Processing of
Lunar Reconnaissance Orbiter Camera
Narrow Angle Camera Image Frames with ISIS 3

featuring

How to Create NAC CDRs

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What is ISIS?

- ***Integrated Software for Imagers and Spectrometers***
  - USGS software to process data from NASA planetary missions
  - Missions/instruments supported
    - Viking, Voyager, Mariner, Galileo, Clementine, MGS, Mars Odyssey, Cassini, Mars Pathfinder, MER, MRO HiRISE, MESSENGER/MDIS NAC & WAC, and LRO NAC & WAC cameras
  - Used to make cartographic products (mosaics and maps)
    - Input is PDS-formatted raw image files => Experiment Data Records (EDRs)
  - Includes visualization capability, radiometric and geometric processing, etc.
  - Both ISIS 2 and ISIS 3 versions currently available
    - ISIS 3 is the correct version for LROC data
    - See http://isis.astrogeology.usgs.gov/UserDocs/index.html
    - 35-year heritage
      - ISIS3 < ISIS2 < PICS < FIPS < pre-FIPS

Supported OS Platforms

- ISIS3 runs on many Unix variants including:
  - Ubuntu, RHEL, Debian, Fedora, SUSE, MacOSX
- ISIS3 does not run on MS Windows
- ISIS requirements (depending on your needs):
  - 64-bit x86 processors (more cores is better)
  - 2GB memory (more memory is better)
  - 10GB to 180GB disk storage for ISIS installation
  - 10GB to many TB disk storage for processing images
  - Quality graphics card (one that support two monitors can be useful)

How to Get ISIS 3

- Start at the ISIS Website
  - http://isis.astrogeology.usgs.gov
    - Installing ISIS
      - http://isis.astrogeology.usgs.gov/documents/InstallGuide/index.html
- User documentation
      - http://isis.astrogeology.usgs.gov/UserDocs/index.html
- List of ISIS applications (alphabetical)
  - http://isis.astrogeology.usgs.gov/Application/alpha.html
  - Run programs from command line or using GUI interface

Where to Get Help in ISIS 3

- Start at the ISIS Support Website
  - https://isis.astrogeology.usgs.gov/IsisSupport/
- Online workshops available
  - http://isis.astrogeology.usgs.gov/IsisWorkshop/index.php/IsisWorkshop

- **Note: ISIS3 is not a PDS product**
  - If you have questions or need installation help, please contact the ISIS Support staff first
  - If you get no timely response, contact Lisa Gaddis (lgaddis@usgs.gov) of the PDS Imaging Node

Cartographic Processing with ISIS

- **Level 0**
  - Ingest PDS Engineering Data Record (EDR) into ISIS
  - Add SPICE (basic geometry)

- **Level 1**
  - Radiometrically calibrate
  - Remove noise
  - *Creates Calibrated Data Records (CDRs)*

- **Level 2**
  - Improve camera pointing
  - Geometrically rectify to a map projection
  - *Creates Reduced Data Records (RDRs)*

- **Level 3**
  - Photometric normalization

- **Level 4**
  - Create mosaic
  - Evaluate mosaic

- **BUT** you can find LROC RDR data here:
  - http://wms.lroc.asu.edu/lroc/rdr_product_select

- These RDRs have already been processed to high level(s)!

Pre-Processing Steps: Get NAC Data

- Find LROC NAC data
    - LROC Science Operations Center interface to PDS Archives
        - http://wms.lroc.asu.edu/lroc/
        - http://lroc.sese.asu.edu/data/
    - Image Atlas, PDS Imaging Node
        - http://pds-imaging.jpl.nasa.gov/search/search.html#QuickSearch
    - ACT-REACT QuickMap for LROC data
        - http://target.lroc.asu.edu/q3/
    - Lunar Orbital Data Explorer, PDS Geosciences Node
        - http://ode.rsl.wustl.edu/moon/

- Download LROC EDR files to local disk
    - Use single or bulk-download options at the above sites to copy the EDR files
    - Recall that NAC images are initially stored as Left and Right frames
        - Example of a "Right" frame: M102064759RE.IMG
   - You may need both for complete coverage of a site

Pre-Processing Steps

- Get ready to start processing:
  - Make sure ISIS3 is installed and running on your system
    - See slide #4
    - As part of the ISIS3 release, you will receive a lunar surface topography model (or a Digital Elevation Model, DEM) so that images will be placed accurately onto the lunar surface during processing
    - The current default DEM is the March 2011 version of the LROC LOLA DEM
  - Create a map template file
    - Used by cam2map to map-project the images
    - See next slides

    - *Note: ">command" here means run in Linux at prompt*

PDS
Planetary Data System

Pre-Processing: Creating a Map Template File

- Use ISIS 3 "maptemplate" GUI to create a pvl file that describes the desired map projection, spatial resolution, etc. of your products
- The same .map file can be used for all frames
  - These parameters must be the same for all frames to make a mosaic
- Can choose (for example):
  - Projection (Mercator, PolarStereographic, etc)
  - Planetocentric or Planetographic
  - Center Longitude
  - Pixel Resolution
- Or you can manually edit an existing .map file
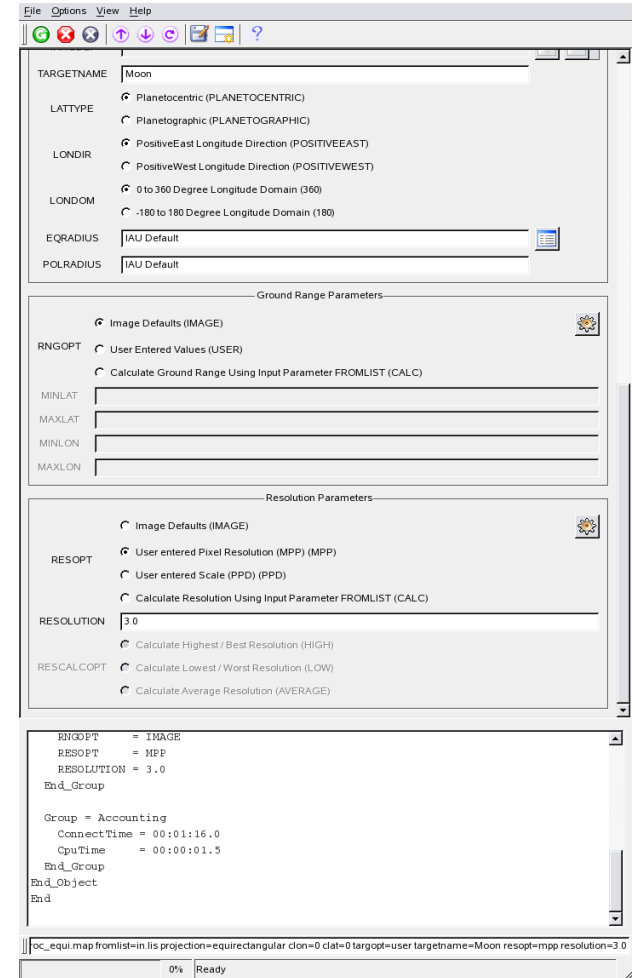
Pre-Processing: Maptemplate Output

■ Sample lroc_equi.map

- Group = Mapping
- ProjectionName   = Equirectangular
- CenterLongitude   = 180.0
- CenterLatitude   = 0.0
- TargetName   = Moon
- EquatorialRadius = 1737400.0 <meters>
- PolarRadius   = 1737400.0 <meters>
- LatitudeType   = Planetocentric
- LongitudeDirection = PositiveEast
- LongitudeDomain   = 360
- PixelResolution   = 3.0 <meters/pixel>   *<< change as needed; use lower resolution for quick-look mosaics or for smaller images*
- End_Group
- End

Level 0 Processing of LROC NAC data

- Ingest NAC EDR to ISIS 3 with "lronac2isis"
  - Converts EDR to ISIS 3 cube file with attached label
  - >lronac2isis from=M102064759RE.IMG to=M102064759RE_lev0.cub
- Update labels with camera pointing information using "spiceinit" and the system defaults
  - >spiceinit from=M102064759RE_lev0.cub
  - Uses the default lunar shape model or DEM

Level 1 Processing of LROC NAC data

- Calibrate image to convert to I/F values using "lronaccal"
  - >lronaccal from= M102064759RE_lev0.cub to=M102064759RE_lev1.cub
- Remove artifacts using "lronacecho"
  - A correction designed to remove an observed brightness "echo" across adjacent pixels in NAC frames
  - >lronacecho from= M102064759RE_lev1.cub to=M102064759RE_lev1.echo.cub
- **Result is a Calibrated Data Record (CDR)**

Level 2 Processing of LROC NAC data

- Map-project image using "cam2map"
  - This creates a Level 2 image, or a Reduced Data Record (RDR)
  - Sinusoidal Projection (default)
    - For more information and examples, see ISIS Map Projection Online workshop
      - http://isis.astrogeology.usgs.gov/IsisWorkshop/index.php/Working _with_Mars_Reconnaissance_Orbiter_HiRISE_Data
  - Interpolation options
    - Nearest Neighbor
    - Bilinear
    - Cubic Convolution (default)

  >cam2map from=M101271375LE_lev1.echo.cub to=M101271375LE_lev2.cub

# Level 3 Processing of LROC NAC data

- Photometric correction
  - This step is not yet used routinely for correcting NAC data
  - Research is being conducted on this topic, for example:
    - Clegg et al., 2013
      - http://www.lpi.usra.edu/meetings/lpsc2013/pdf/2171.pdf
    - Boyd et al., 2012
      - http://lunarscience.nasa.gov/lsf2012/lunar-reconnaissance-orbiter-camera-narrow-angle-camera-global-photometric-solution-empirical-functi

Level 4 Processing of LROC NAC data

- Create a mosaic of NAC images using "automos"
  - \>ls -1 *lev2.cub > lev2.lis
  - \>automos fromlist=lev2.lis mosaic=testmos.cub

  or

  - \>automos fromlist=lev2.lis mosaic=testmos.cub grange=user minlat=X maxlat=X minlon=X maxlon=X matchbandbin=false

- View and evaluate images or mosaic
  - \>qview testmos.cub

Level 4 Processing of LROC data

- View cubes and/or mosaic
  - >qview testmos.cub

  - Zoom, Pan, Stretch

  - Track, Measure

  - Color composite

  - Link, Blink, Plot

  - Save, Print
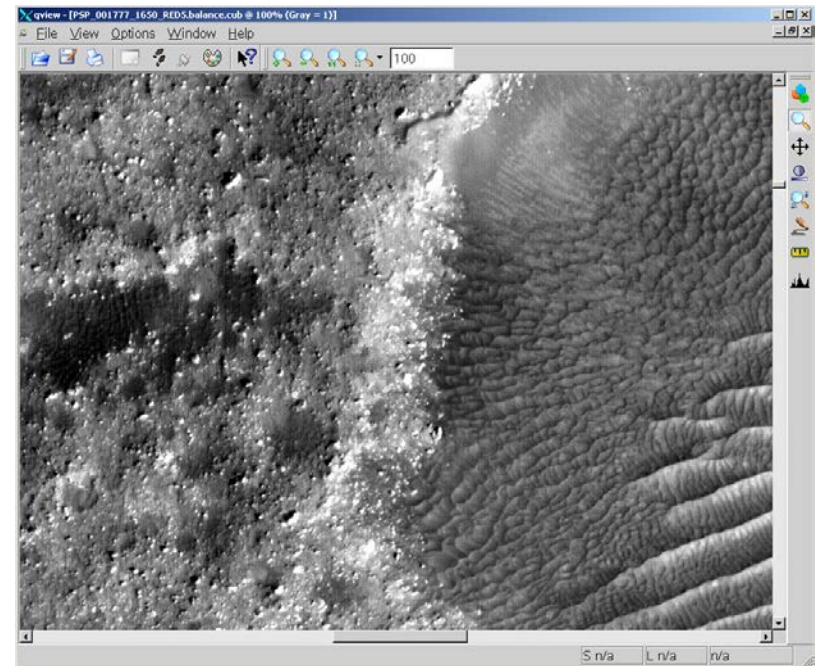
Exporting ISIS3 files

- Within ISIS3
  - Directly from qview or
  - >isis2std from=LROCfile.cub to=LROCfile.png
- GDAL: Geospatial Data Abstraction Library
  - See http://www.gdal.org/
  - Open Source library, supports PDS v3, ISIS2, and ISIS3 file formats
  - Binaries available for Mac, Windows, Linux
  - Export raw and many other image file formats
  - Maintains projection information and some metadata to output
  - Utility applications have stretching (scaling options), map projection support, clipping, resampling and mosaic capabilities
  - To output lossless geoJpeg2000
    - >gdal_translate -of JP2KAK -co quality=100 input.cub out.jp2
    - This .jp2 product retains geospatial information and can be exported directly into an Arc GIS project

Finding Help

- For ISIS 3, start at the ISIS Support Website
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Finding Help

- For help using LROC NAC data

    - LROC Instrument Overview (Space Science Reviews, 2010: http://link.springer.com/article/10.1007%2Fs11214-010-9634-2

    - LROC EDR/CDR PDS Product Description: http://lroc.sese.asu.edu/data/LRO-L-LROC-2-EDR-V1.0/LROLRC_0001/DOCUMENT/LROCSIS.PDF

    - LROC RDR Product Description: http://lroc.sese.asu.edu/data/LRO-L-LROC-5-RDR-V1.0/LROLRC_2001/DOCUMENT/RDRSIS.PDF

    - For questions regarding LROC PDS products, send email to the address lroc_dn@ser.asu.edu. For questions regarding the LROC PDS Data Node interface, send email to the address lroc_webmaster@asu.edu.