Lunar CRater Observation and Sensing Satellite

LCROSS

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JHU/APL

Mission Overview

The LCROSS Mission is a Lunar Kinetic Impactor employed to reveal the presence & nature of water ice on the Moon

- LCROSS Shepherding S/C (S-S/C) directs the 2000[kg] (4410[lb]) Centaur into a permanently-shadowed crater at 2.5[km/s] (1.56 [miles/s])
- ~200 metric tons (220 tons) *minimum* of regolith will be excavated, leaving a crater the size of ~1/3 of a football field, ~15 feet deep.
- The S-S/C decelerates, observing the Centaur ejecta cloud, and then enters the cloud using several instruments looking for water
- The S-S/C itself then becomes a 700[kg] (1,543[lb]) 'impactor' as well
- Lunar-orbital and Earth-based assets will also be able to study both clouds, (which may include LRO, Chandrayaan-1, HST, etc)

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Project Team

A fast, capable team:

- ARC provides the overall project management, systems engineering, risk management, and SMA for the mission
- Northrop-Grumman provides the S/C and S/C integration for this mission as well as launch systems integration support
- ARC provides the Science, Payloads, and Mission Ops for this mission
- ARC, JPL, and GSFC provides the Navigation and Mission Design role
- JPL is providing DSN services
- KSC/LM is providing Launch Vehicle services
- JHU-APL is providing avionics environmental testing

The LCROSS Science Team

Tony Colaprete (ARC)	Principal Investigator
Geoff Briggs (ARC)	Deputy Principal Investigator
Kim Ennico (ARC)	Payload Scientist, I&T
Diane Wooden (ARC)	Observations/Analysis
Jennifer Heldmann (SETI)	Observation Coordinator
Tony Ricco (Stanford)	NIR Spectrometers
Luke Sollitt (NGST)	Imaging systems
Andy Christensen (NGST)	Science Requirements
Erik Asphaug (UCSC)	Impact Processes/Analysis
Don Korycansky (UCSC)	Impact Processes/Analysis
Peter Schultz (Brown)	Impact Processes/Analysis
Ben Bussey (JHU-APL)	LPRP Representative

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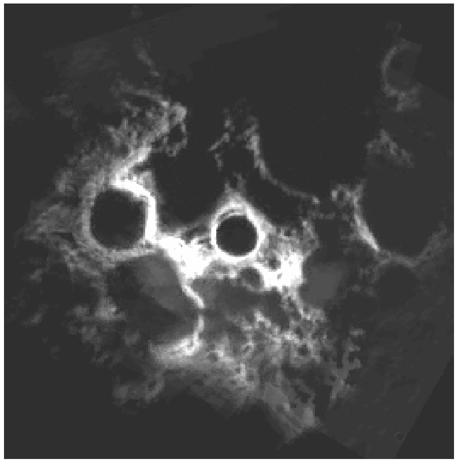
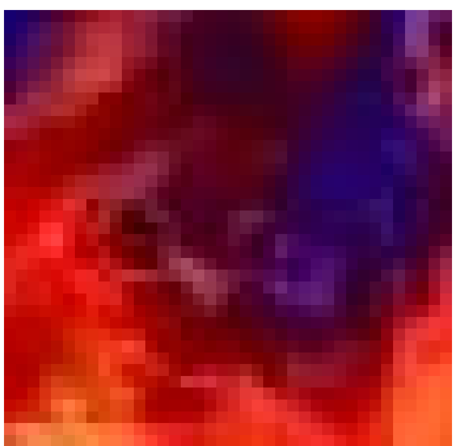
Mission Measurement Objectives

The LCROSS mission rational:



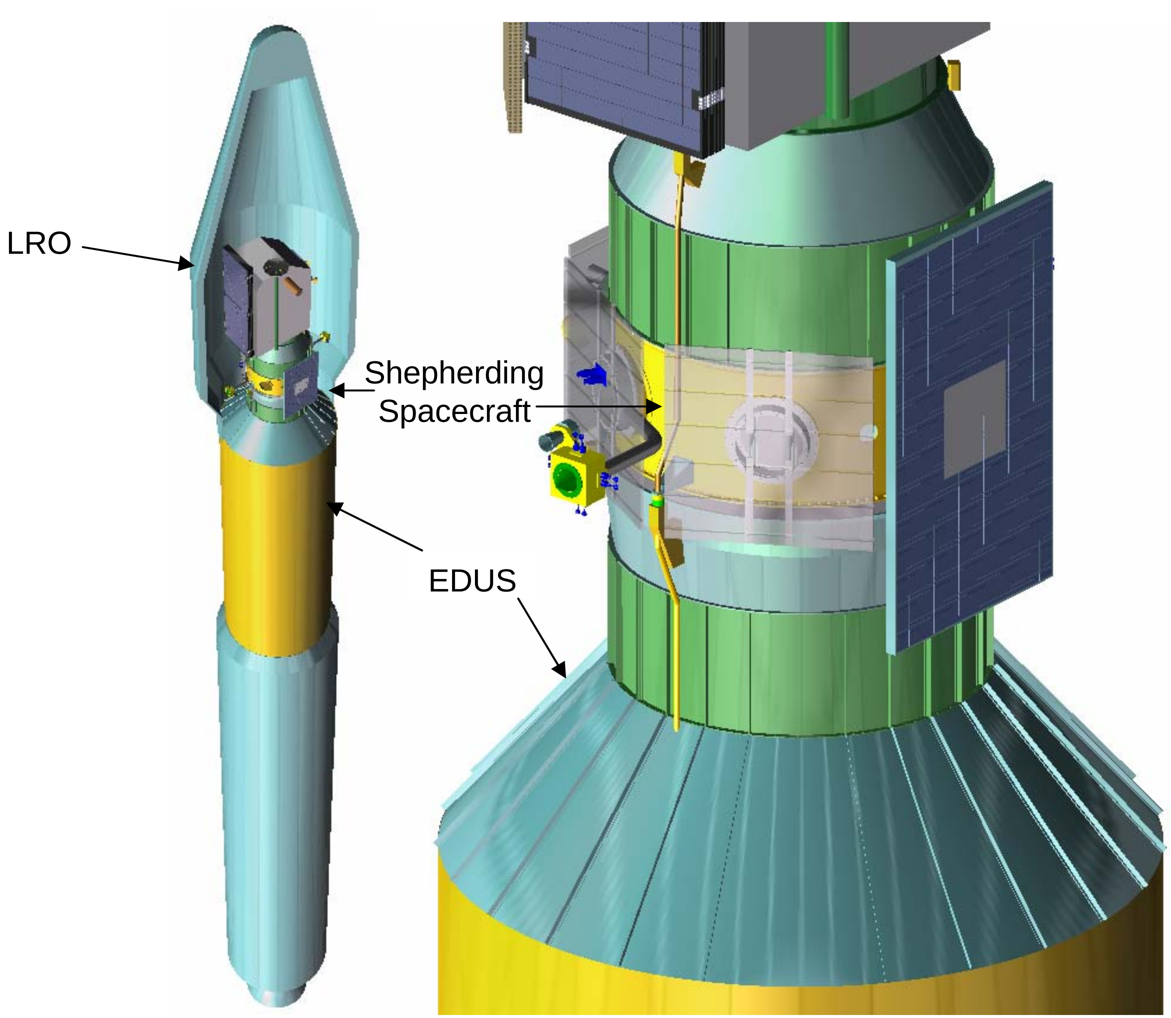
- The nature of lunar polar hydrogen is one of the most important drivers to the long term Exploration architecture
- Need to understand Quantity, Form, and Distribution of the hydrogen
- The lunar water resource can be estimated from a minimal number of “ground-truths”
- Early and decisive information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



Instrument Deck

9 Instruments:

1 Visible Context Camera

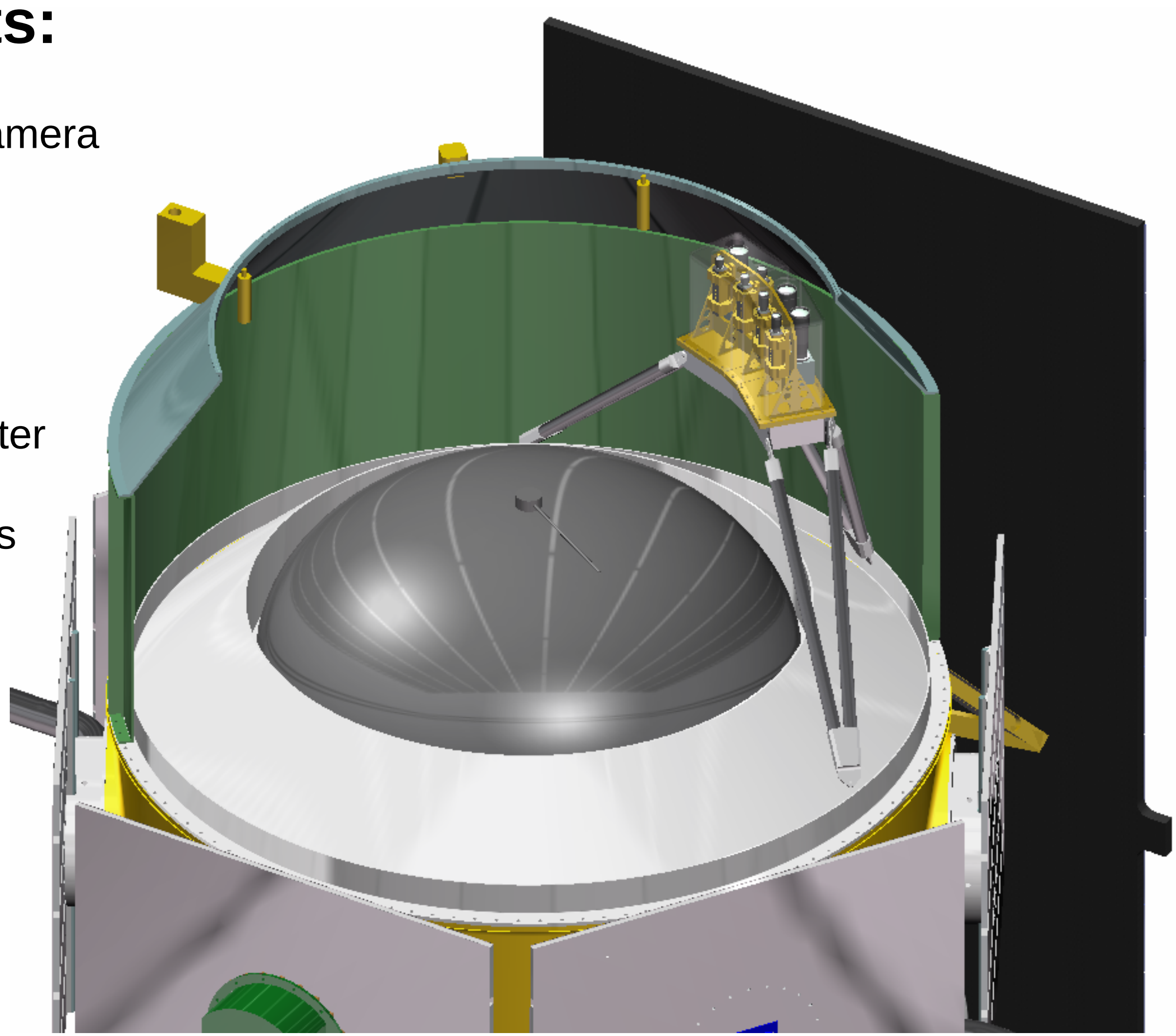
2 NIR Cameras

2 mid-IR Cameras

1 Visible Spectrometer

2 NIR Spectrometers

1 Total Visible Luminance Photometer



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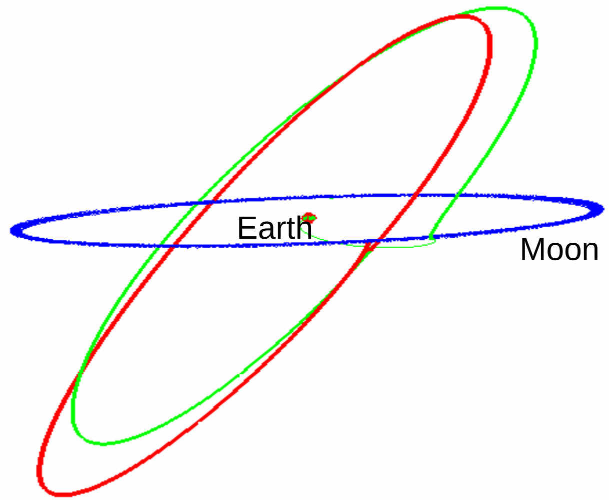
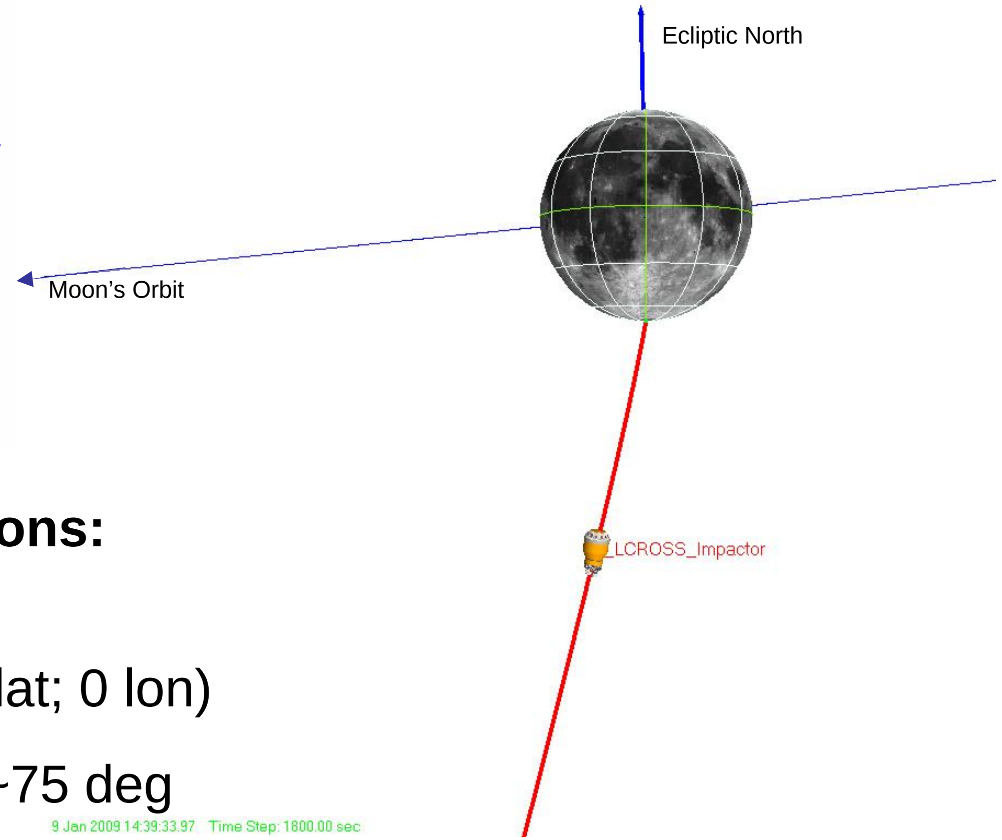
LCROSS Orbit Description



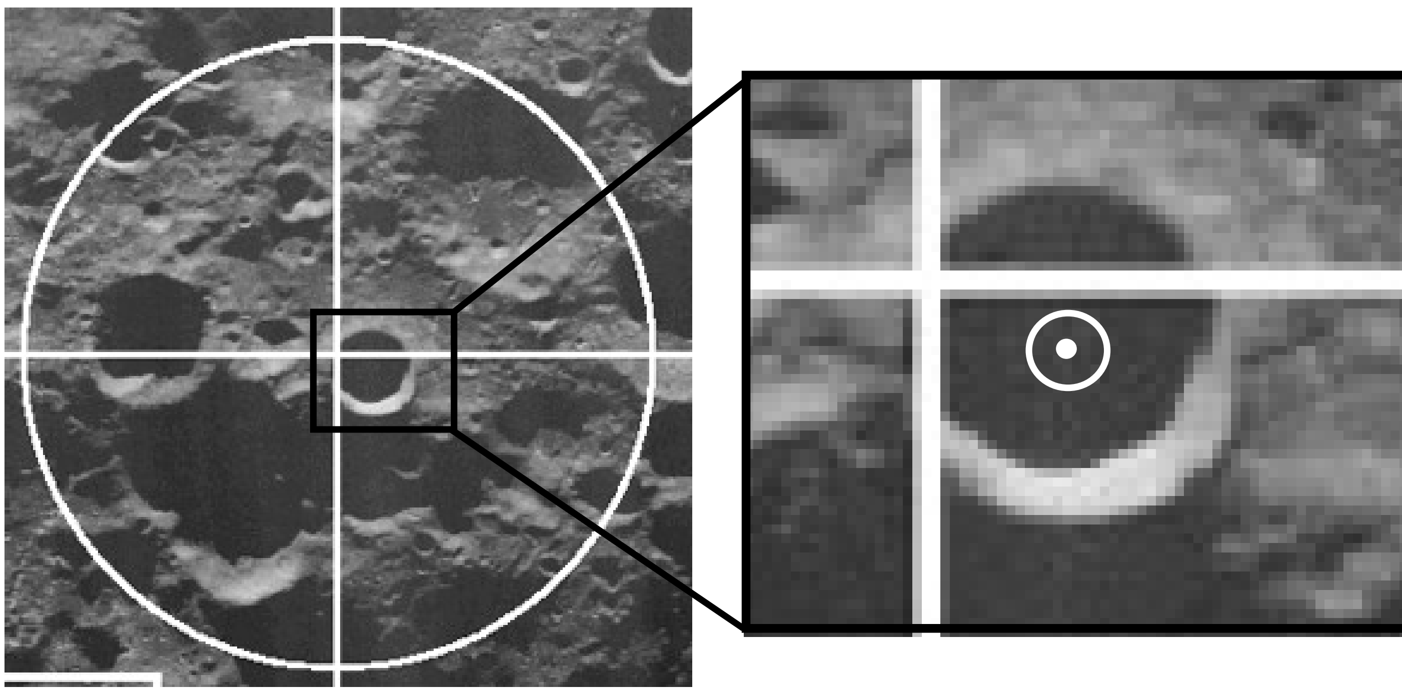


Nominal Impact Conditions:

- Target impact site:
Shackleton Crater (-89.5 lat; 0 lon)
- Incident impact angle: ~75 deg
- Impact velocity: 2.5 km/sec

Impact Accuracy

- Impact accuracy better than 3km (3-sigma) expected for EDUS
- S-S/C can be directed to impact within 100m of EDUS and can retarget if necessary



The LCROSS Impact

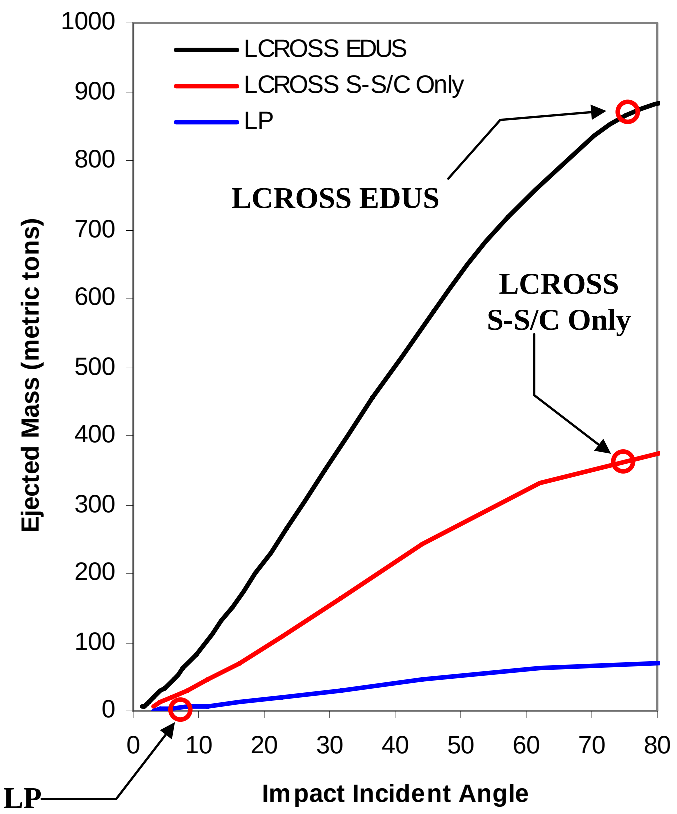
The use of impacts to "survey" is a proven approach (e.g., Ranger, Apollo, Deep Impact)

The larger the amount of excavated material the greater the success:

- Larger – Avoids lateral heterogeneity
- Deeper – Avoids vertical (depth) heterogeneity
- More Ejecta – Increases observability

The total excavated amount scales ~linearly with impact mass

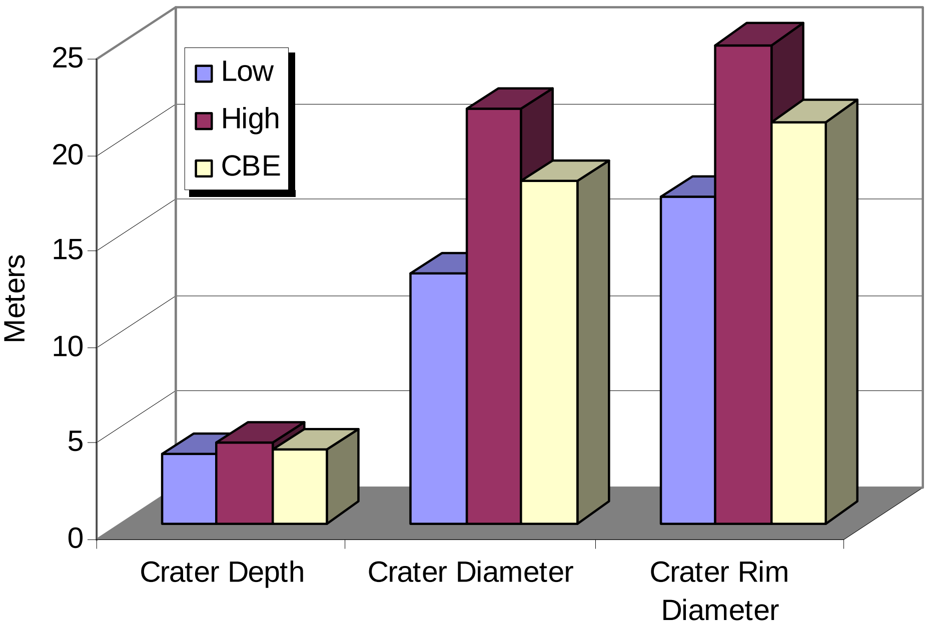
⇒ The larger the mass the more successful the impact experiment



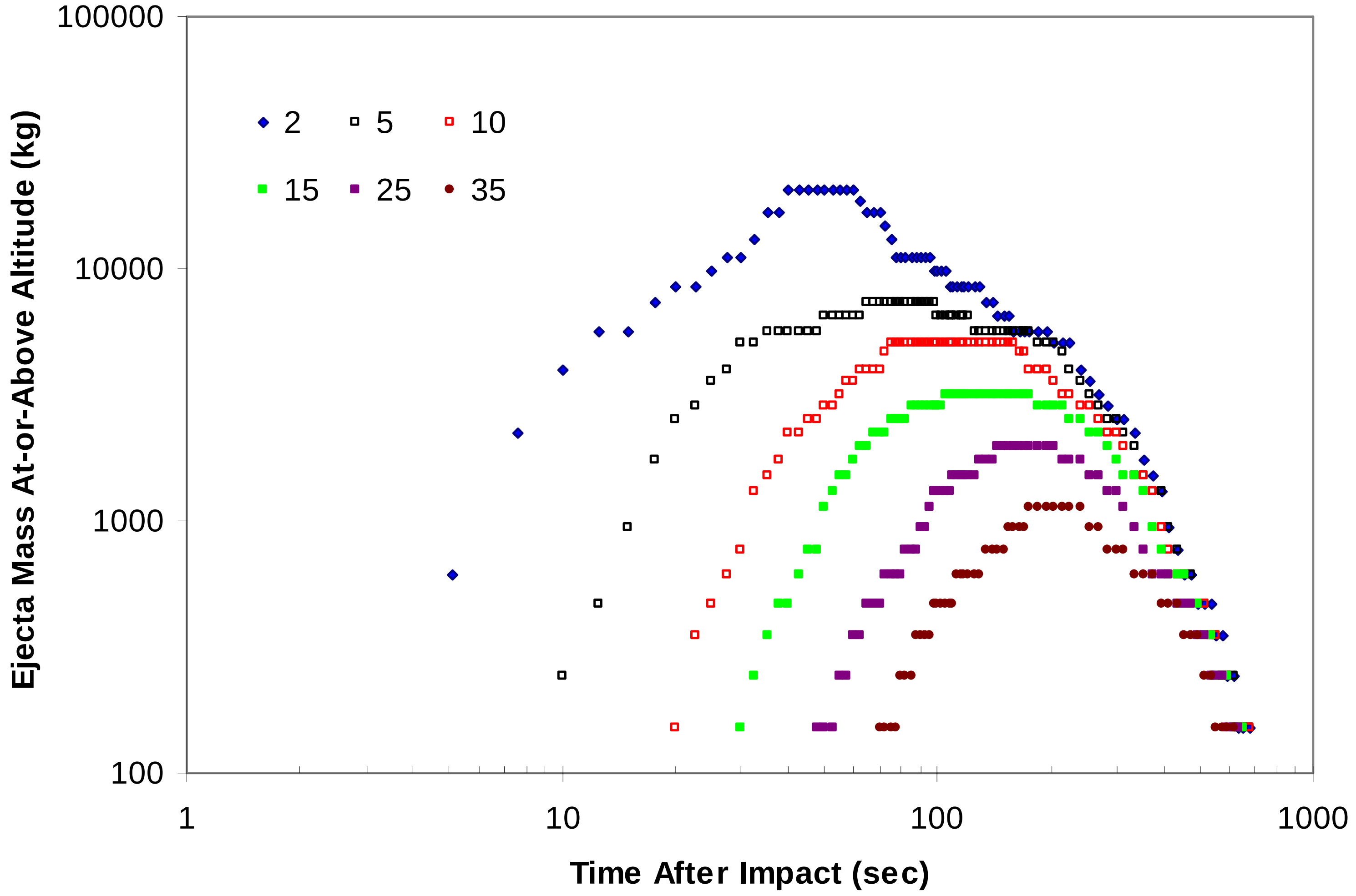
Current Best Estimate Impact Model (CBEIM)

- The CBIEM summarizes the results of numerous impact models / assessments.
- Used as the base to drive mission design and instrument selection.
- Efforts continue to refine the model with an update due December, 2006.

CBEIM Crater Size



Ejecta Mass Above an Altitude



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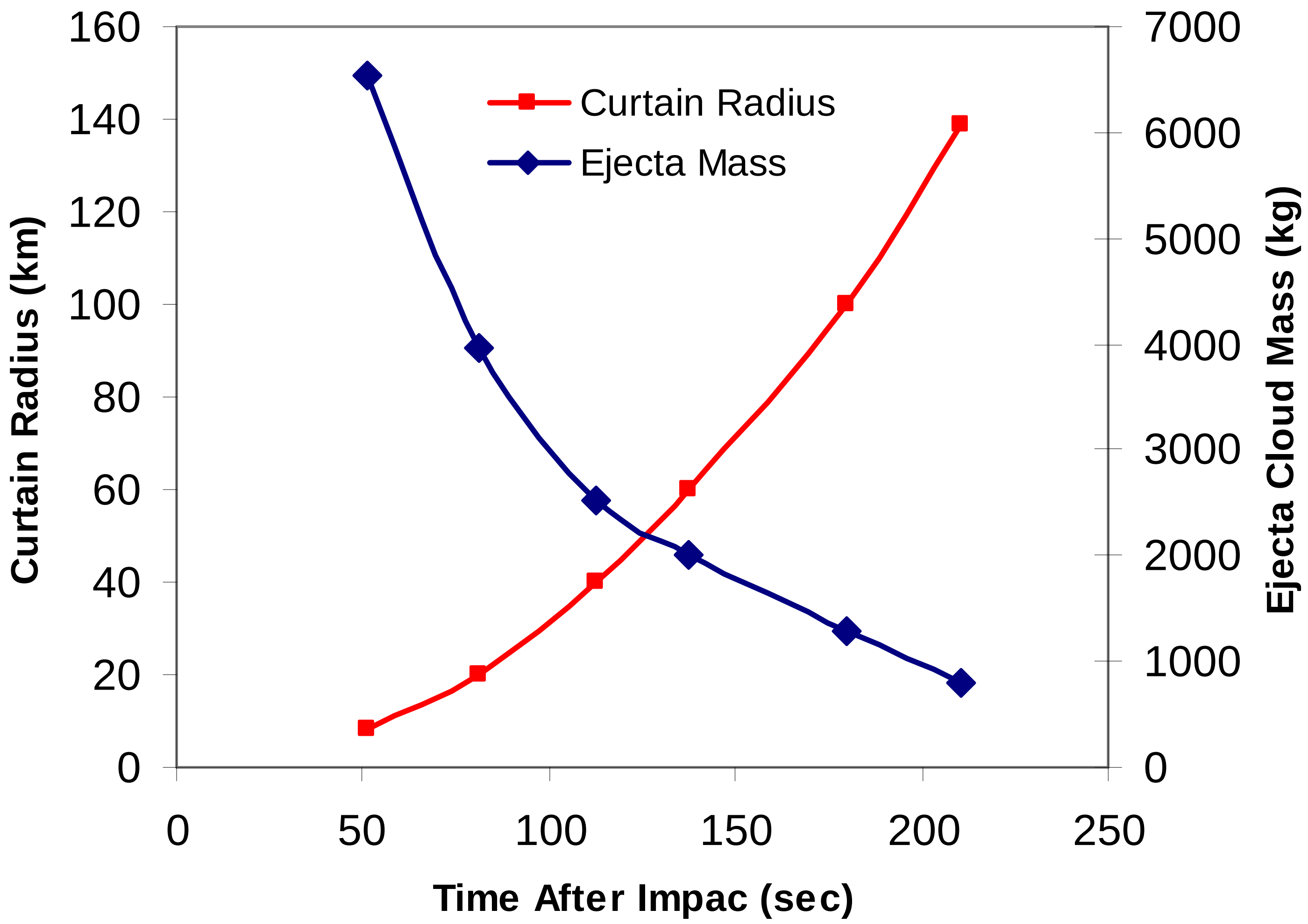
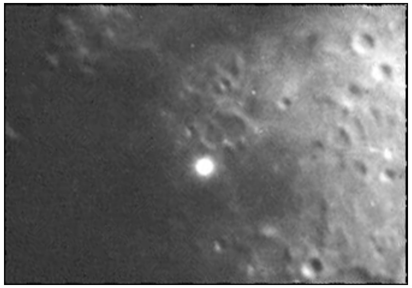
Ejecta Curtain Geometry



Stages of the Impact Process

Impact Flash and Vapor Cloud



Visible Component:

- Compaction / Intergrain Strain
- τ~0.1 sec
- F~0.001-1 μW m^{-2} (r=1000 km)

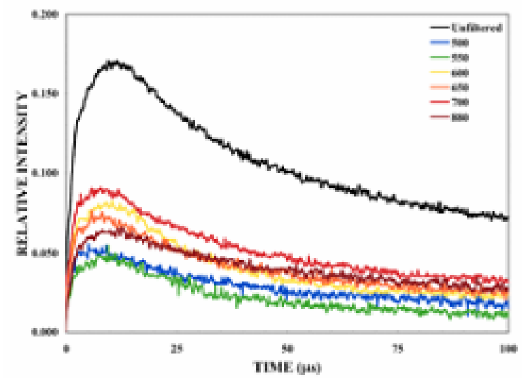
NIR Component:

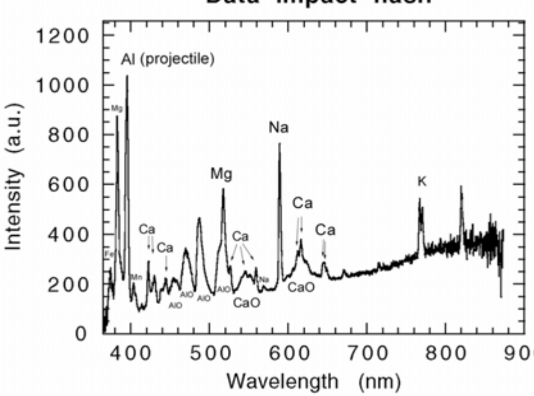
- Blackbody Emission of Vapor Cloud
- τ~1 sec
- F~0.01-10 mW m^{-2} (r=1000 km)

Total energy sensitive to target properties such as material strength, density and water content.

Shape of the curve reflects the penetration depth, changes in material competence

A variety of visible and NIR spectral emissions relate to composition of target material and the fraction of the impactor which vaporizes





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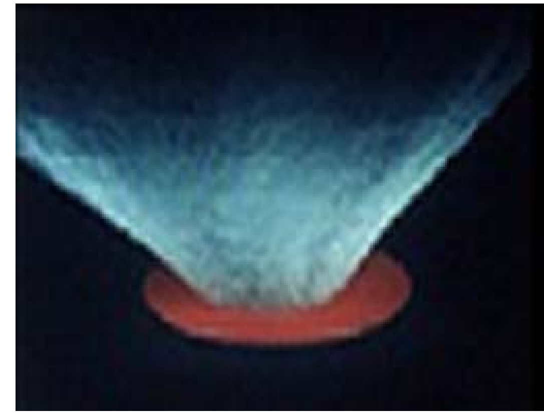
Stages of the Impact Process

Ejecta Curtain Evolution

After the flash, target material is ejected outward on ballistic trajectories.



Visible Component:

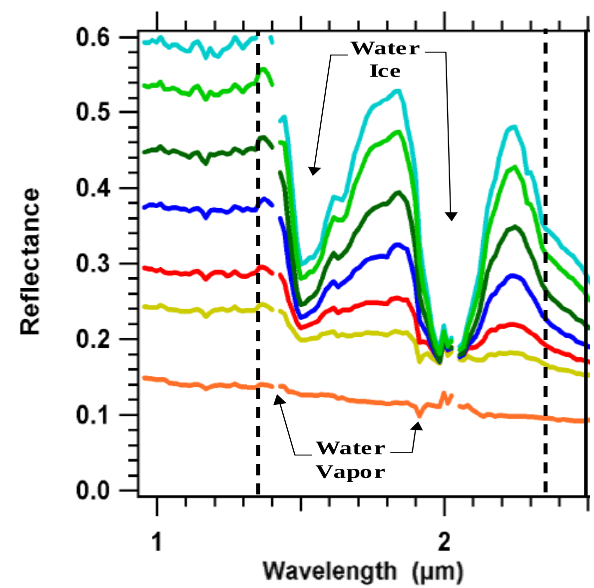
- Curtain illuminated by sunlight
- Spectral brightness dependant on particle density, size, composition, shape
- Excitation / Florescence from species such as OH- and H_2O+

NIR Component:

- Curtain illuminated by sunlight
- Spectral brightness dependant on particle density, composition, size, shape

Mid-IR Component

- Curtain thermal emission
- Evolution sensitive to initial ejecta temperature (~100 K), particle size, volatile composition (water) and solar exposure
- Grains with radii <100 μm will warm within ~1-100 seconds to ~250 K after solar exposure.
- Spectral brightness dependant on particle density, composition, size, shape



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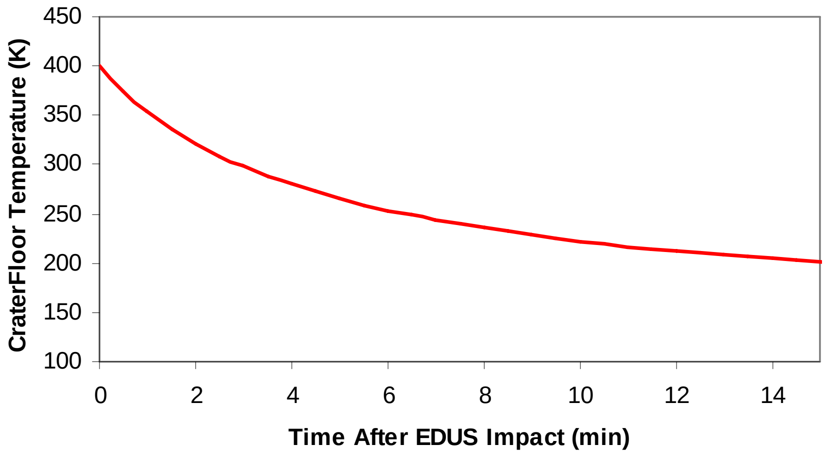
Stages of the Impact Process

Curtain Clearing / Crater Exposure

After ~5 minutes the bulk of the ejecta “settles” exposing the fresh crater

Mid-IR Component

- Remnant thermal emission from the crater (λ=6-15 μm)
- At 5 minutes post impact the crater temperature will be ~200 K, against a ~100 K background
- Crater temperature sensitive to water content
- Determination of crater size



Prospecting for Water

…using 6.5 Billion Joules

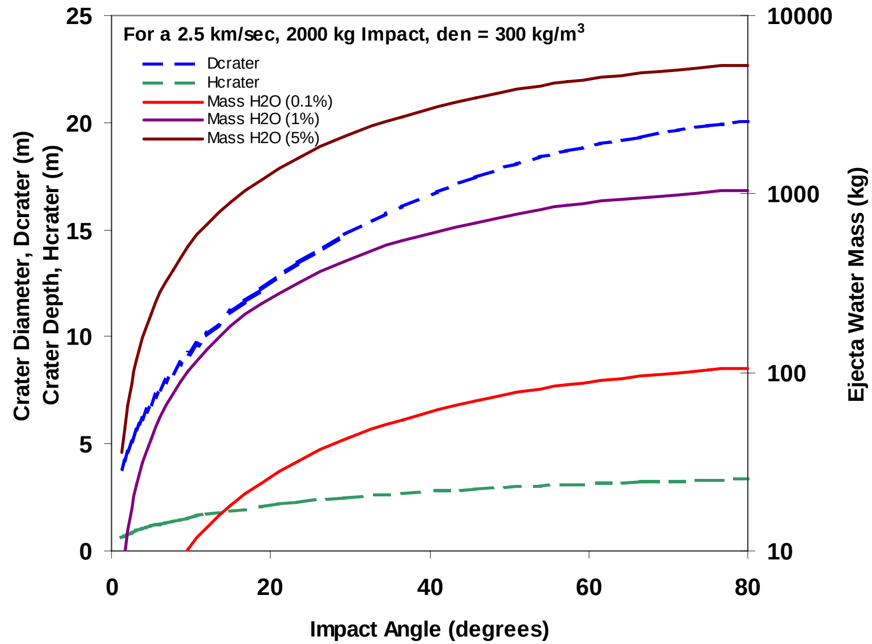
The Atlas Centaur Impact:

- Mass: ~2000 kg
- Velocity: 2.5 km/sec
- Angle: ~75 degrees

Minimize false positives by controlling EDUS contamination

- Total H/O bearing materials (e.g. LOX, H_2, H_2O in batteries) kept below reported and kept below 100 kg

Minimize false negatives by combining multiple detection methods



Crater Diameter, Depth and Excavated Water

(Assumes a 10 cm desiccated Layer with uniform water mixing below)

The LCROSS S-S/C Payload

9 Instruments:

1 Visible Context Camera:
4 color, 6 degree FOV, <0.5 km resolution at T-10 min to S-S/C impact

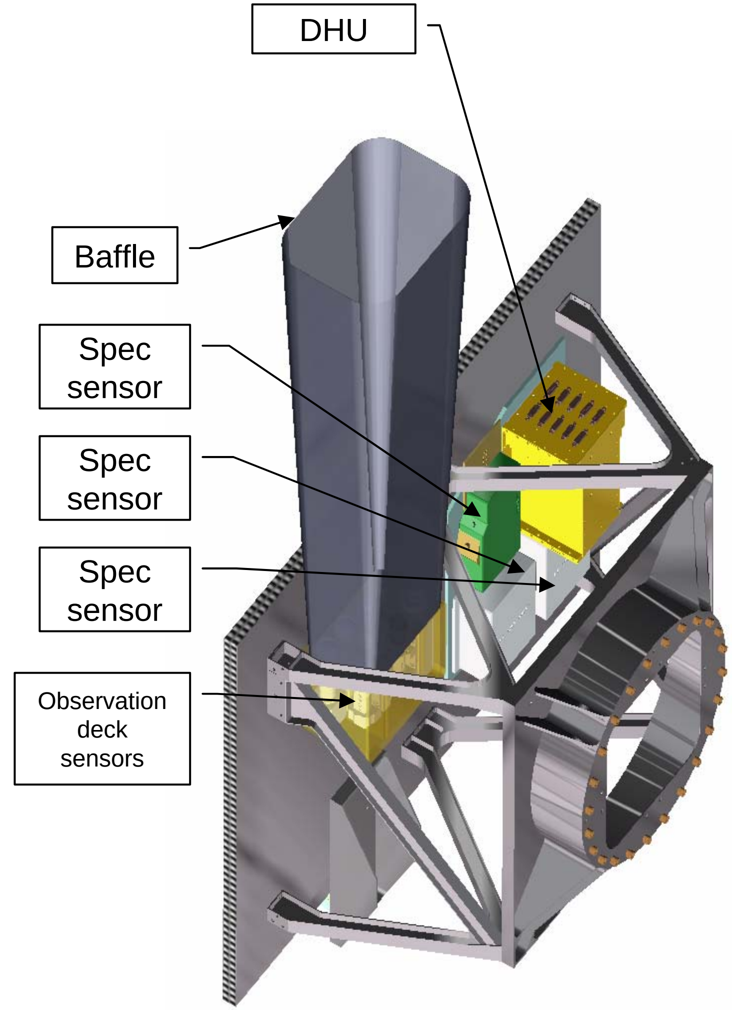
2 NIR Cameras
1.4 µm water ice band depth maps
1 km resolution at T-10 min

2 mid-IR Cameras
7 and 12.3 µm
< 0.5 km resolution

1 Visible Spectrometer
0.25 to 0.8 µm, ~0.002 µm resolution

2 NIR Spectrometers
1.35 to 2.45 µm, 0.012 µm resolution, 6° FOV

1 Total Visible Luminance Photometer
Broadband from 0.6 – 1.2 µm, sample rate >1000 Hz, < nW NEP @ 1000 Hz



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LCROSS Measurement Plan

Flash Photometry
- Total brightness in visible and NIR wavelengths

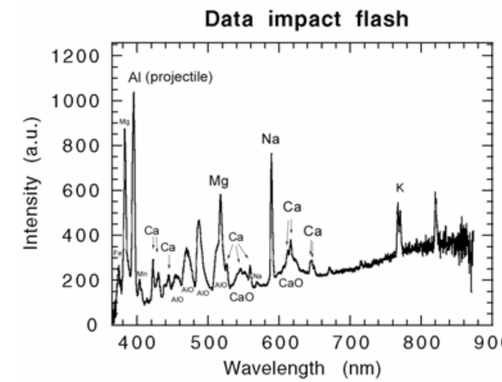
Visible Spectroscopy
- Visible emission (e.g., OH^{-}, $H2O^{+}$)
- Surface and ejecta curtain reflectance/absorption

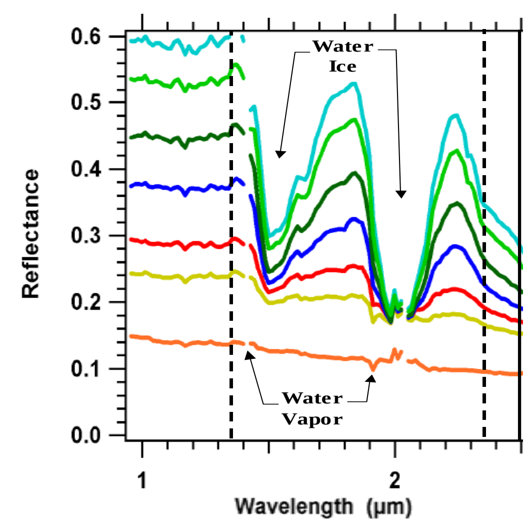
NIR Spectroscopy
- Surface and ejecta curtain reflectance/absorption

NIR Imaging
- Surface and ejecta curtain reflectance
- Band-depth maps (λ=1.4 μm)

Middle IR Imaging
- Surface and ejecta curtain temperatures
- Band-depth maps (λ=12 μm)

Visible Imaging
- Surface and ejecta curtain reflectance





Measurement / Technique Trace

Measurement	Requirement	Flash Photometry	Visible Spectroscopy	NIR Spectroscopy	NIR Imaging	Mid-IR Imaging	Visible Imaging
Total Water	PRJ4.1.1-.4	Indirect / Weak	Indirect / Strong	Direct / Strong		Indirect / Weak	
Water Ice	PRJ4.1.1-.3		Indirect / Weak	Direct / Strong	Indirect / Strong	Indirect / Strong	Indirect / Weak
Water Vapor	PRJ4.1.1-.3		Indirect / Strong	Direct / Strong			
Organics	PRJ4.1.3		Indirect / Strong	Indirect / Weak			
Hydrated Minerals	PRJ4.1.3			Indirect / Strong			
Target Properties	PRJ4.1.5,4.1.7	Direct / Strong		Indirect / Weak	Indirect / Weak	Indirect / Strong	Indirect / Weak
Curtain Morphology	PRJ4.1.8,4.1.4				Direct / Strong	Direct / Strong	Direct / Strong
Thermal Evolution	PRJ4.1.8	Indirect / Weak	Indirect / Weak		Indirect / Weak	Direct / Strong	
Mineralogy	PRJ4.1.5		Indirect / Strong	Indirect / Strong			
Particle Size	PRJ4.1.6		Indirect / Strong	Indirect / Strong	Indirect / Weak	Indirect / Weak	Indirect / Weak

Legend	
Direct / Strong	(green)
Indirect / Strong	(yellow)
Indirect / Weak	(orange)

Direct / Strong = Very direct measure with little modeling / assumption; highly sensitive

Indirect / Strong = Indirect measure with the goal removed by several steps; highly sensitive

Indirect / Weak = Indirect measure with the goal removed by several steps; moderately sensitive

Instrument Sensitivity Studies

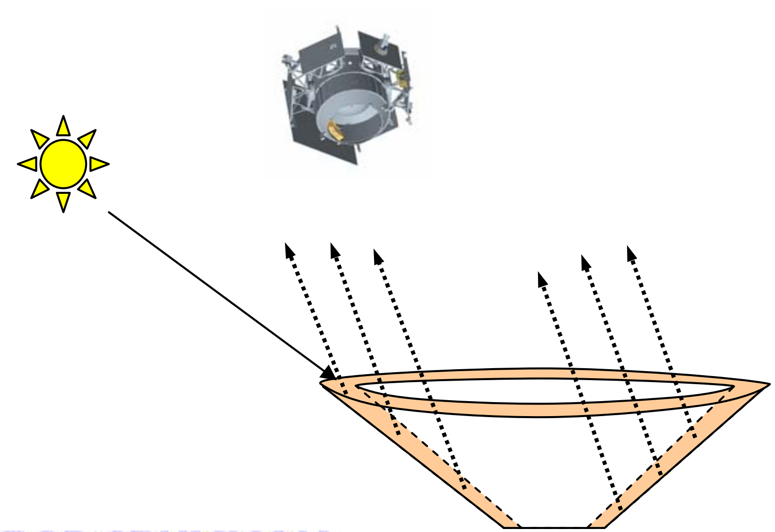
Instrument sensitivity calculated using CBEIM, scattering calculations, and instrument performance models

LCROSS S-S/C Utilizes backscattered solar light to make water absorption measurements (Differential Absorption Spectroscopy)

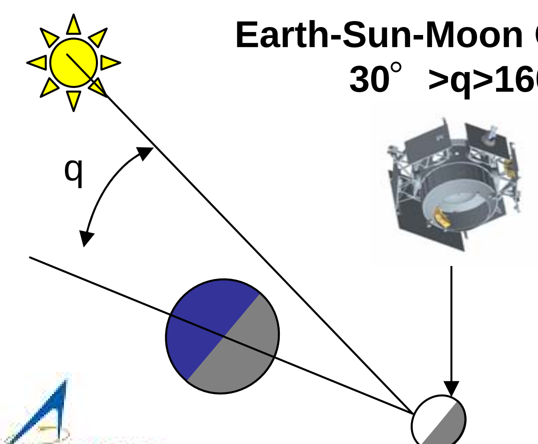
Ejecta Curtain Scattering Assumptions (for NIR):

- Dominant Particle Radius = 45 mm
- Particle Density = 2000 kg/m^3
- Single Scatter Albedo = 0.8
- Asymmetry Factor = 0.8
- q = 30°

Backscatter Geometry from an Solar Illuminated Curtain



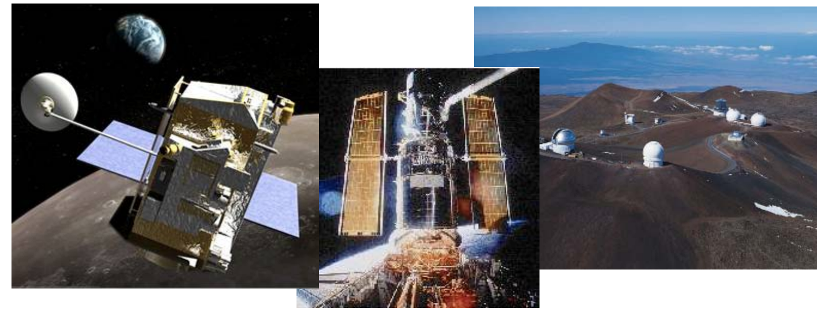
Earth-Sun-Moon Geometry
30° >q>160°



Impact Observations Support

Potential Supporting Platforms

- LRO
- International lunar missions
- Earth-orbiting
- Ground based



These platforms can provide unique vantage points and capabilities to monitor the impact event for water.

LCROSS provides support to these missions in the form of science rationale, impact expectations, observation recommendations, and technical data for observation (e.g., timing, direction for telescope pointing).

- Working directly with Facility/Instrument leads to plan observations (e.g., HST, SWAS, LRO, Keck).
- LCROSS Co-I has participated in the observation of SMART-1 to gain experience in observing the moon using large earth based telescope.
- Information will be provided through a web portal, modeled after the very successful Deep Impact mission.