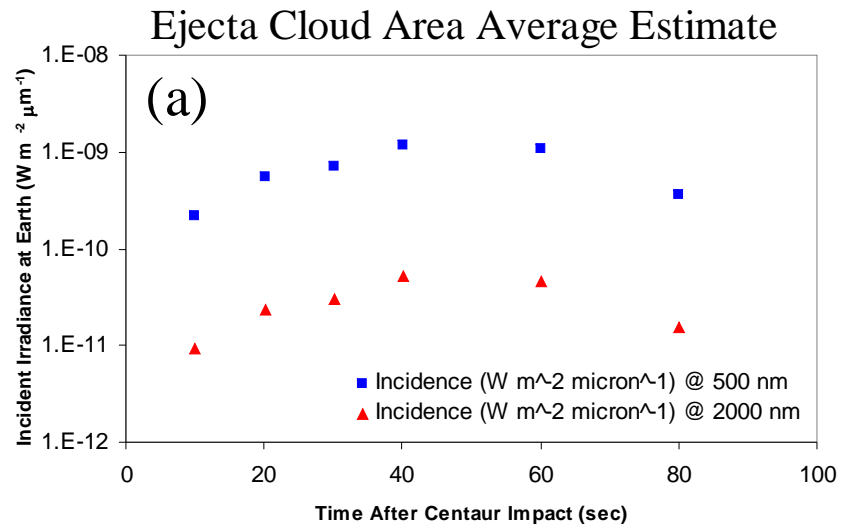
Impact Expectations: Earth Incidence



The Incident Flux at Earth from the ejecta cloud was estimated using the Area Average and Edge/Middle models presented on the previous slides ($r=40 \mu\text{m}$).

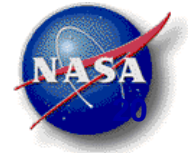
(a) The Incidence at Earth using the radiance estimates and ejecta cloud projected area from the Area Average model.

(b) The Incidence at Earth using the radiance estimates and ejecta cloud projected area from the Edge/Middle Average model. Incidence is only shown for the cloud edge.

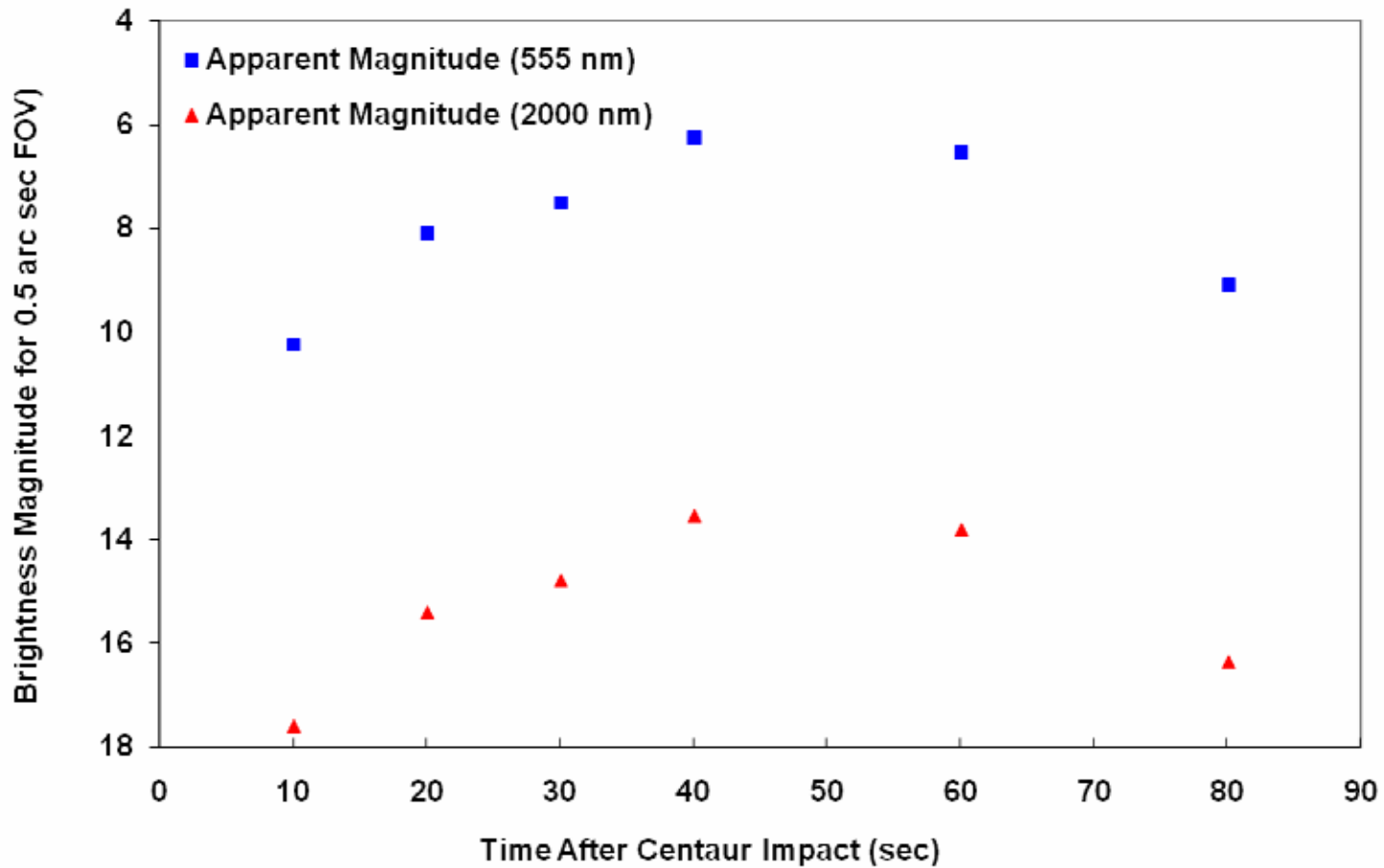




Impact Expectations: Earth Brightness

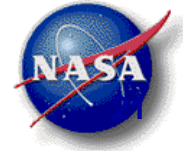


Apparent Magnitude of curtain edge on for a 0.5 arc sec FOV

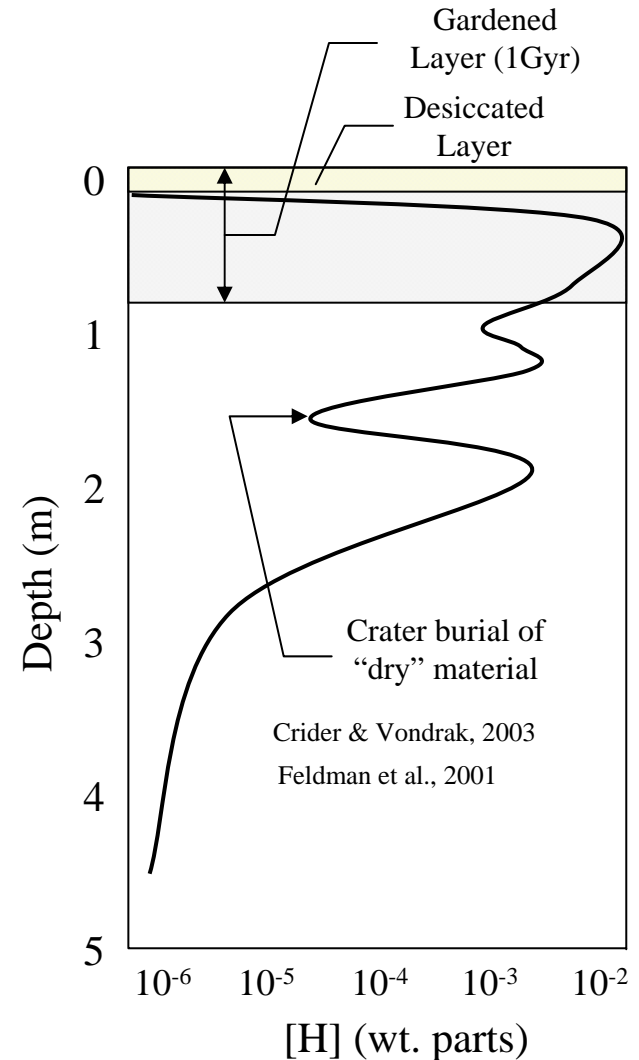
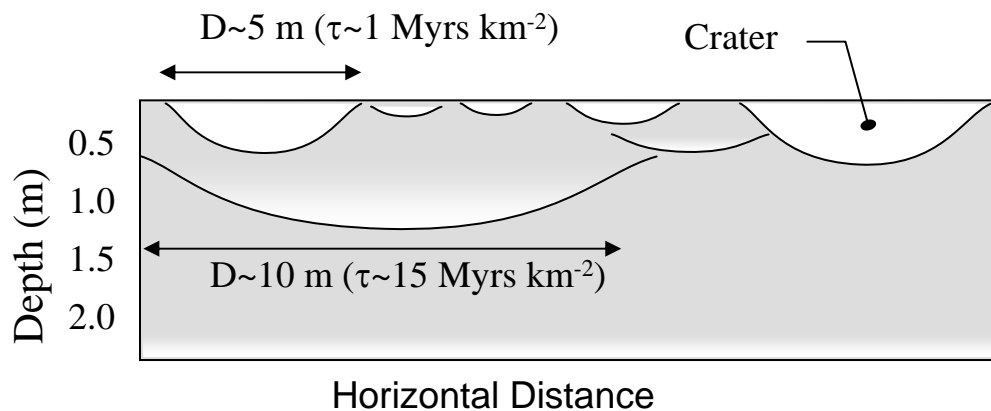




The LCROSS Experiment: Smooth or Chunky?



- Lunar Prospector was sensitive to hydrogen in the top ~1 m of regolith, the extent which is expected to be gardened in ~1Gyr
- Impacts which excavate to ~1 m deep and have diameters of ~10 m occur on timescales of $\tau \sim 15$ Myrs/km², or about sixty 10 m craters km⁻² on a surface 1 Gyrs old.
- This crater density results in a mean distance between 10 m diameter craters of ~150 m on a 1 Gyo surface.





Lunar Polar Hydrogen – Chances of a “Slash”



- If the 1-meter-deep heterogeneity is controlled by 10 m which are out of equilibrium with diffusive and space weathering processes, then the aerial fraction that is in equilibrium, i.e., “wet” is:

$$\sim 1 - \text{Crater Diameter}^2 / \text{Crater Spacing}^2 = 1 - 10^2 / 100^2 = 99\%$$

⇒ Top meter sensed by LP is near the derived value: high concentration pockets (WEH greater than few %) in the top meter *not* likely.

- Diffusive and space weathering processes likely to enforce their own horizontal modulation due to environmental effects (e.g., temperature and porosity)

