Mini-RF:
LRO Data Users Workshop

Josh Cahill
Planetary Exploration Group

JOHNS HOPKINS UNIVERSITY
Applied Physics Laboratory

Overview

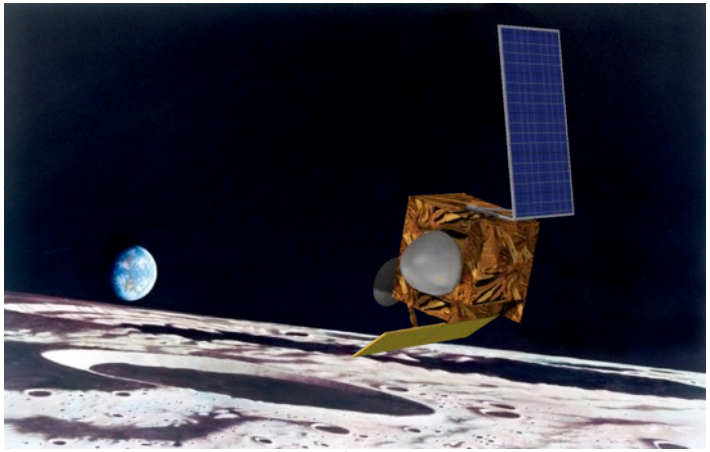
- About Mini-RF
- Where to Find Data
- What data is available
- How to process in ISIS
- Mosaics that are available
- Bistatic -> Angela

Mini-RF: Lunar SAR Instruments

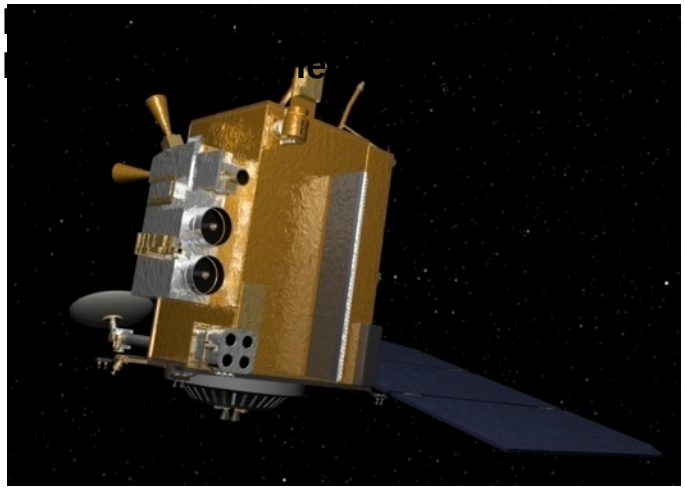
Mission Ended

Build 1: Forerunner Chandrayaan-1

Indian Space Research Organization (ISRO)
Launched 21 October 2008



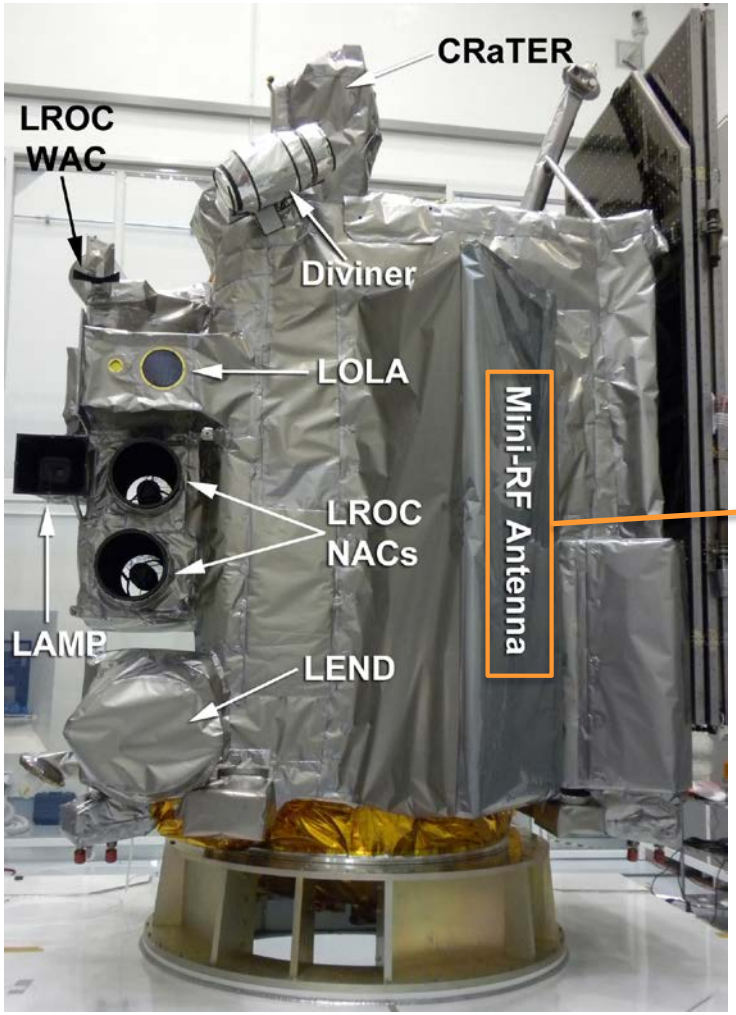
Build 2: LRO Lunar Reconnaissance Orbiter

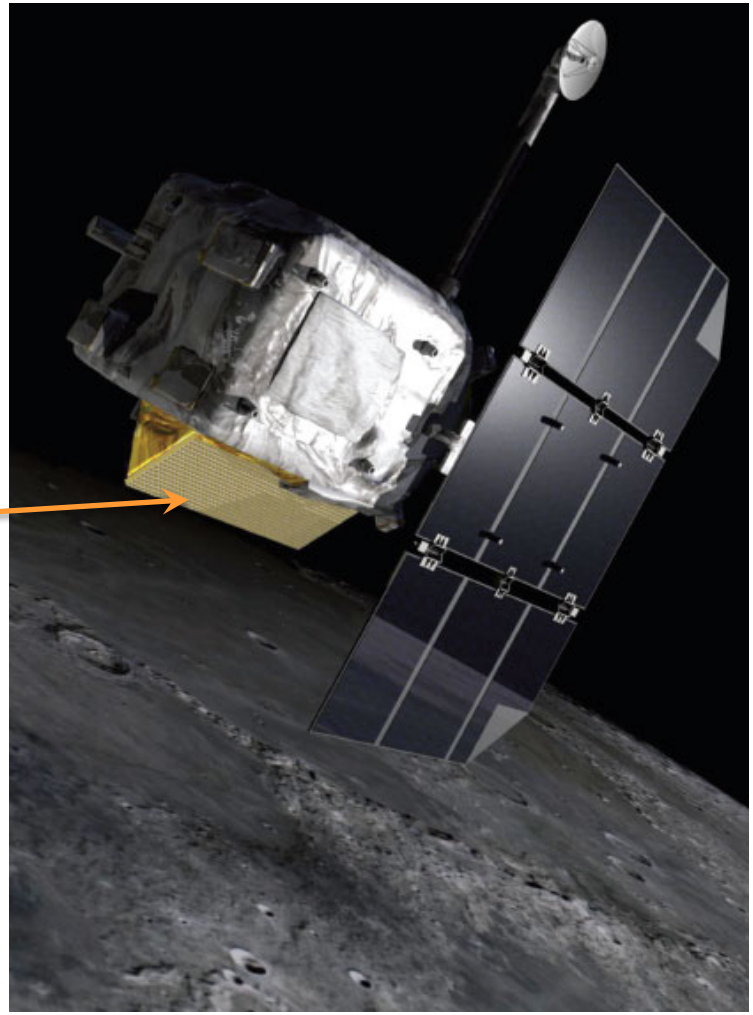


In Operations

Lunar Reconnaissance Orbiter

What is Mini-RF?





As Mounted on the Spacecraft

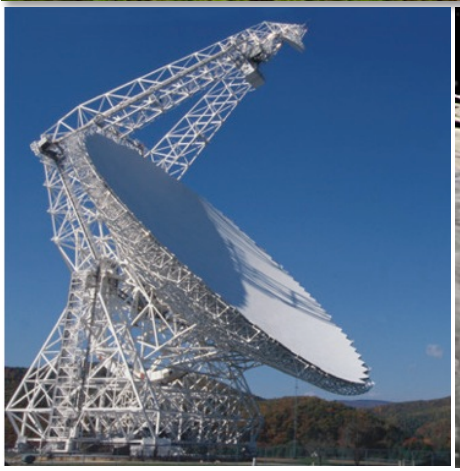
Chandrayaan-1

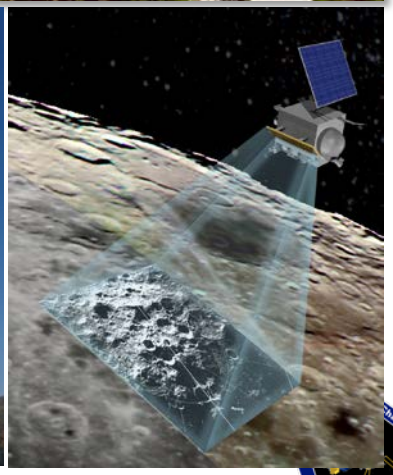
Magellan

LRO

Instrument Description

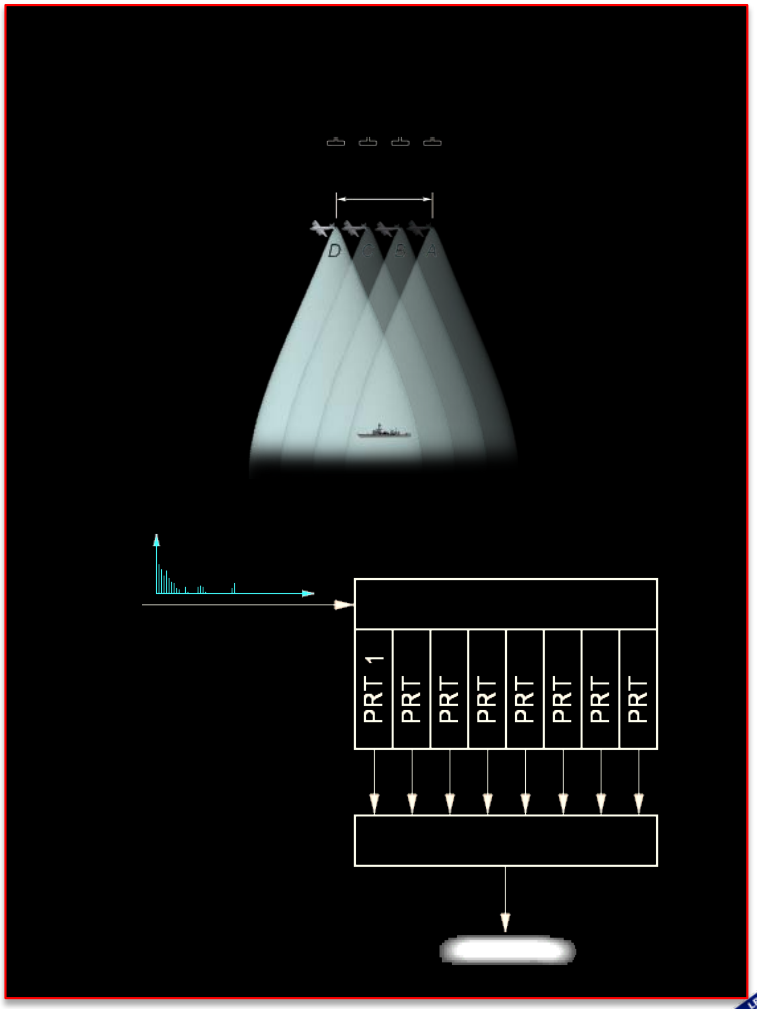
- Two-band, two-resolution imaging radar
  - S-band (λ=12.6 cm)
  - X-band (λ=4.2 cm)
  - SAR Baseline 150 m
  - Zoom 15x30 m
- Hybrid-architecture polarimetric SAR
  - Transmit LCP; Receive *H*- and *V*- linear coherently
  - Four Stokes parameters derived
- Mini-RF can measure topography
  - Interferometry: 15 m/pix spatial, sub-meter vertical resolution
  - SAR-stereo: 30 m/pix spatial, ~10 m vertical
- Low mass and power requirements
  - 13 kg, 150 W



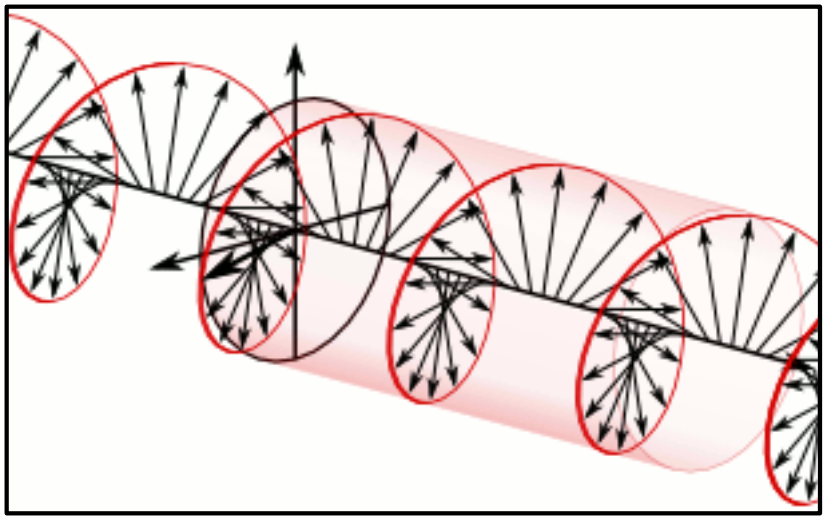


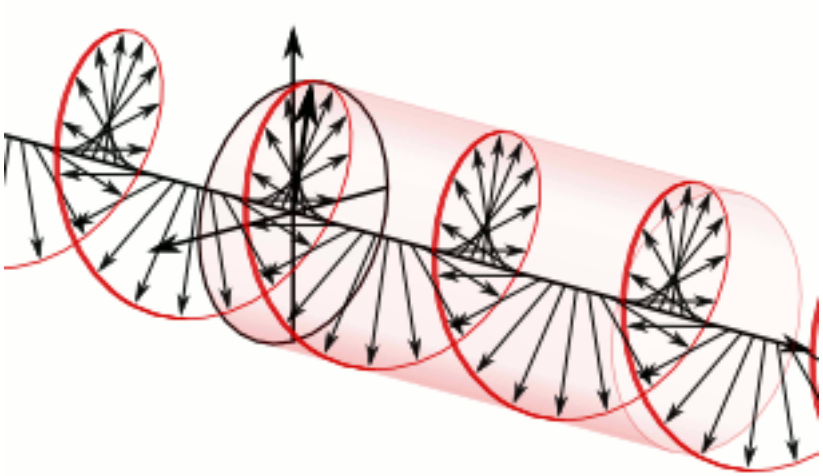
Synthetic Aperture Radar

- A Hybrid Dual-Polarized **Synthetic Aperture** Radar?
  - A form of radar that uses the relative motion between an antenna and its target to obtain higher resolution information.

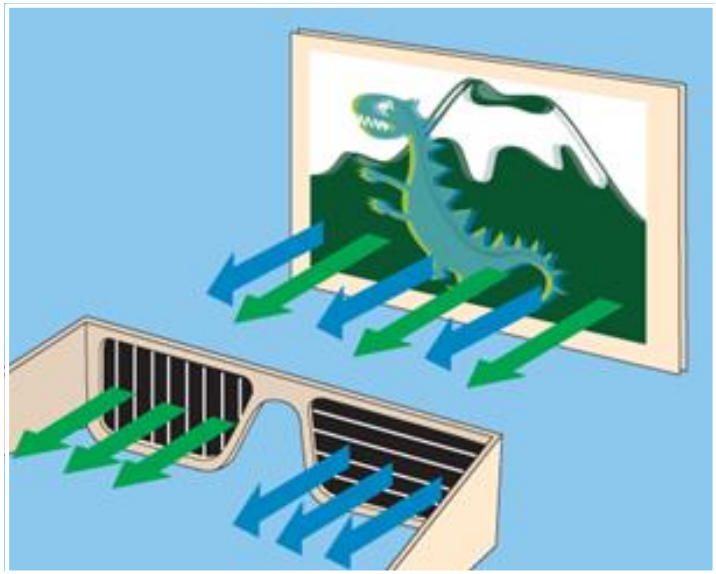


Dual Polarized Signal

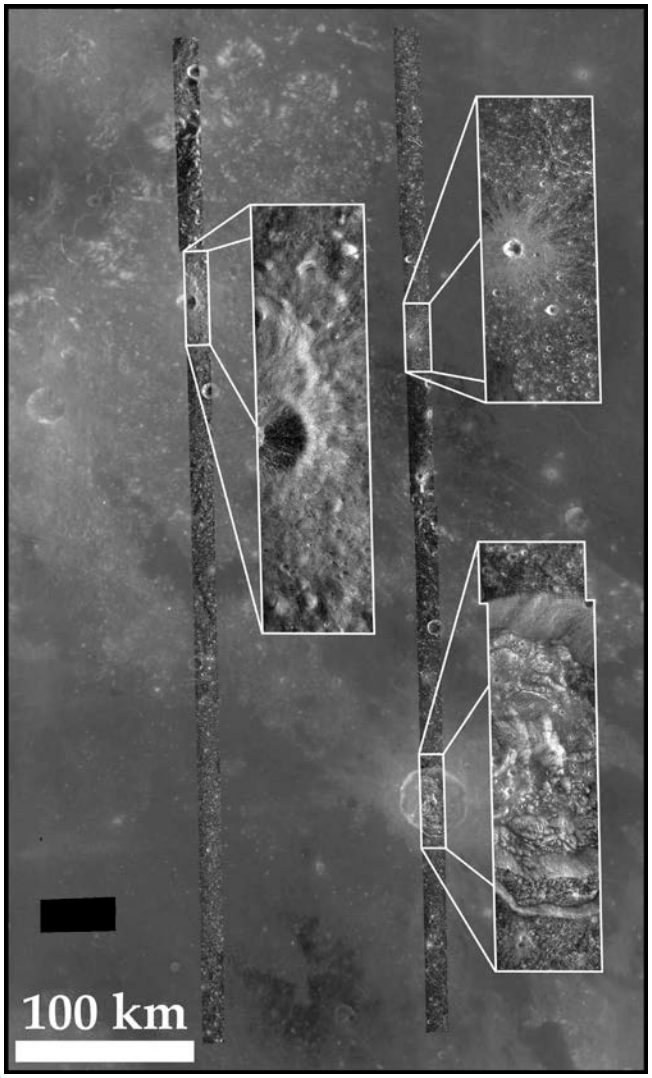




- A Hybrid **Dual-Polarized** Synthetic Aperture Radar
  - And, to top it off ……it's dual polarized
    - Polarization is a property of waves that can oscillate with more than one orientation.

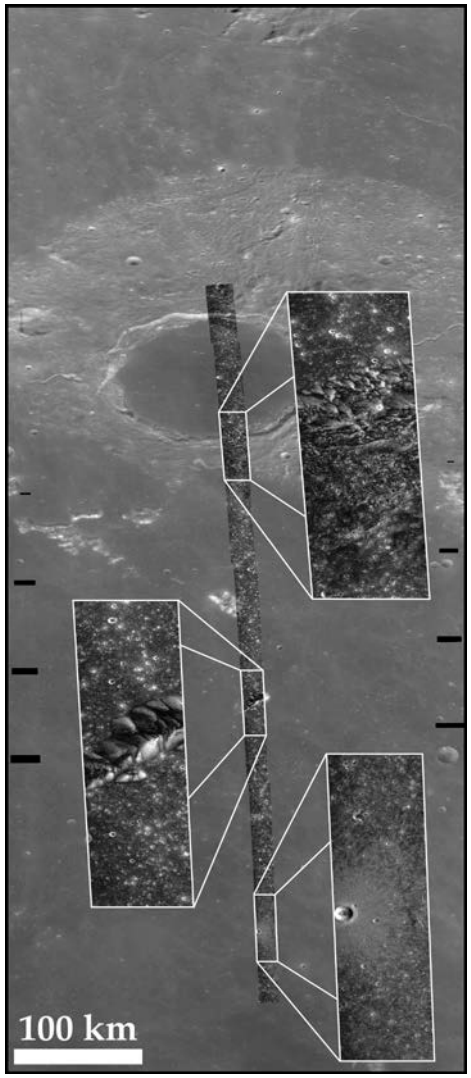


Examples of Mini-RF Data



Typical strip is 1920 x 10 km

Mini-RF SAR data co- registered with Clementine UVVIS context mosaics.



MINI-RF: DATA PRODUCTS

Basic Data Products Often Used and We Provide

Polarization Info: H, V, Re, Im

Stokes Products (S_1, S_2, S_3, S_4)

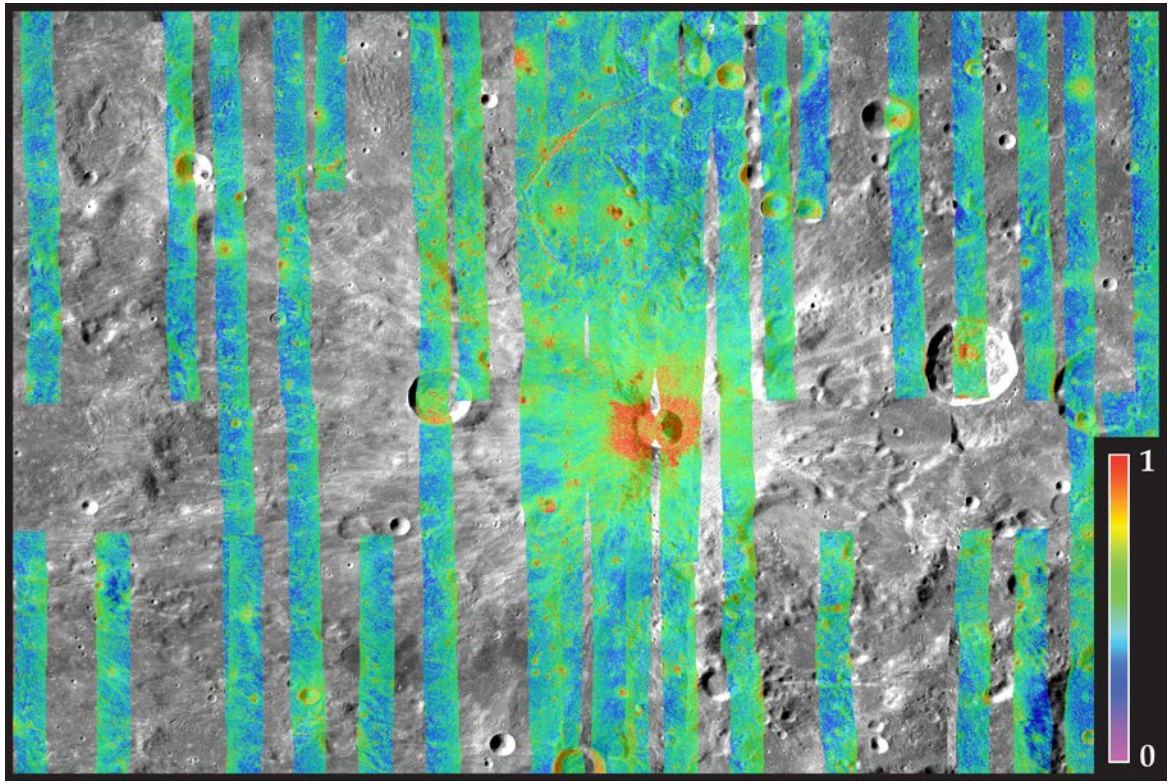
SC = (S_1-S_4)

OC = (S_1+S_4)

CPR = (S_1-S_4)/(S_1+S_4) = SC/OC

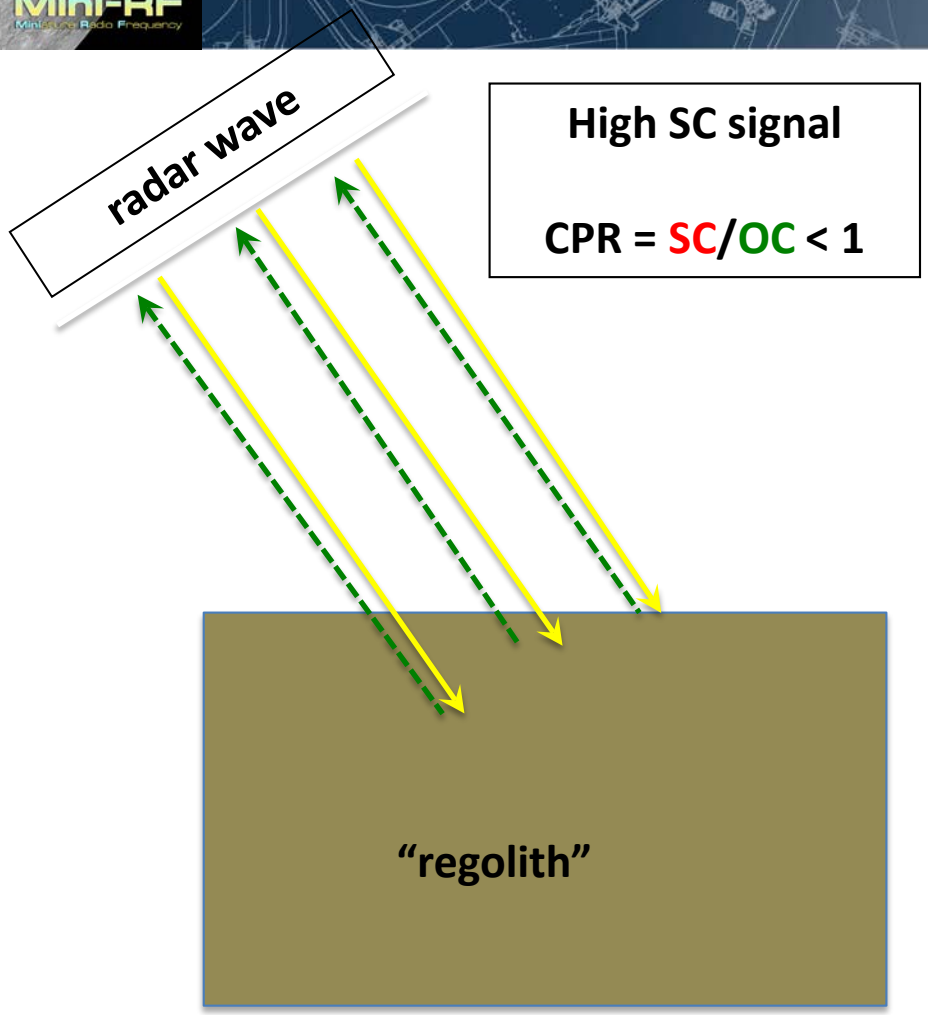
– Indicator of the roughness of a surface, as determined by the distribution of wavelength-scale and larger radar scatterers (*e.g.*, boulders).

– Young, fresh craters are distinctive in radar images obtained with the Mini-RF instrument because of the surface roughness associated with their ejecta deposits.



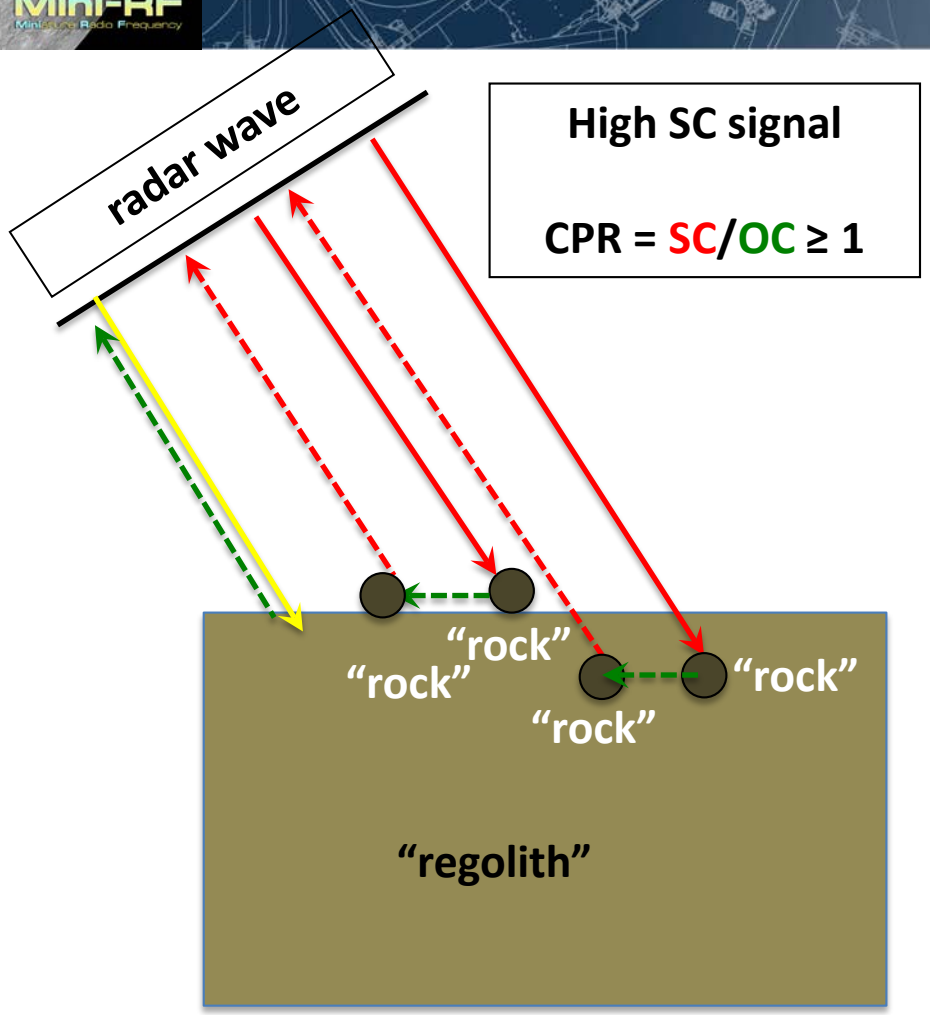
How do we interpret radar?

Interpretation of Roughness



Surfaces 'smooth' at the scale of the wavelength will have a low Circular Polarization Ratio

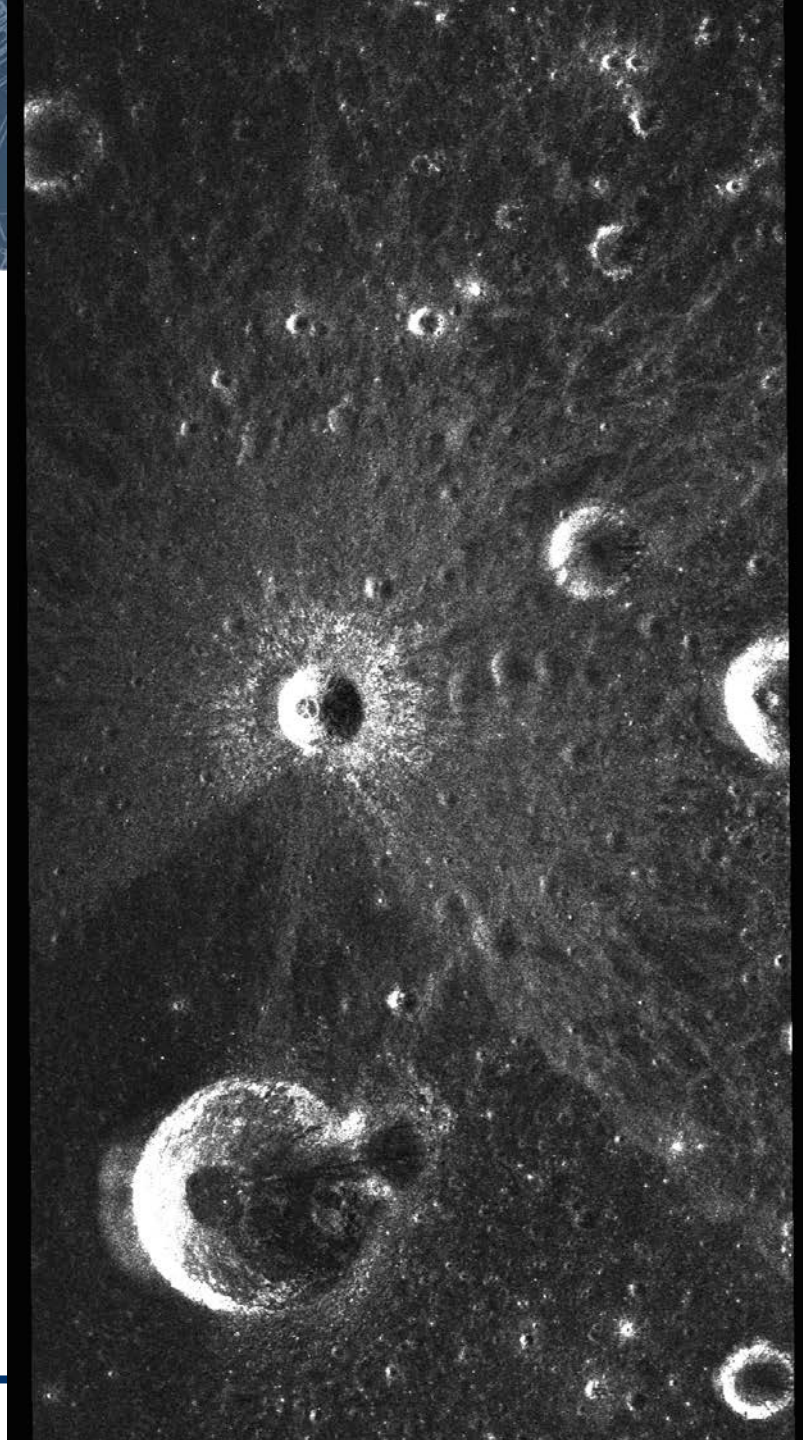
Interpretation of Roughness



If there is a corner reflector the polarization will change twice returning as it was transmitted in the particular case.

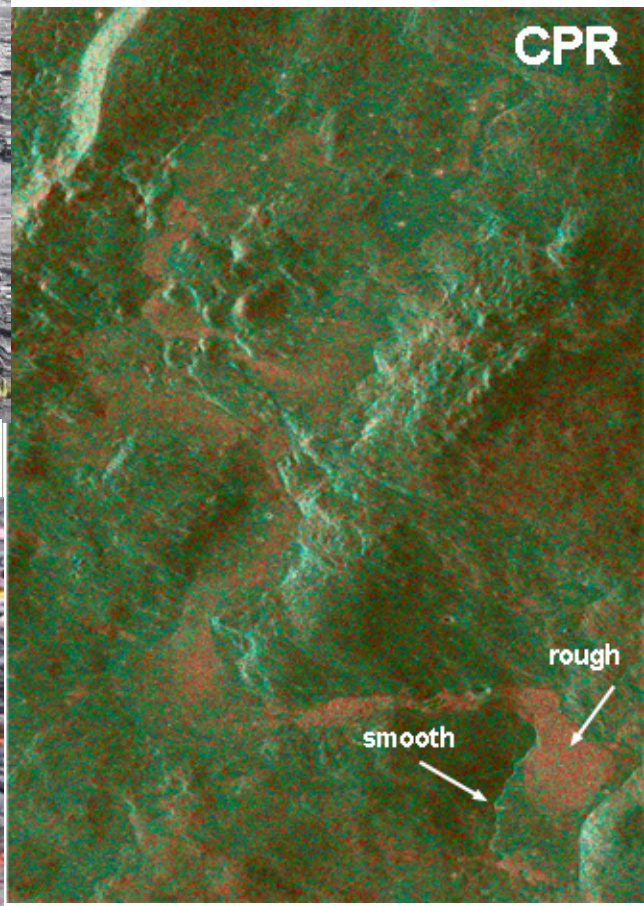
Mini-RF Maps Crater Ejecta Blankets

- Mini-RF maps the roughness of the lunar surface. In doing so it can map the ejecta blankets that surround impact craters
- Mini-RF can see ejecta that are not visible in optical images.
- This could be because the extended ejecta cause subtle variations in surface roughness or that Mini-RF is detecting subsurface effects.
- Mapping the continuous and discontinuous ejecta blankets that surround impact craters will help us to better understand the physics of impact cratering.



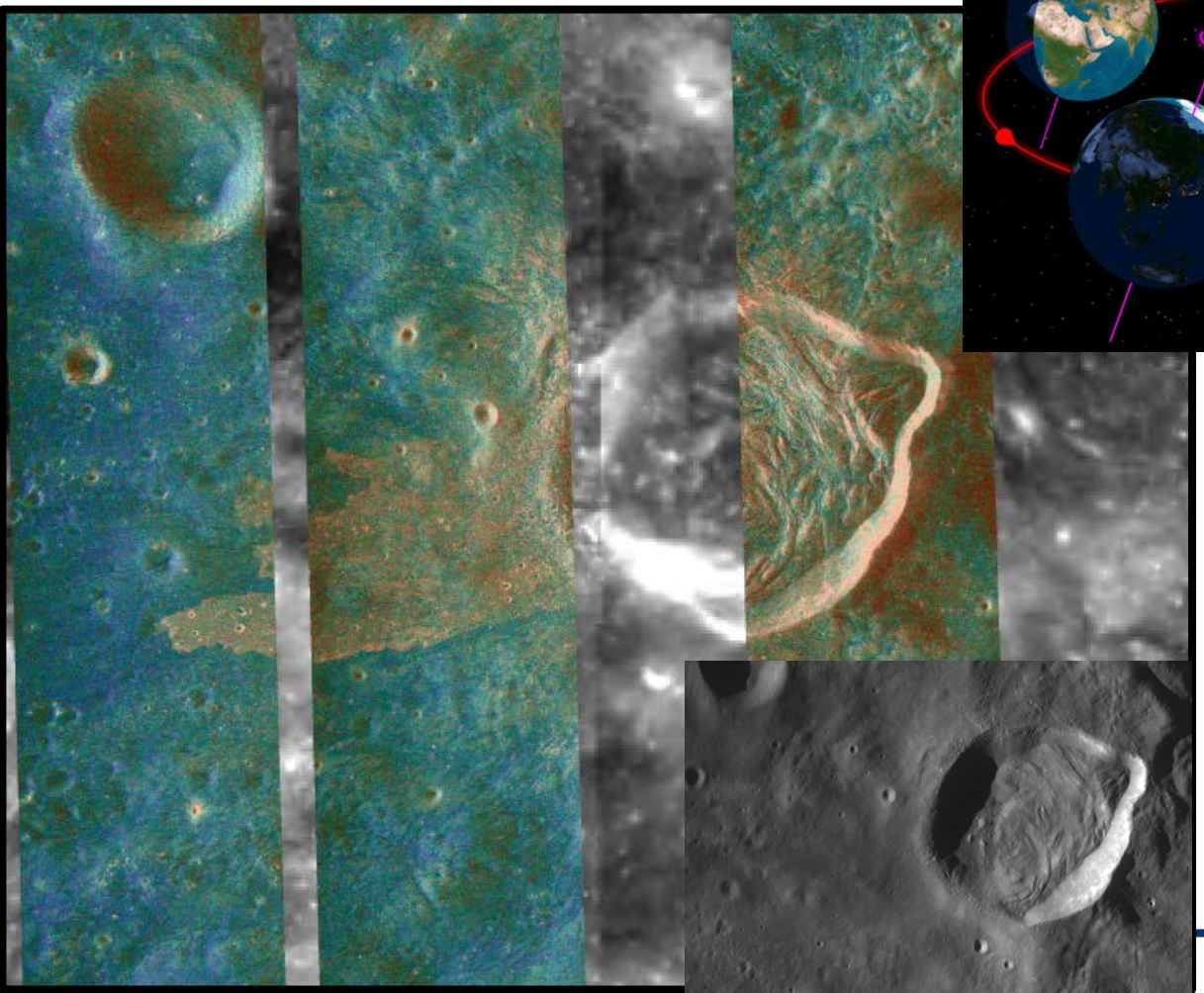
Oblique impact crater in mare Nubium. Both the continuous and extended ejecta blankets are detected

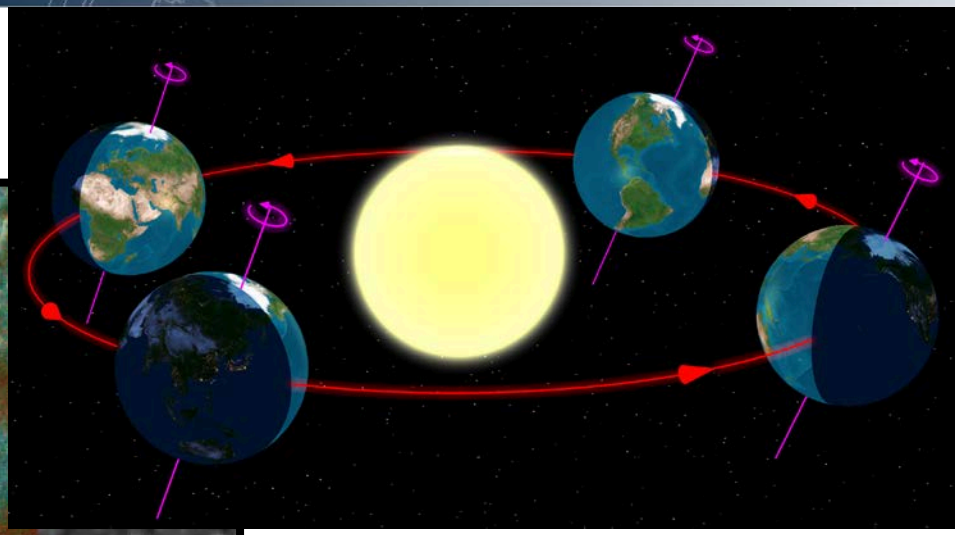
Melt Flow Roughness



Imaging Shadowed and Subsurface Deposits

- Imaging subsurface deposits

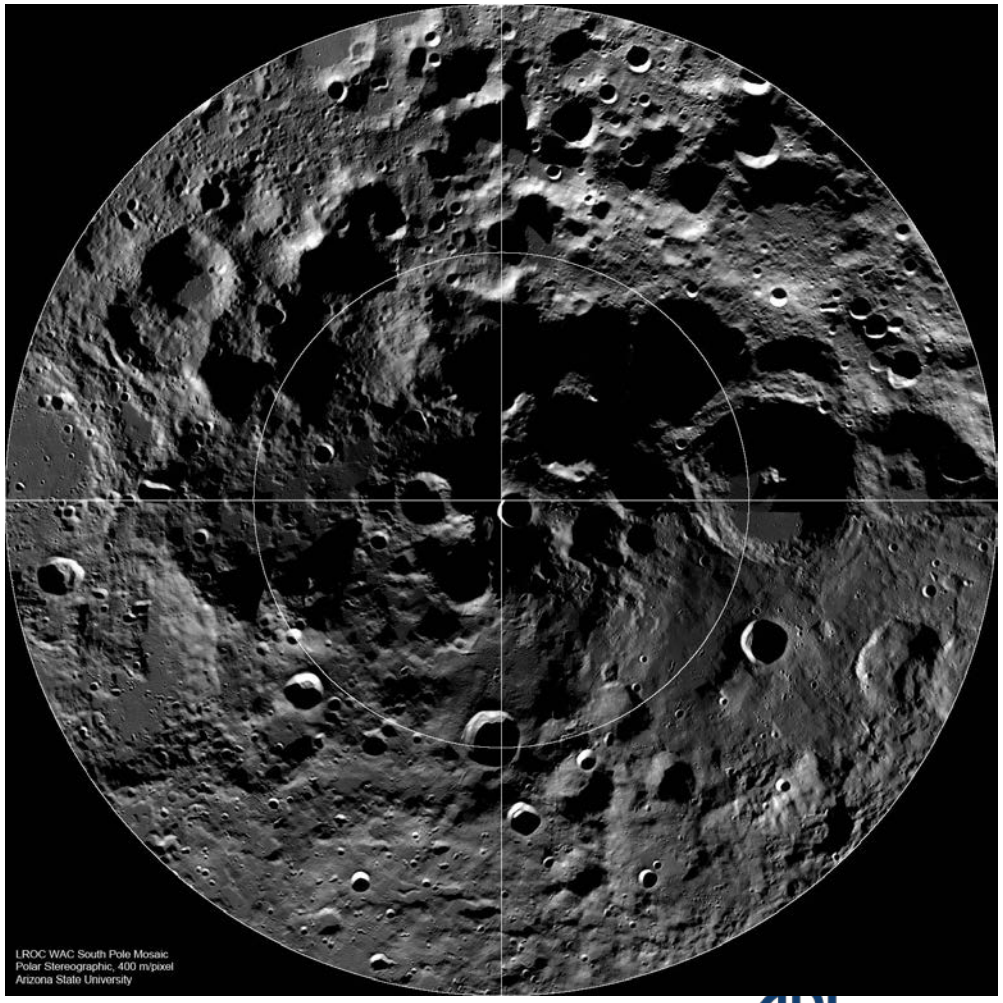


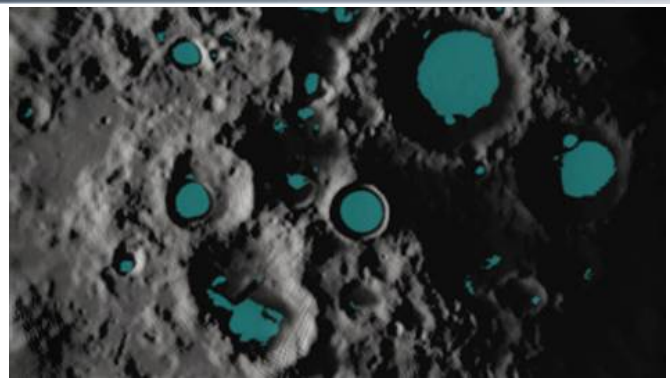


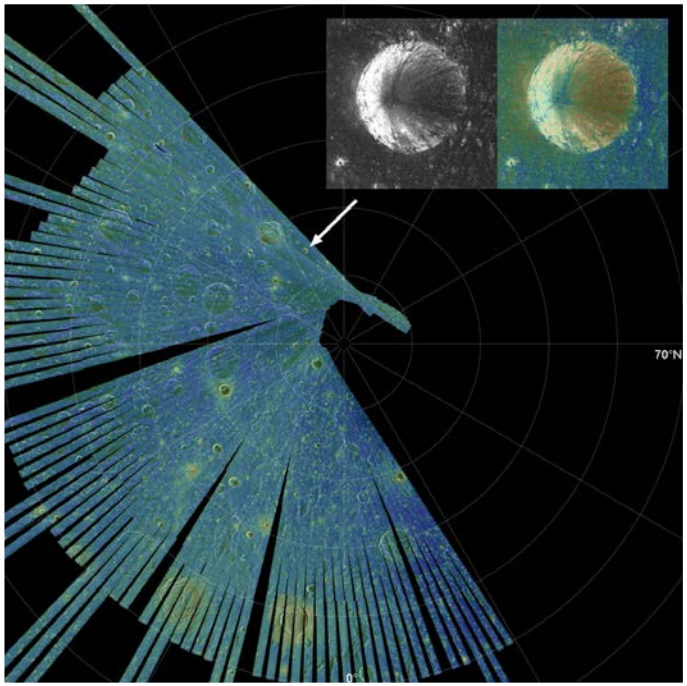
- Imaging at night
- Key towards Mini-RF's total data collection
- LROC didn't usually image at night

Imaging in Permanent Shadow

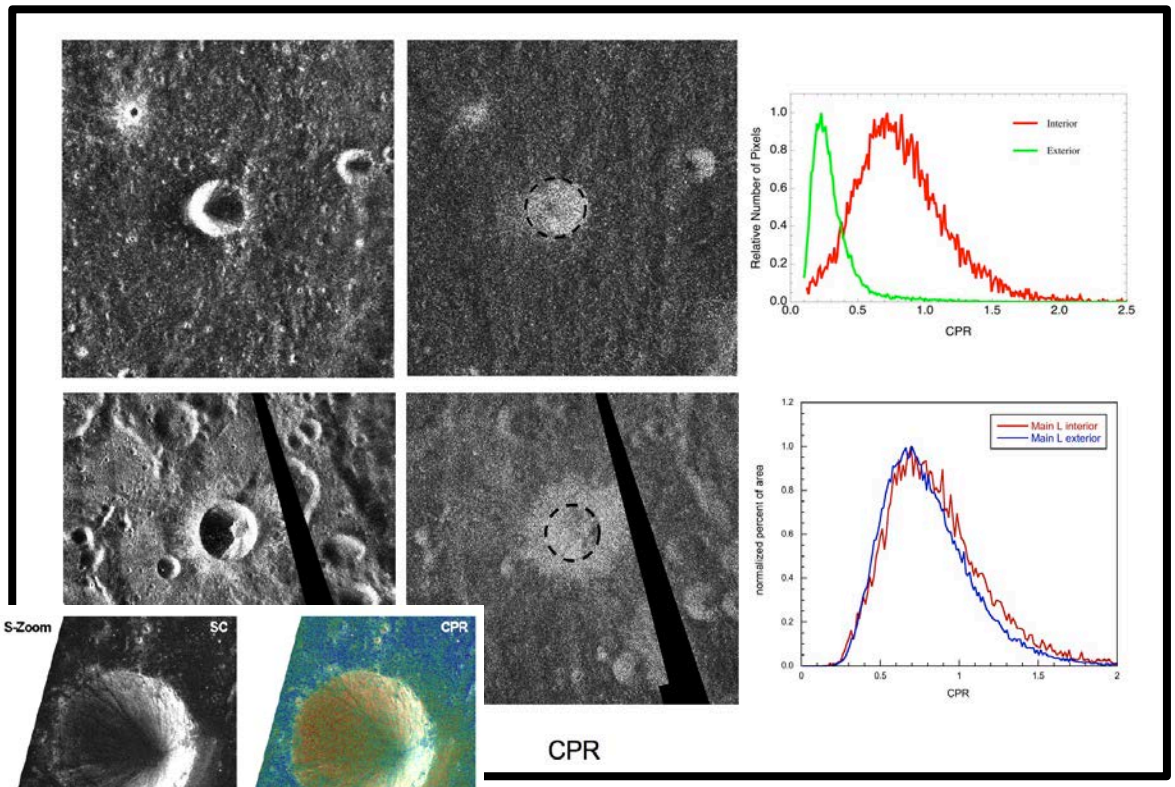
- It leads to permanent shadow

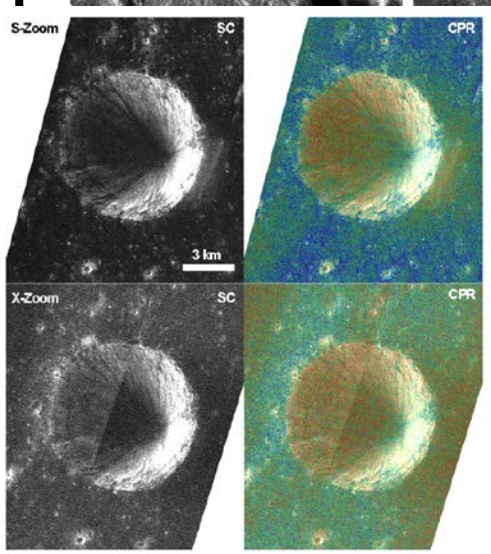


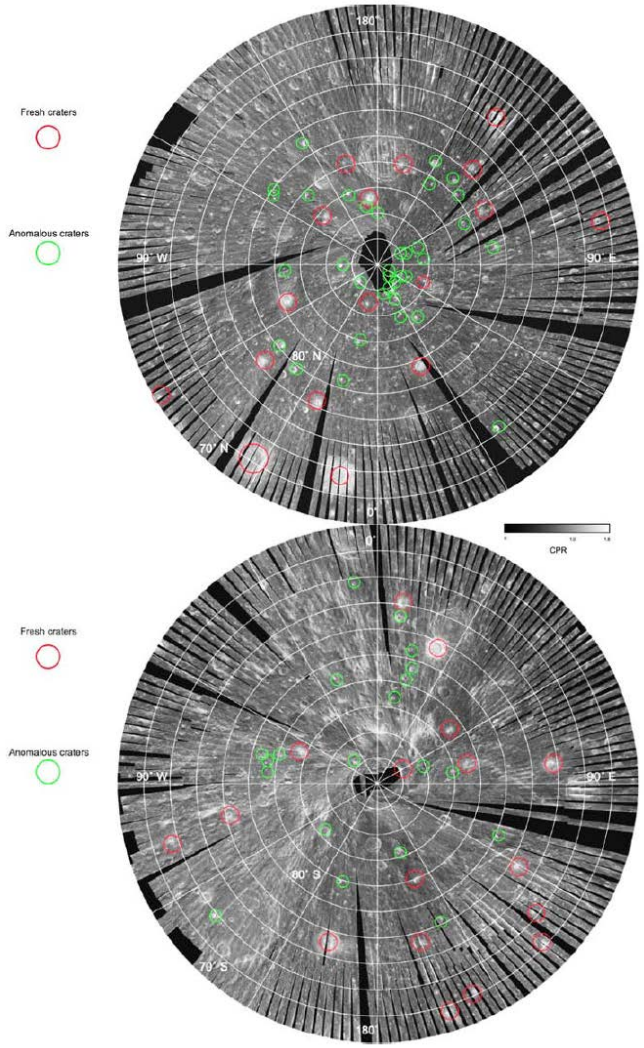




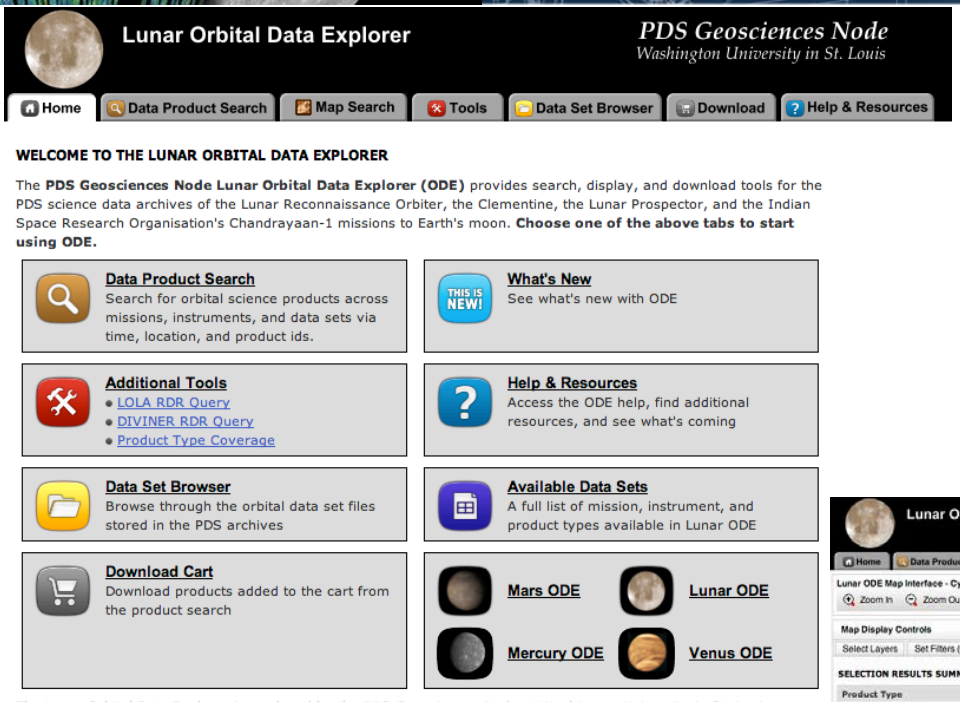
Searching for Ice



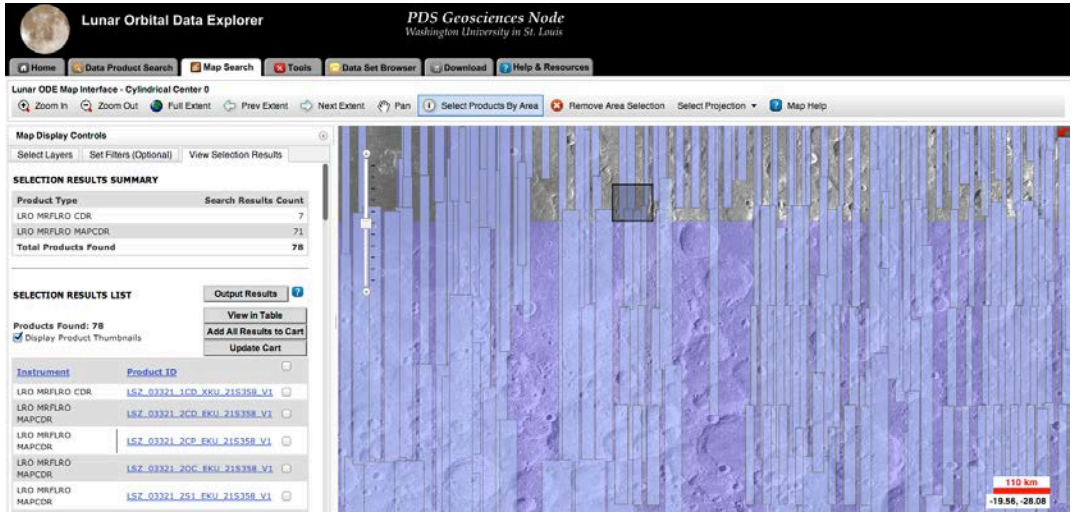




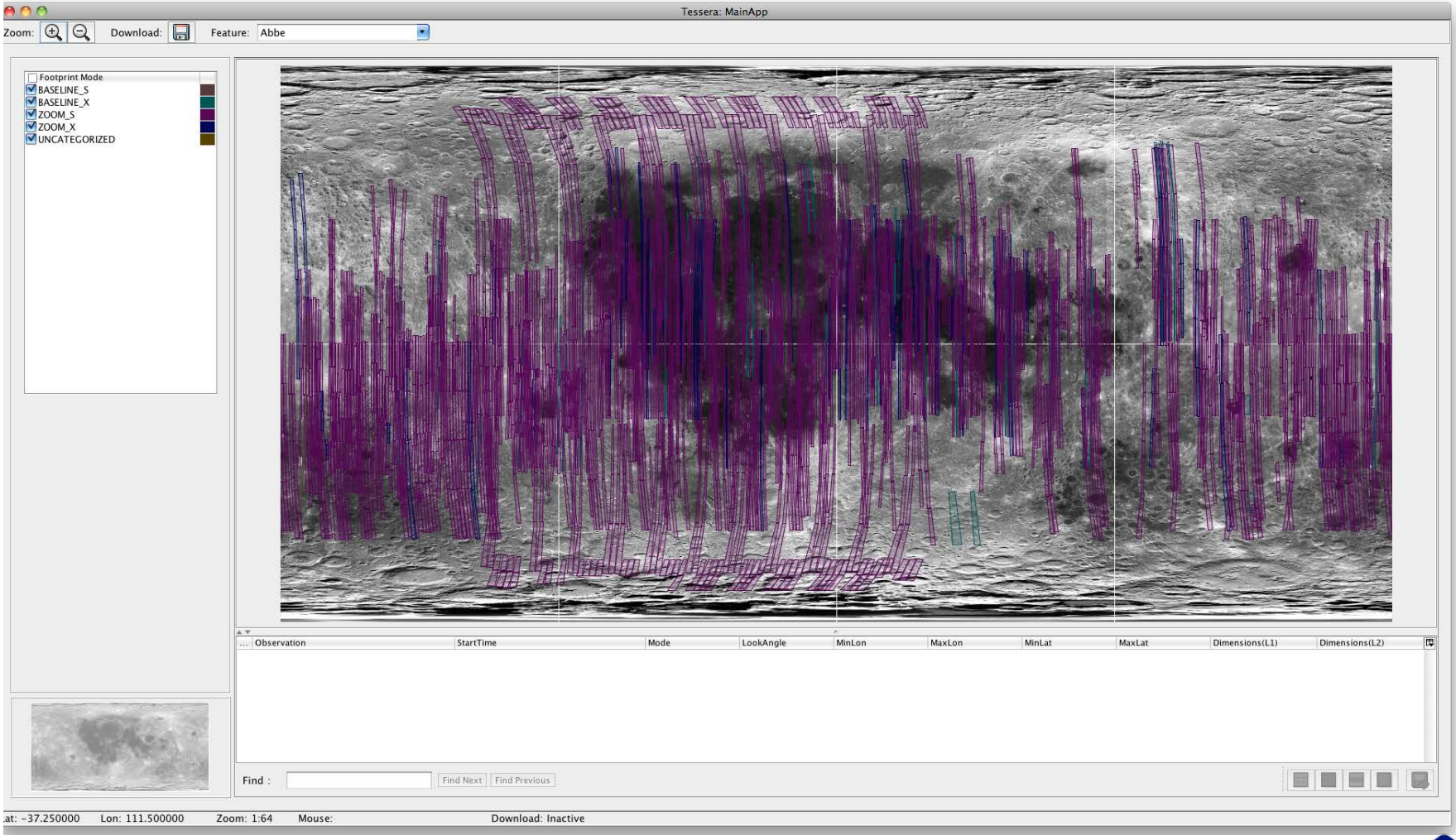
Where To Find Data: Planetary Data Explorer



- LRO Mini-RF Data can be accessed through planetary data explorer
- Mini-SAR too!

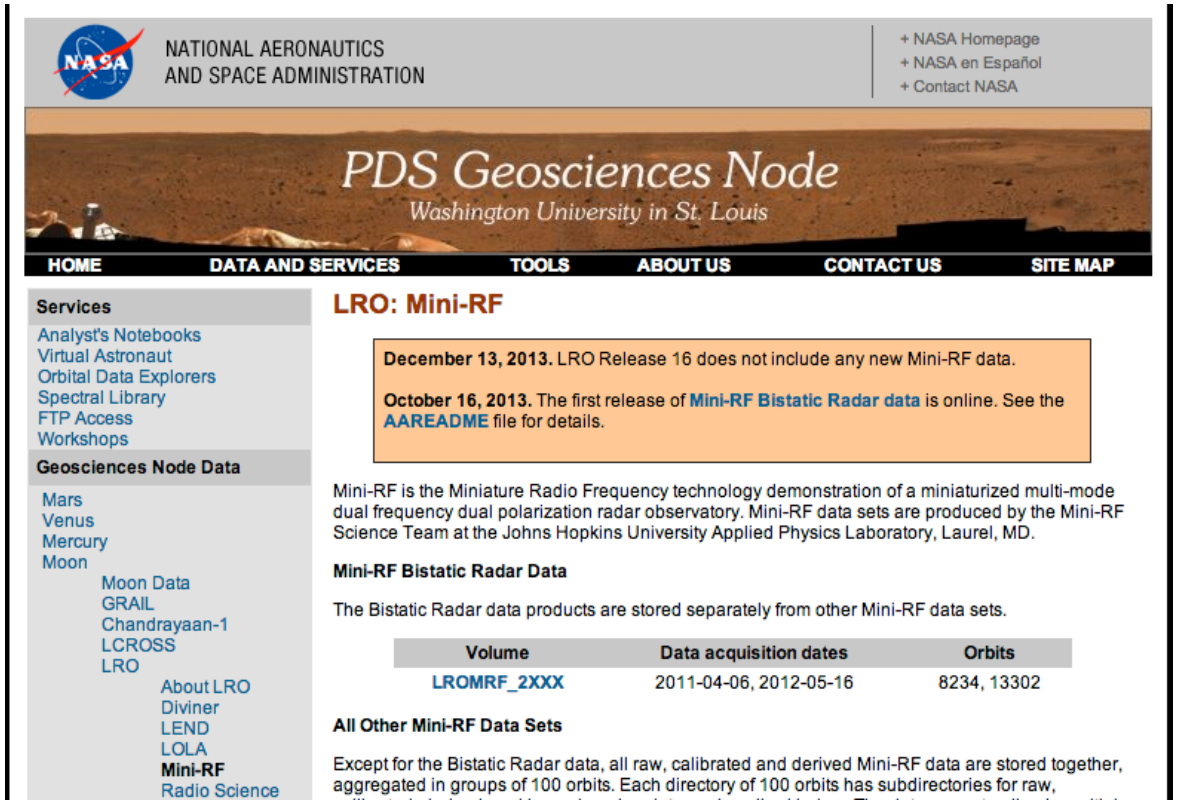


Tessera: Data Access Tool



Where To Find Data

- Planetary Data System – Wash. U. Node (pds-geosciences.wustl.edu)
- http://pds-geosciences.wustl.edu/missions/lro/mrf.htm



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

+ NASA Homepage
+ NASA en Español
+ Contact NASA

PDS Geosciences Node
Washington University in St. Louis

HOME | DATA AND SERVICES | TOOLS | ABOUT US | CONTACT US | SITE MAP

Services
Analyst's Notebooks
Virtual Astronaut
Orbital Data Explorers
Spectral Library
FTP Access
Workshops

Geosciences Node Data
Mars
Venus
Mercury
Moon
Moon Data
GRAIL
Chandrayaan-1
LCROSS
LRO
About LRO
Diviner
LEND
LOLA
Mini-RF
Radio Science

LRO: Mini-RF

December 13, 2013. LRO Release 16 does not include any new Mini-RF data.

October 16, 2013. The first release of **Mini-RF Bistatic Radar data** is online. See the **AAREADME** file for details.

Mini-RF is the Miniature Radio Frequency technology demonstration of a miniaturized multi-mode dual frequency dual polarization radar observatory. Mini-RF data sets are produced by the Mini-RF Science Team at the Johns Hopkins University Applied Physics Laboratory, Laurel, MD.

Mini-RF Bistatic Radar Data

The Bistatic Radar data products are stored separately from other Mini-RF data sets.

Volume	Data acquisition dates	Orbits
LROMRF_2XXX	2011-04-06, 2012-05-16	8234, 13302

All Other Mini-RF Data Sets

Except for the Bistatic Radar data, all raw, calibrated and derived Mini-RF data are stored together, aggregated in groups of 100 orbits. Each directory of 100 orbits has subdirectories for raw,

Data Available by Orbit

- Monostatic data was collected until Dec. 25th,2010 (Merry Christmas!)

Volume	Data acquisition dates	Orbit range
LROMRF_0001	2007-07-13 to 2010-01-19	200-2599
LROMRF_0002	2010-01-19 to 2010-06-17	2600-4499
LROMRF_0003	2010-06-17 to 2010-07-23	4500-4999
LROMRF_0004	2010-07-23 to 2010-12-05	5000-6699
LROMRF_0005	2010-12-05 to 2011-01-23	6700-7302

Data Available

- PDRs: While available need a specialized processor (VEXCEL)
- CDRs: ('LEVEL 1' unprojected .img and .lbl files
- CDR-INSAR (small number) coming soon
- CDR-MAPs: ('LEVEL 2' projected .img and .lbl files – again can be brought into ISIS)
- CDR-MOSAICs

The Mini-RF archive includes these data sets:

Raw Data Products

PDR - Packetized Data Records
(Directories DATA/SAR/.../RAW and DATA/SAR/.../HOUSEKEEPING)

Calibrated Data Products

CDR - Calibrated Data Records
(Directory DATA/SAR/.../LEVEL1)

CDR-INSAR - Interferometric Calibrated Data Records -- to be released later

Derived Data Products

CDR-MAP - Map-Projected Calibrated Data Records
(Directory DATA/SAR/.../LEVEL2)

CDR-MOSAIC - Polar Mosaic Calibrated Data Records
(Directory DATA/SAR/MOSAICS

Level 1 Data

- CDRs: ‘LEVEL 1’
- Non-Orthorectified
- Unprojected
- .img, .lbl, .txt files
- Products Include
  - ‘’cd’ -> H, V, Re, Im (4 Bands)
- ISIS Compatible
  - mrf2isis

[To Parent Directory]

5/18/2012	9:28 AM	7884	aareadme.txt
4/4/2011	12:56 PM	<dir>	calib
6/16/2011	1:16 PM	<dir>	catalog
3/15/2011	9:56 AM	<dir>	data
4/4/2011	12:57 PM	<dir>	document
9/17/2013	9:50 AM	28574	errata.txt
4/11/2011	4:28 PM	<dir>	extras
6/6/2012	11:05 AM	<dir>	index
4/4/2011	12:54 PM	3182	voldesc.cat

4/4/2011	12:36 PM	<dir>	06700_06799
5/27/2011	10:19 AM	<dir>	06800_06899
5/27/2011	10:19 AM	<dir>	06900_06999
5/27/2011	10:19 AM	<dir>	07000_07099
5/27/2011	10:19 AM	<dir>	07100_07199
5/27/2011	10:19 AM	<dir>	07200_07299
5/27/2011	10:19 AM	<dir>	07300_07399
6/4/2012	4:34 PM	<dir>	mosaics

[To Parent Directory]

4/4/2011	1:16 PM	4745674784	lsz_06800_2cd_eku_10n173_v1.img
4/4/2011	1:13 PM	5116	lsz_06800_2cd_eku_10n173_v1.lbl
5/2/2011	4:57 PM	270515	lsz_06800_2cd_eku_10n173_v1.txt

Level 2 Data

- CDRs: ‘LEVEL 2’
- Non-Orthorectified
- Equirectangular projections
- .img, .lbl, .txt files
- Products Include
  - ‘cd’ -> H, V, Re, Im (4 Bands)
  - Stokes denoted ‘s1, s2, s3, s4’
  - ‘cp’ -> CPR
  - ‘oc’ -> opposite sense
  - ‘sc’ -> same sense
- ISIS Compatible
  - mrf2isis

[To Parent Directory]

5/27/2011 10:18 AM	<dir>	housekeeping
5/27/2011 10:18 AM	<dir>	level1
6/9/2011 10:37 AM	<dir>	level2
5/27/2011 10:19 AM	<dir>	raw

4/4/2011 12:36 PM	<dir>	06700_06799
5/27/2011 10:19 AM	<dir>	06800_06899
5/27/2011 10:19 AM	<dir>	06900_06999
5/27/2011 10:19 AM	<dir>	07000_07099
5/27/2011 10:19 AM	<dir>	07100_07199
5/27/2011 10:19 AM	<dir>	07200_07299
5/27/2011 10:19 AM	<dir>	07300_07399
6/4/2012 4:34 PM	<dir>	mosaics

[To Parent Directory]

4/4/2011 1:16 PM	4745674784	lsz_06800_2cd_eku_10n173_v1.img
4/4/2011 1:13 PM	5116	lsz_06800_2cd_eku_10n173_v1.lbl
5/2/2011 4:57 PM	270515	lsz_06800_2cd_eku_10n173_v1.txt
4/4/2011 2:33 PM	9023205888	lsz_06800_2cd_eku_34n172_v1.img
4/4/2011 2:28 PM	5110	lsz_06800_2cd_eku_34n172_v1.lbl
5/2/2011 4:57 PM	404447	lsz_06800_2cd_eku_34n172_v1.txt
4/4/2011 1:32 PM	25107356064	lsz_06800_2cd_eku_58n171_v1.img
4/4/2011 1:19 PM	5112	lsz_06800_2cd_eku_58n171_v1.lbl
5/2/2011 4:57 PM	537884	lsz_06800_2cd_eku_58n171_v1.txt
4/4/2011 1:12 PM	296702920	lsz_06800_2cp_eku_10n173_v1.img
4/4/2011 1:12 PM	4327	lsz_06800_2cp_eku_10n173_v1.lbl
4/4/2011 3:34 PM	563950368	lsz_06800_2cp_eku_34n172_v1.img
4/4/2011 3:33 PM	4328	lsz_06800_2cp_eku_34n172_v1.lbl
4/4/2011 10:44 AM	1569111488	lsz_06800_2cp_eku_58n171_v1.img
4/4/2011 10:43 AM	4328	lsz_06800_2cp_eku_58n171_v1.lbl

Quikview JPEG Data

- CDRs: jpegs are not in the same place
- Look in ‘Extras’ > ‘Quikview’
- JPEG Products Include
  - ‘cd’ -> H, V, Re, Im (4 Bands)
  - Stokes denoted ‘s1, s2, s3, s4’
  - ‘cp’ -> CPR
  - ‘oc’ -> opposite sense
  - ‘sc’ -> same sense

[To Parent Directory]

5/18/2012	9:28 AM	7884	aareadme.txt
4/4/2011	12:56 PM	<dir>	calib
6/16/2011	1:16 PM	<dir>	catalog
3/15/2011	9:56 AM	<dir>	data
4/4/2011	12:57 PM	<dir>	document
9/17/2013	9:50 AM	28574	errata.txt
4/11/2011	4:28 PM	<dir>	extras
6/6/2012	11:05 AM	<dir>	index
4/4/2011	12:54 PM	3182	voldesc.cat

[To Parent Directory]

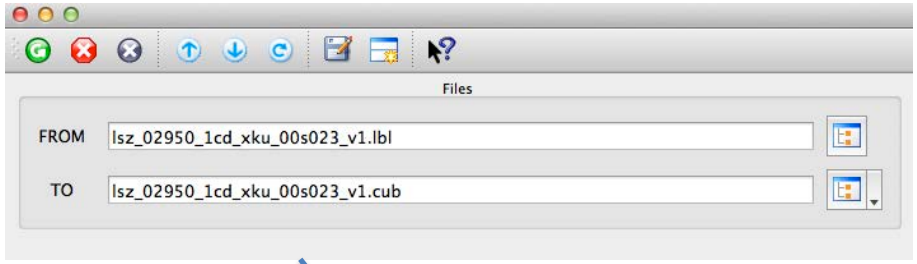
5/18/2012	12:39 PM	3523	extrinfo.txt
6/9/2011	10:41 AM	<dir>	orbnum
4/30/2010	4:17 PM	16260	processing_parms.txt
6/6/2012	10:24 AM	<dir>	quikview

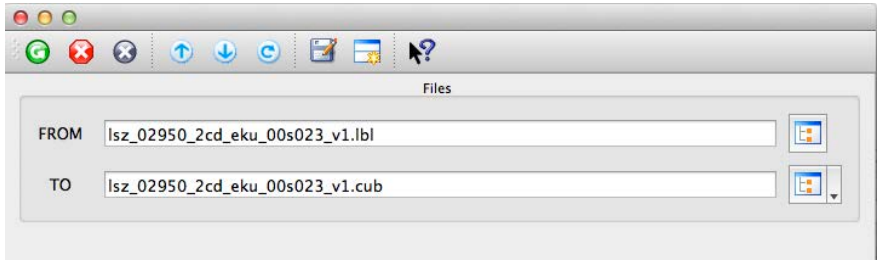
[To Parent Directory]

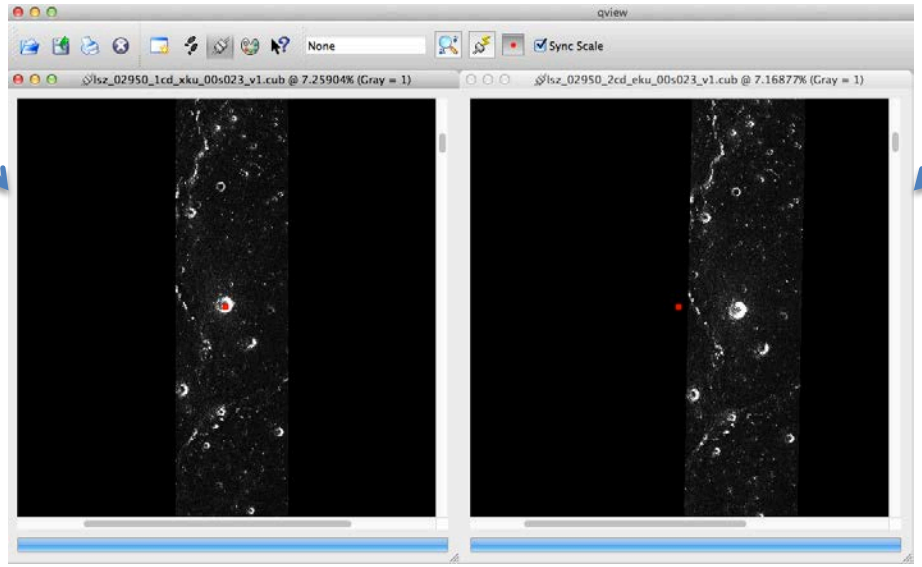
4/1/2011	8:49 AM	3277764	lsz_06800_2cp_eku_10n173_v1.jpg
4/1/2011	8:49 AM	3951678	lsz_06800_2cp_eku_34n172_v1.jpg
4/1/2011	8:49 AM	6385835	lsz_06800_2cp_eku_58n171_v1.jpg
4/1/2011	8:57 AM	2894629	lsz_06800_2s1_eku_10n173_v1.jpg
4/1/2011	8:58 AM	3498037	lsz_06800_2s1_eku_34n172_v1.jpg
4/1/2011	9:00 AM	5610988	lsz_06800_2s1_eku_58n171_v1.jpg

Data Processing Level 1 and 2: ISIS

- ‘mrf2isis’ will process both Level 1 and 2 files in for all data product arrays (S_1, CPR, OC, SC, etc.)





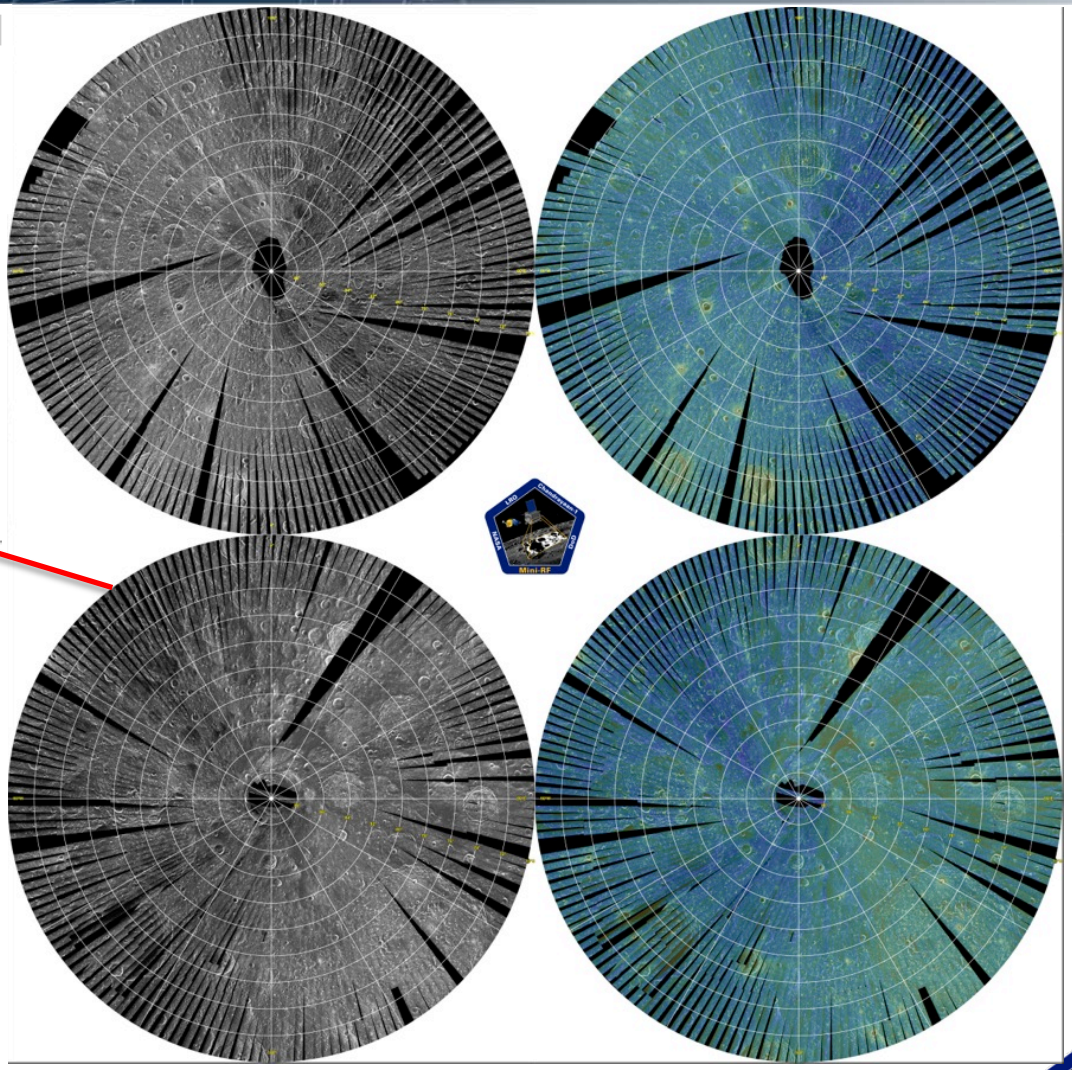


- To orthorectify image use ‘spiceinit’ to LOLA altimetry in ISIS3 base data

Level 3: Near Complete Polar Coverage

Volume	Data acquisition dates	Orbit range
LROMRF_0001	2007-07-13 to 2010-01-19	200-2599
LROMRF_0002	2010-01-19 to 2010-06-17	2600-4499
LROMRF_0003	2010-06-17 to 2010-07-23	4500-4999
LROMRF_0004	2010-07-23 to 2010-12-05	5000-6699
LROMRF_0005	2010-12-05 to 2011-01-23	6700-7302

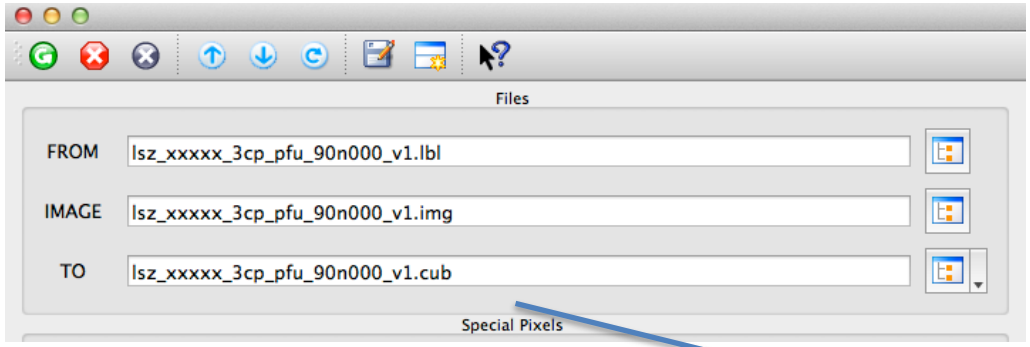
```
 4/4/2011  12:36 PM        <dir> 06700_06799
5/27/2011  10:19 AM        <dir> 06800_06899
5/27/2011  10:19 AM        <dir> 06900_06999
5/27/2011  10:19 AM        <dir> 07000_07099
5/27/2011  10:19 AM        <dir> 07100_07199
5/27/2011  10:19 AM        <dir> 07200_07299
5/27/2011  10:19 AM        <dir> 07300_07399
 6/4/2012   4:34 PM        <dir> mosaics
```

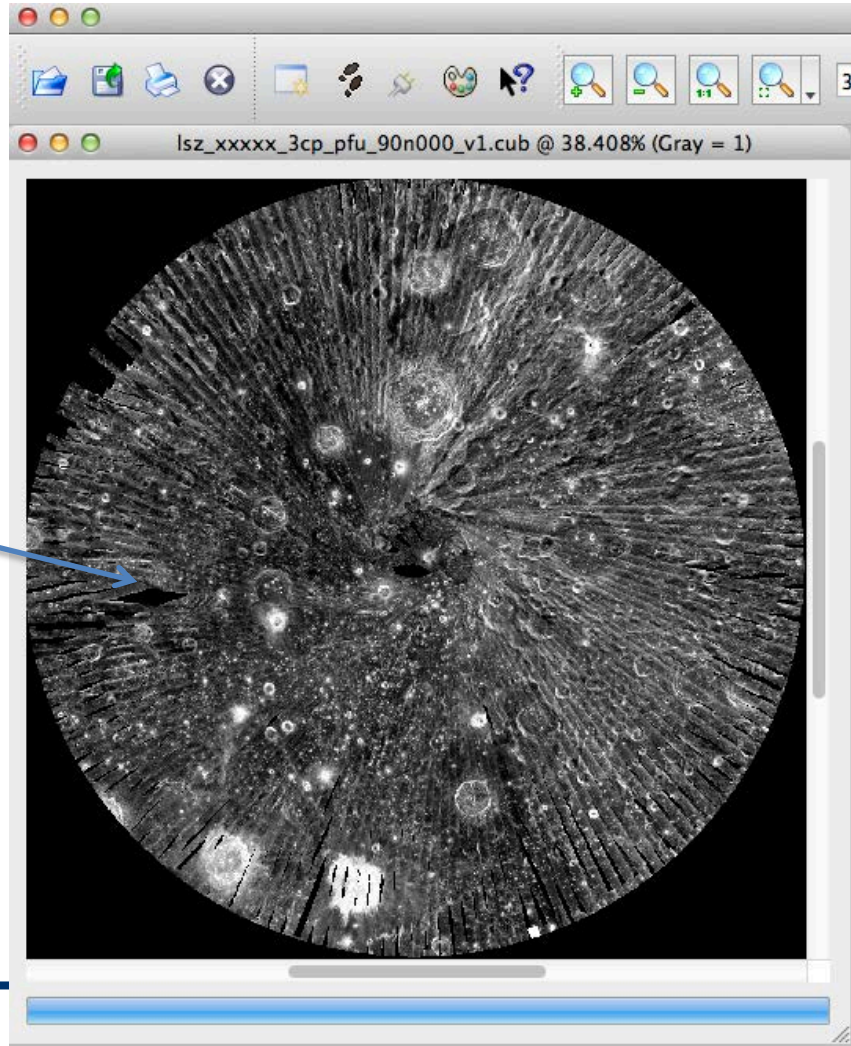


- Polar Mosaics Are available in S- Band if you dig into LROMRF_0005 directory
- Resolutions: 32 & 256 ppd
- S_1 and CPR products
- Both look directions combined

Data Processing Level 3 Mosaics: ISIS

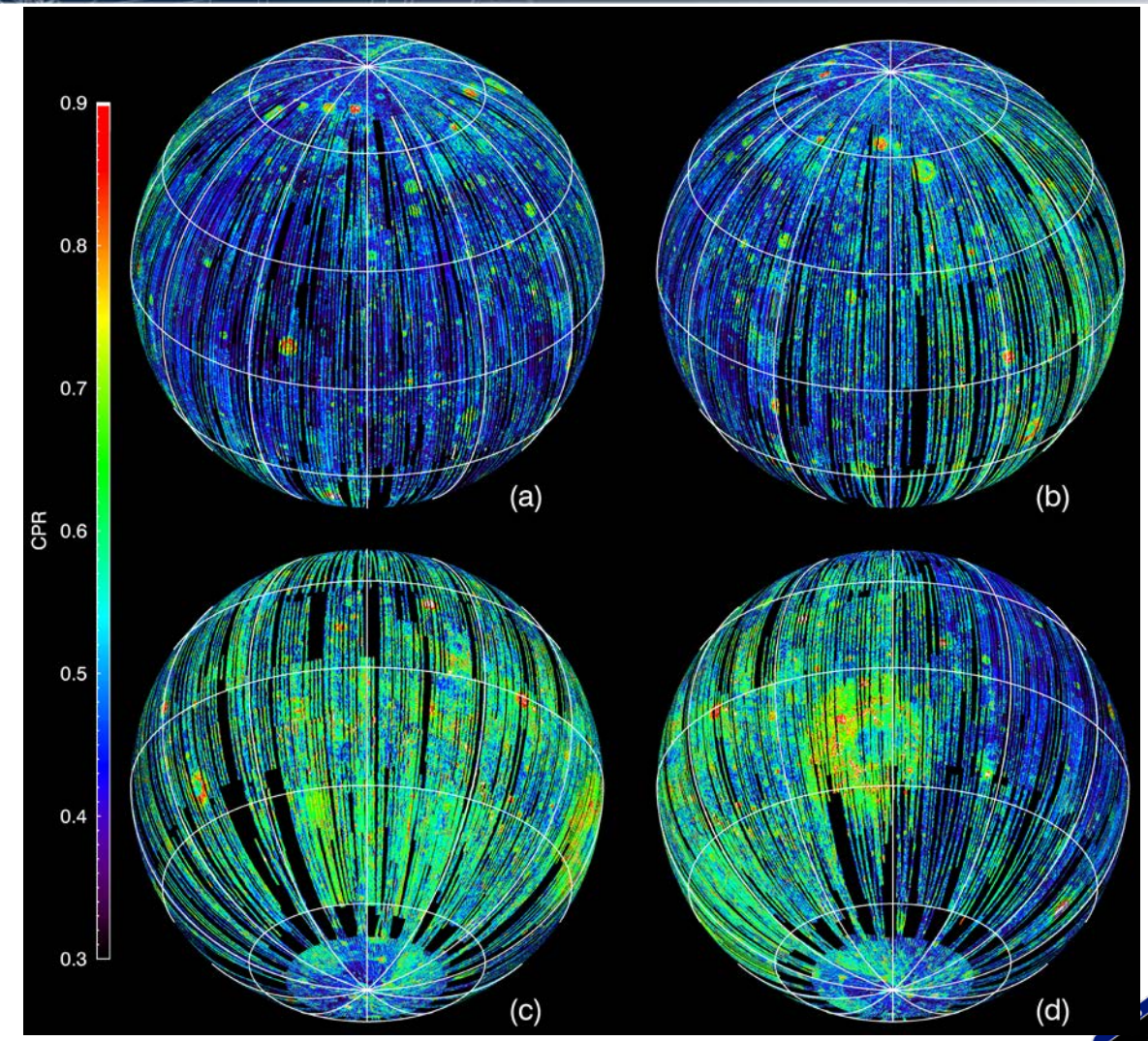
- ‘mrf2isis’ WILL NOT process the mosaics
- Need to use ‘pds2isis’





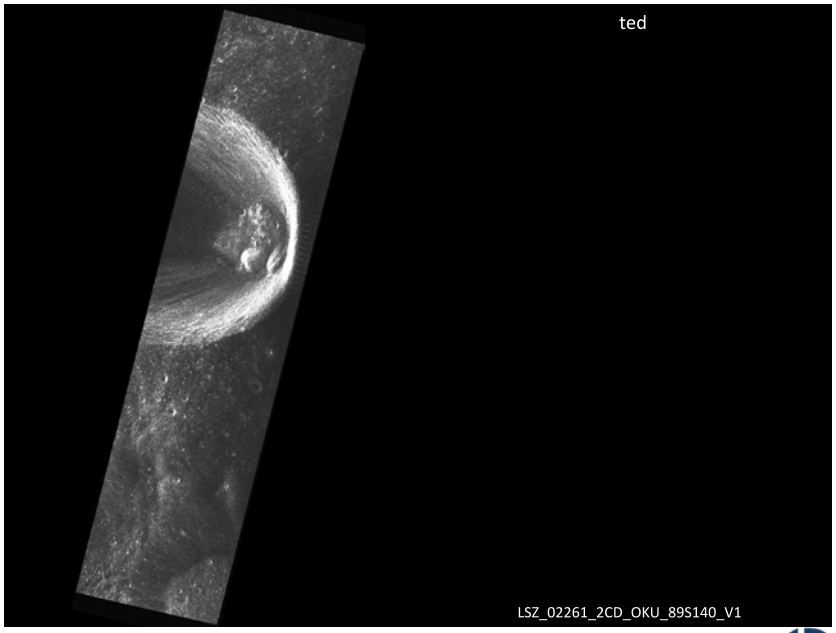
Near Complete Global Coverage

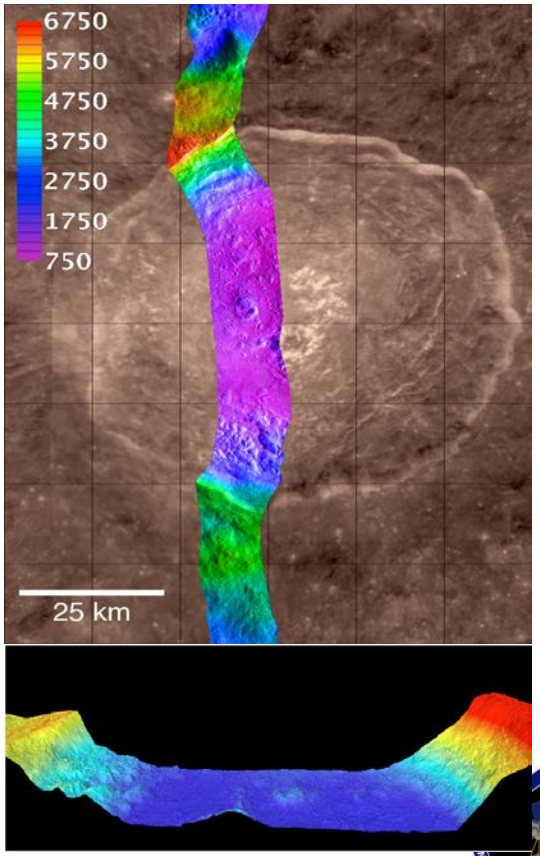
- Global S-band is coming to the PDS
- Data set was not in the SIS for submittal to PDS
- Is being reviewed as a separate delivery to the PDS
- 128 ppd
- Stokes products, CPR, OC, SC, m-chi, etc.



Additional Monostatic Data

- Controlled Data Sets coming available soon (regional)
- Isolated collects of roll-derived high resolution stereo topography
- Several rolled collects of lunar poles



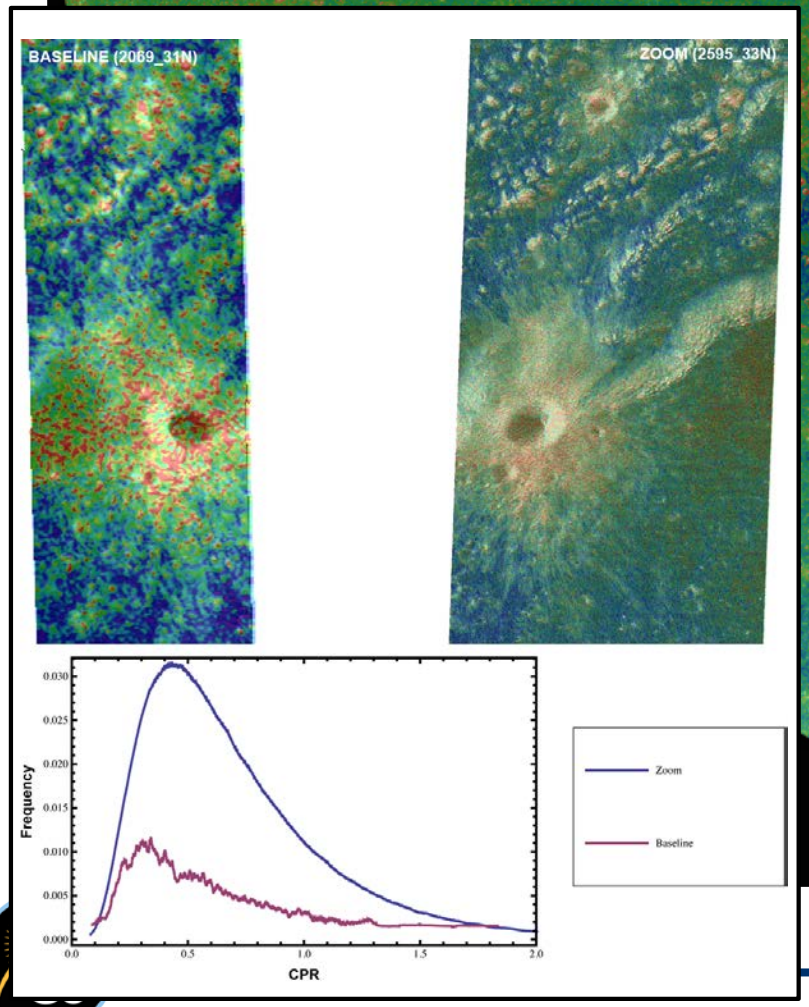


Monostatic Mini-RF Data Set

- Mini-RF is a highly capable instrument, obtaining data about lunar surface properties,
- Tech-demo Mini-RF was only supposed to make a very small number of mono-static collects.
- Mini-RF is a unanticipated and first Global S-band data set of the Moon which the LRO Project and Mini-RF team is giving the Planetary community.
  - 67% of lunar surface mapped
  - >95% polar regions covered
  - >17 TB of (>45 TB with products) Mini-RF delivered to NASA public data archive (PDS)
- The best has not yet been pulled from this data set!

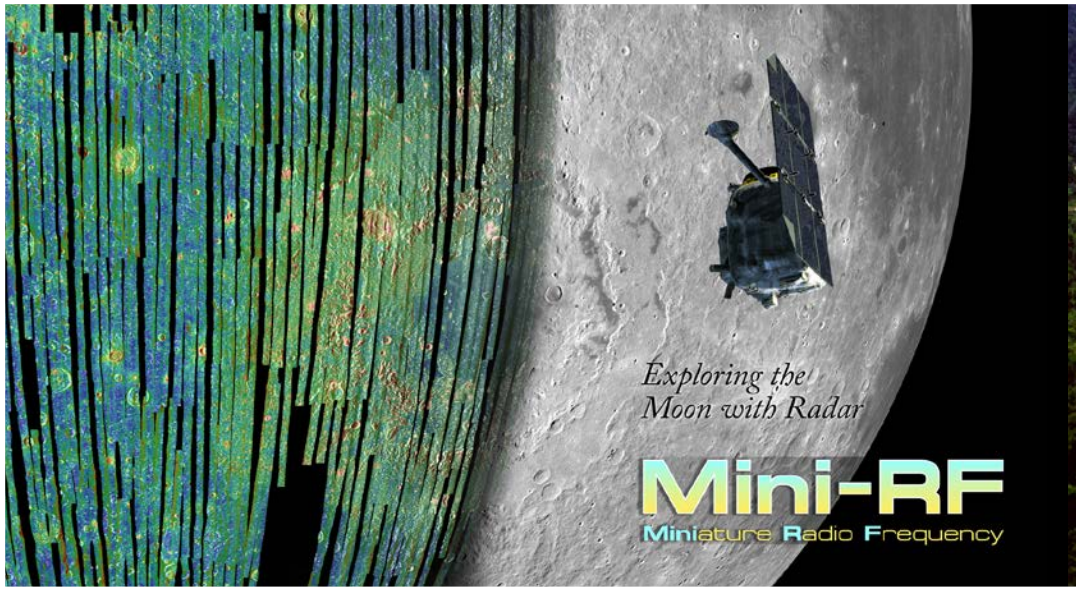
<u>PLEASE SEE LYNN CARTER'S POSTER # 2152 ON TUESDAY</u>

Mini-RF/Ground Comparison



Please See Lynn Carter's Poster # 2152 on Tuesday

Mini-RF Reborn!!!: A Hybrid Dual-Polarized Synthetic Aperture Bistatic Radar in Orbit around the Moon



JOHNS HOPKINS UNIVERSITY
Applied Physics Laboratory

Exploring the
Moon with Radar
Mini-RF
Miniature Radio Frequency

Exploring the
Moon with Radar
Mini-RF
Miniature Radio Frequency