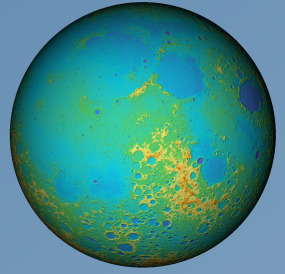


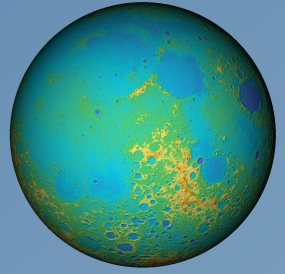
Lunar Reconnaissance Orbiter Data Workshop LROC

46th LPSC

March 15, 2016

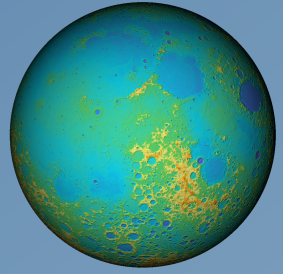
The Woodlands

Overview

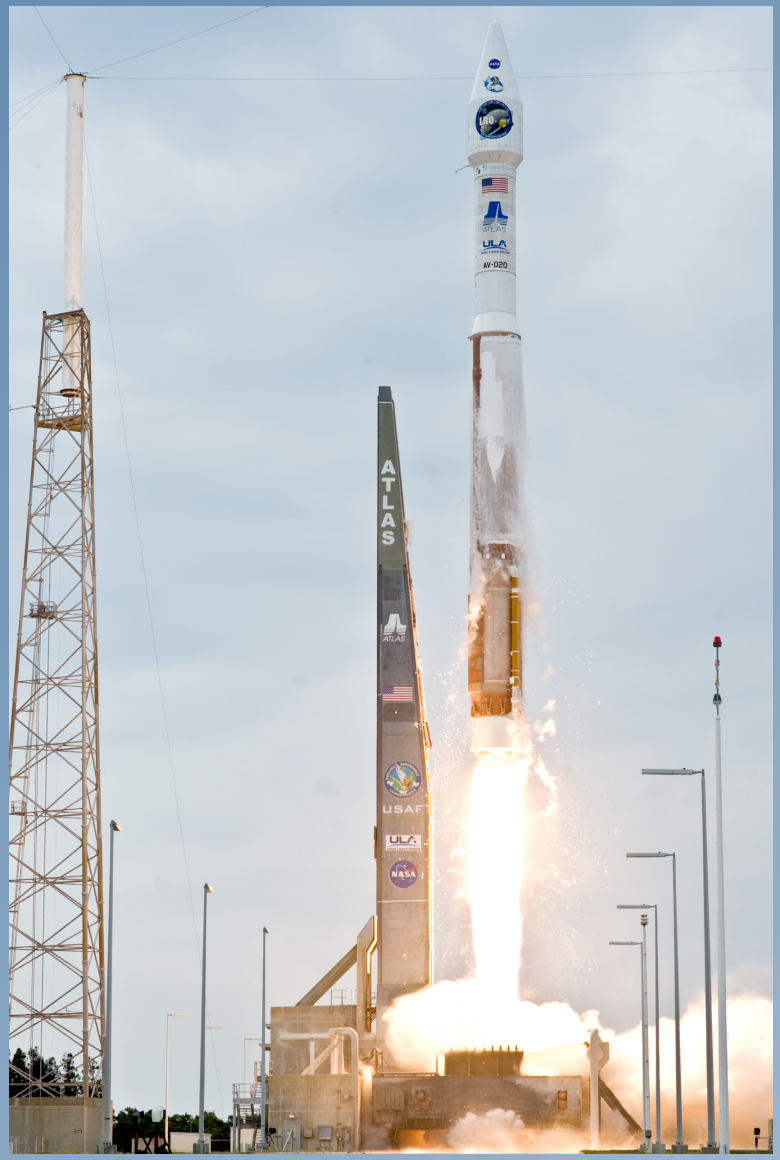


- Mission Review
- Instrument Review
  - NAC / WAC
- Product naming, what is available, data quality
  - EDR / CDR / RDR
- Searching & Downloading Products
- Basic Data Processing - radiometric calibration, basic map projection
- Advanced Data Processing - photometric calibration, controlled mosaics

LRO Mission



- Launched June 18, 2009 17:32 EDT (2,096 days … and counting)
- 7 Instruments: CRaTER, DLRE, LAMP, LEND, LOLA, LROC, Mini-RF
- Polar Orbit
  - Mapping 50 km w/ two month low orbit
  - Stable (30 km x 190 km)
- Mission Phases: Commissioning, Mapping (ESMD), Science (SMD), Extended Science (ESM), Extended Science 2 (ESM2)
- Data downlink allocation: 430 Gbits/day

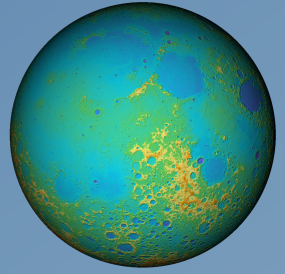


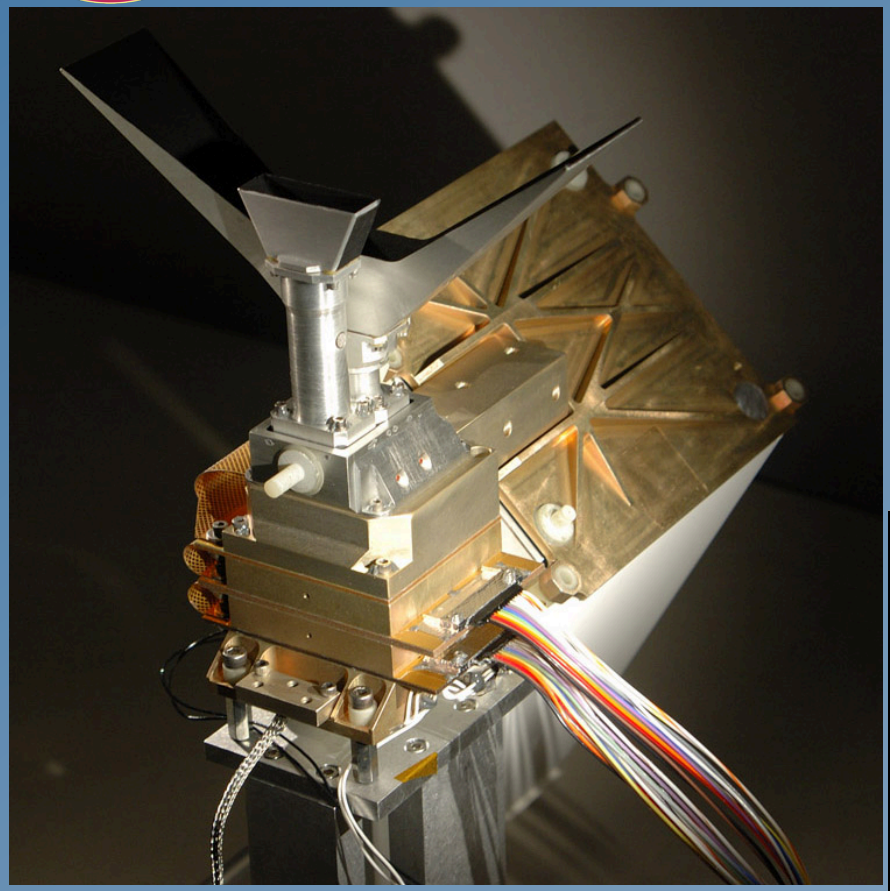
LROC NAC

- NACR – NACL (not stereo)
- 1x5064 Kodak KLI-5001G CCD
- 2.85° per NAC

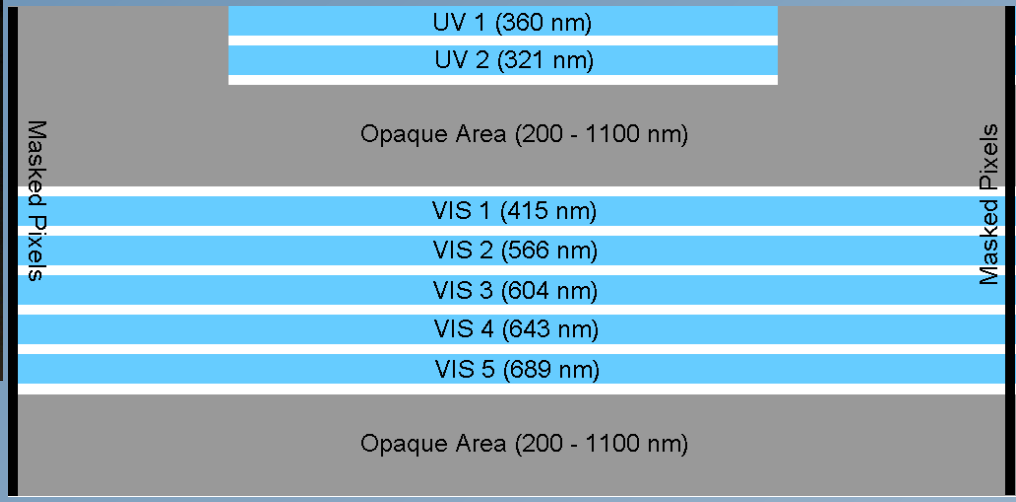
Image Format: 5064 x 50k lines (max)
Imaging Mode: native, xtrack summing

LROC WAC





- Kodak KAI-1001 1024x1024 CCD
- 2 UV (321 / 360) - 5 VIS (415 / 566 / 604 / 643 / 689)
- FOV: 91.7° (vis) / 61.4° (color) / 60° (UV)

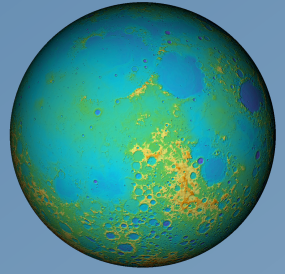


WAC Detector Layout

Image format:

- 1024 x 14 pixels monochrome (push frame)
- 704 x 14 pixels 5-filter (vis) (push frame)
- 128 x 4 2-filter UV color

What's in a Name?
PDS Naming Schemes



- EDR & CDR
  - [Target][CP][MET][Instrument][PDSProduct]
    - Moon / Earth / Calibration / Star
    - clock partition (one digit = 1)
    - 9 digit Mission Elapsed Time *
    - Right / Left / Monochrome / Color / VIS / UV
    - EDR / CDR

M1141772961ME
E103093560RC
C1109049397CC
S1124325043LE

- RDR
  - Constructed using product name, map projection and coordinate of the center of the map mosaic. Products also include site designator in the name. WAC may include band (for multi-band products).

NAC_DTM_ARISTARCHU5_E250N3110.IMG
NAC_ROI_APOLLO16HIA_E091S0152.IMG
WAC_GLOBAL_O000N0000_100M.IMG
WAC_GLD100_E300N2250_256P.IMG
WAC_ROI_NEARSIDE_DAWN_O000N0000_256P.IMG

NAC_POLE_P862S0750.IMG
WAC_EMP_643NM_E300N0450_064P.IMG
WAC_MOVIE_N20101008T2121.IMG
WAC_VIS_E235S1590_100MPP.IMG
WAC_ORBITS_11270_11607.IMG

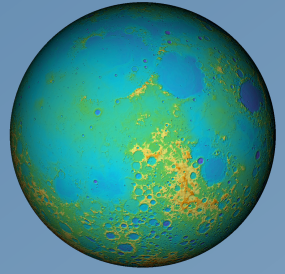
DATA_QUALITY_ID

- PDS keyword (EDR/CDR), 8 bit value
  - Bit 1: No temperature telemetry or FPA temperature not in the range -50° C to 50° C
  - Bit 2: Count of DNs >= 250 exceeds 0.1%
  - Bit 3: WAC DN count <= 5 exceeds 0.1%; NAC DN count = 0 exceeds 0.1%
  - Bit 4: Observation is missing data packets due to downlink transmission error
  - Bit 5: SPICE SPK or CK information is missing or incorrect
  - Bit 6: Observation header, data bits or instrument housekeeping information is incorrect or missing
  - Bit 7 & 8: Reserved for Future Use
- Some NAC/WAC images cannot be calibrated and/or map projected

Available Products?

- EDR v1.8 (Engineering Data Records)
  - Companded, 8 bit
- CDR v1.9 (Calibrated Data Records)
  - Decompanded, 16 or 32 bit, calibrated
- RDR (Reduced Data Records)
  - 16 bit, map projected products
  - Complies with LRO whitepaper "*A Standardized Lunar Coordinate System for the Lunar Reconnaissance Orbiter and Lunar Datasets*"

Where do I find LROC products?



LROC PDS Data Node

- *http://wms.lroc.asu.edu/lroc*

LROC WMS Service

- *https://webmap.lroc.asu.edu*

NASA PDS Imaging Node

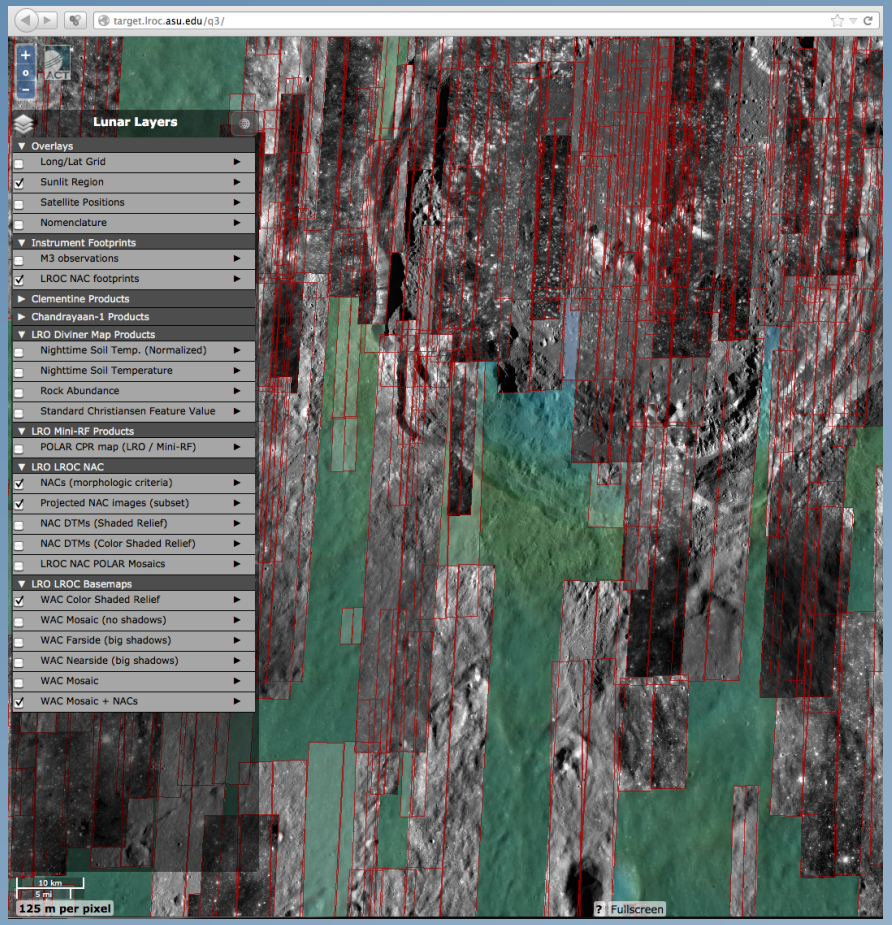
- *http://pds-imaging.jpl.nasa.gov/*

PDS Lunar ODE

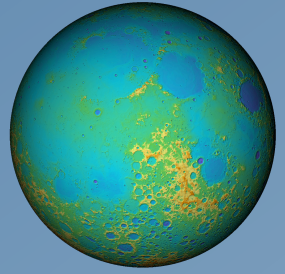
- http://ode.rsl.wustl.edu/moon/

Others

- LROC QuickMap *http://target.lroc.asu.edu/q3/*



LROC PDS Data Node



4 interfaces for exploring LROC data

- WMS Browser
- EDR / CDR Thumbnail Browser
- EDR / CDR Search
- RDR Search

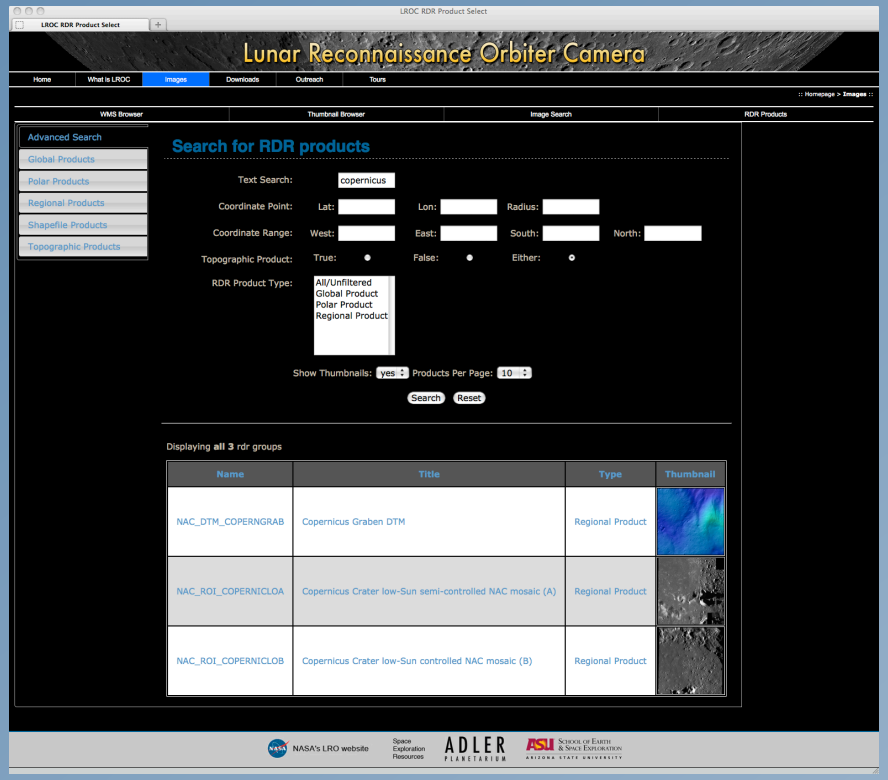
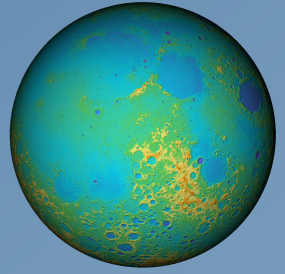
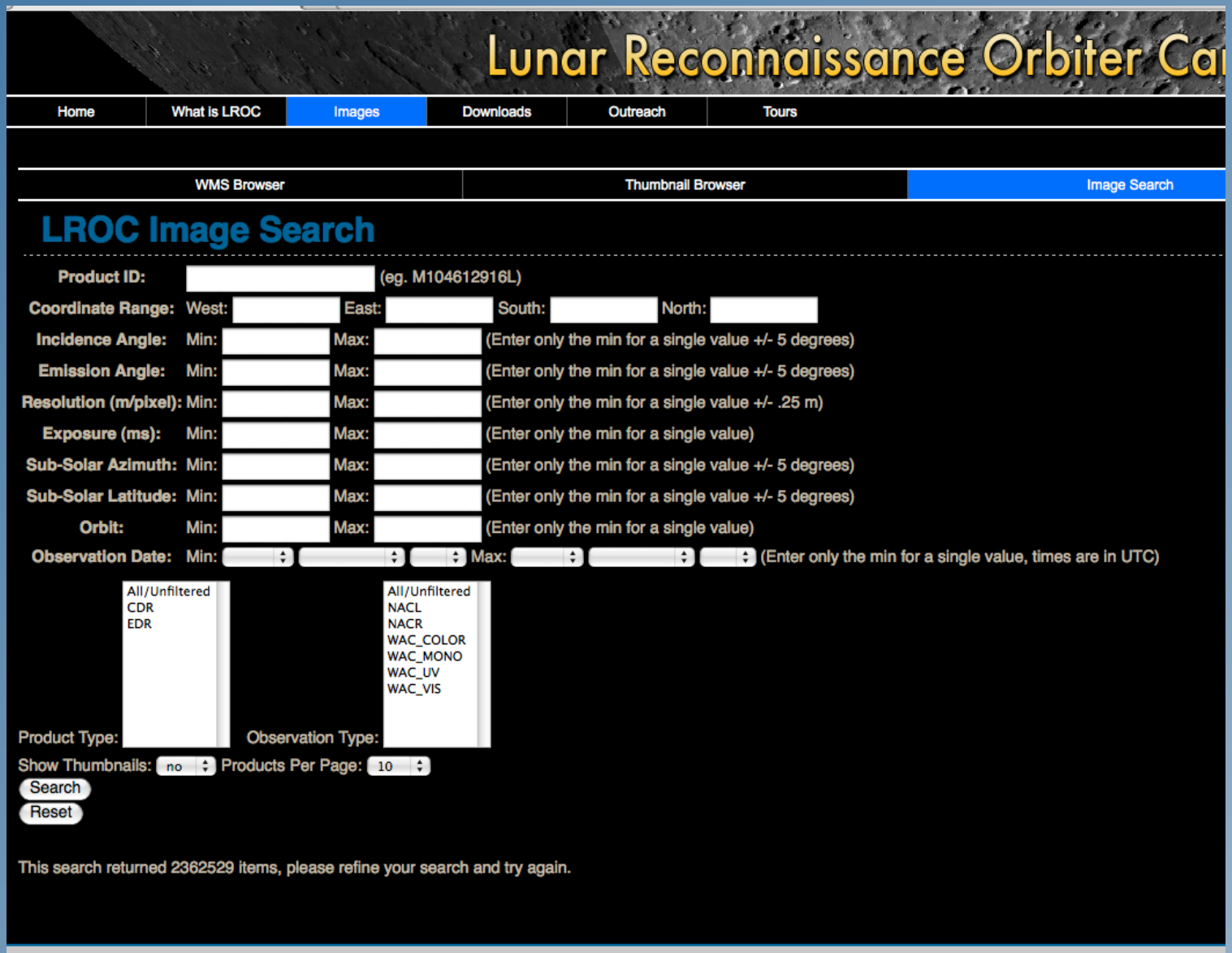


Image Search Interface



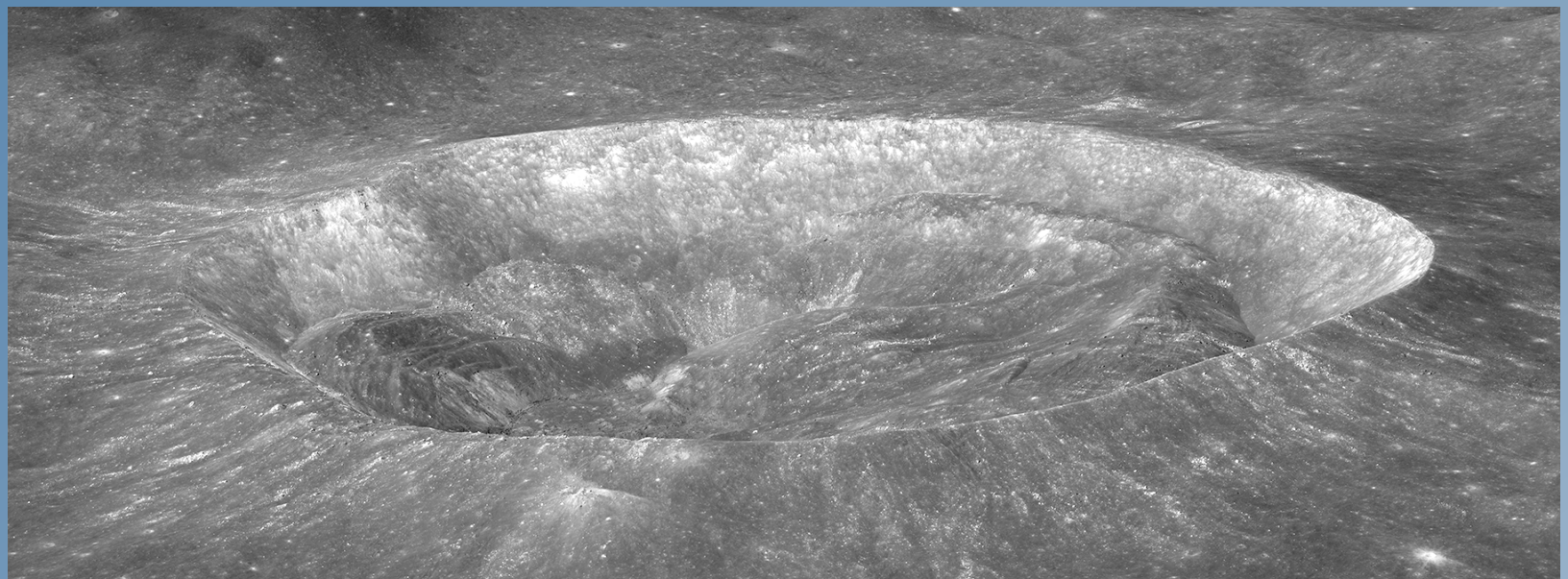


- 12 search fields
- Thumbnails
- Download list

Demo!

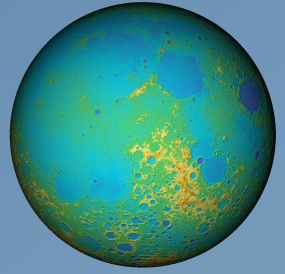
ISIS v3.4.8

- Need software (~1.4 GB), base data (~5.1 GB) and LRO data (~125 GB)
- Installation via rsync (need high speed network link, very slow otherwise)
- SPICE kernels need to be updated every 3 months
- Lots of scratch disk space for data processing (~4x NAC)

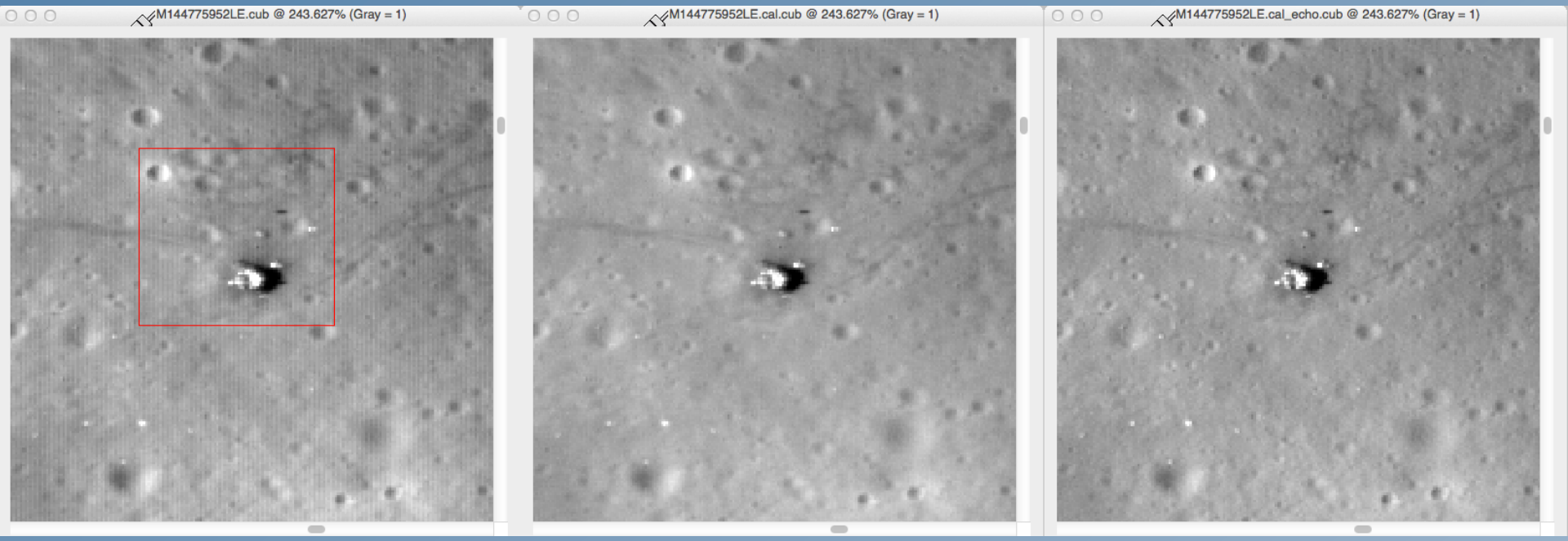


Oblique view of Larmor Q crater, looking east-to-west. M174081337

NAC Level 1 Processing



```
% lronac2isis from=M144775952LE.IMG to=M144775952LE.cub
% spiceinit  from=M144775952LE.cub spksmithed=true  cksmithed=true
% lronaccal from=M144775952LE.cub to=M144775952LE.cal.cub
% lronacecho from=M144775952LE.cal.cub to=M144775952LE.cal_echo.cub
```



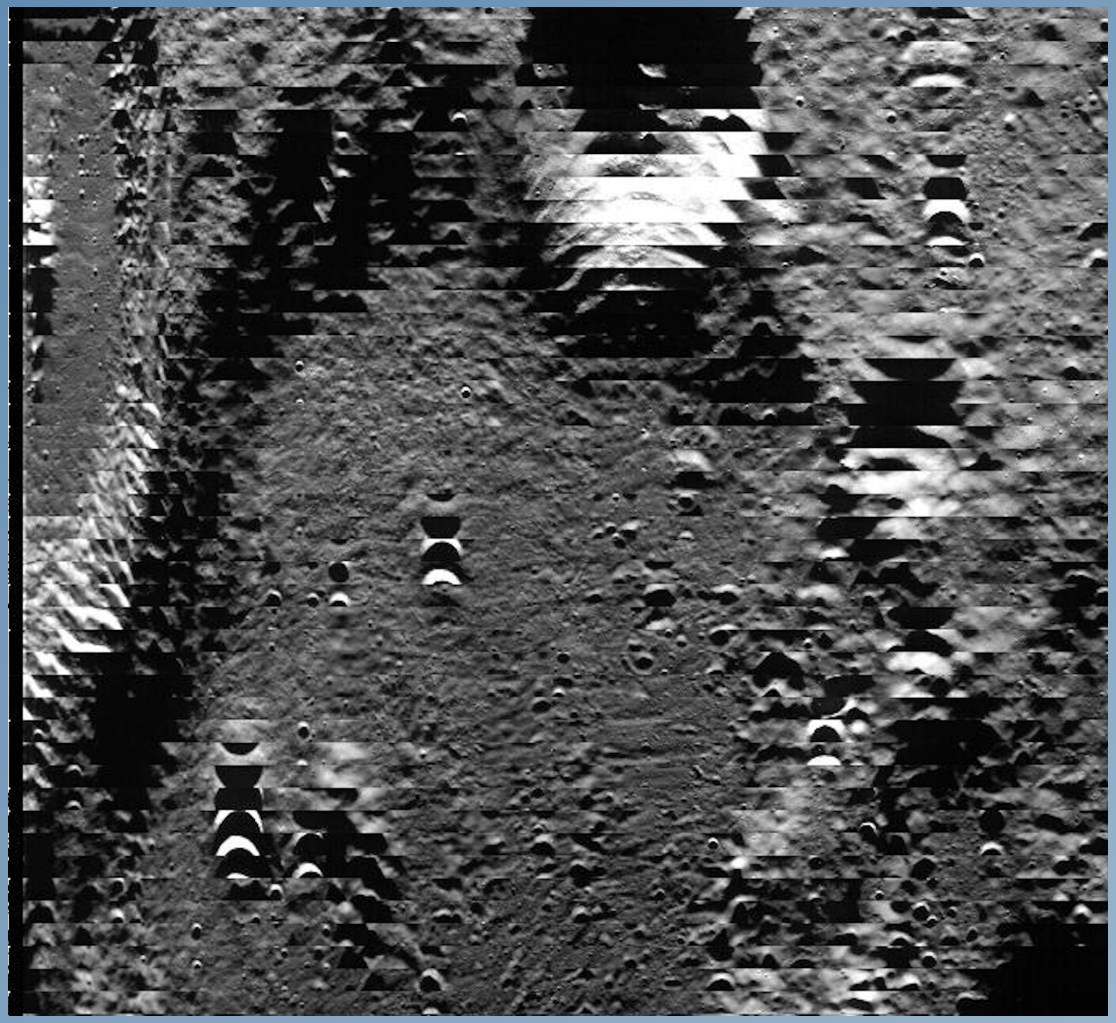
Calibration: masked pixels, dark current, nonlinearity, flat field and radiometric

WAC Level 1 Processing

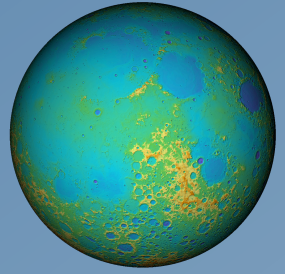
1. lrowac2isis
   - splits WAC image into 2 (VIS/UV/BW) or 4 files (COLOR)
2. spiceinit
   - on every file created in step 1
3. lrowaccal
   - on every file created in step 1

Calibration: dark current, flat field, radiometric, temperature

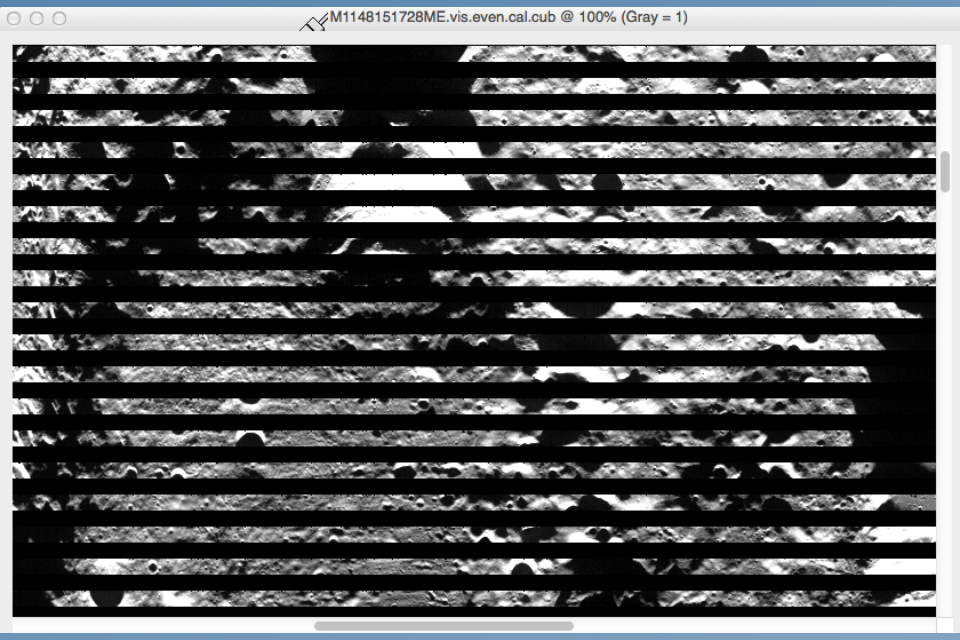
M1148151728ME

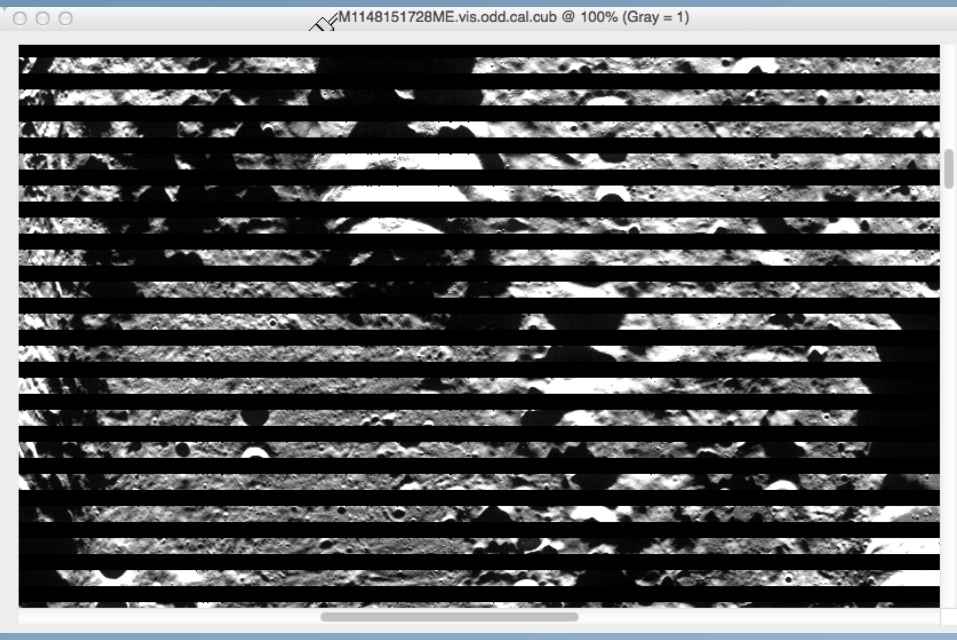


WAC Level 1 (cont.)

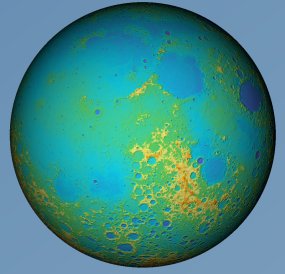


```
% lrowac2isis from=M1148151728ME.IMG to=M1148151728ME.cub
% spiceinit from=M1148151728ME.vis.even.cub spksmithed=yes cksmithed=yes
% spiceinit from=M1148151728ME.vis.odd.cub spksmithed=yes cksmithed=yes
% lrowaccal from=M1148151728ME.vis.odd.cub to=M1148151728ME.vis.odd.cal.cub
% lrowaccal from=M1148151728ME.vis.even.cub to=M1148151728ME.vis.even.cal.cub
```



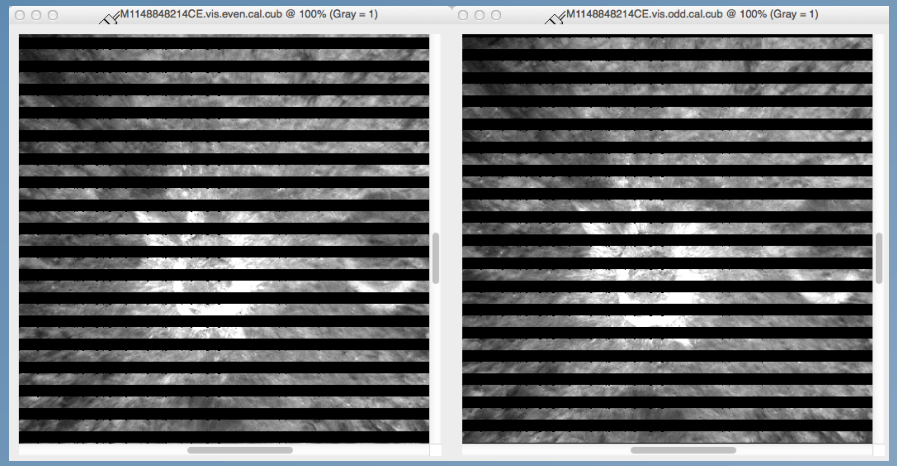


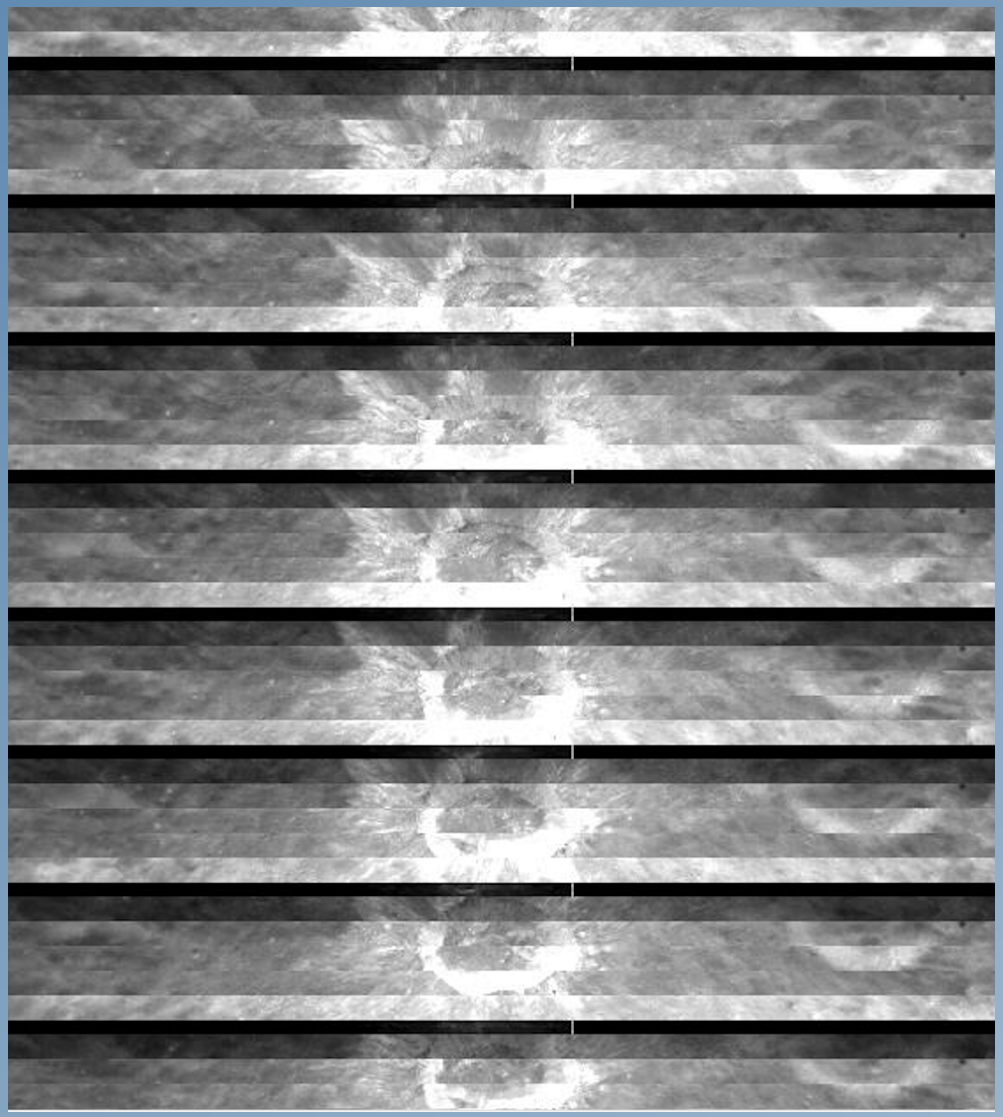
WAC Level 1 (cont.)



M1148848214CE
begets….

M1148848214CE.uv.even
M1148848214CE.uv.odd
M1148848214CE.vis.even
M1148848214CE.vis.odd

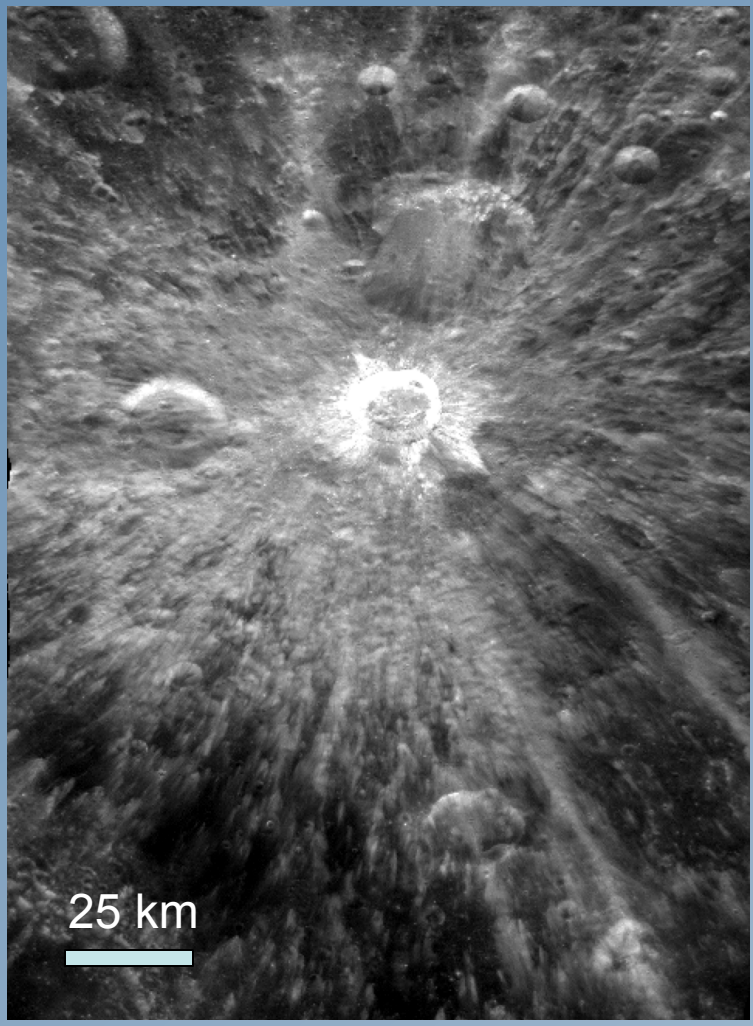




Level 2 Processing

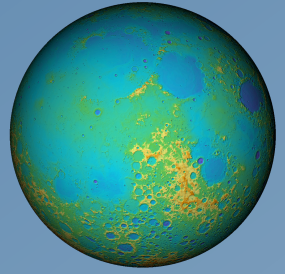
- NAC pair into single image
- WAC single band image
- WAC multi-band image
  - registration of bands

- ISIS Commands:
  - cam2map
  - mapmos or automos



M1148848214CE (415nm)

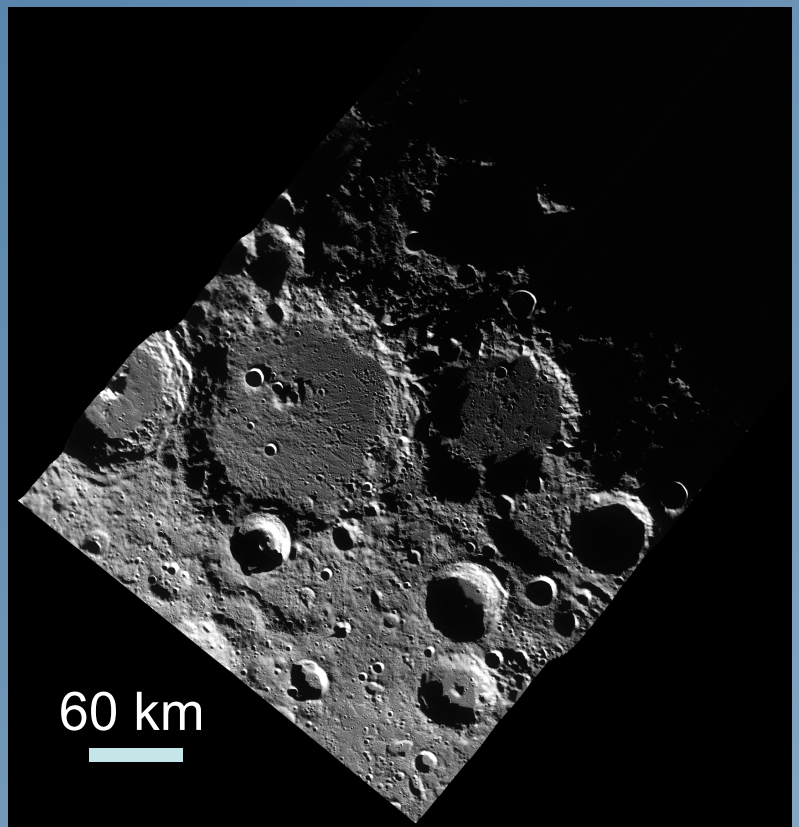
WAC Level 2



% cam2map from=M1148151728ME.vis.even.cal.cub map=mymap.map to=M1148151728ME.vis.even.map.cub

% cam2map from=M1148151728ME.vis.odd.cal.cub map=mymap.map to=M1148151728ME.vis.odd.map.cub

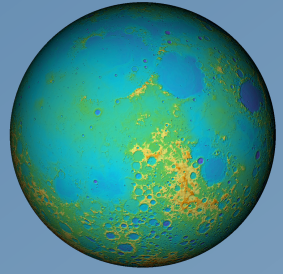
% automos fromlist=automos.lst mosaic=M1148151728ME.map.cub




```
Group = Mapping
 ProjectionName      = Orthographic
 CenterLatitude      = 87.7 <degrees>
 CenterLongitude     = 246.7 <degrees>
 LatitudeType        = Planetocentric
 LongitudeDirection  = PositiveEast
 LongitudeDomain     = 360 <degrees>
 PixelResolution     = 260.0 <meters/pixel>
End_Group
```

WAC Mono	204MB
WAC 7-band	906MB

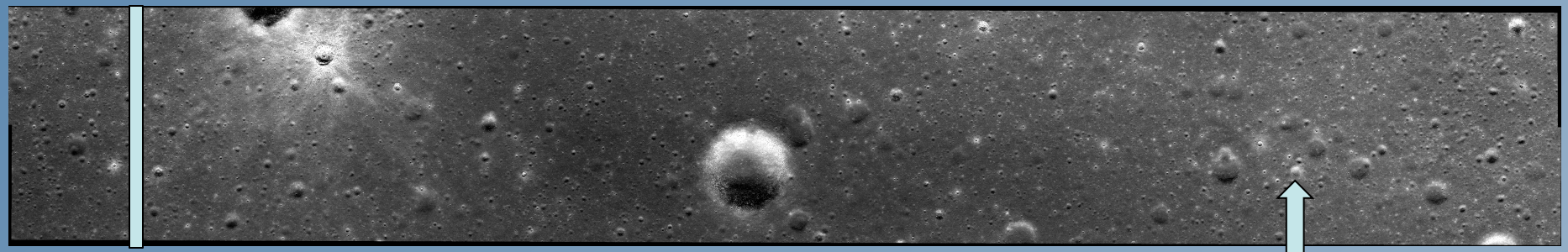
NAC Level 2



```
% cam2map from=M144775952LE.cal_echo.cub
map=mymap.map to=M144775952LE.map_5mpp.cub
pixres=map
% cam2map from=M144775952RE.cal_echo.cub
map=mymap.map to=M144775952RE.map_5mpp.cub
pixres=map
% automos fromlist=automos.lst mosaic=M144775952LR.cub
```

```
Group = Mapping
 ProjectionName  = SimpleCylindrical
 CenterLongitude = 336.551 <degrees>
 LatitudeType       = Planetocentric
 LongitudeDirection = PositiveEast
 LongitudeDomain    = 360 <degrees>
PixelResolution    = 5.0 <meters/pixel>
End_Group
```

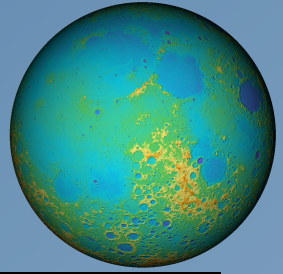
NAC Pair: IMG 512 MB grows to 9 GB (@ 5mpp)



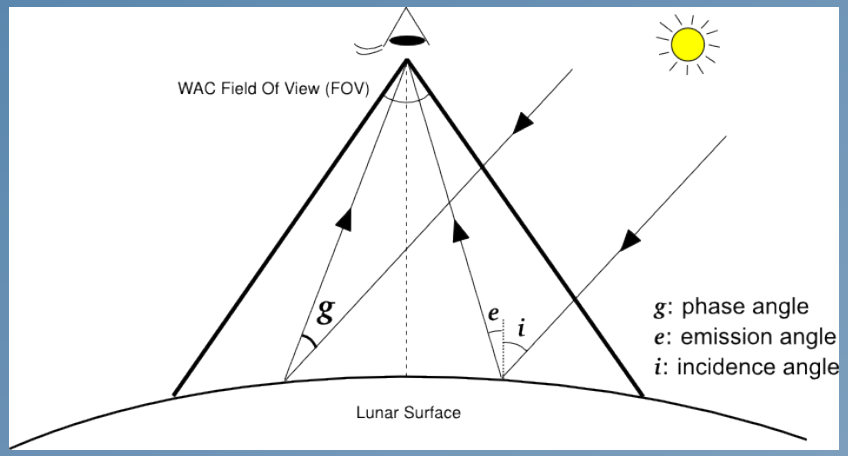
4.3km across

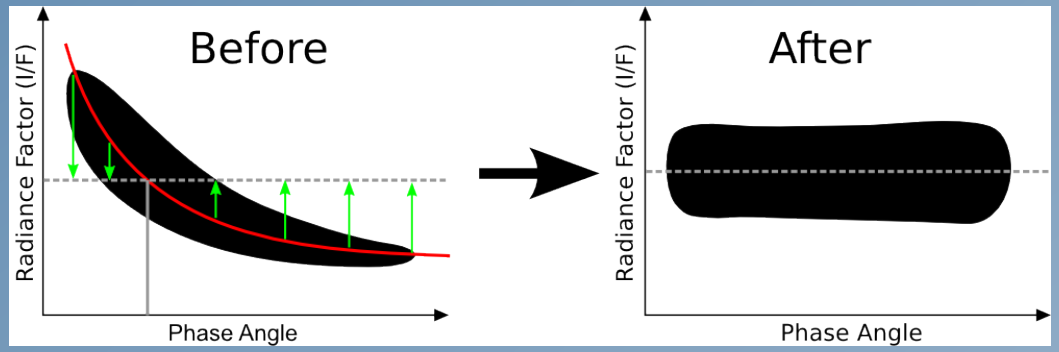
Apollo 12 Landing Site
North to the Right.

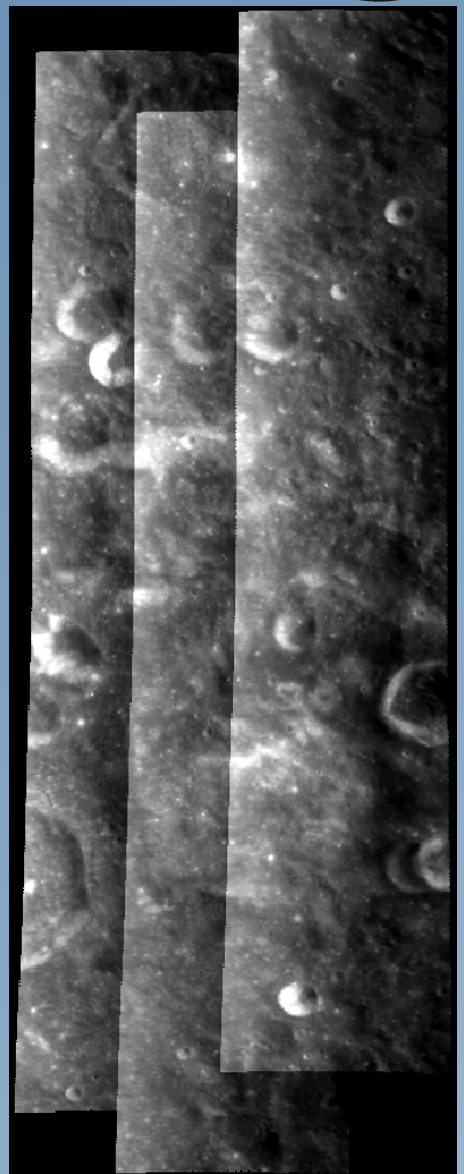
Photometric Correction



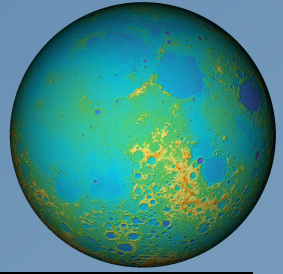
- NAC - photomet, lronacpho*
- WAC – photomet, lrowacpho







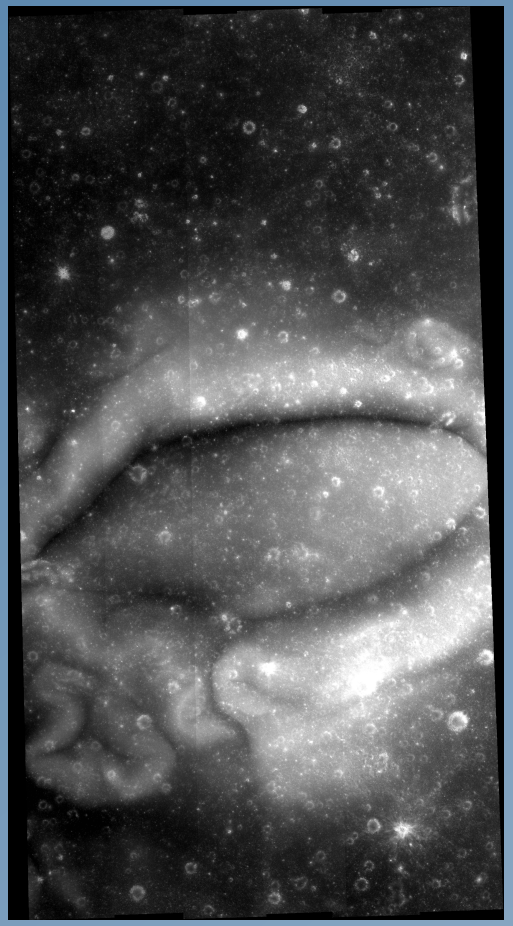
Multi-Image Mosaics

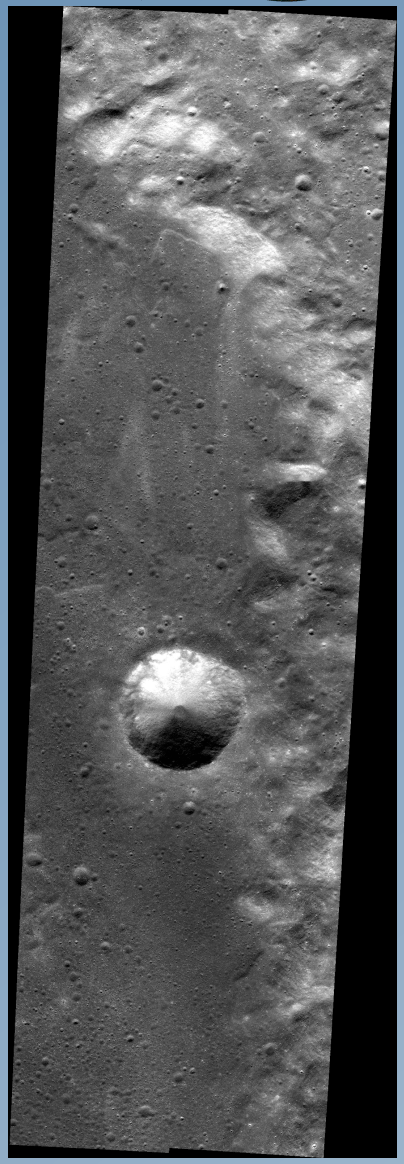


Compton-Belkovich F & G

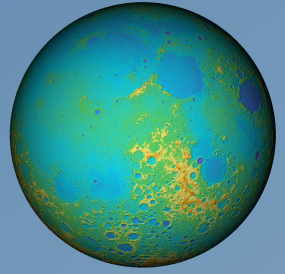
Luna 21

Reiner Gamma

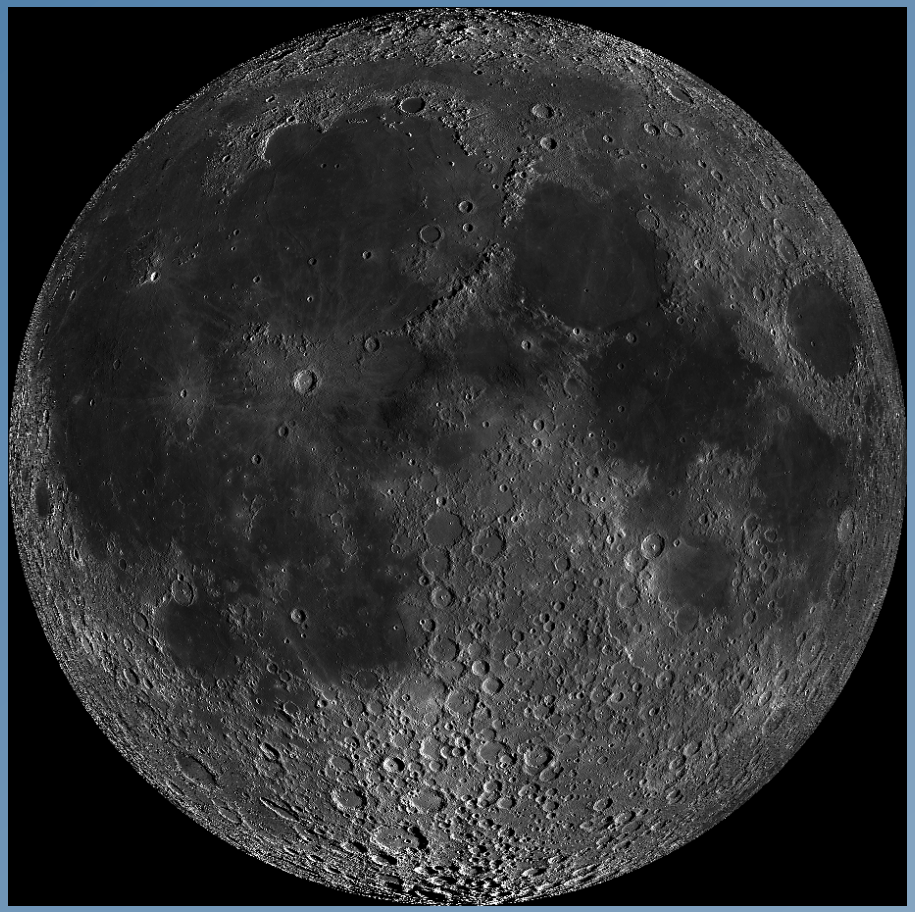




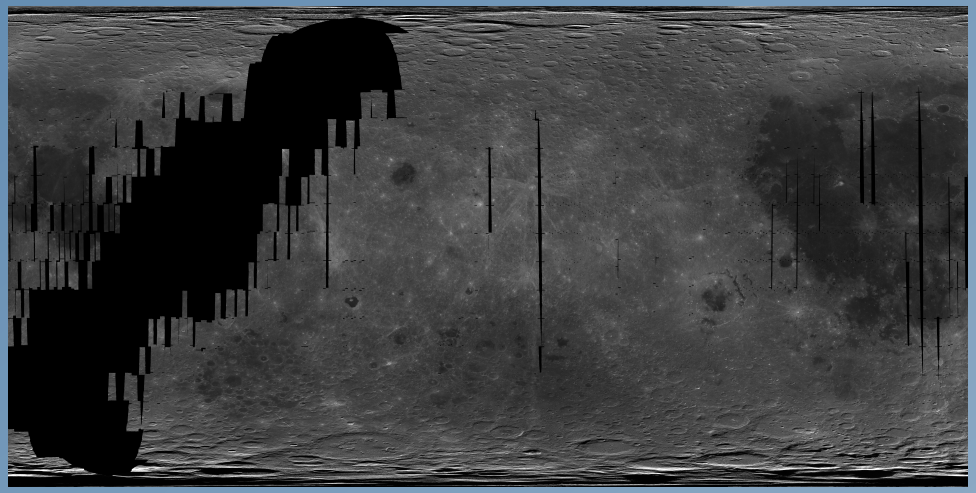
Multi-Image Mosaics (cont.)



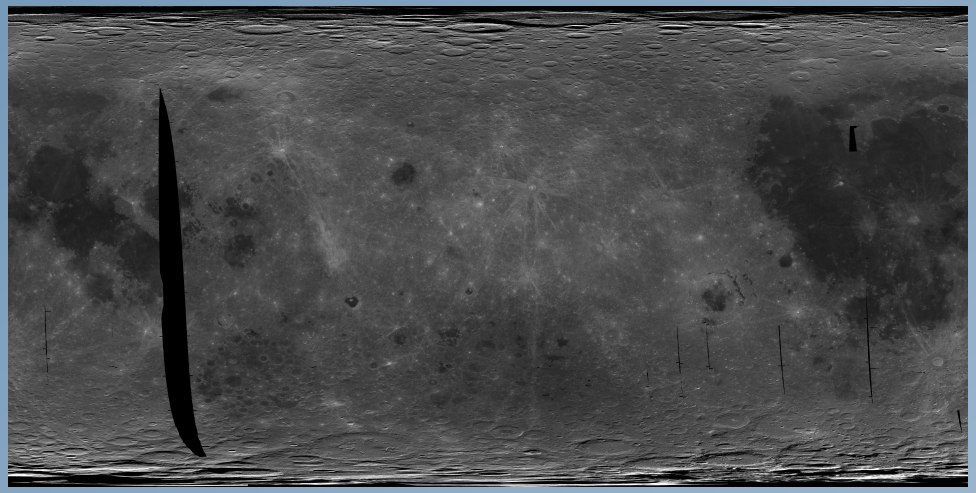
WAC Nearside Dawn



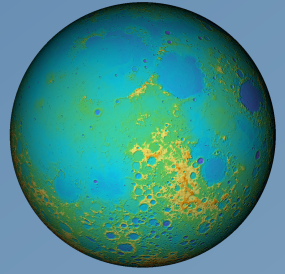
WAC Orbits 03100-03529



WAC Orbits 18876-19293

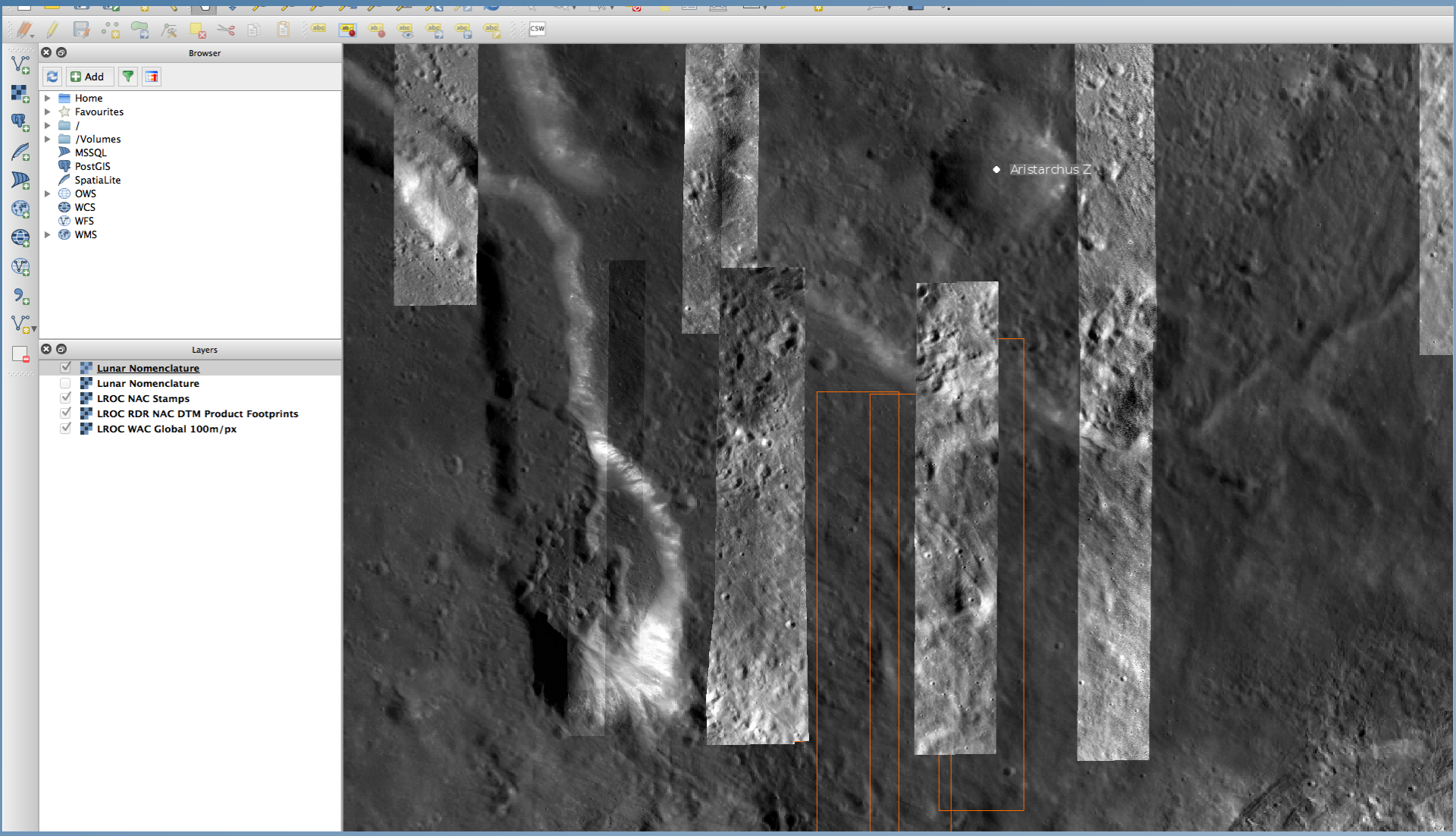


Web Mapping Service
(aka WMS)

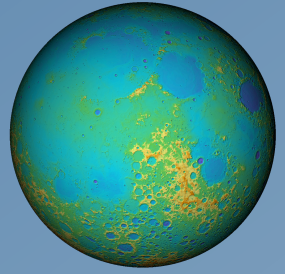


- Protocol to deliver raster and vector information, in a map projection, to a client in a predefined image format (JPEG/PNG/TIFF).
- Existing WMS implementations had severe issues dealing with global datasets, so we developed Lunaserv.
- All LROC PDS data products available (also includes other planetary bodies to demonstrate capabilities)

QGIS + Lunaserv



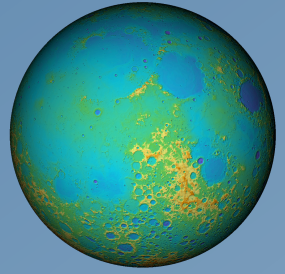
Resources



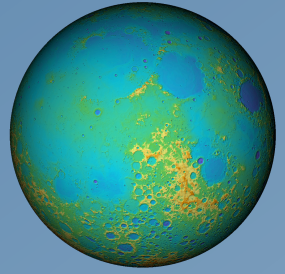
1. LROC EDR/CDR Product SIS - *http://lroc.sese.asu.edu/data/LRO-L-LROC-2-EDR-V1.0/LROLRC_0001/DOCUMENT/LROCSIS.PDF*
2. LROC RDR Product SIS - *http://lroc.sese.asu.edu/data/LRO-L-LROC-5-RDR-V1.0/LROLRC_2001/DOCUMENT/RDRSIS.PDF*
3. Robinson et. al., *Lunar Reconnaissance Orbiter Camera (LROC) Instrument Overview*, Space Science Reviews, Vol 150, pg81-124
4. Wagner et. al., *"New mosaicked data products from the LROC Team"*, 46th LPSC, abstr #1473
5. Archinal et. al., "*Status of geodetically controlled high-resolution LROC mosaics",* 46th LPSC, abstr #1571
6. Estes et. al., *" Lunaserv WMS software enhancements"*, 46th LPSC, abstr #1507 (or visit our booth)
7. Mahanti et. al., "*How old are small lunar craters? – A depth to diameter ratio based analysis"*, 46th LPSC, abstr#1615
8. Speyerer et. al., "*Dynamic Moon revealed with high resolution temporal imaging*", 46th LPSC, abstr#2325
9. Lawrence et. al., "*Characterizing mare deposits in the Australe region"*, 46th LPSC, abstr#2739
10. Stopar et. al., "*Interpretations of volcanic deposts associated with small lunar cones"*, 46th LPSC, abstr#1474
11. Sato et. al., "*New LROC WAC TiO2 abundance map of the Moon*", 46th LPSC, abstr#1111
12. Boyd et. al., "*Investigating surface textures using LROC NAC photometry*", 46th LPSC, abstr#2841
13. Povilatis et. al., "*Comparison of large and mid-size lunar crater distributions*", 46th LPSC, abstr#2880
14. Meyer et. al., "*Lunar light plains and cryptomaria southwest of Orientale*", 46th LPSC, abstr#1692

Come Visit Our Booth…

#7

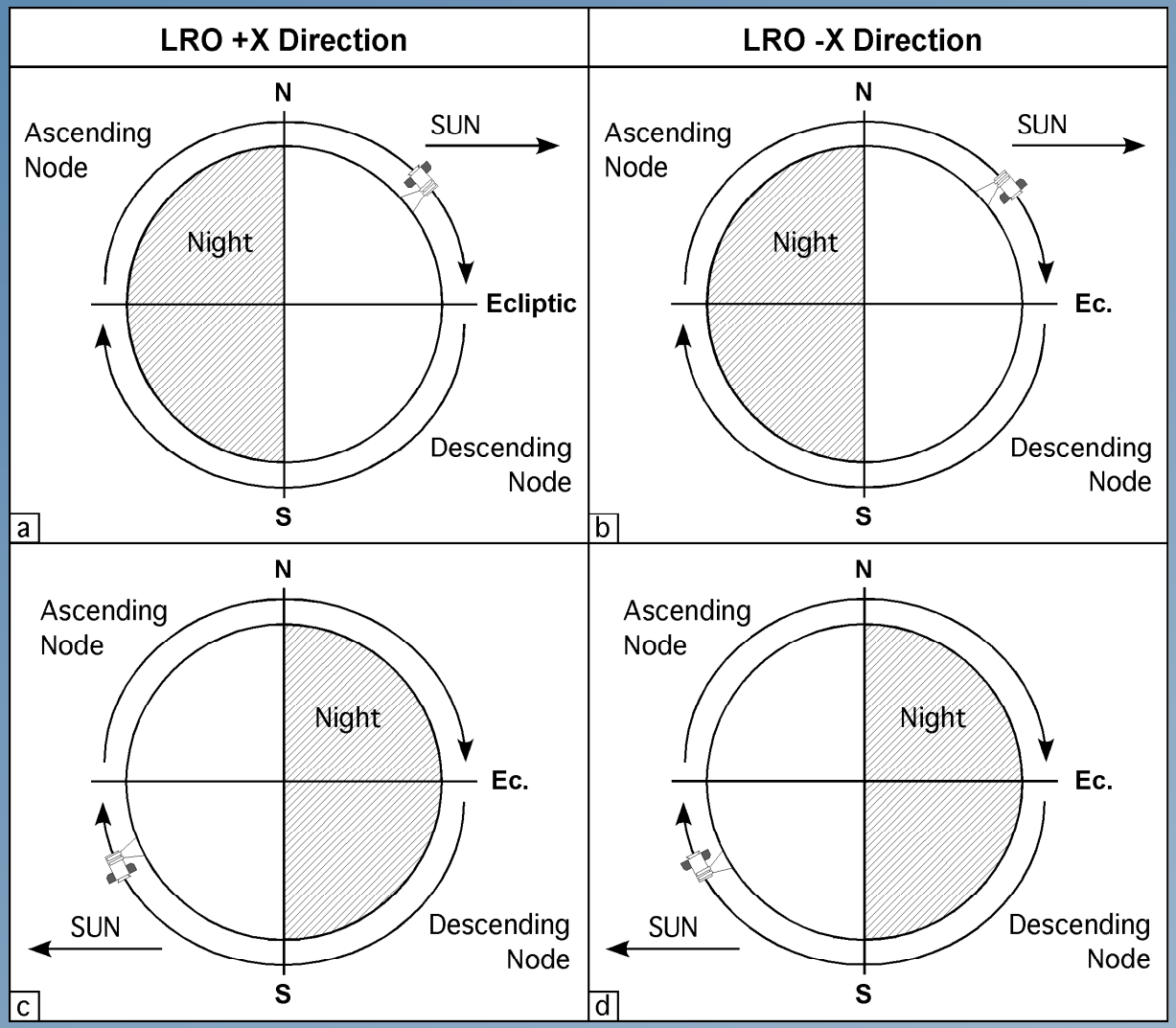


Backup Slides



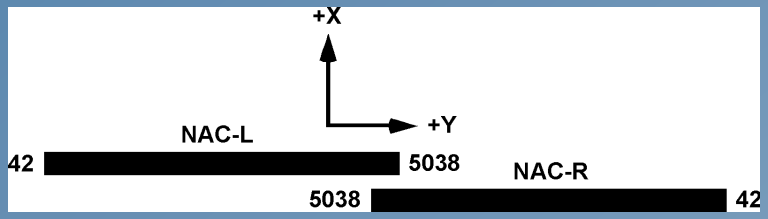
Spacecraft Orientation

The four possible cases of LRO orientation based on LRO direction of travel (+X or –X axis forward) and lighting conditions at a given node crossing



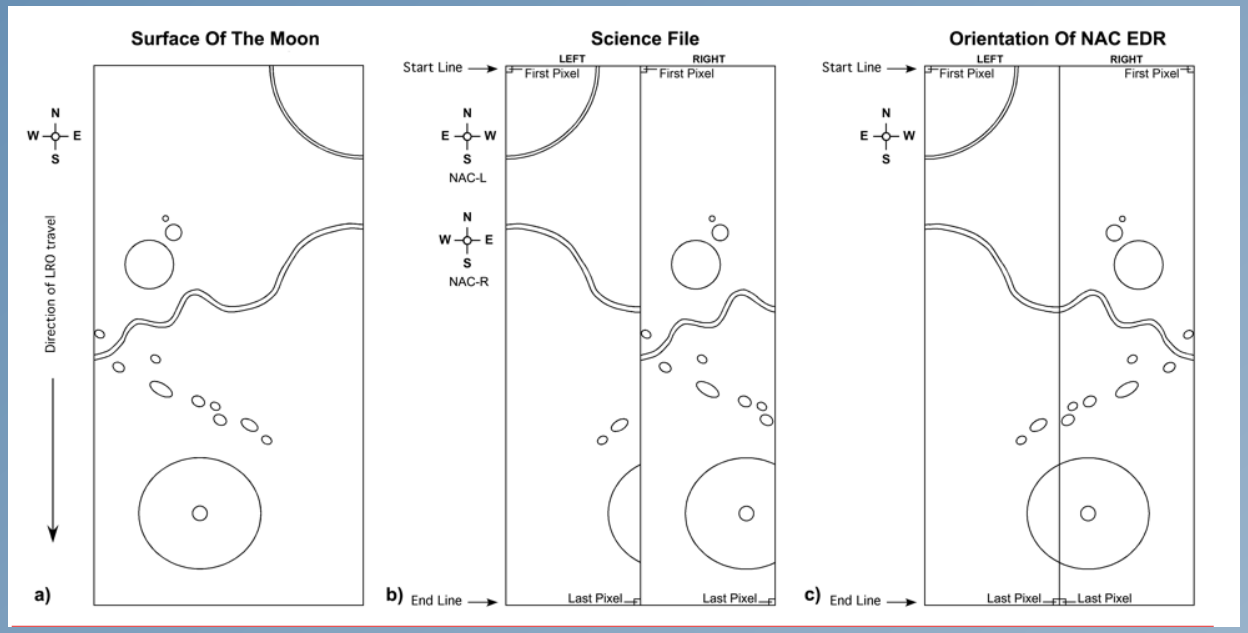
Detector Orientation

- NAC-R CCD oriented 180° relative to NAC-L CCD



- NAC-R flipped to match NAC-L orientation

User never sees the before flip NAC-R image (only in telemetry file)



ISIS Script

```
# Script to process NAC images into mosaic
ls *IMG | sed –e ‘s/.IMG//g’ >list
lronac2isis -batchlist=list from=\$1.IMG to=\$1.cub
spiceinit -batchlist=list from=\$1.cub
lronaccal -batchlist=list from=\$1.cub to=\$1.cal.cub
trim -batchlist=list from=\$1.cal.cub to=\$1.tr.cub
left=40 right=40
cam2map -batchlist=list from=\$1.tr.cub to=\
$1.map.cub map=equi.map pixres=map
```