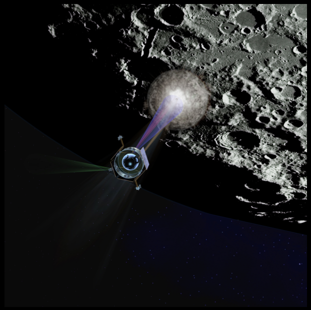


LCROSS Impact Update

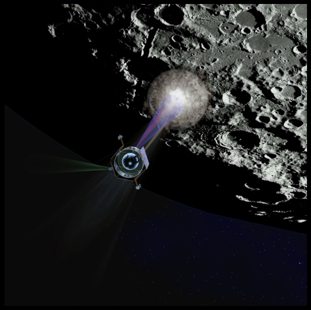
K. Fisher canopus56@yahoo.com prepared for Salt Lake Astronomical Society
Revised: 9-18-2009 Original: 9-16-2009

"In these matters the only certainty is that nothing is certain." Pliny the Elder

"It is far better to foresee even without certainty than not to foresee at all." Henri Poincare

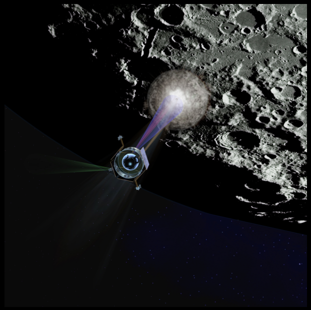
"From principles is derived probability, but truth or certainty is obtained only from facts." Tom Stoppard

"For my part I know nothing with any certainty, but the sight of the stars makes me dream." Vincent Van Gogh



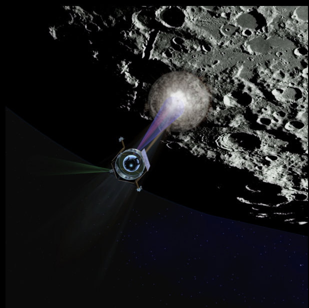
What

- 2200 kg spent Centaur Atlas booster impacts into the Moon at 2 kms.
- Makes a hole 20 meters in diameter and 3 meters deep.
- Throws several metric tons of dust into the air.
- Dust rises to 30km high in an ejecta plume and reflects sunlight. Heats up from -90 C to plus 200C.
- Light signal contains a spectra that may evidence water ice.



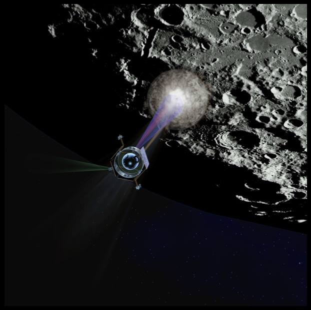
What

- Animations: Index list - see url - http://groups.google.com/group/lcross_observation/web/animations
  - KQUED broadcast url - http://www.kqed.org/quest/television/nasa-ames-rocket-to-the-moon
  - Pumice Test for Deep Impact – url: http://deepimpact.umd.edu/gallery/vid4.html
  - NASA LCROSS First-Steps Video – url: http://www.nasa.gov/mission_pages/LCROSS/multimedia/arc-LCROSS_First_Step.html



Why

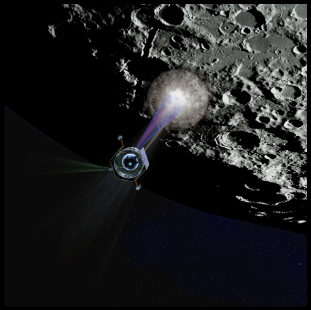
- There is ice at the poles of Mercury, Earth and Mars. Then why not the Moon?
- It costs $15,000 to lift from the Earth and land on the Moon one ½ bottle liter of water.
- To see if there are any water ice layers trapped within the top 1 meter of the lunar regolith.
- The LCROSS experiment and current theories say nothing about water ice layers that may be trapped below a depth of 1 meter.



Why

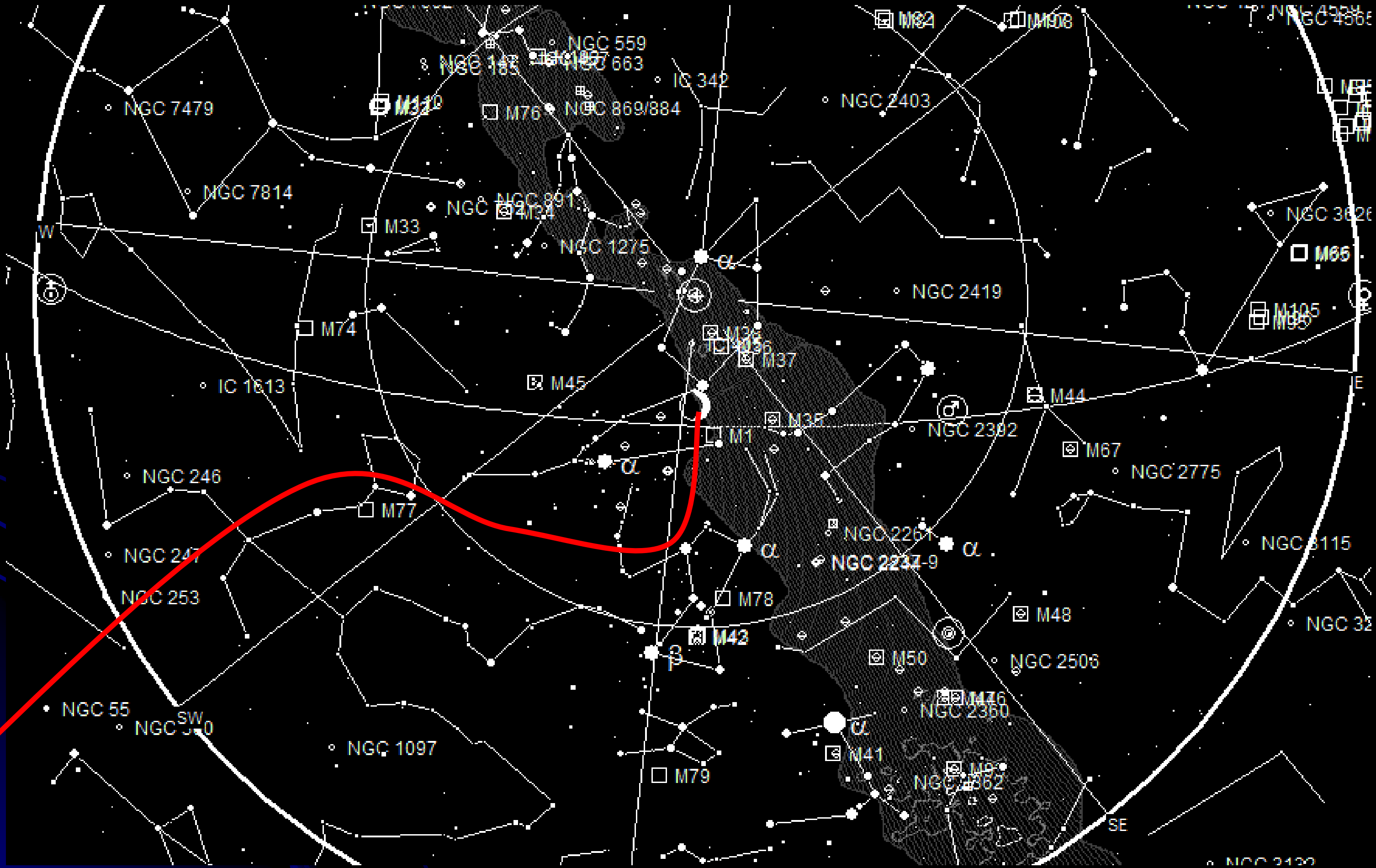
- Maximum estimated potential volume of water ice in the top 10 degrees from both poles and top 1 meter regolith layer in permanently shadowed regions may be equal to the volume of water in the Great Salt Lake – in theory.

Image: NASA Earth Observatory

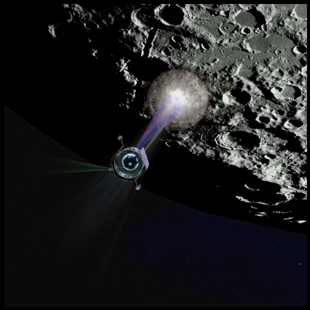


When

- October 9, 2009 11:30UT

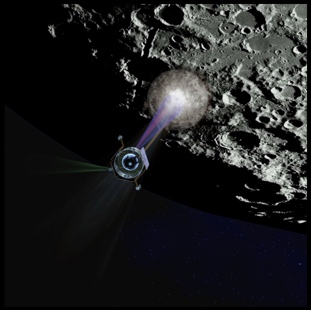


Alt-Az Horizon View – Salt Lake City 10-9-2009 5:30 MDT – South at bottom



Where

- The Moon will be about 1 degree from 1.7 mag bet Taurus (Alnath). between the Horn stars of Taurus at about 70 degrees altitude and at 71% illuminated fraction with lunar west illumination a few days after the full Moon.



Where

Lunar west of the southern lunar pole is a small unnamed 17 km diameter crater on the rim of Cabeus A. It has been designated Cabeus A1.

Coordinates of impact target

Cabeus A1 17km dia.
81.55°S 43.1°W

Image: Slooh widefield 9-10-2009

Coordinates for GOTO handboxes that offer automatic lunar crater targeting.

Cabeus A 48km dia.
82.2°S 39.1°W

Cabeus 100km dia.
84.9°S 35.5° W

Where

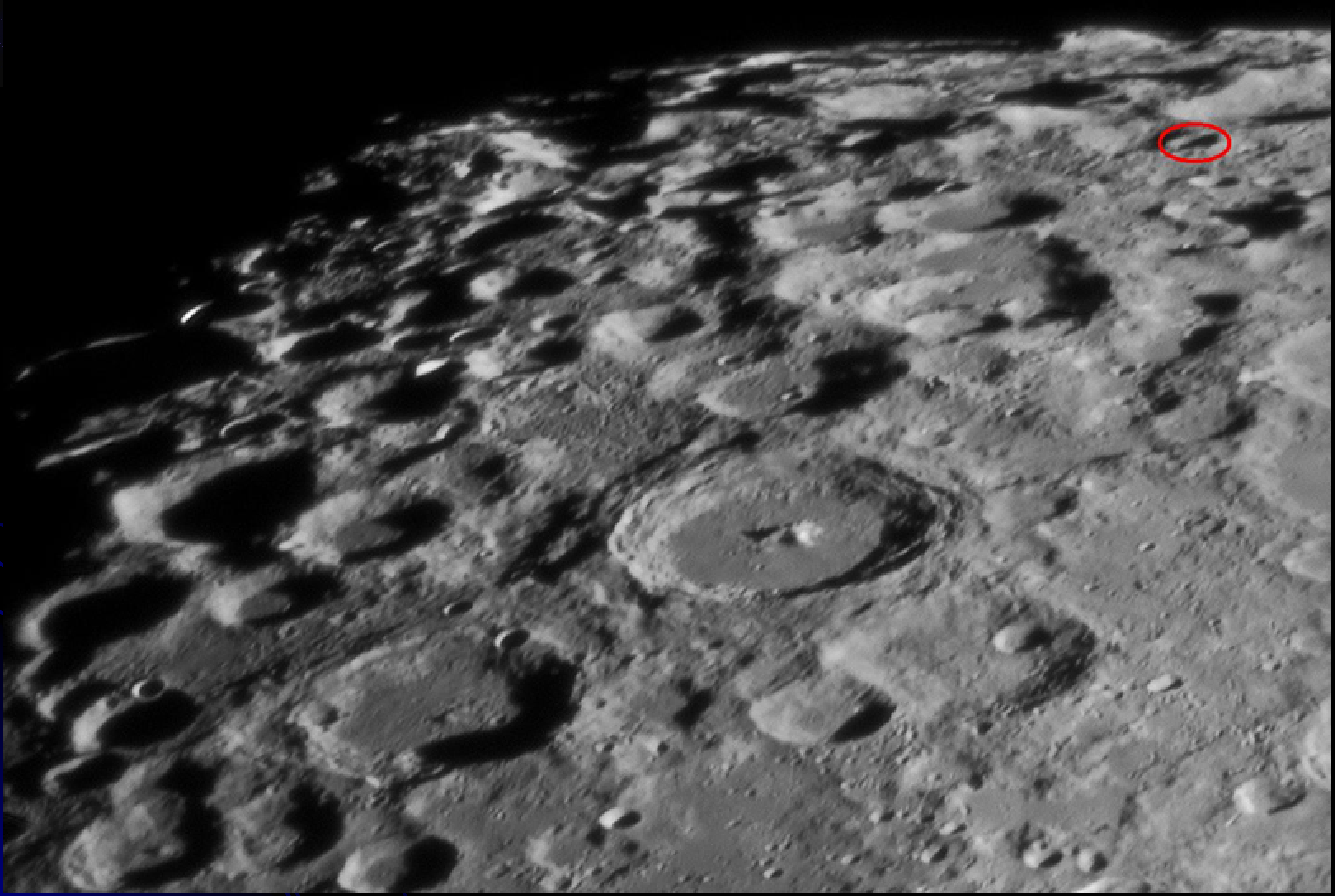
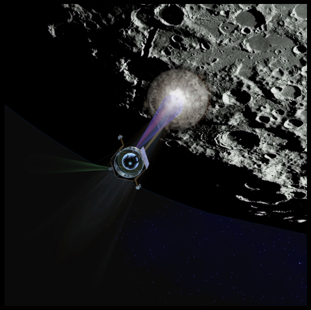
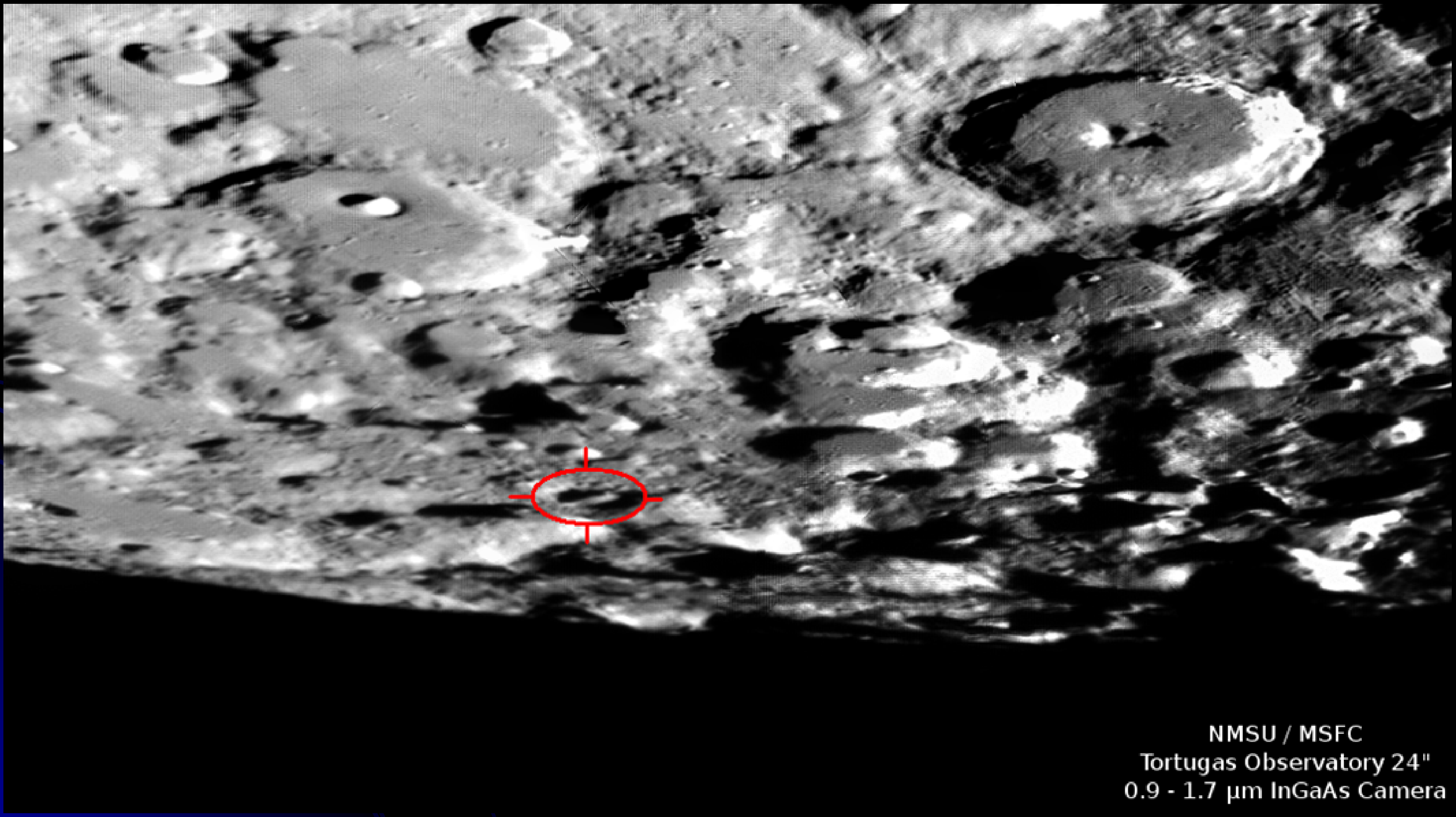
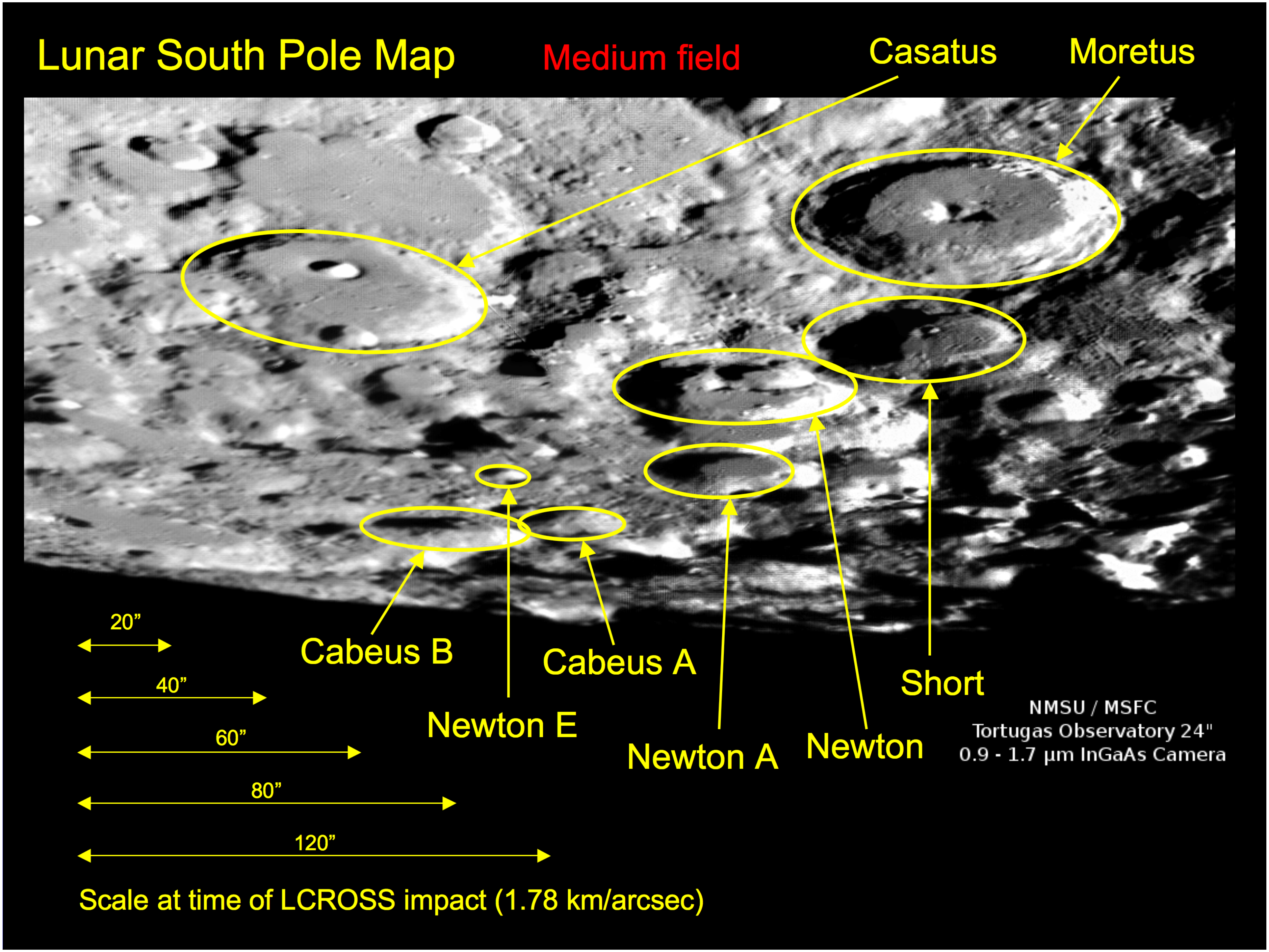


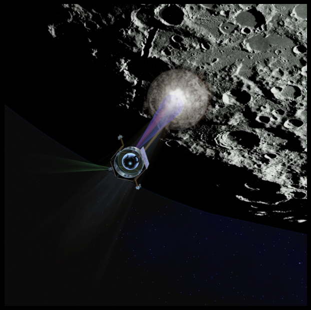
Image credit: Stefan Lammel 9-9-2009 Used with permission.



Where




Lunar South Pole Map
Medium field
Casatus
Moretus
Cabeus B
Newton E
Cabeus A
Newton A
Newton
Short
NMSU / MSFC
Tortugas Observatory 24"
0.9 - 1.7 µm InGaAs Camera
20”
40”
60”
80”
120”
Scale at time of LCROSS impact (1.78 km/arcsec)



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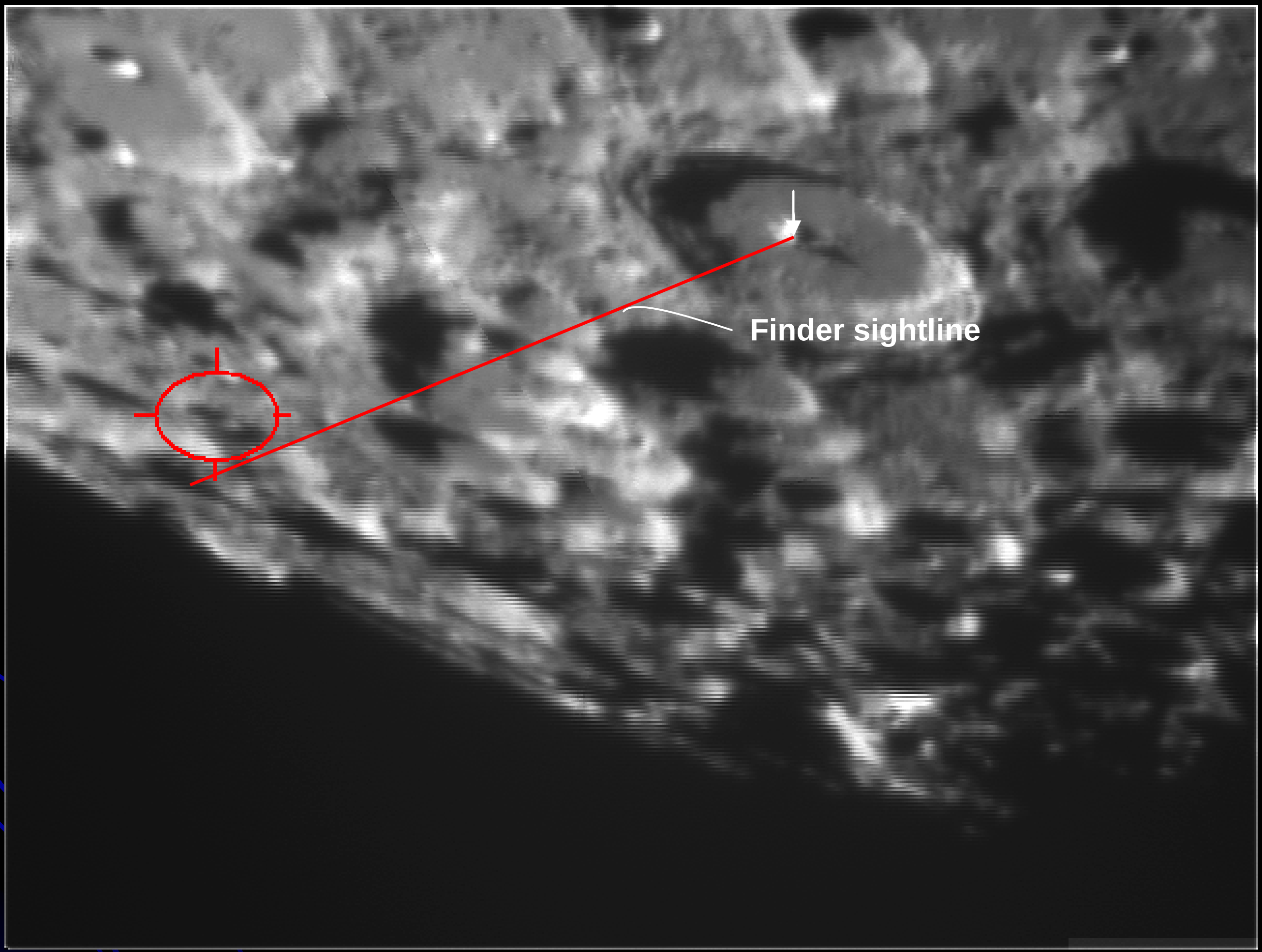
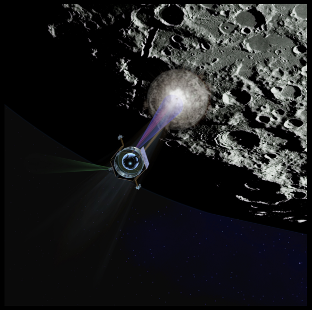


Image: K. Fisher 9-10-2009



Where

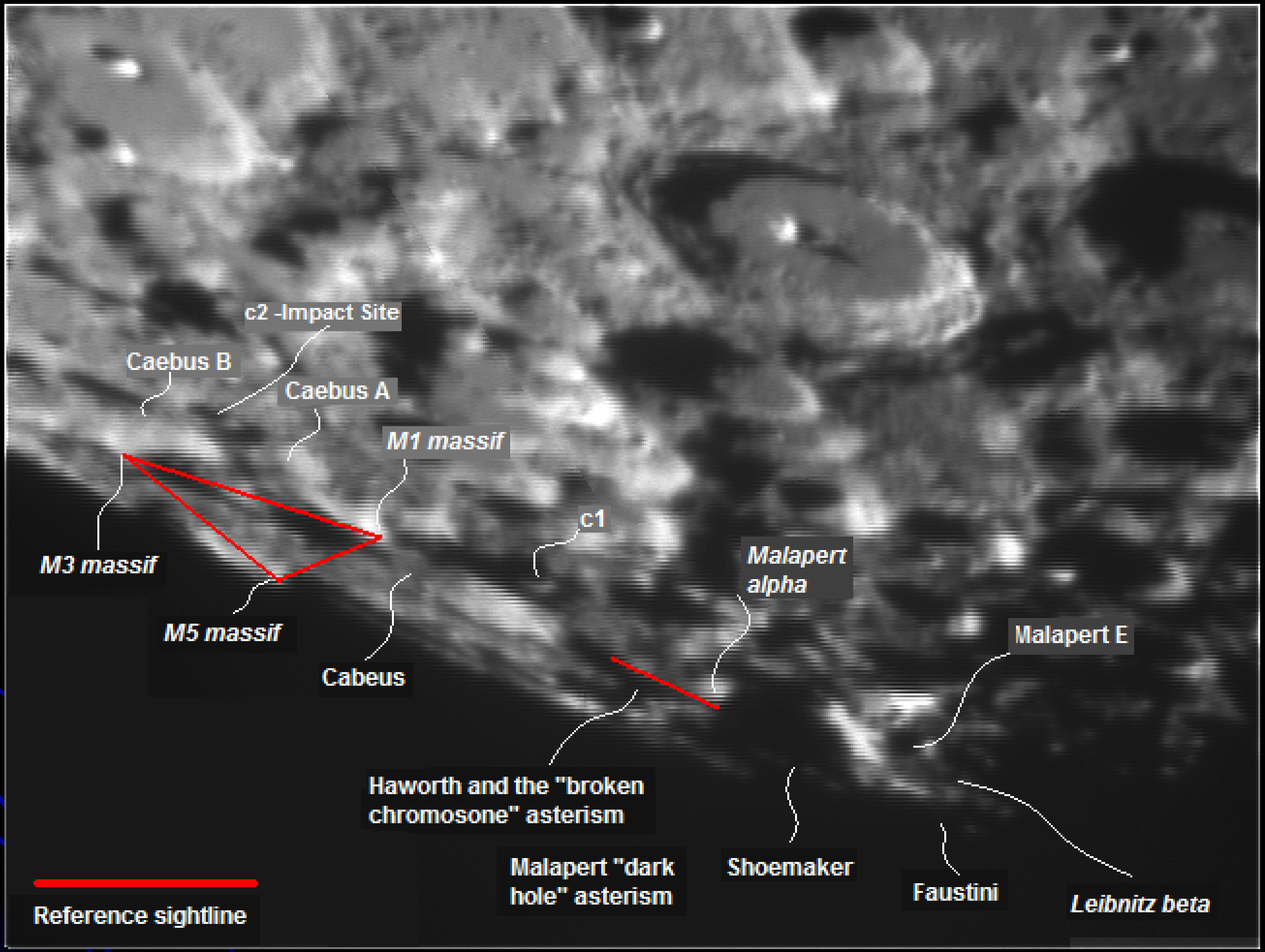
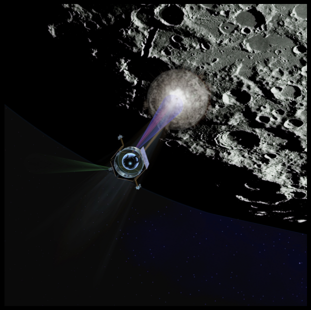


Image: K. Fisher 9-10-2009



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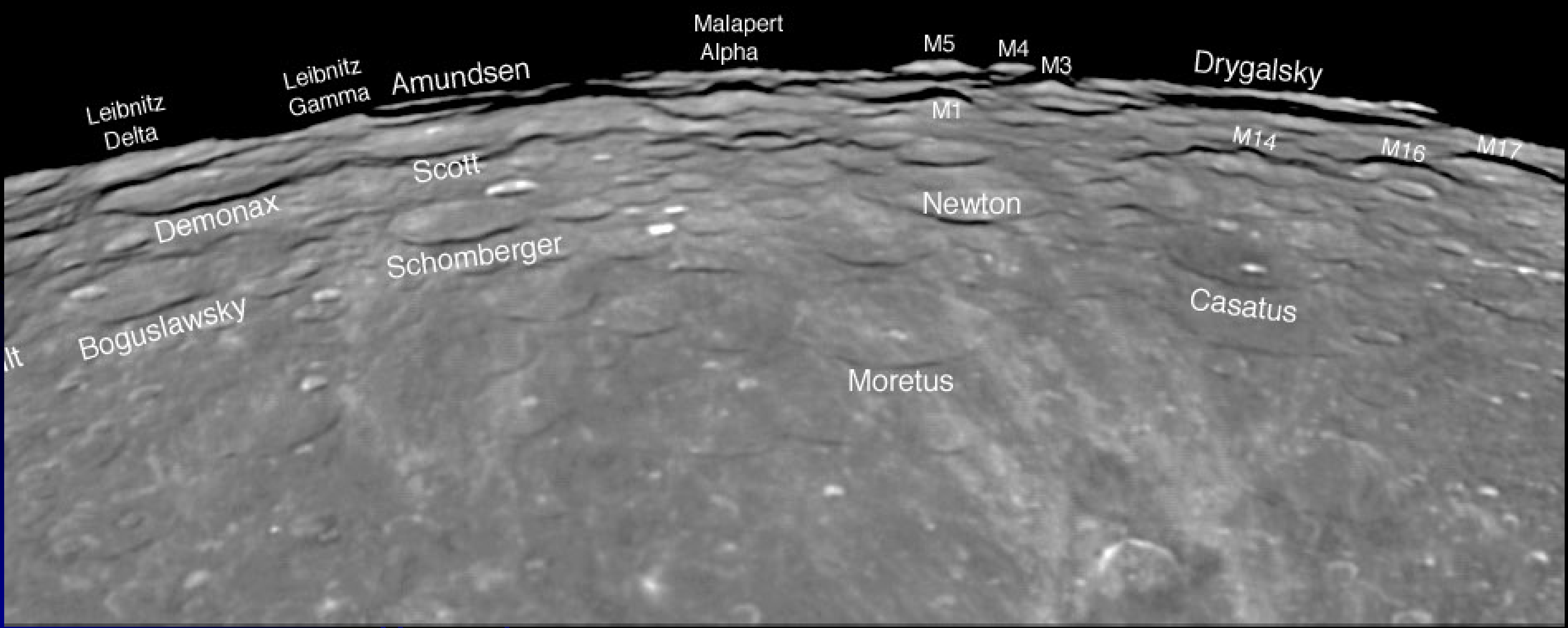
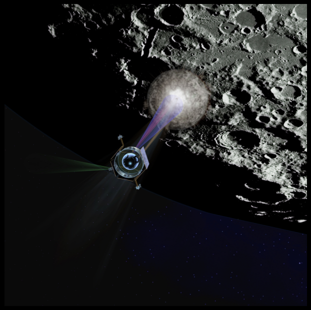


Image: Tom Bash. Used with permission.

Where



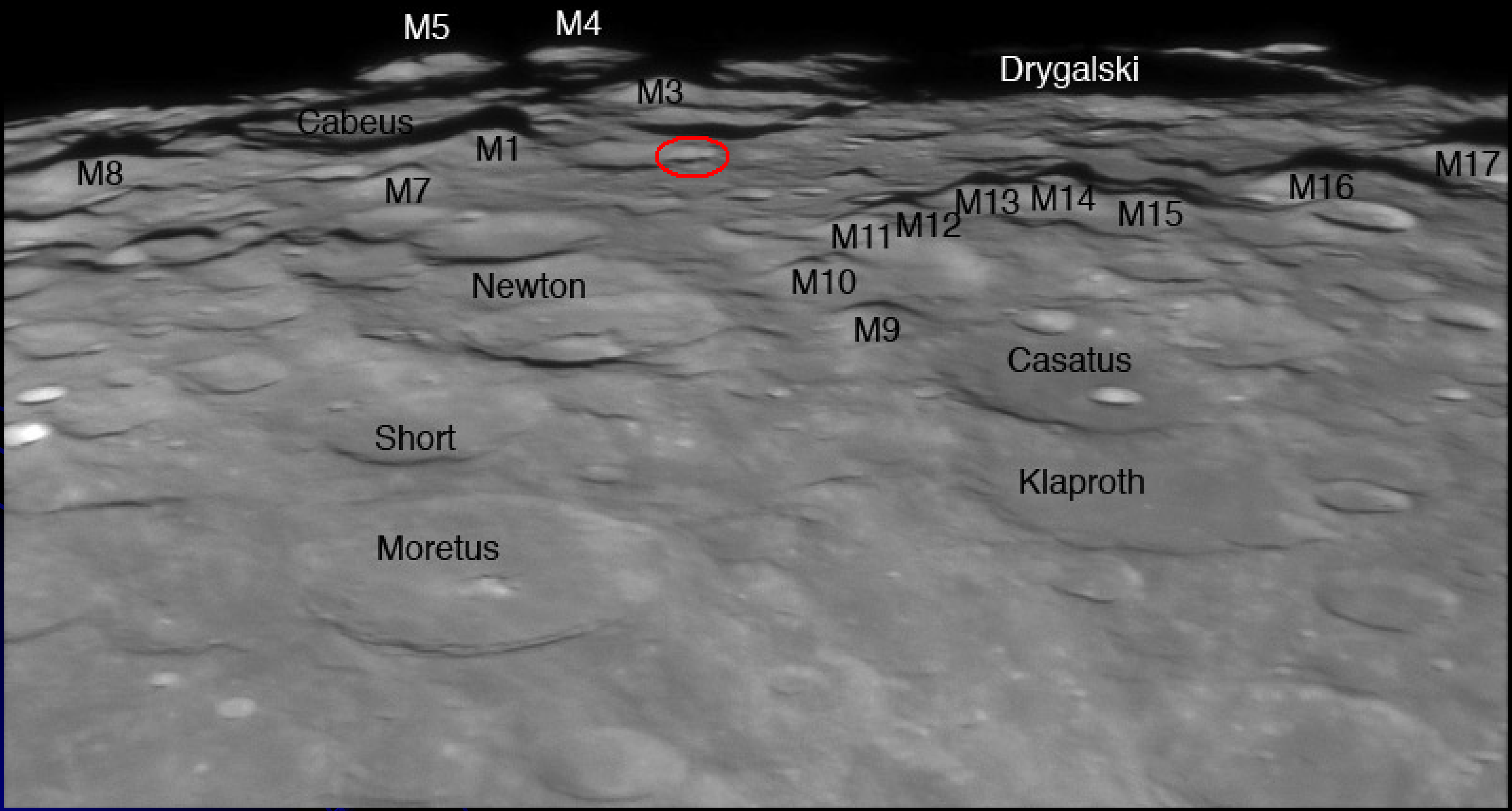
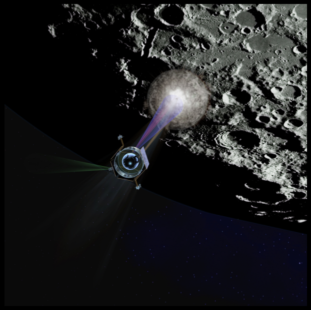


Image: Tom Bash. Used with permission.



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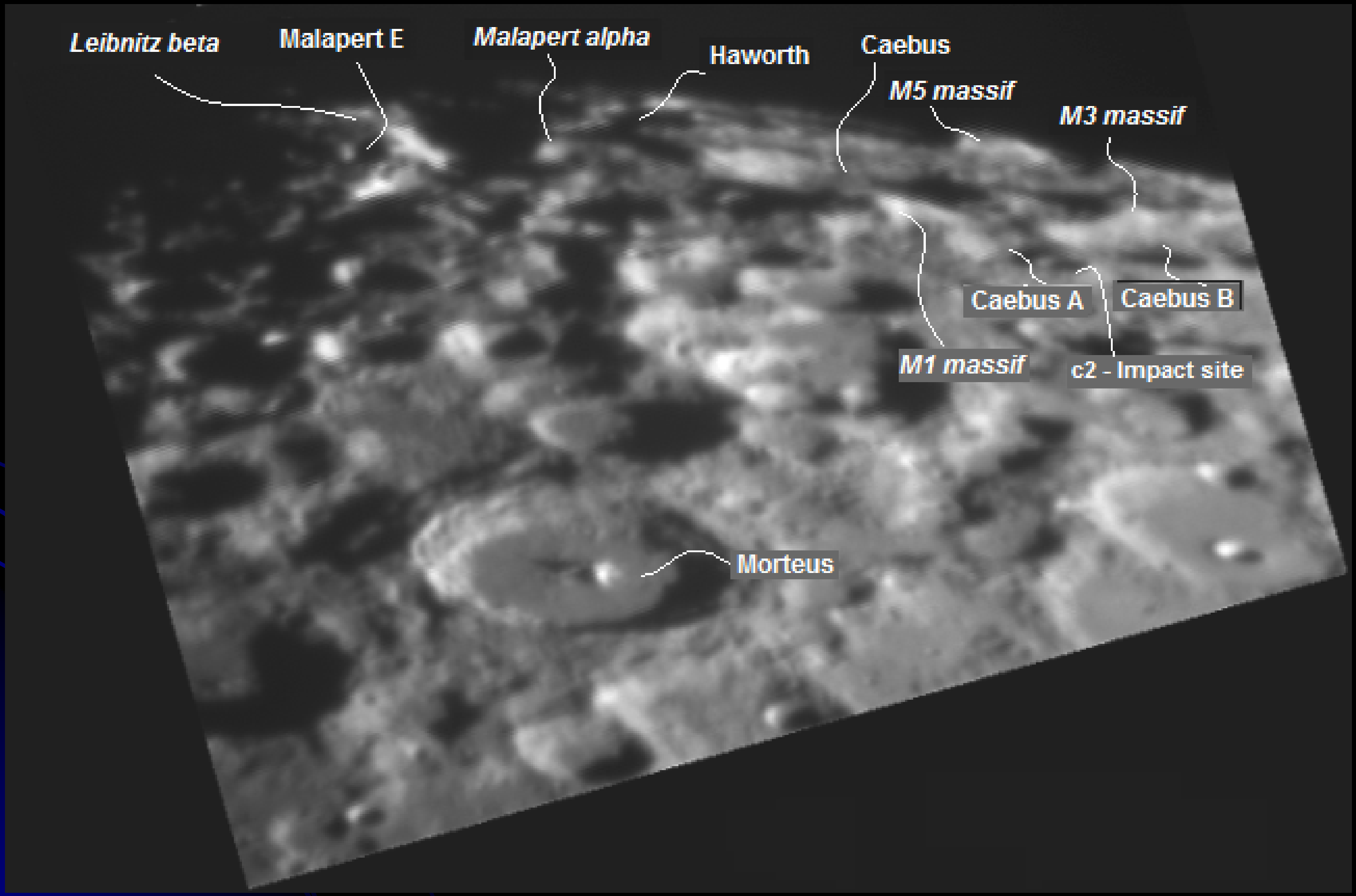
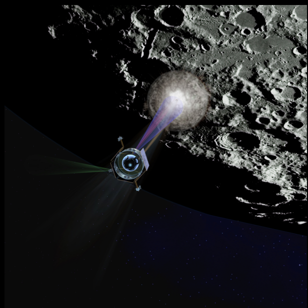


Image: K. Fisher 9-10-2009



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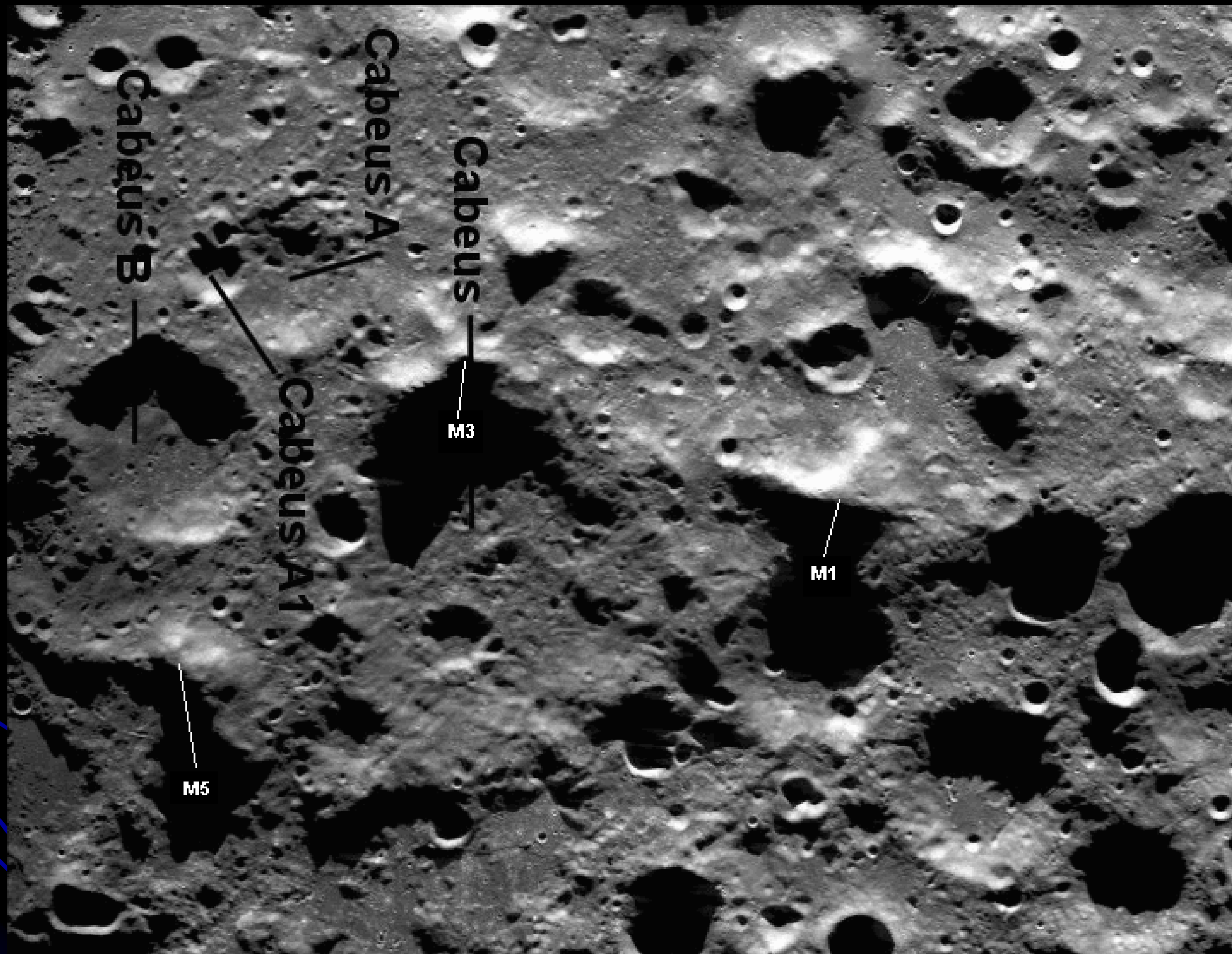
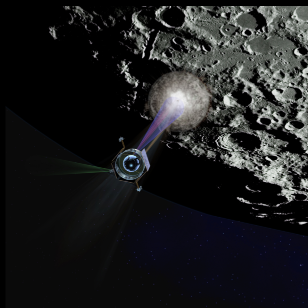


Illumination does not correspond to Oct. 9. Solar illumination will come from 331 degs az at impact. See red sun az angle arrow.

Image: NASA/JPL

Where



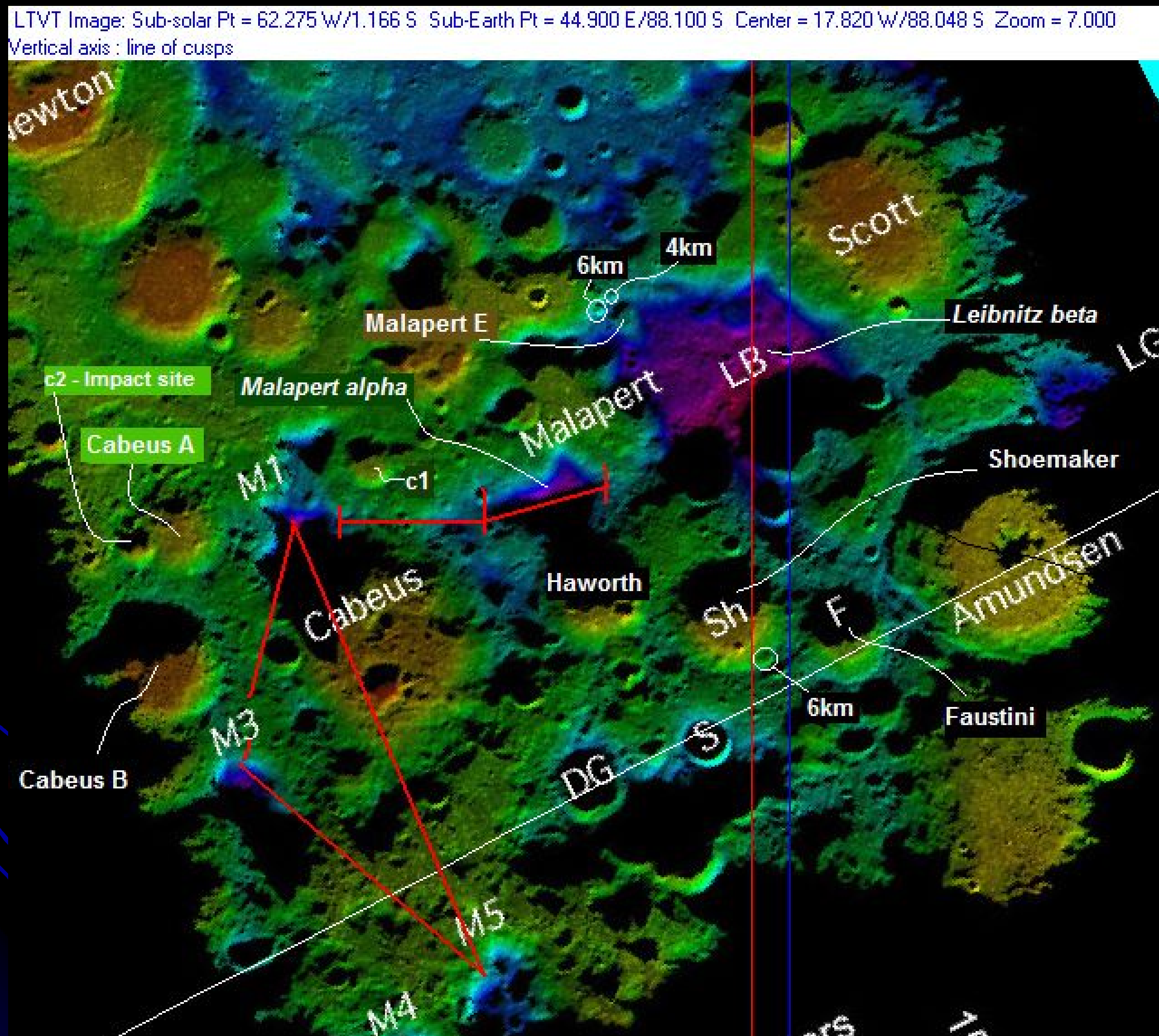
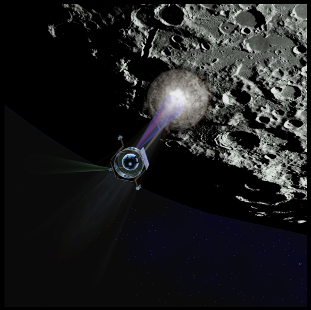


Image: NASA/JPL (Base topo map only)

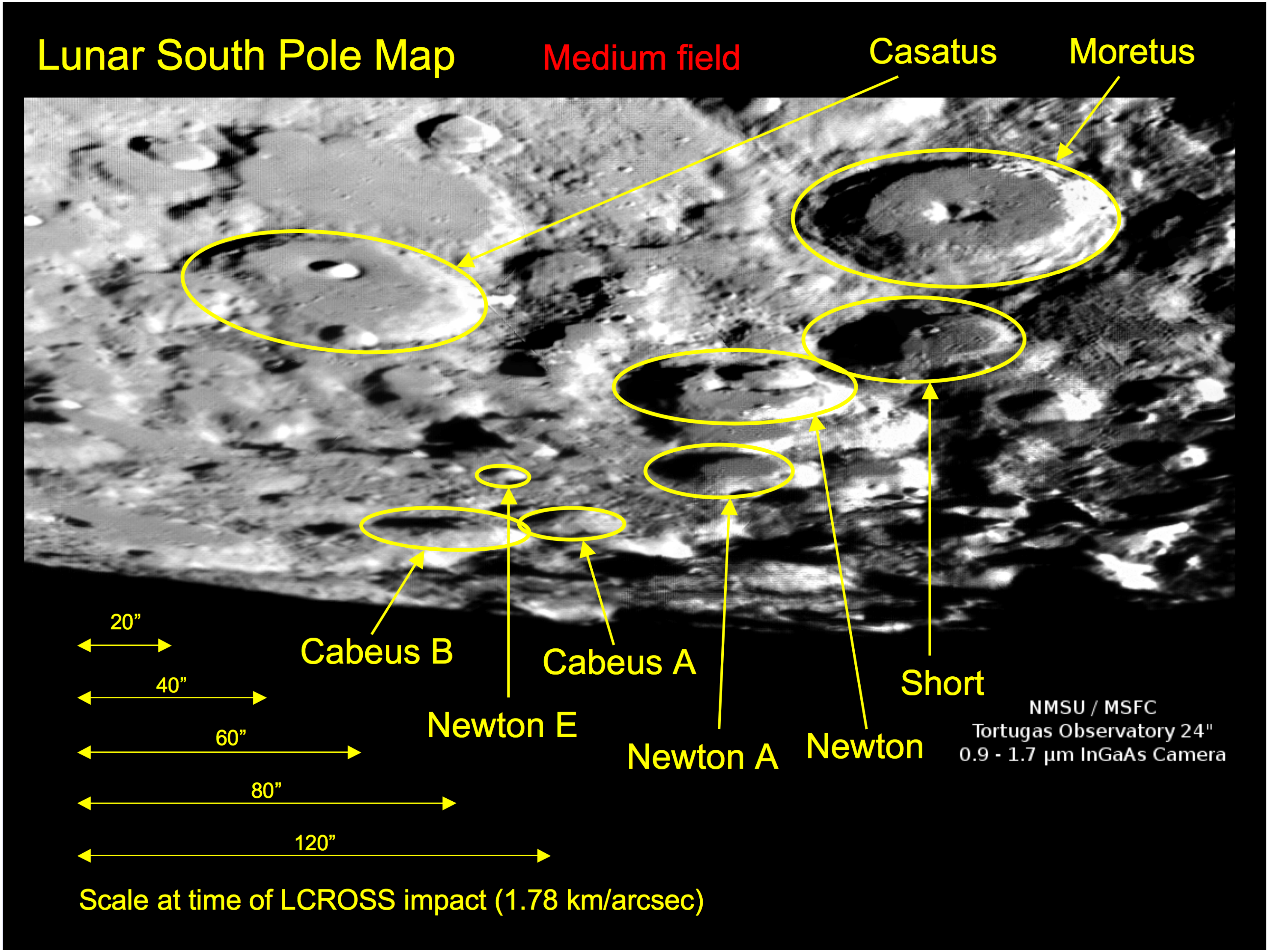


How big

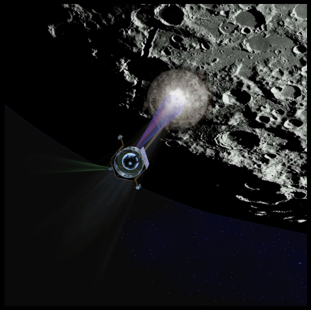
- 10km wide (5.6 arcsecs) by 5km (~3 arcsecs) with 3km (1.7 arcsecs) sticking above the rim.

External link to NASA First Step Video. Impact simulation is at minute 1:39.

NASA LCROSS First-Steps Video
url: http://www.nasa.gov/mission_pages/LCROSS/multimedia/arc-LCROSS_First_Step.html



Lunar South Pole Map
Medium field
Casatus
Moretus
Cabeus B
Newton E
Cabeus A
Newton A
Newton
Short
NMSU / MSFC
Tortugas Observatory 24"
0.9 - 1.7 μm InGaAs Camera
20"
40"
60"
80"
120"
Scale at time of LCROSS impact (1.78 km/arcsec)



How big

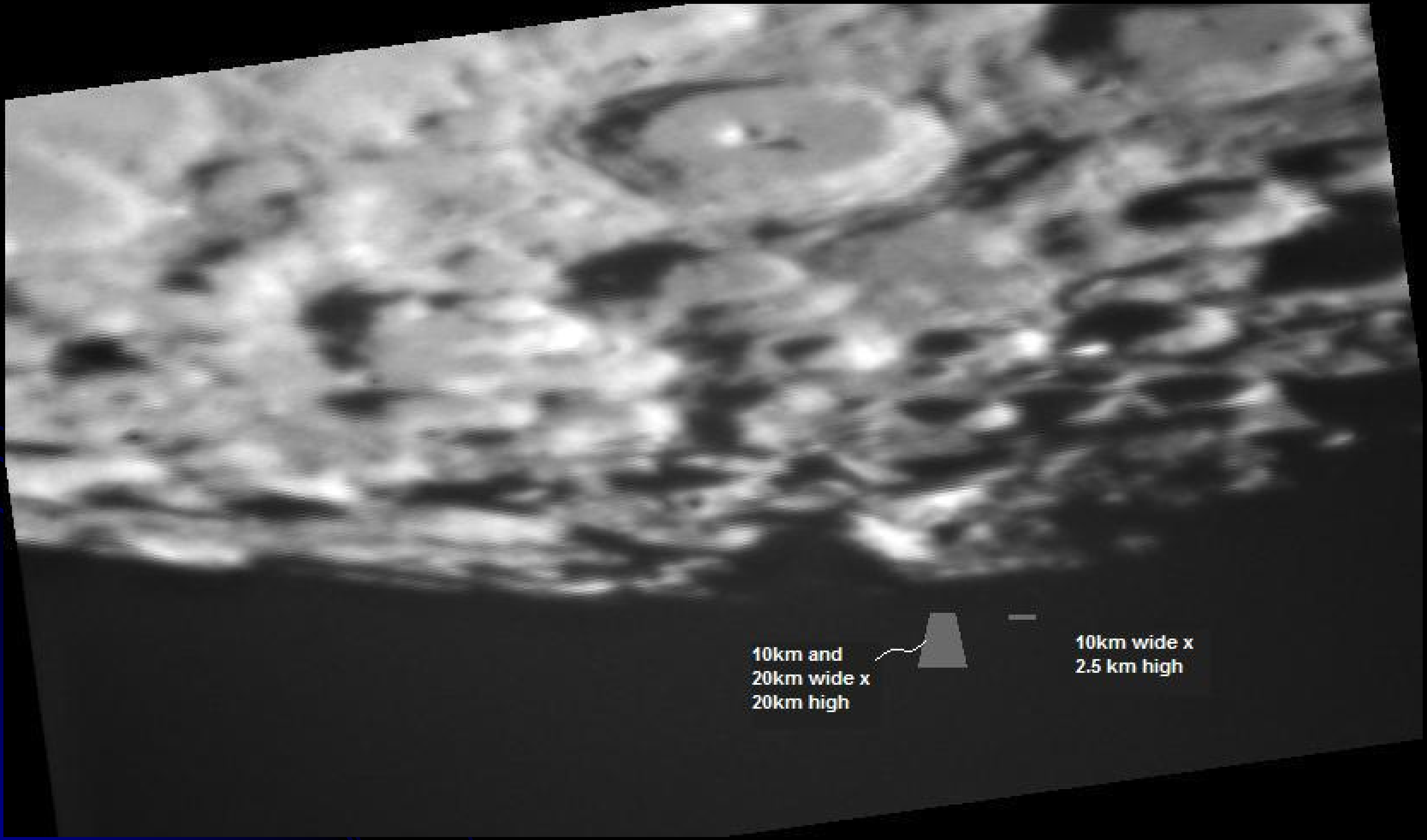
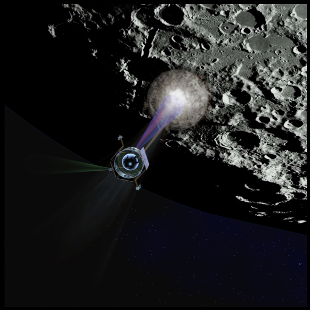


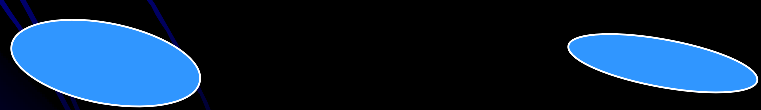
Image: K. Fisher 9-8-2009

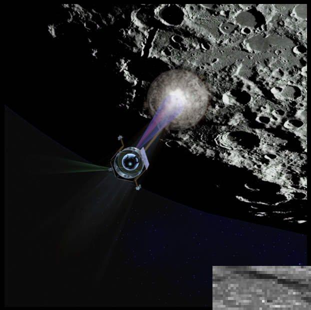


How big

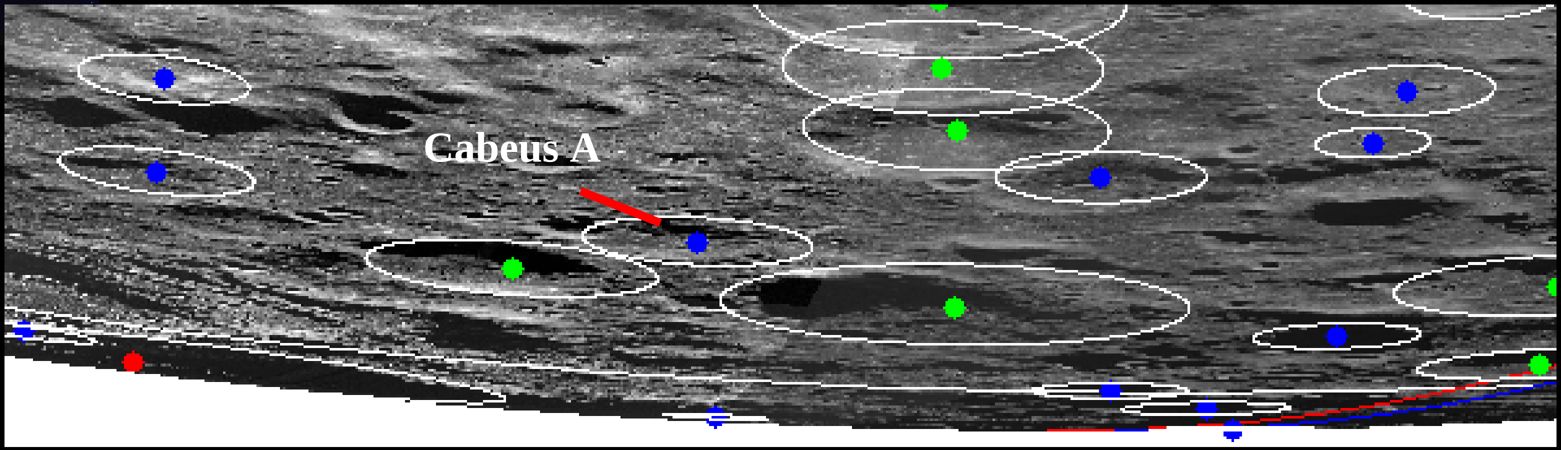
- Libration changes between 9-10-2009 and the 10-9-2009 impact will make Cabeus A1 look more linear than in the above images. Cabeus A1 will look more vertically “squished”.   The crater will appear closer to the southern lunar limb.
  - Libration in latitude on 9-10 ~ -5 degs
  - Libration in latitude on 10-9 ~ -3 degs

Sept. 9 Oct . 9

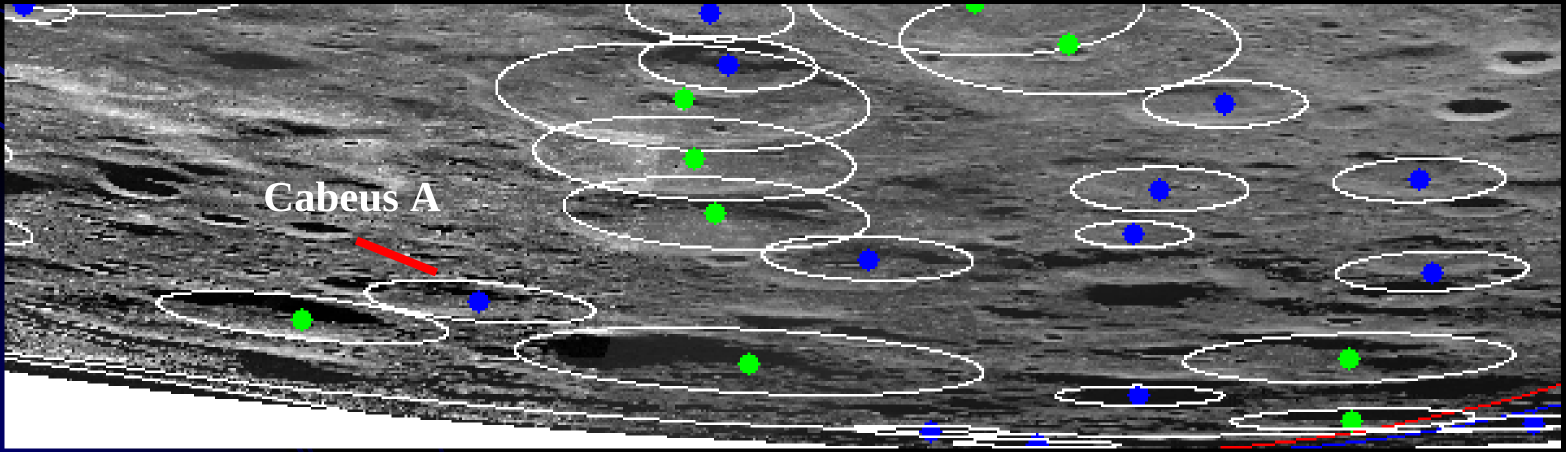




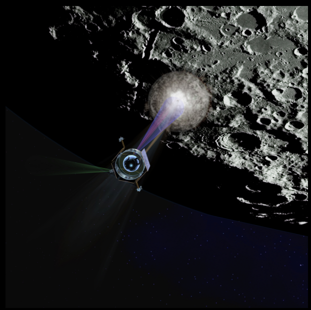
How big



South polar libration on Sept. 9 (above) compared to Oct. 10 (below)

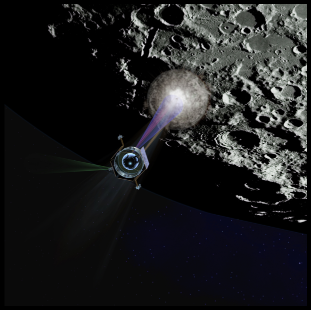


Images: Simulated lunar views generated using LTVT. http://ltvt.wikispaces.com/LTVT



How bright

- Cabeus A1 will become its brightest at 30 secs after impact reaching 4.0 mpsas (2.5 stellar magnitudes).
- The average large scale surface brightness of the Moon varies between 4 and 6 mpsas.
- The NASA-JPL Horizon ephemeris system models the average surface brightness of the sunlit porition of the Moon at 4.8 mpsas.
- The dark shadowed portion of Cabeus A1 should become as bright as the surface brightness of the surrounding terrain.



Bright enough?

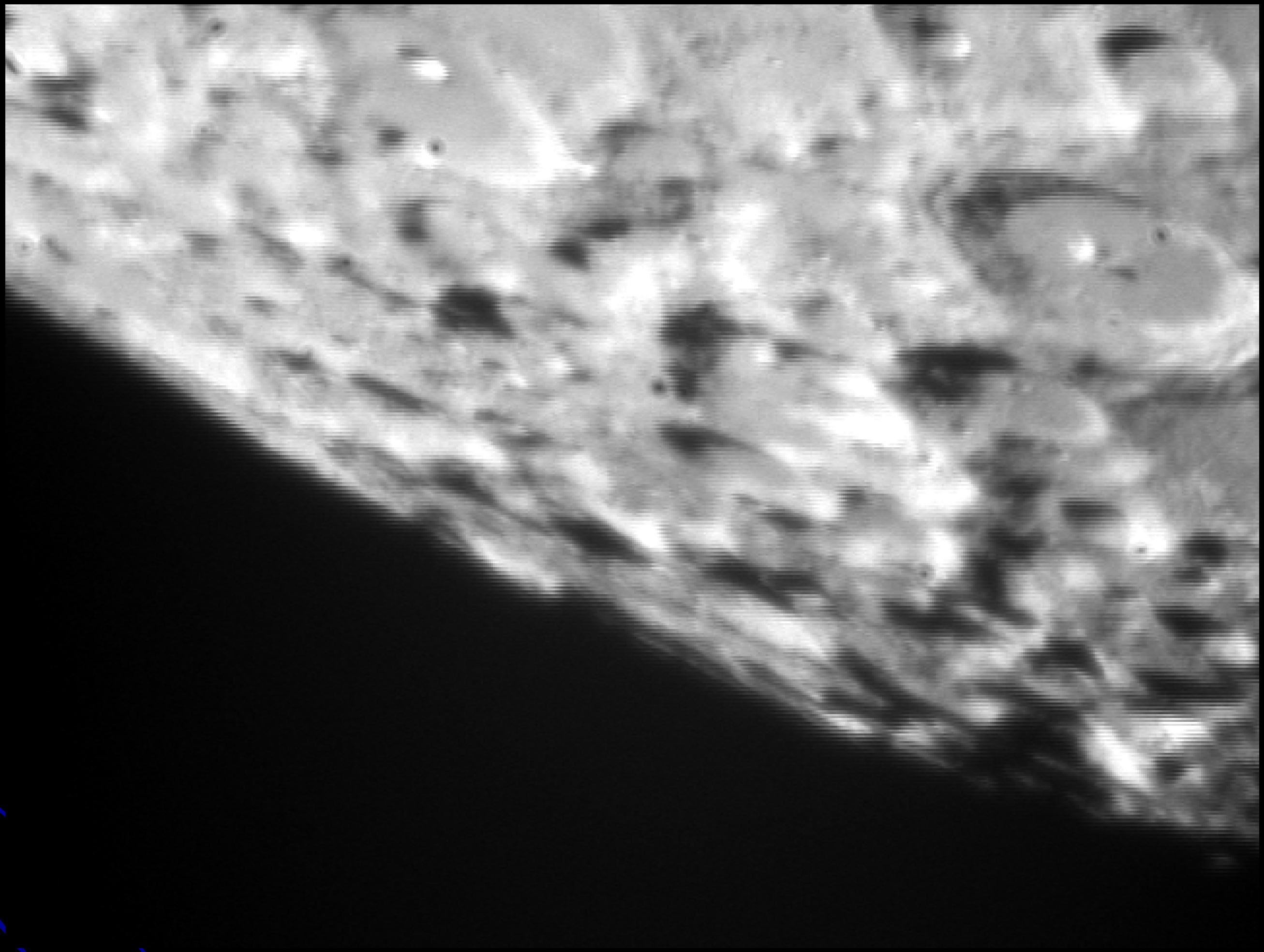
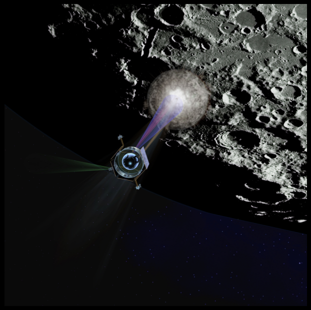


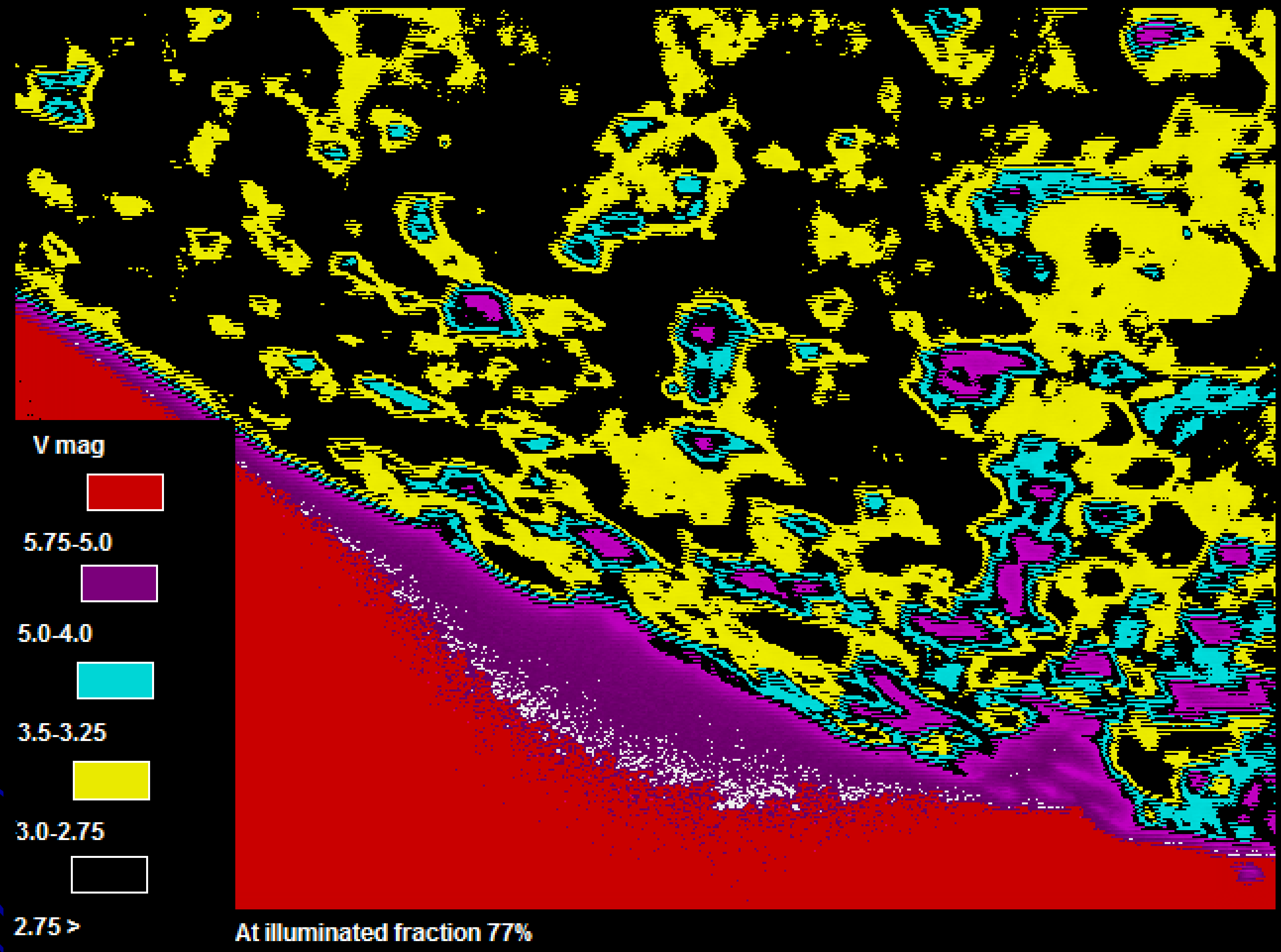
Image: K. Fisher 9-10-2009

The site-specific absolute and differential magnitude between the shadow within Cabeus A1 and the surrounding terrain has not been characterized. Is the shadowed portion of Cabeus A1 brighter than 4.0 mpsas?

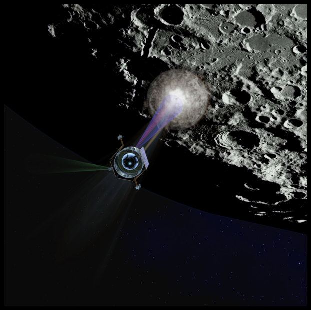


Bright enough?

Image: K. Fisher 9-10-2009

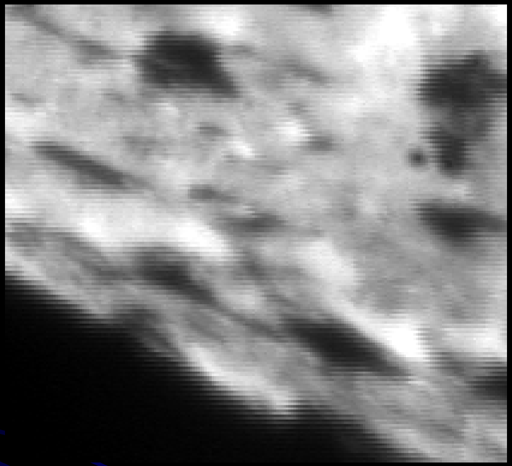


Differential magnitude experiment with amateur CCD camera. Absolute magnitudes are not scientifically valid. Is there a 1.5 magnitude difference between the surrounding surface and the dark shadow within Cabeus A1?

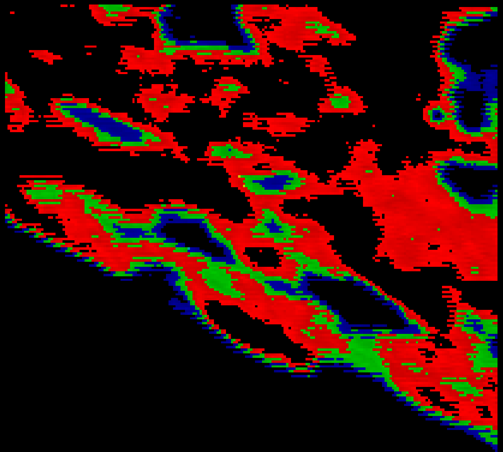


Bright Enough?

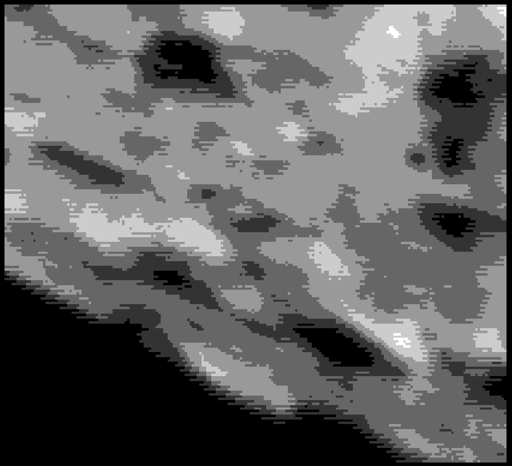
Raw



Colorgram slice



10 level quantized



Images: K. Fisher 9-10-2009

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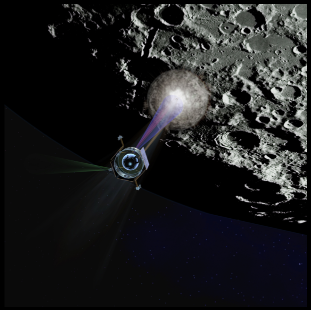
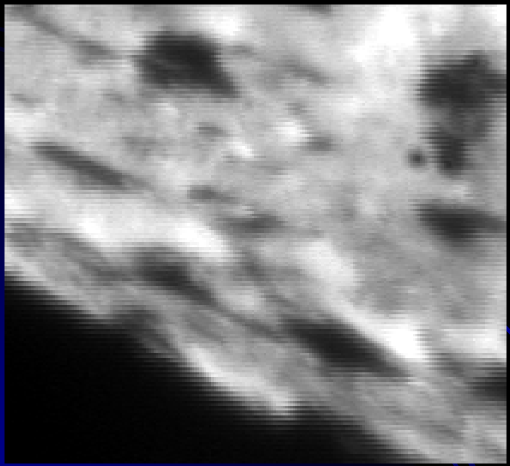


Bright Enough?

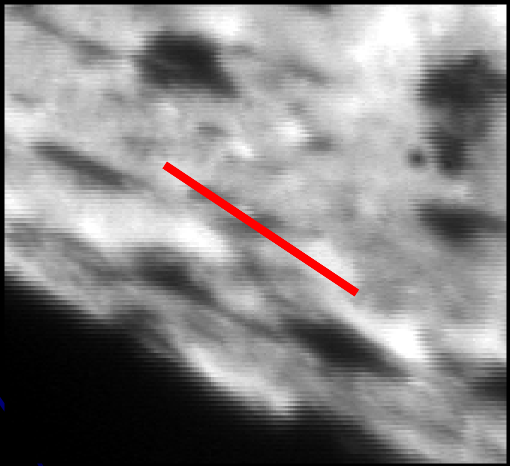
- A pixel value line profile on an amatuer image that crosses Cabeus A1 and Cabeus A suggests about an 0.75 to 1.25 stellar magnitude difference between the shadowed portion of Cabeus A1 and its brighter rim.

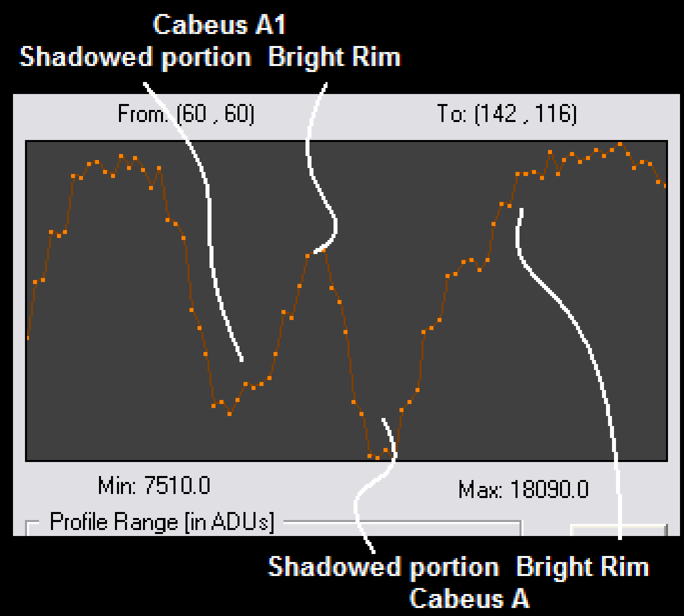
Histogram on single dark subtracted test frame created with Line Profile Tool

Raw

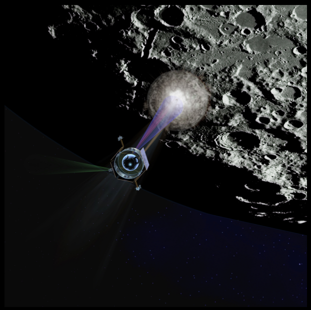


Raw with Line Profile Tool



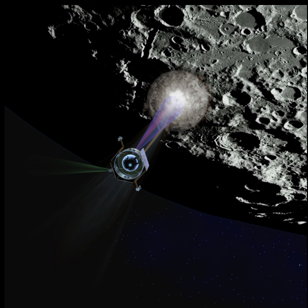


Images: K. Fisher 9-10-2009



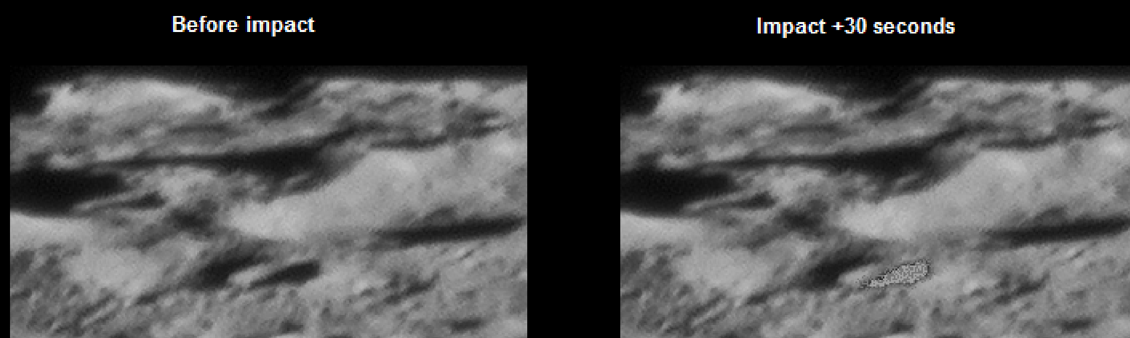
What will I see?

- Basically a contrast effect.   As the ejecta plume brightens to match the apparent brightness of the surrounding terrain, the crater will appear to fill-in.
- Cabeus A1 may take on a flat-top shape, a raised muffin shape, or disappear altogether for about 20 seconds.



What will I see?

Author’s hypothetical simulated impact image

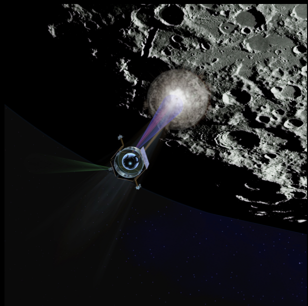


Base image credit: Stefan Lammel 9-9-2009 Used with permission.

- but anybody’s guess is a good as mine!

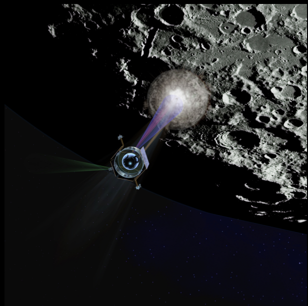
Uncertainty – Plume 4-6 mpsas

- LCROSS is a unique, novel experiment. Novel experiments involve systematic uncertainty flowing from the design and the unknown nature of independent variables.
- <u>Uncontrollable risks:</u>
  - The predicted 4-6 mpsas plume brightness is a best modeled value. Experimental unknowns that may result in an unobservable low plume brightness include:
    - <u>Plume model is wrong:</u> The plume prediction model may be wrong.
    - Soil different than assumed in the model: The lunar soil at the point of impact may have different characteristics than that assume in plume brightness models.
    - <u>Surface different than assumed in the model:</u> The impactor may strike an angled small hill or crater side. The angled surface will disperse the impact energy. The modeled plume assumes striking a flat surface.
    - Bad guiding: Guidance fails on the shepherding satellite and the impactor hits the wrong spot.
    - <u>Impact model is wrong:</u> In 2008, Russian scientists criticized that modeling of the impact erred because NASA LCROSS had used a solid, instead of hollow, impactor modeling. In early 2009, the LCROSS Team reran their computations for a hollow impactor and retested in the Ames high-velocity impact gun using a hollow sphere.
    - Since there is no way to really measure site specific grain size at Cabeus A1 except by driving an impactor into it – well, know you get the inherent experimental or systematic uncertainty problem.
  - Weather.
  - It’s an experiment. Sometimes experiments have unexpected results or fail.



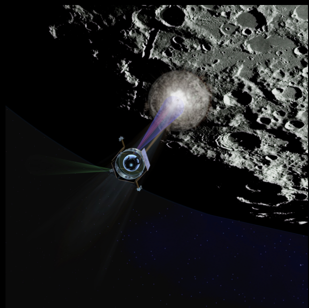
Uncertainty – Plume 4-6 mpsas

- Controllable risks:
  - No good site specific data on the apparent brightness in mpsas of the shadowed portion of Cabeus A1 or the apparent brightness in mpsas of the surrounding lunar surface has been collected. Solution: collect photometry.
  - Personal skill with your own telescope-camera system.



How to visually observe it

- Scope: 5 inches of aperature and above.
- Eyepiece: A good planetary 4mm – 6mm
- No filters, no aperature stopping.
- Visual observing will be at a high magnification, so lunar glare should not be a problem.
- If lunar is a problem, add one-half of a polarizing Moon filter to your eyepiece to polarize the light.
- Aperature stopping and glare reduction filters will reduce the amount of light coming off the faint ejecta plume, preventing you from seeing it.



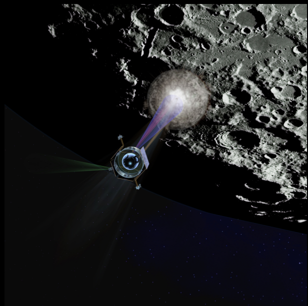
How to visually observe it

- Magnification: lunar planetary detail magnification suitable for your scope.
  - Knisley’s useful magnification guideline:

    Used For: Specific planetary lunar detail
    Useful Mag Description: Very high
    Low Mag Per Inch of Aperature: 30.0
    High Mag Per Inch of Aperature: 41.9
    Low Exit Pupil mm: 0.7
    High Exit Pupil mm: 0.6
- For a 10" aperature scope, the guidance magnification range is 300 to 410 power.

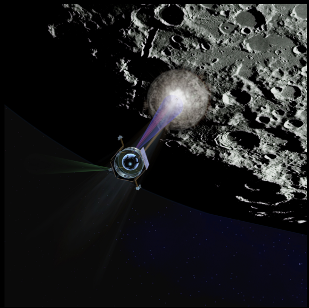
How to visually observe it

- Tracking
  - Because of the high magnification, tracking is necessary. High magnification may present a problem for box mounted Dobs.
  - Alt Az GOTO scope users may want to switch to equatorial mode.
    - With a Meade ETX 125, Alt Az tracking was do-able but needed bothersome adjustments at 300x even with training.
    - The Meade ETX 125 with polar equatorial tracked smoothly and needed minor adjustments.



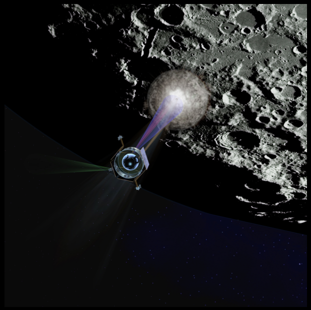
Visual workflow checklist

Activity	Duration	Timeline mins
Arrive at site locate observing stall	10 minutes	T-85
Setup and polar align scope	30 minutes	T-75
Target and focus on Cabeus A1	15 minutes	T-45
Retarget Cabeus A1. Sleep scope and camera	5 minutes	T-30
Break	20 minutes	T-25
Restart scope, retarget.	15 minutes	T-10



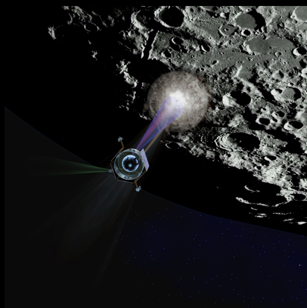
How to image it

- Equipment:
  - Match camera pixel size and equipment focal length.
  - See Sinnott's Effective Focal Length to Pixel Size nomogram, url - **http://media.skyandtelescope.com/images/Linked.gif**



How to image it

- Cleaning your optics
  - DSO imagers may not realize how much dust you have in your secondary optical train (camera, filters, etc.)
  - DSO imagers capture dark background images.
  - Many dust particles can hide in the dark background of DSO pics.
  - DOS imagers may find when they train their cameras on the bright Moon that you have a screen covered dust donuts in what you thought was a clean optical train.
- Recommendation:
  - Give yourself some extra time to clean your optics and camera.
  - Slightly defocusing on the brightest part of the sunlit portion of the Moon will give a good pseudo white flat for testing how clean you got your optics.
  - Remember to bring gear needed to clean your optics.

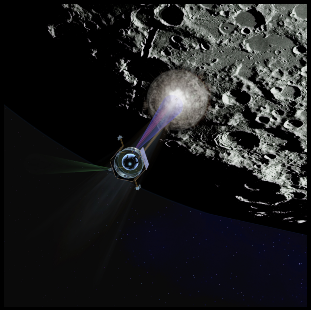


How to image it

- LCROSS Team imaging guidance – CCD and LPI cameras

  "Many advanced amateurs have Charge-Coupled Device (CCD) imaging equipment. Due to the relatively short exposures needed for plume imaging compared to what these cameras are designed for, auto-guiding and cooled detectors would not be necessary. Using CCDs would therefore be similar to imaging with a DSLR camera. CCD cameras can be calibrated, and therefore can provide much more detailed scientific information than either DSLR or video cameras. Tri-color imaging with CCD cameras is also possible, but usually requires a 'stationary' target due to the multiple exposures through different filters needed. The plume would 'smear' between exposures. However, color information could be an extra boon to the scientific community to warrant the effort of obtaining tri-color data."

Source: LCROSS Team Citizen Science About Page http://apps.nasa.gov/lcross/about/ (9-15)

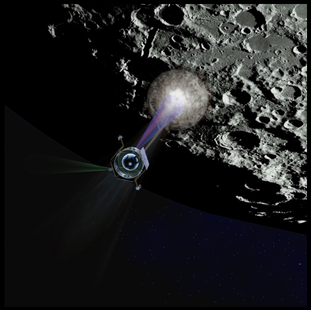


How to image it

- LCROSS Team imaging guidance – Video

  "Video imaging is generally more difficult, but good low-light video cameras are commercially and easily available. C-mount cameras are best, which have no intervening lens and can be used prime-focus on a telescope with an appropriate C-mount/T-adapter to the telescope's focusing tube. Black and white cameras are much more sensitive than color cameras. Low-light cameras are excellent choices, but cameras with variable gain and frame integrating features are far superior in imaging sensitivity and control. The small chip size of many of these cameras (1/3") dictates an EFL of around 2,000 mm be used. As with still photography, if 9th magnitude stars away from the Moon can be imaged, there is a good chance the plume with be recorded."

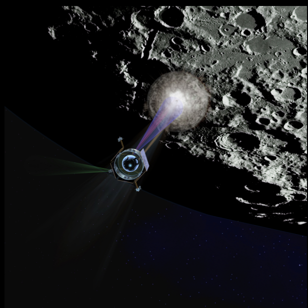
Source: LCROSS Team Citizen Science About Page http://apps.nasa.gov/lcross/about/ (9-15)



How to image it

- LCROSS Team imaging guidance – filters
  - "However, observations are not trivial as the dust cloud may have a brightly lit Moon surface behind it, depending on the exact impact site selected, making it more difficult to see the dust cloud due to the poor contrast; bright dust against a bright Moon surface. The dust will polarize the scattered light but using polarimetery can help with the observation."
  - Translation: Put one-half of a variable Moon filter into your optical train.

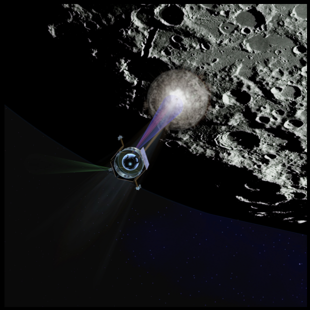
Source: LCROSS Team Citizen Science About Page http://apps.nasa.gov/lcross/about/ (9-15)

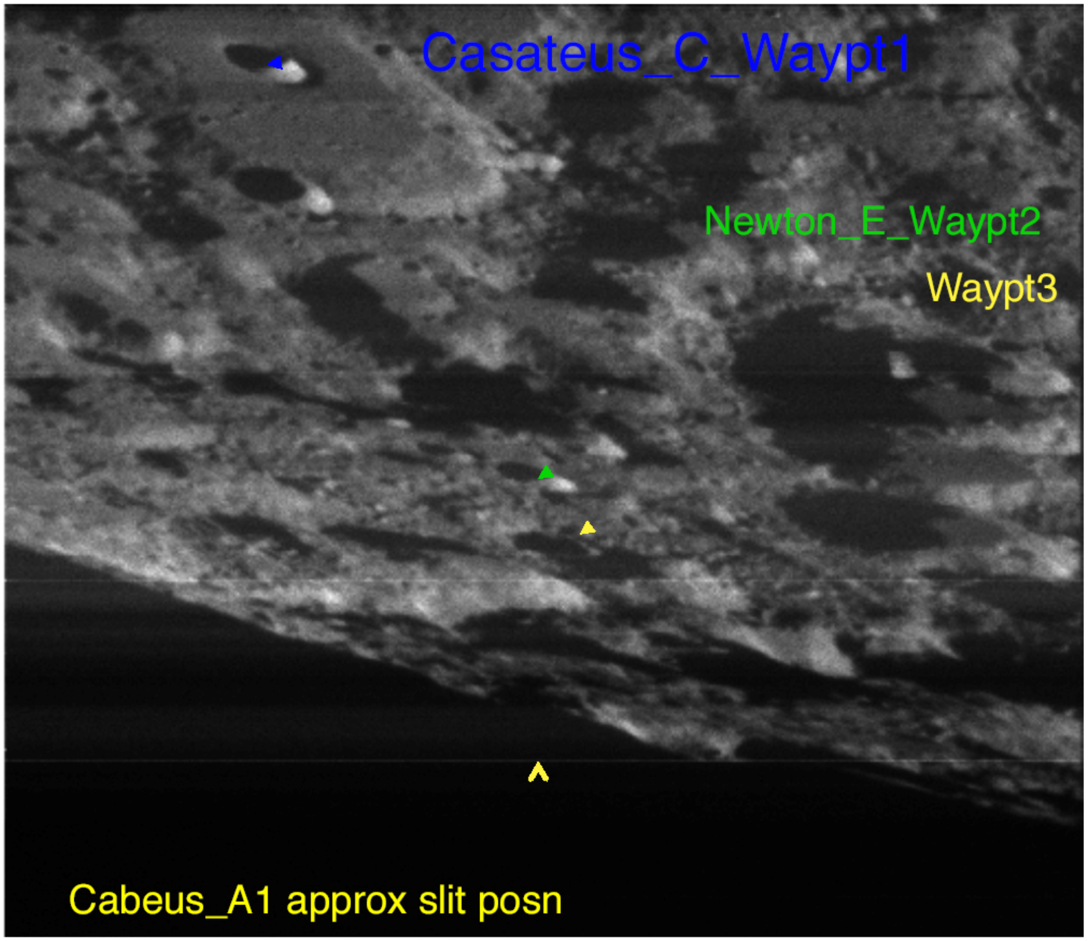


How to image it

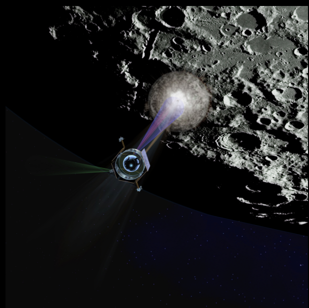
- Other LCROSS Team related filter tip
  - When making the Gemini North targeting image made for spectroscopy, the investigator used a V-block filter "in two formats, at G-band (398-552 nm)+ RG610 (blue blocking) to avoid saturation." (See next slide for image.)
  - This might be a filter strategy for amateurs to explore.

How to image it



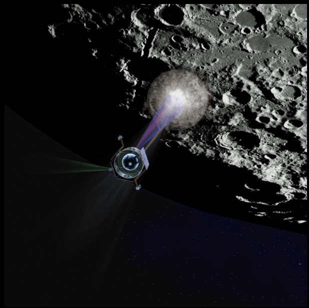


2009-sep 11 13:12UT Gemini-N Acquisition Camera
LCROSS GBOC Mauna Kea Spectroscopy Team including
Wooden, Woodward, Lucey, Harker, Young, Kelley, Geballe, Stephens, Roth, et al.



How to image it

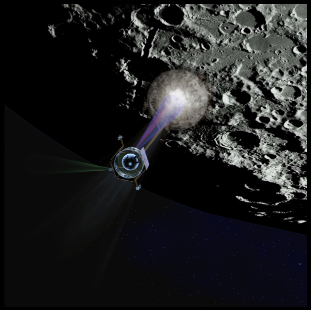
- This author’s alternative imaging protocol
  - High focal length imaging is preferred in order to minimize the percent of the sunlit lunar disk captured in a frame.
  - High focal lengths dictate that large pixel DSLR cameras and CCD cameras are disfavored relative to small pixel sized fast moderate and high-end lunar imaging cameras.
  - Typical exposures are at elfs above 3000mm, f/20 to f/30 at 0.01 to 0.06 (V filter) seconds.



How to image it

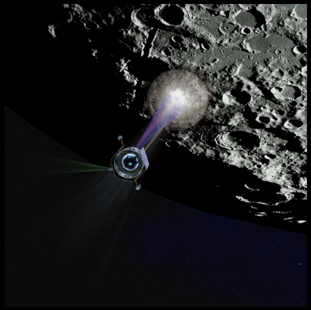
- This author's alternative imaging protocol
  - High effective focal length imaging is indicated by the need to minimize lunar glare.
  - Lunar glare is proportional to the fraction of the Moon's disk that appears in your image frame.
  - A higher fraction of Moon in your image, the higher the lowest pixel value you can capture on a feature the is partially illuminated in low-light. This effects your ability to see changes in the shadowed portion of Caebus A1.
  - Higher efls mean a lower fraction of the Moon will appear in an image frame.

Image: Slooh widefield 9-10-2009



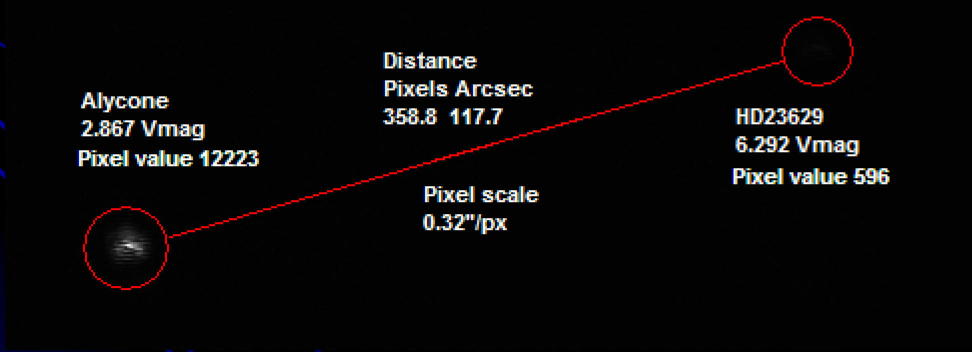
How to image it

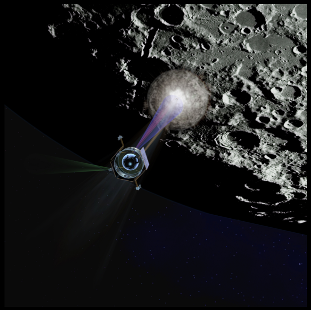
- This author’s alternative imaging protocol
  - The goal of this protocol is to set the pixel value of the brightest edge of the rim of Cabeus A1 to 75% of your camera's well capacity in ADUs.
- Optional exposure calibration to a 2.5 mag star
  - Calibrate an exposure to a 2.5 mag A-O-B star.
  - Exposure calibration stars: theta Auriga 2.6 mags; zeta Per 2.8mags B0.5V, delta Orion 2.2 mags O9.5II, gamma Gem 1.9 mags AOIV, beta Auriga 1.9 mags A2IV.
  - The stellar calibration frame can also be used to measure the image scale of your camera.



How to image it

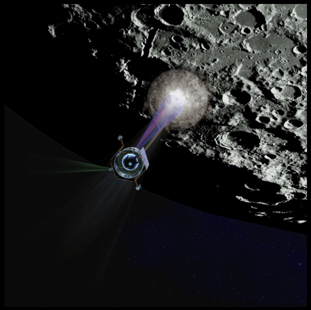
- Optional exposure calibration to star
  - Store 10 to 20 reference images of your calibration star with a close by star in order to compute the image scale and ADUs of your lunar image after the impact.





How to image it

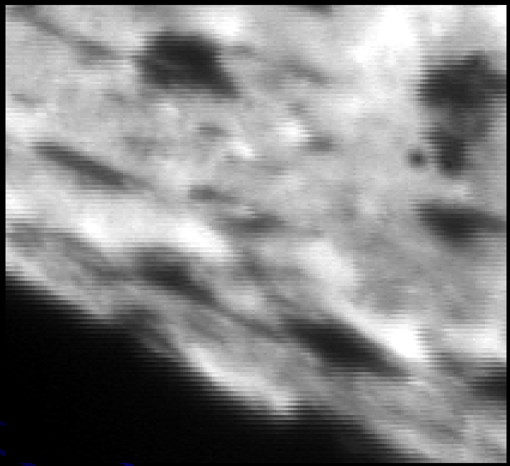
- Exposure calibration to crater line profile measurement
  - Slew and target Cabeus A1. Make focus adjustment.
  - Take test frames.
  - Open test frames in your image processing software and take a profile measurement across Cabeus A1, covering the bright rim, the sunlit crater floor, the shadowed crater floor and the opposite bright rim.
  - Adjust exposure time until test frames are such that the Cabeus A1 bright crater rim is between 50%-75% of your ADU well capacity.
  - Check that the pixel values that cover the range for the dark shadowed portion of Cabeus A1 are somewhere above 25% of the your ADU well capacity.



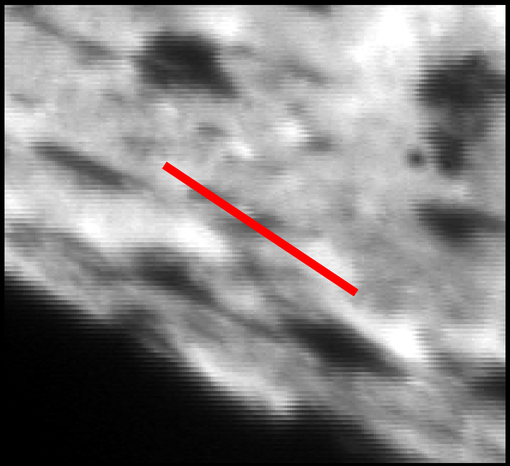
How to image it

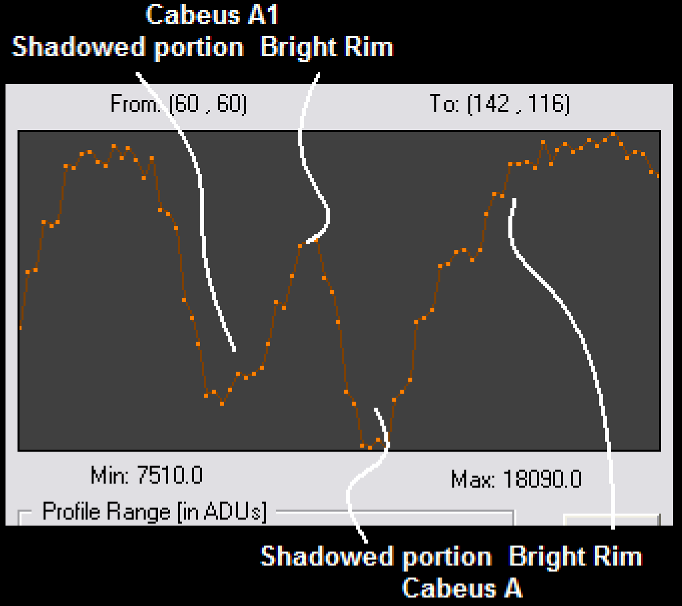
Histogram on single dark subtracted test frame created with Line Profile Tool

Raw



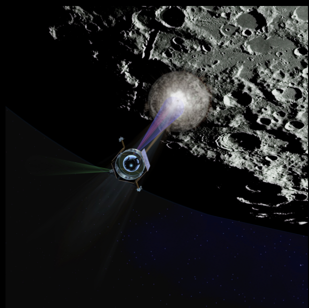
Raw with Line Profile Tool





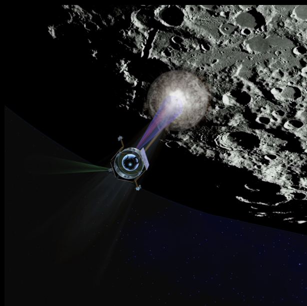
Images: K. Fisher 9-10-2009

Example of pre-impact exposure calibration using the Line Profile Tool in AIP4WIN across Cabeus A1. Calibrate image exposure time so that all pixels in the pixel value range between the bright rim of Cabeus A1 and the dark shadow portion of the crater are between about 50% and 75% of your well capacity in ADUs. Tweak adjustment so the brightest parts of lunar surface in the image frame are not overexposed, while still preserving exposure of key Cabeus A1 pixel value range. You may want to elect to overexpose the brightest parts of the image frame in order to best match the Cabeus A1 region-of-interest to your well ADU capacity.



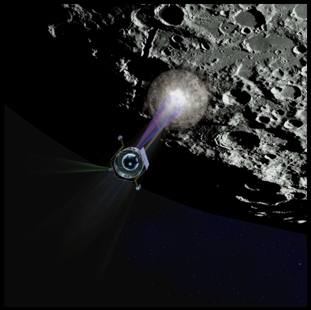
How to image it

- This author's alternative imaging protocol
  - Finish by making your white flats with a white light box and taking your darks.
  - Re-target Cabeus A1 and sleep your scope until about 15 minutes before the impact.



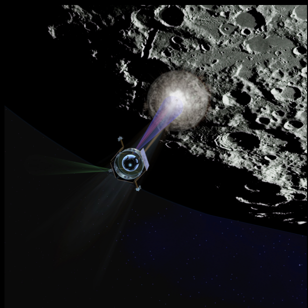
Timing when to look or image

- Group observing with a portable dish TV receiver as a central component is recommended.
- NASA TV will be broadcasting the impact live – Ranger 9 style.
- With a portable dish setup, a group of observers will have a time certain to start and stop their imaging cameras.
- Alternatively, one club member can monitor the NASA TV website and run a cell phone tree notifying remote observers and imagers.
- Group observing allows supports sharing of white light boxes for making white flats.



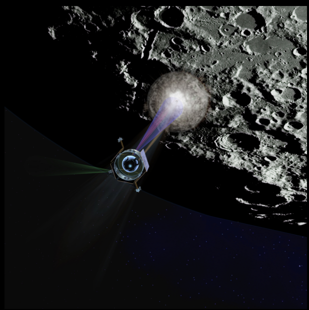
Imaging workflow checklist

Activity	Duration	Timeline mins
Arrive at site locate observing stall	10 minutes	T-150
Setup and polar align scope	30 minutes	T-140
Image calibration star	20 minutes	T-110
Defocus on bright Moon and clean optics	15 minutes	T-90
Target and focus on Cabeus A1	15 minutes	T-75
Make dark and white flats	20 minutes	T-60
Retarget Cabeus A1. Sleep scope and camera	5 minutes	T-40
Break	20 minutes	T-35
Restart scope, retarget and warm-up camera before impact	15 minutes	T-15



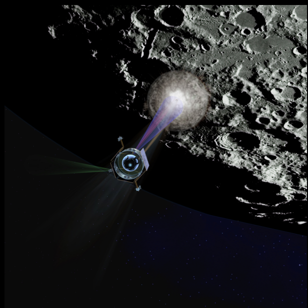
How to watch it live on a feed from the nose cone cam

- NASA TV on the internet
  - http://www.nasa.gov/multimedia/nasatv/index.html
- NASA TV on your local cable or dish provider
- LCROSS Team nose cone cam internet feed
  - To be announced. See http://www.nasa.gov/mission_pages/LCROSS/news/index.html



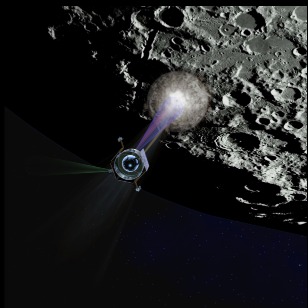
Kinematics

- During first 30 seconds, the ejecta curtain will vertically rise 5000 meters as it reaches maximum brightness.
- Vertical average speed:
  - 167 meters sec-1
  - 610 kilometers hour-1
  - 547 feet sec-1
  - 373 miles hour-1
- For period Impact +12 seconds to Impact + 30 seconds, the ejecta curtain will rise for 3000 meters above the crater rim.



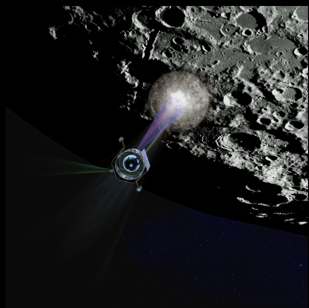
Kinematics

- A lunar occultation recording setup might be used to capture a video and audio time-stamped AVI file at 1/60 to 1/30 frames per second.
- Post impact the video recording can be analyzed by plotting time against the average pixel value for the area within Cabeus A1’s rim.



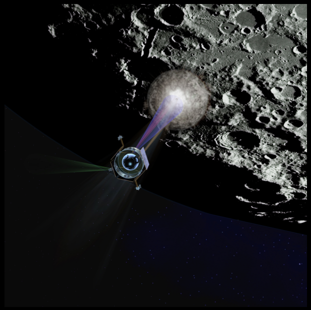
Kinematics

- Equipment – a very basic video with audio time stamp recording setup
  - LPI camera (Celestron NexStar LPI)
  - Laptop for video-audio recording
  - USB Audio-digital converter (Belkin)
  - Audio time signal source
    - Digital metronome (Ibanez)
    - Short-wave radio tuned to NIST WWW time signal (Radio Shack)



Practice Run – Sept. 27

- The last practice date for testing your imaging setup and south polar navigation at high-magnification is September 27.
- On September 27, the Moon will be illuminated at about a 71% illuminated fraction.
- But the Sun will be coming from the lunar east instead of the lunar west.
- Cabeus A1 will be in shadow on the west side of the south lunar pole.
- The Moon will be low in the sky at about 26 degrees altitude 30 instead of at the 70 degrees altitude on October 9.



Practice Run – Sept. 27

- Small southern polar craters on Sept. 27 that are analogous in size, but not in illumination to Caebus A1 on October 9.

Crater	Latitude	Longitude	Dia. km
Schomberger G	77.1S	E7.7	17
Schomberger H	77.4S	E4.0	17
Schomberger L	80.6S	E17.5	17
Simpelius J	76.1S	E8.4	17

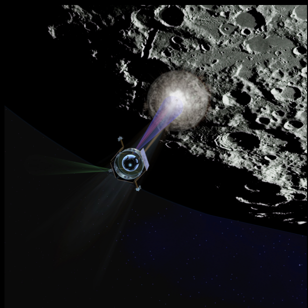
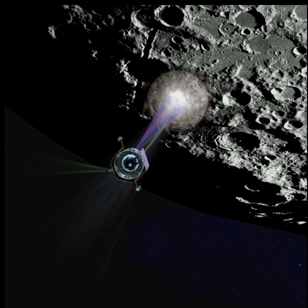


Image processing

- Image processing programs that support region-of-interest masking will probably be favored, e.g. Photoshop.
- That way a few selected crisp frames can be stacked, but the bright lunar surface and the shadowed portion of Caebus A1 can be gamma stretched separately.
- Note that Registax processing, by design, erases any changes between a series of registered images. E.g. – Registax “erases” dust donuts that drift across the stationary lunar surface background of a registered AVI recording.
- Registax also might digitally erase the ejecta curtain – a moving object – when processing an AVI file.
- A better strategy might be to hand review images and manually collect two or three crisp images that are within single second time frames.
- Stack and process those groups of two or three frames.
- Then assemble the result into an animated gif or in one time-series image using transparent layers.
- Difference image processing, which is normally applied to comets, might be a processing strategy to explore in this context.



Sharing your images

- The NASA LCROSS Citizen Science page is intended as a public gallery on which images from the global amateur community can be posted.

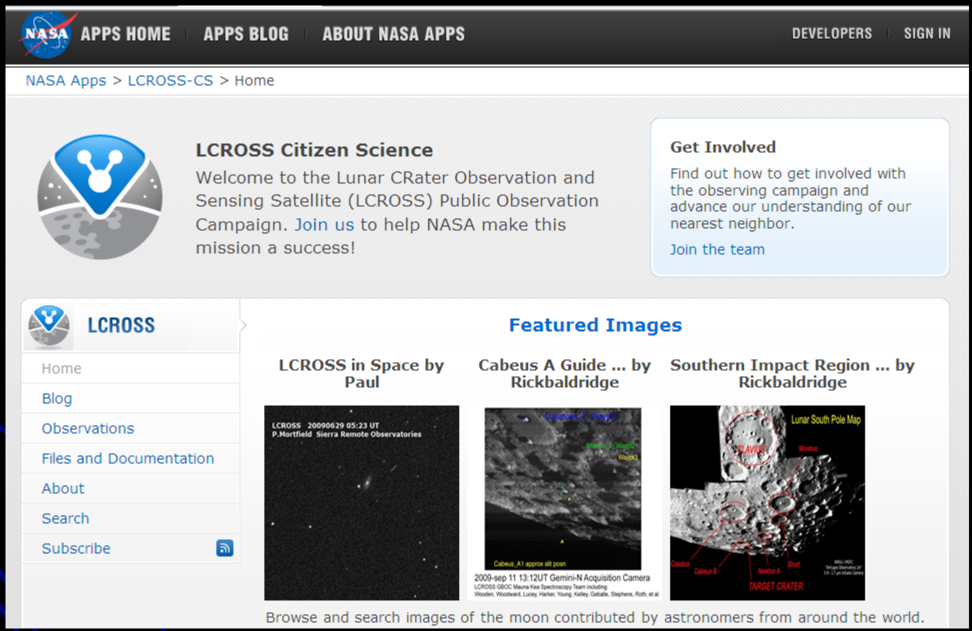
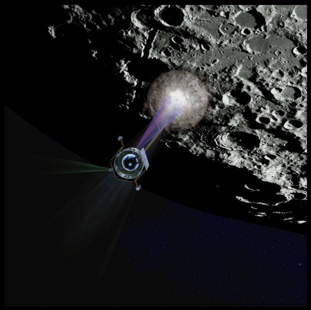


Image: LCROSS Team Citizen Science Page http://apps.nasa.gov/lcross/ (9-15)



Web links

- LCROSS Observation Group Finders page
  - http://groups.google.com/group/lcross_observation/web/finders
- Jim Mosher's LCROSS Impact Wiki Page
  - http://ltvt.wikispaces.com/LCROSS+Impact
- New Mexico State Univ. Tortugas Observatory LCROSS Site Finders (9-2009)
  - http://astronomy.nmsu.edu/rthamilt/LCROSS/media.shtml
- NASA LCROSS Citizen Science Site (9-2009)
  - http://apps.nasa.gov/lcross/
- LCROSS Team Observation Campaign Page
  - http://lcross.arc.nasa.gov/observation.htm
- Selenology Today No. 15 (Sept. 2009)
  - http://digilander.libero.it/glrgroup/selenologytoday15.pdf
- NASA LCROSS News and Info Page
  - http://www.nasa.gov/mission_pages/LCROSS/news/index.html