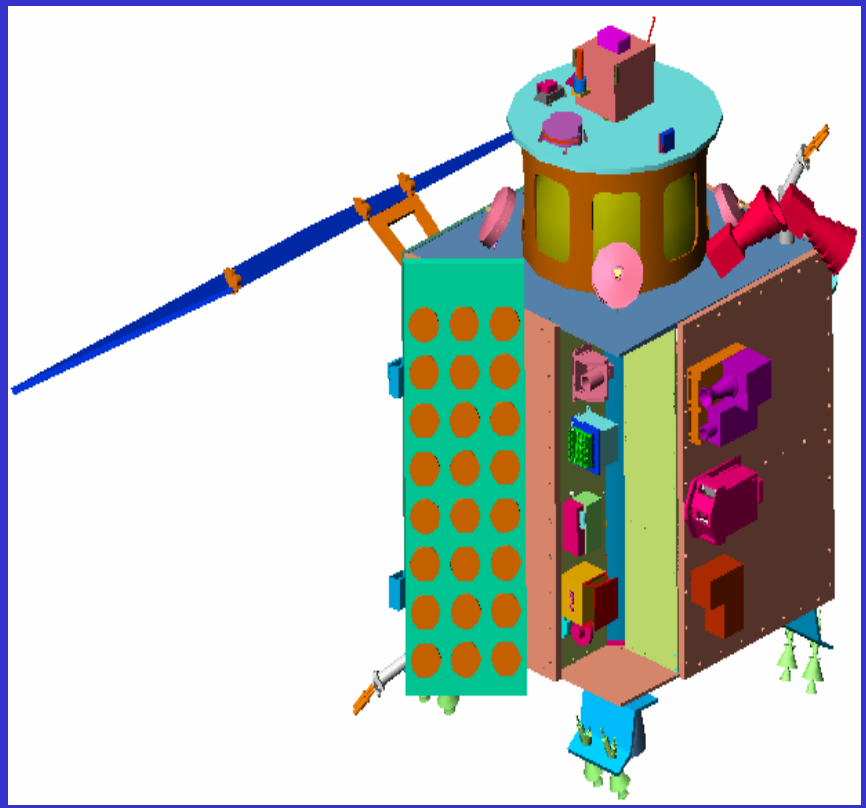
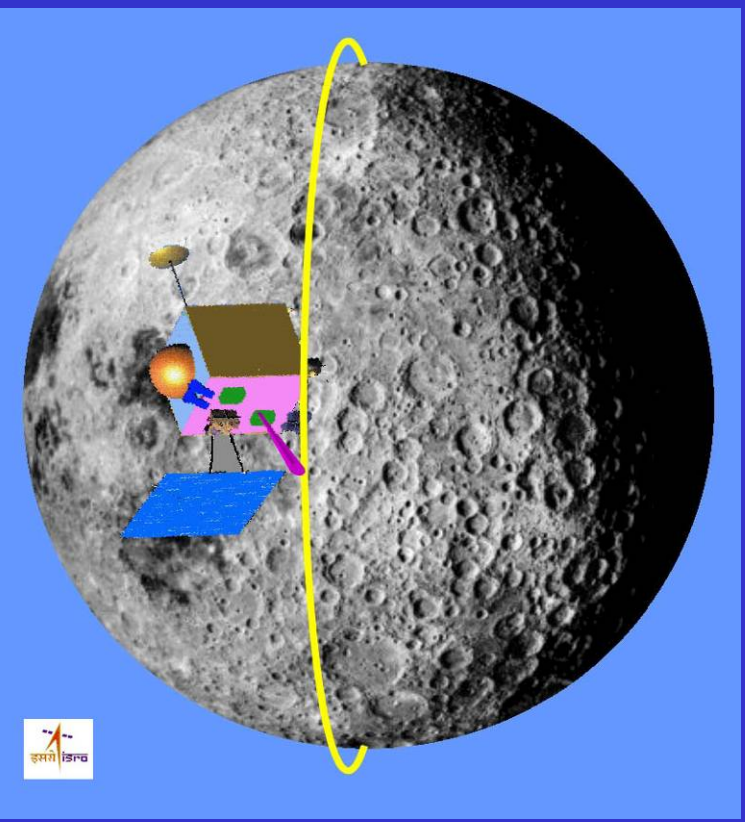
Chandrayaan-1 Mission: An update



Indian Space Research Organization

Ben Bussey
JHU/APL

Chandrayaan-1 Mission



Launch: Feb/March 2008

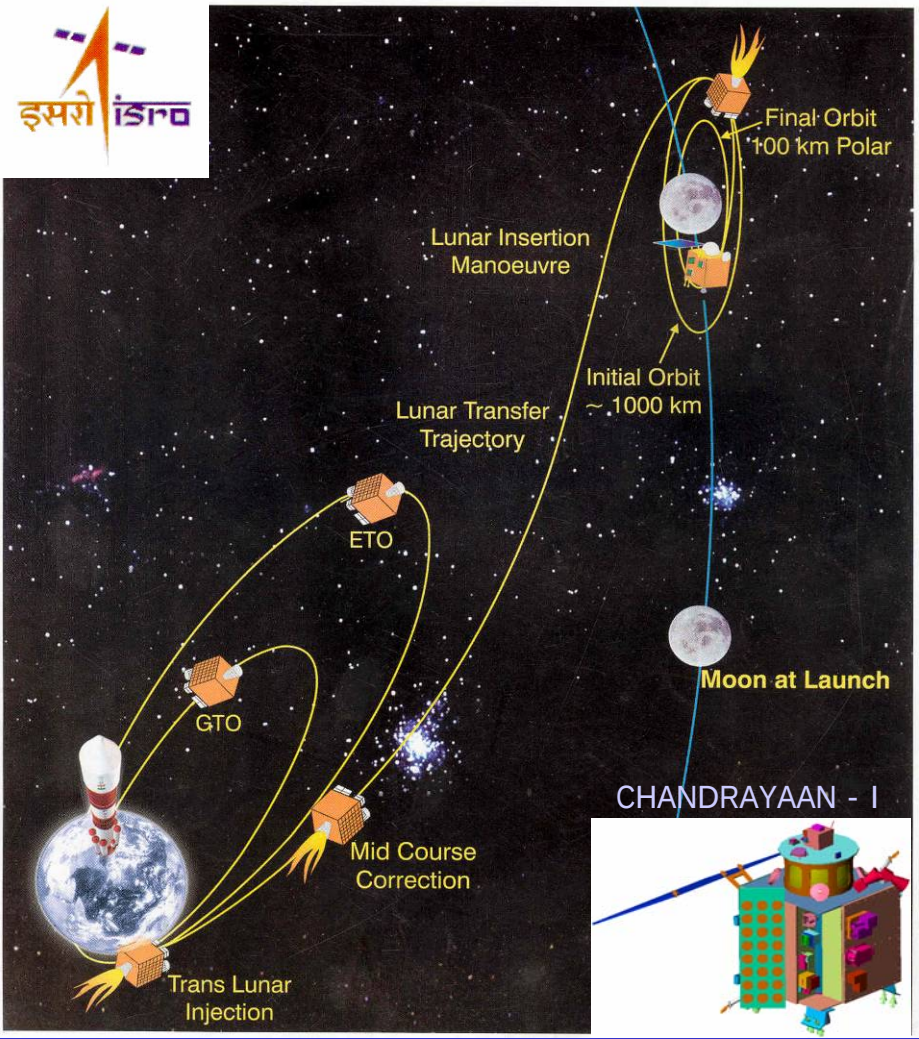
Spacecraft: 1.5 m 3-axis stabilized cuboid . Approx 500 kg in lunar orbit

Configuration: 100 km polar orbiter

Observation Period : 2 years

Payload : 11 instruments

Chandrayaan-1 Mission



Mission Sequence:

- **Launch into 240 km X 36000 km GTO by PSLV**
- **Two consecutive in-plane perigee maneuvers to achieve 386,000 km apogee (Lunar Transfer Trajectory - LTT)**
- **Coasting for 5 ½ days in LTT prior to lunar encounter**
- **Satellite in near circular 1,000 km orbit of the moon**
- **In-plane corrections to reduce orbit height to 200 km, polar**
- **Study of orbit perturbations for 1-2 weeks**
- **Reduce orbit altitude to 100 km circular, polar**
- **Two year primary mission**

Chandrayaan-1 Mission

Understanding the origin and Evolution of the Moon

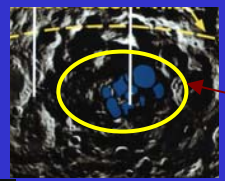
Physical Properties of the Moon

- Topography
- Gravity
- Magnetic Field
- Radiation Environment

The bulk chemistry of Moon

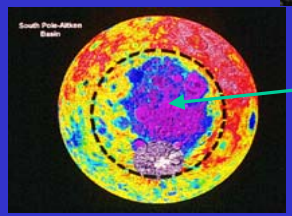
Nature of the Lunar Crust

The Lunar Far-side: Rock types, Chemistry



Special Regions of Interest:

Polar Regions ,



South Pole Aitken Region,

Selected Basins and Craters with central uplift

Nature of the Magma Ocean and Lunar Interior

Nature of Volatile Transport on Moon (Water on Moon?)

Objectives of the Chandrayaan-1 Mission

Understanding the Origin and Evolution of the Moon *through*

Simultaneous Mineralogical, Chemical & Photo-geological Mapping at high resolutions

Direct estimation of lunar surface concentration of the elements Mg, Al, Si, Ca, Ti and Fe with high spatial resolution (20 km)

High resolution UV-VIS-NIR mapping of the lunar surface to identify Fe, Al, Mg, Ti bearing mineral with high spatial resolution (100m)

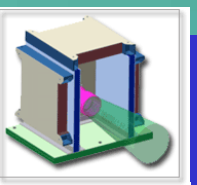
3D mapping of lunar surface at very high spatial resolution (~5 m)

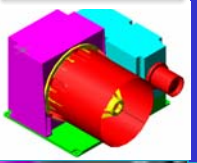
Volatile Transport to colder/ polar regions (using Pb-210 as tracer)

CHANDRAYAAN-1

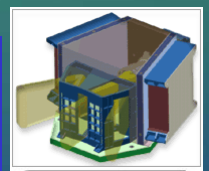
INDIA'S FIRST PLANETARY MISSION

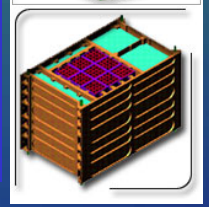
Baseline Payloads



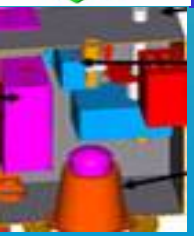


- Hyper Spectral Imager (HySI) (0.4-0.9 micron)
- Terrain Mapping Camera (TMC)
- Lunar Laser Ranging Instrument (LLRI)
- High Energy X -γ ray Spectrometer (HEX)(10-200keV)
- An Impact Probe with Mass-Spec., Altimeter & Video-imager

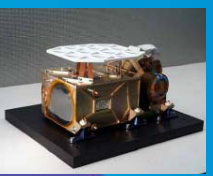


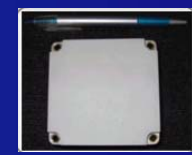


Announcement of Opportunity Payloads

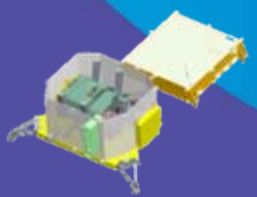


- Chandaryaan-1 Imaging X-ray Spectrometer(CIXS)(1-10KeV)-ESA
  Collaboration between RAL, UK and ISAC, ISRO
- Sub KeV Atom Reflecting Analyser (SARA)-ESA
  Collaboration between Swedish Space Physics Lab. and SPL, VSSC, ISRO



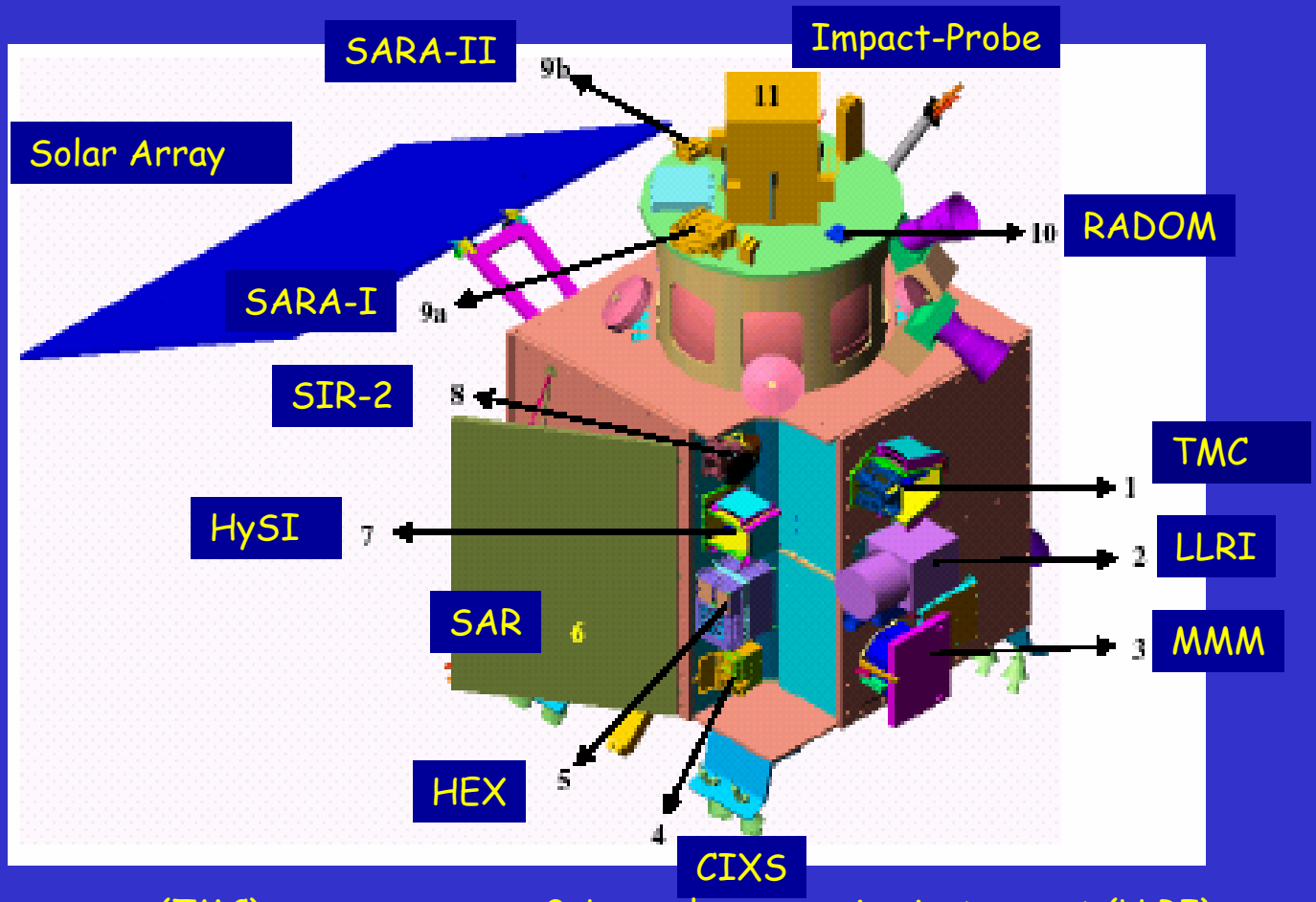


- IR Spectrometer (SIR-2) (0.85-2.4 micron) Germany,- ESA
- Radiation Dose Monitor Experiment (RADOM), Bulgaria
- Miniature Synthetic Aperture Radar (MiniSAR), USA
- Moon Mineralogy Mapper (MMM), (0.7-3 micron),USA



Chandrayaan-1 Mission

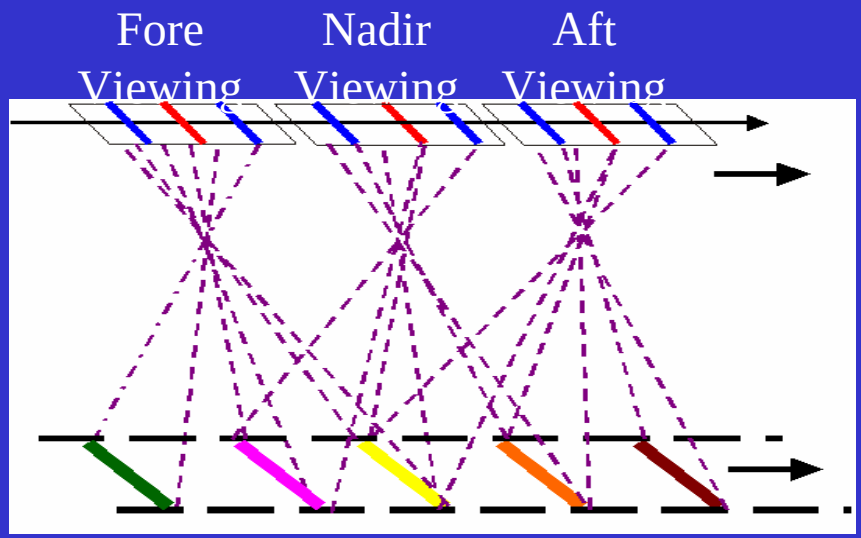
PAY LOAD ACCOMMODATION



1. Terrain mapping camera (TMC);
2. Lunar laser ranging instrument (LLRI).
3. Moon mineralogy mapper (MMM);
4. Chandrayaan Imaging X-ray Spectrometer (CIXS);
5. High energy X-ray spectrometer (HEX);
6. Miniature synthetic aperture radar (mini-SAR) antenna
7. Hyper spectral imager (HySI);
8. Infrared Spectrometer (SIR-2);
9. Sub-keV atom reflecting analyzer [SARA]
10. Radiation dose monitor (RADOM);
11. Impact probe. The blue panel is the canted solar array.

Chandrayaan-1 Mission

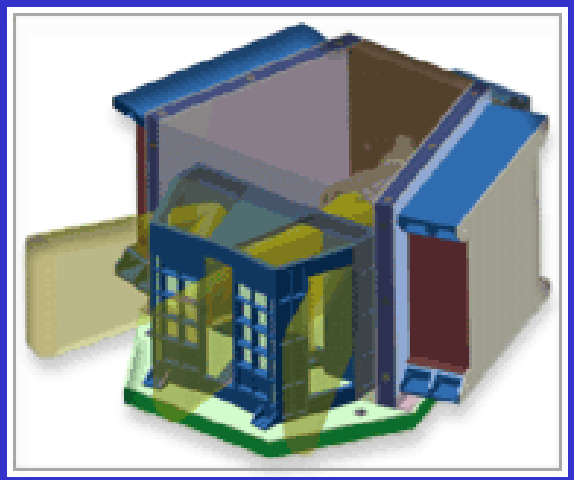
Terrain Mapping Camera (TMC)



Stereoscopic instrument in Panchromatic band for

- ***Topographic mapping***

with high spatial (5m) and altitude (<10m) resolution.



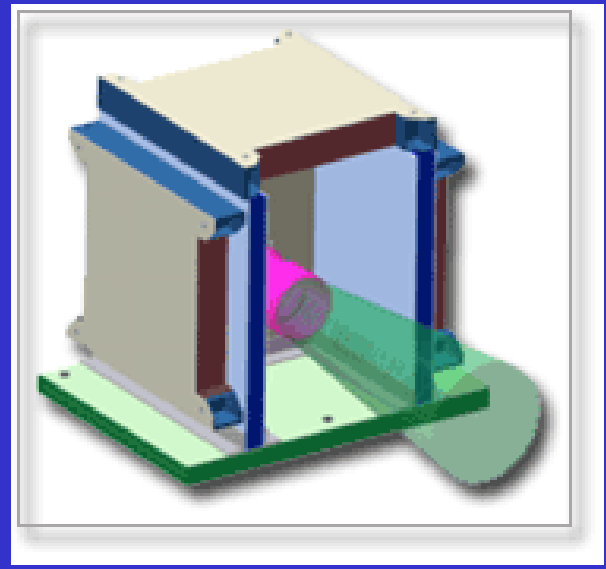
Designed and Developed at the Space Application Center, Ahmedabad

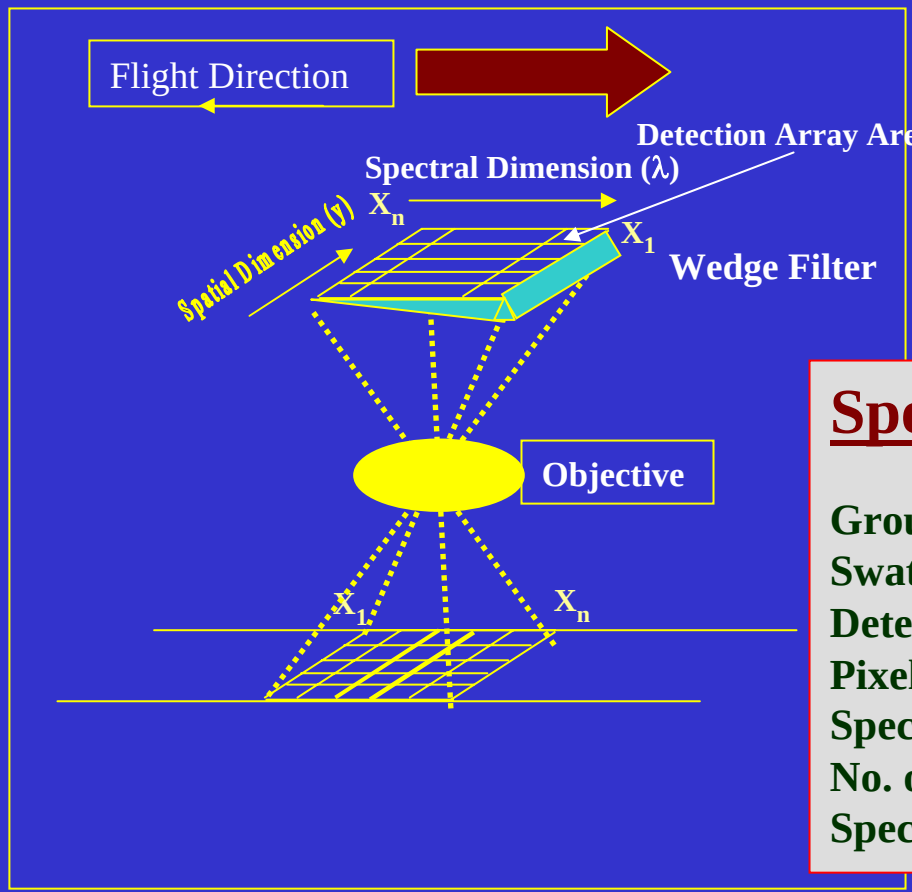
Specifications

Ground Resolution : 5m (100 km orbit)
Swath: 20 km
Lens focal length:14cm; F/No: 4
Detector: APS 8000 Elements Linear Array
Quantisation: 10 bits

Hyper Spectral Imager (HySI)

- *Mineralogical mapping in UV-VIS-NIR with high spectral resolution (<15nm).*





Designed and Developed at the Space Application Center, Ahmedabad

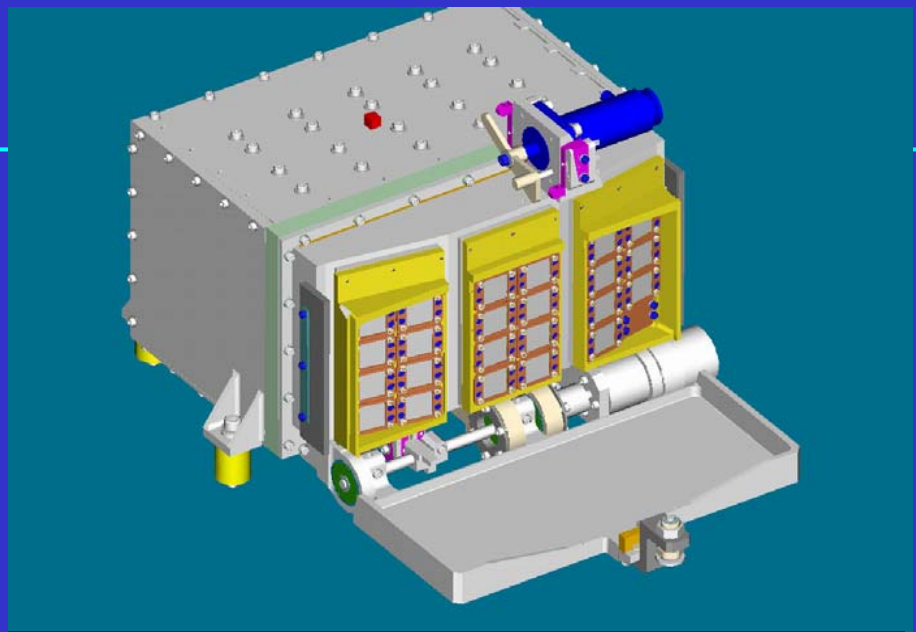
Specifications

Ground Resolution: 80 m
Swath: 20 km
Detector Pixel Array: 500X500
Pixel Size: 50 µm; **F/No.:** 4
Spectral Range: 400 – 900nm
No. of Spectral Bands: 32
Spectral Resolution: 15 nm

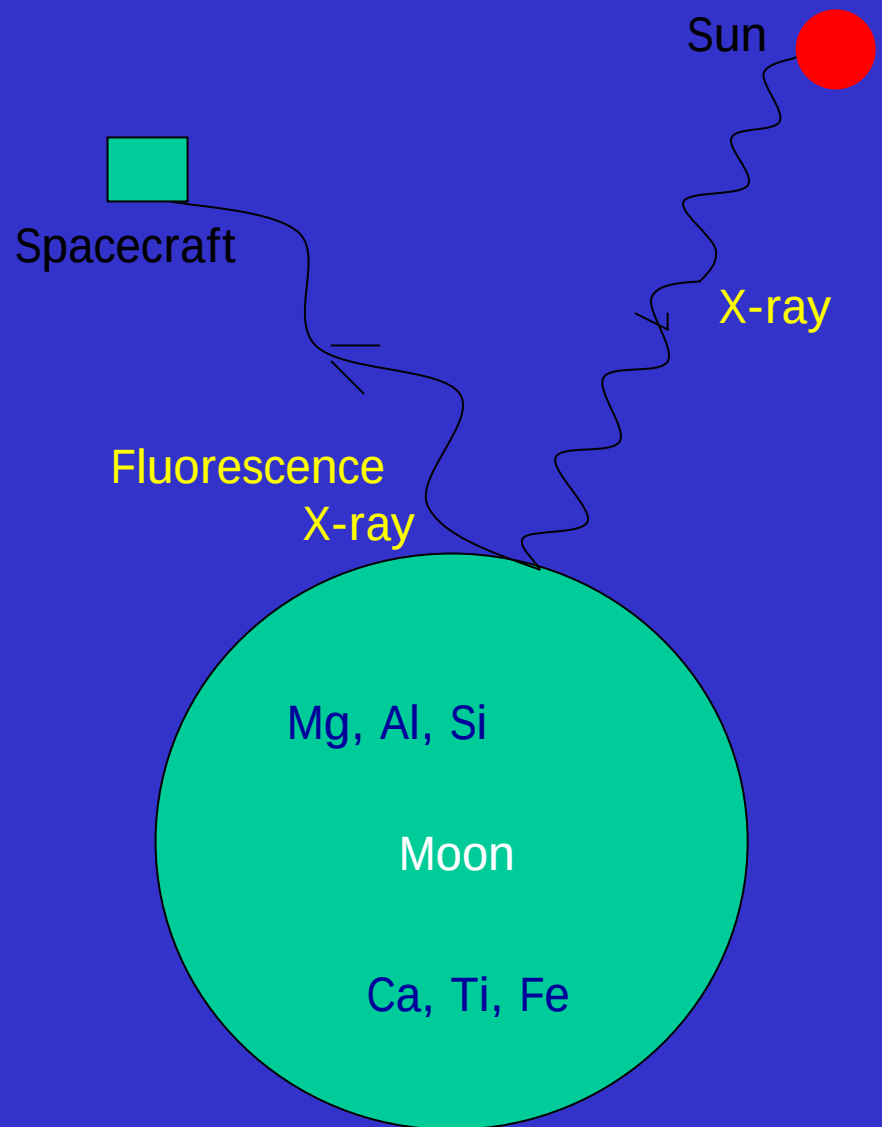
Chandrayaan-1 Mission

The Low Energy X-ray Payload (LEX-CIXS)

- *Chemical (Elemental) Mapping of Lunar Surface based on Solar X-ray induced fluorescence emission (FOV:20x20 Km)*

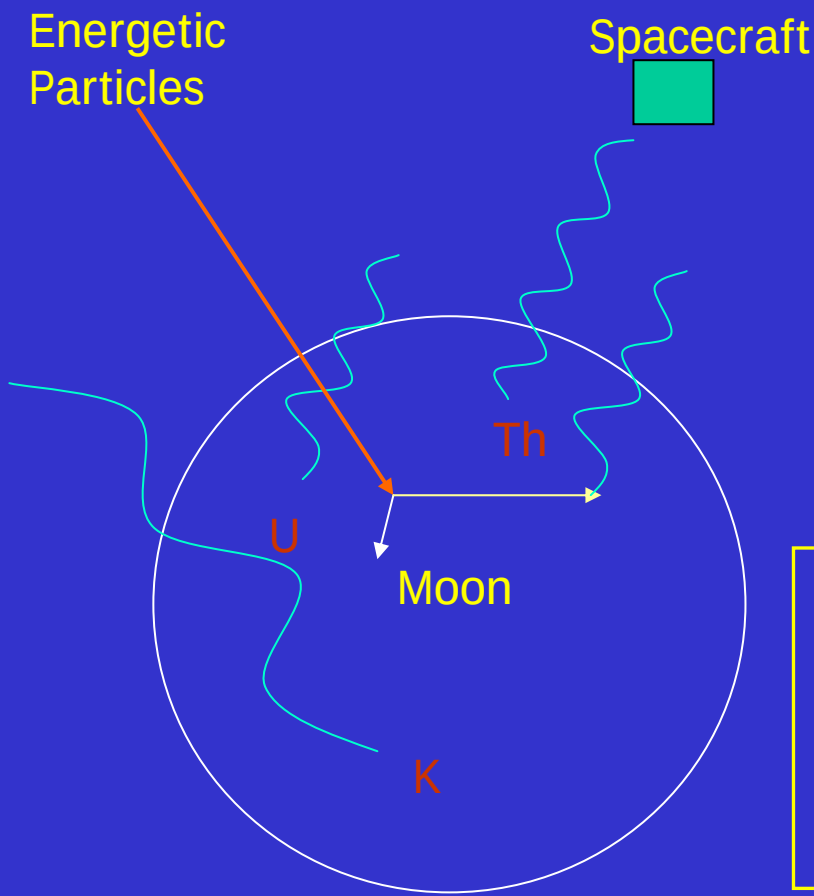


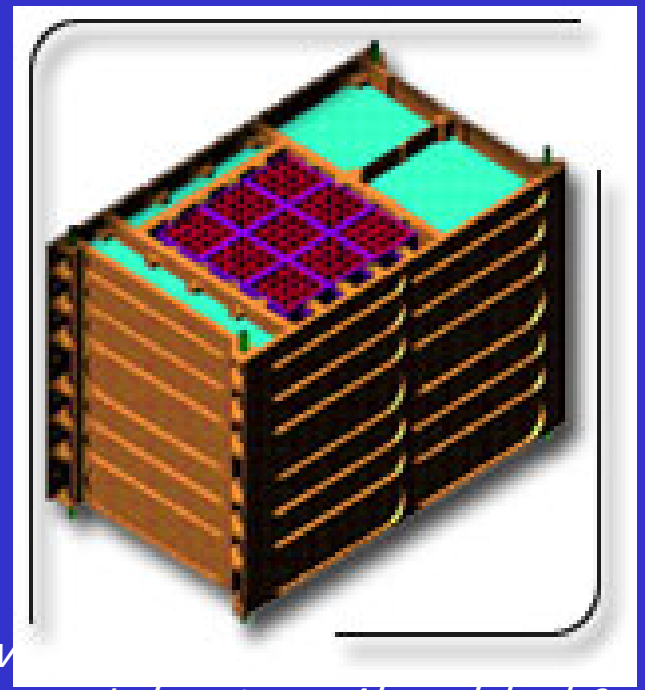
Indo-UK Collaboration:
Rutherford Appleton Laboratory and
ISRO Satellite Center, Bangalore



High Energy X- γ Ray (HEX) PAYLOAD

- **Volatile Transport on Moon through detection of 46.5 keV line from Pb-210;**
  First attempt to detect low-energy gamma-rays (<300keV) from a planetary surface





Dev *Laboratory, Ahmedabad & ISRO Satellite Center, Bangalore*

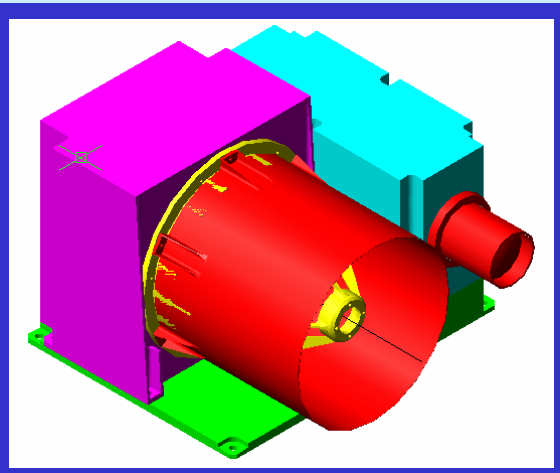
Basic Feature

New Detector: Cd-Zn-Te Array; Area: 144 cm^2

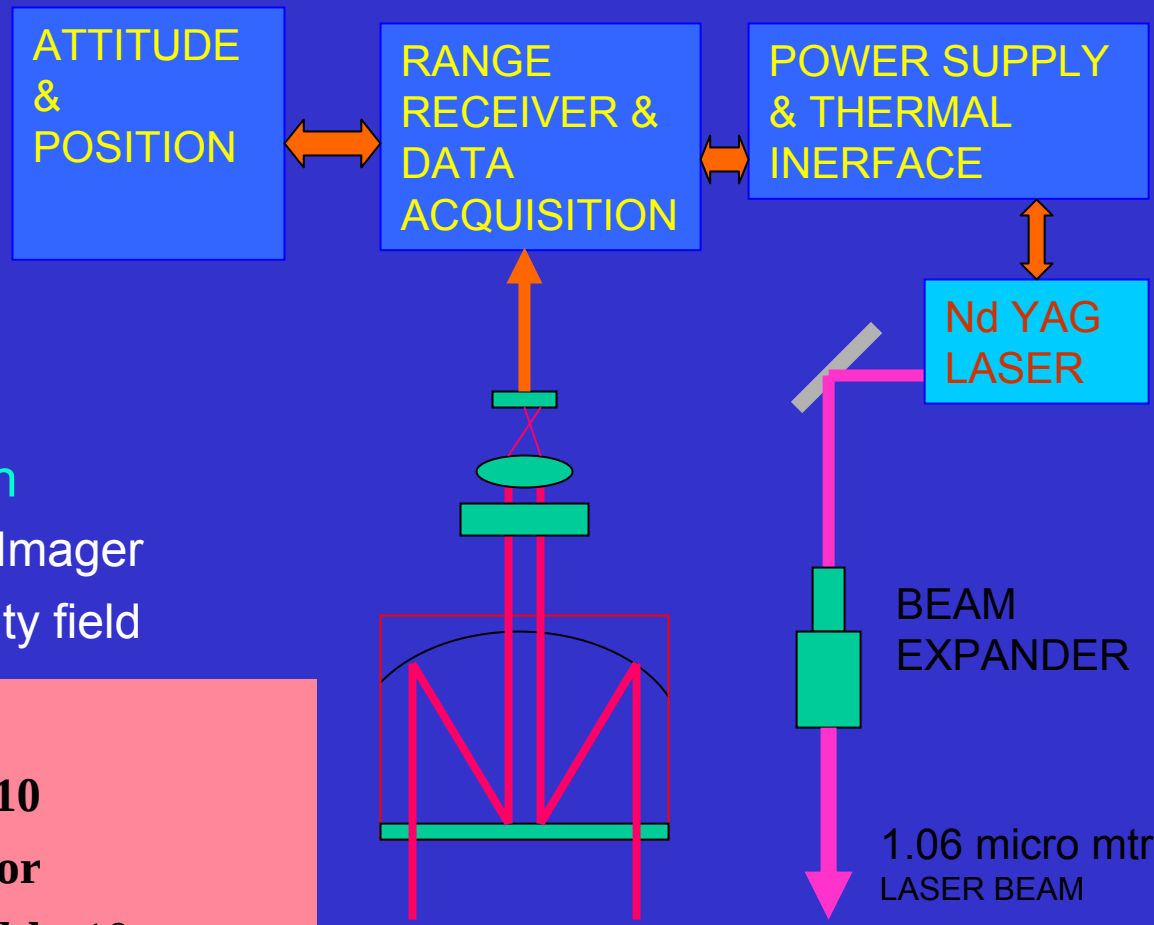
Energy Range: 20-270 keV

FOV: 40km x 40km; Wt.: 15 kg; Power: 23 W

Chandrayaan-1 Mission



Lunar Laser Ranging Instrument



Primary Objective:

Determine Global Topographic Field of Moon

- Supplement TMC and HYPC Imager
- Improved model of lunar gravity field

Specifications:

Optics: Reflective, 150 mm dia, f/10

Detector: Avalanche photo detector

Repetition Rate: 10 Hz; **Pulse Width:** 10 ns

Laser Energy: 20 mJ; **Vertical Resolution:** 5 m

Developed at Laboratory for Electro-Optics System, Bangalore

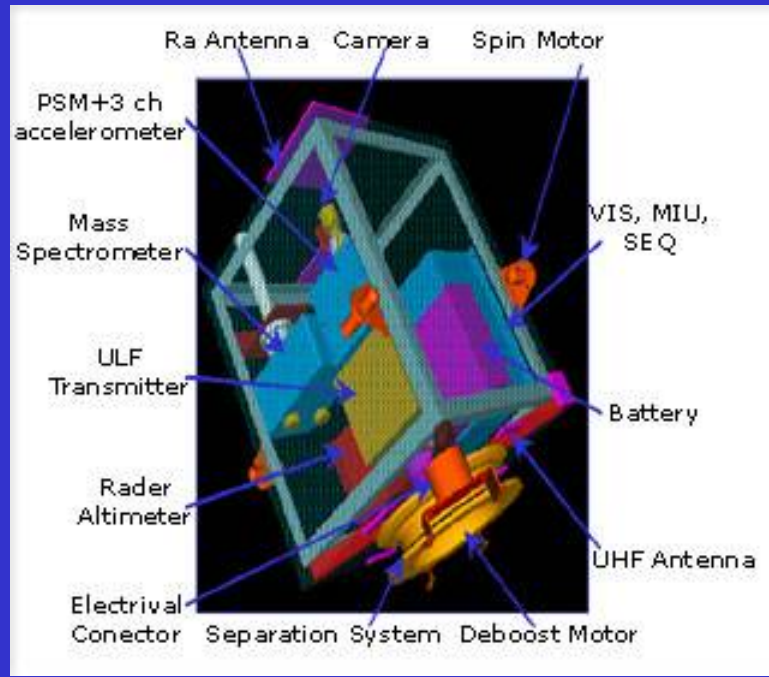
Moon Impact Probe(MIP)

Primary objective:

Landing the probe at desired location and to qualify some technologies for soft landing mission.

Radar Altimeter & Video-imager for aiding and documenting landing of the probe

A mass spectrometer to study transient lunar atmosphere



Developed at Vikram Sarabhai Space Center, Thiruvananthapuram

Chandrayaan-1 Mission

A new era of International Cooperation

Based on science objectives and spacecraft resources, several proposals were accepted from International communities following review; they will complement/add to the Indian experiments to meet the basic science goals of the mission.

I. IR spectrometers for mineral mapping (SIR-2 and MMM)

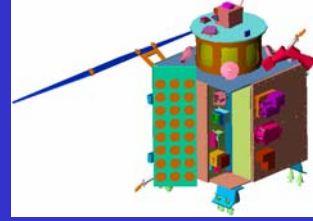
II. An experiment to detect neutral atoms (SARA)

III. An experiment to search for water-ice at the poles (mini-SAR)

IV. An experiment to monitor energetic particle environment (RADOM)

There will be strong Indian collaboration in all experiments

Chandrayaan-1 Mission (AO Payloads)

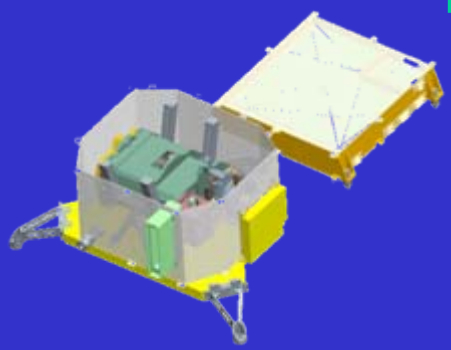


Moon Mineral Mapper: An Imager in VIS-NIR band

P. I. Dr. C. Pieters, Brown University , USA

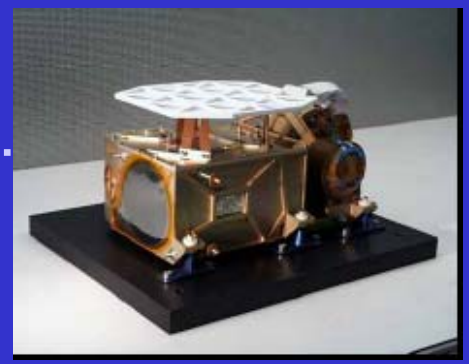
Spectral range: 0.7 to 3 micron

sampling at 10 nm (Area array)



SIR-2: A near-infrared Spectrometer

P. I. Dr. Urs Mall,
Max-Planck Institute, Lindau, Germany



Spectral range: 0.85 to 2.2 micron with a resolution <10 nm (Line array)

The first version of SIR was on board SMART-1 Mission

Basic Science Objective : *Mineral (Chemical) Mapping of Lunar Surface*

These Instruments, together with HySI, LEX (CIXS) and SARA, will provide a very detailed mapping of surface composition of the Moon

Chandrayaan-1 Mission (AO Payloads)

SARA: Sub-KeV Atom Reflecting Analyzer

P. I. Dr Stas Barabash, Swedish Institute of Space Physics &
Dr. A. Bharadwaj, Space Physics Laboratory, India

Basic Science Objective : *Imaging of*

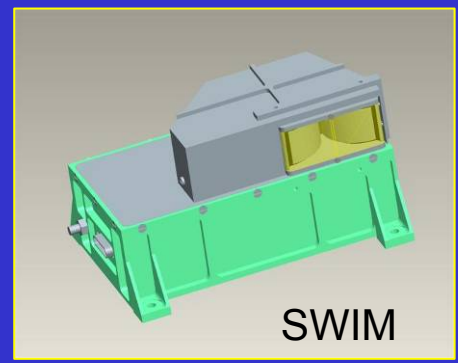
(i) Moon's surface composition
(ii) lunar surface magnetic anomalies

Anticipated Highlights:

Surface composition of permanently shadowed areas and complement data on surface composition

Surface magnetic anomalies: magnitudes and plausible causes

Figure 3. CENA technological model

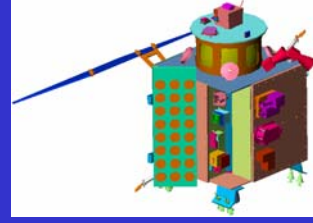


RADOM: Radiation Dose Monitor

P.I. Dr. Tsvetan P. Dachev , Bulgarian Academy of Sciences

Charge particle (electron, proton) detector,
Energy spectra and radiation dose monitor

Chandrayaan-1 Mission (AO Payloads)



Mini-SAR: A Multifunction Miniature Synthetic Aperture Radar

P. I. Dr. Paul D. Spudis: Applied Physics Laboratory, Johns Hopkins University

Basic Science Objective:

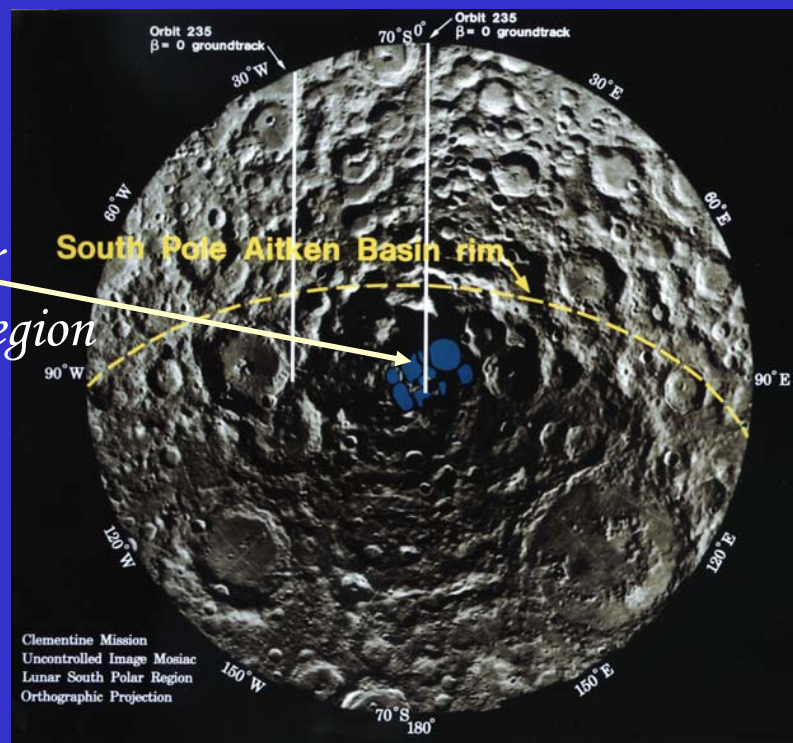
Mapping and elucidation of the properties of plausible Water-Ice deposits in the permanently shadowed lunar polar regions

Possible evidence of water on Lunar Poles

Clementine Mission

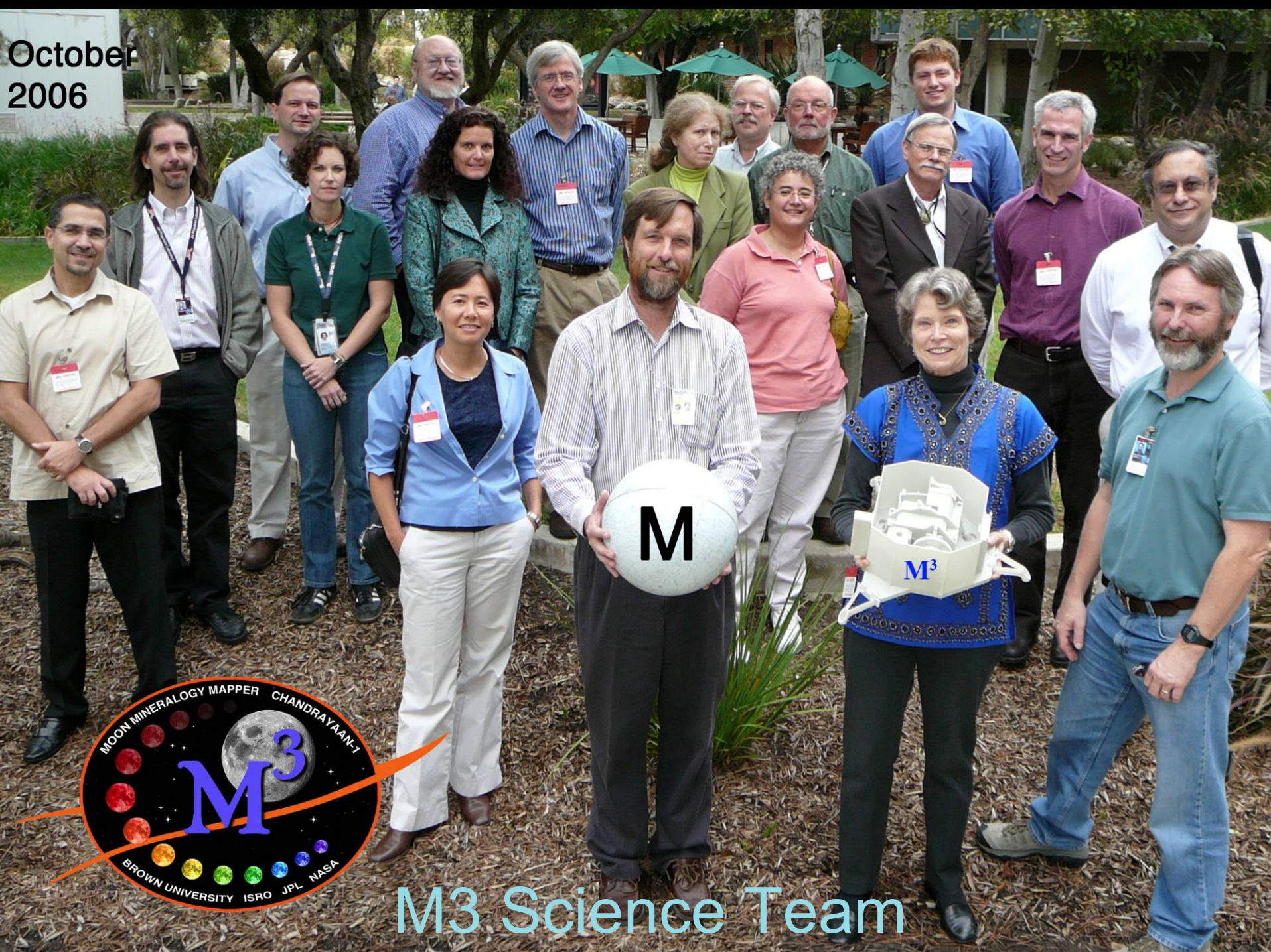
Radar Reflection mimicking radio -scattering behaviour of ICE

Signature of Water (Hydrogen) : blue region



Prospector Mission

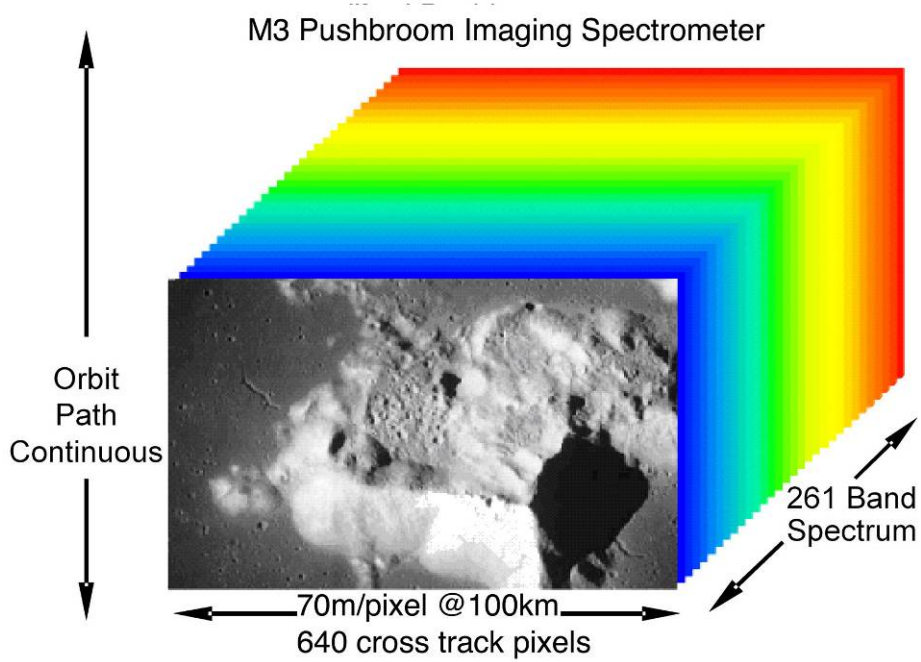
Neutron Spectrometer data suggesting presence of Hydrogen (Water?) in Polar Regions



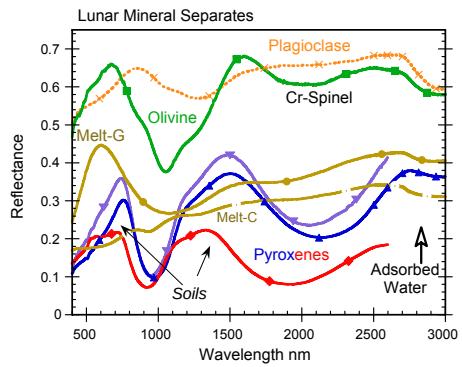
M3 Science Team

Moon Mineralogy Mapper (M3)

- M3 is a NASA Discovery "Mission of Opportunity"
  - Team led by PI: C. Pieters
  - Built by JPL
- M3 is a pushbroom imaging spectrometer
  - Two spatial dimensions
  - One spectral dimension

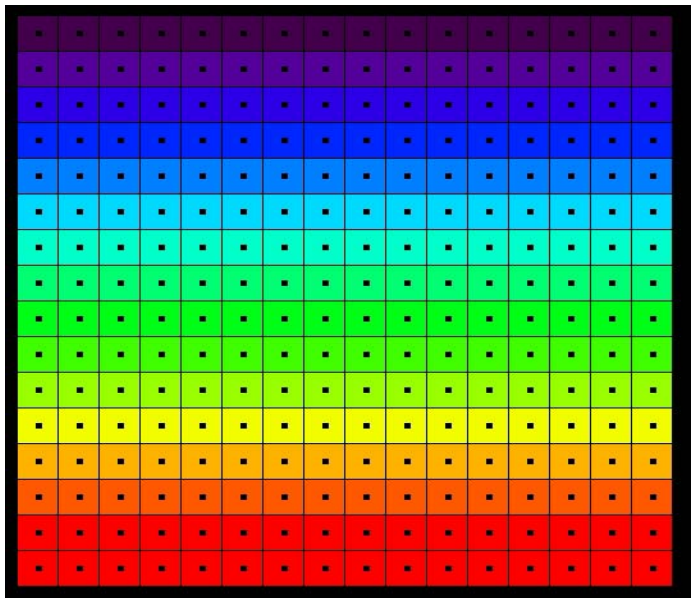


M3 covers the spectral range where diagnostic features occur for all common rock-forming minerals **and** hydrous phases.



M3 Measurements

M3 design provides spectral and spatial Uniformity <10% of a pixel across detector FOV.



Chandrayaan-1 Two-year mission plan:

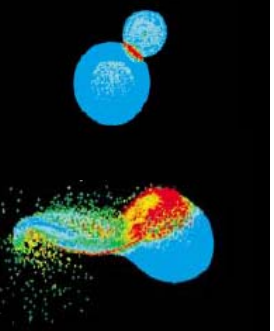
All M3 Reflectance Spectra

- 0.70 to 3.0 μm [0.43 to 3.0 μm projected]
- 40 km FOV, contiguous orbits
- high SNR
- 1 Gbyte/orbit

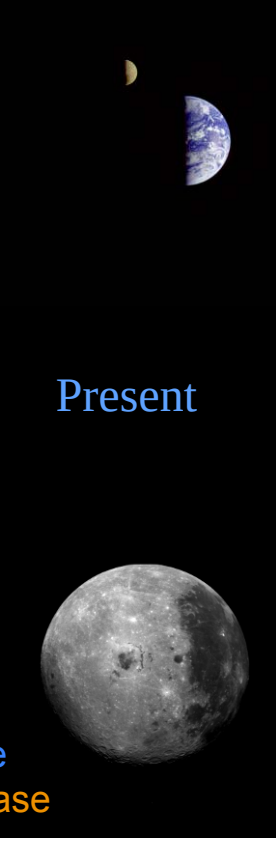
- Targeted Mode: Optimum
  - Resolution (100 km orbit):
    - 70 m/pixel spatial
    - 10 nm spectral [260 bands]
  - 3 optical periods [10 - 30% coverage]
    - 10 to 15 deg latitude/orbit
- Global Mode: Full Coverage
  - Resolution (100 km orbit):
    - 140 m/pixel spatial
    - 20 & 40 nm selected (86 bands, ~3x spectral averaging)
  - 1 optical period [~100%]

Lunar Mineralogy Reflects Early Geologic Evolution

Keystone to the Terrestrial Planets

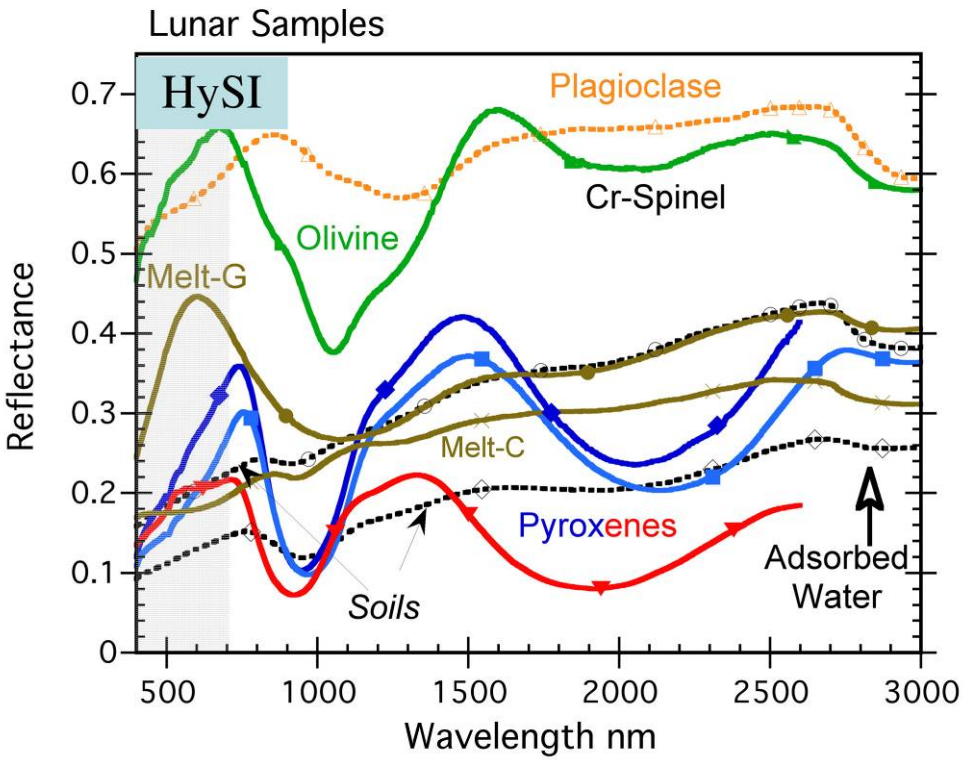


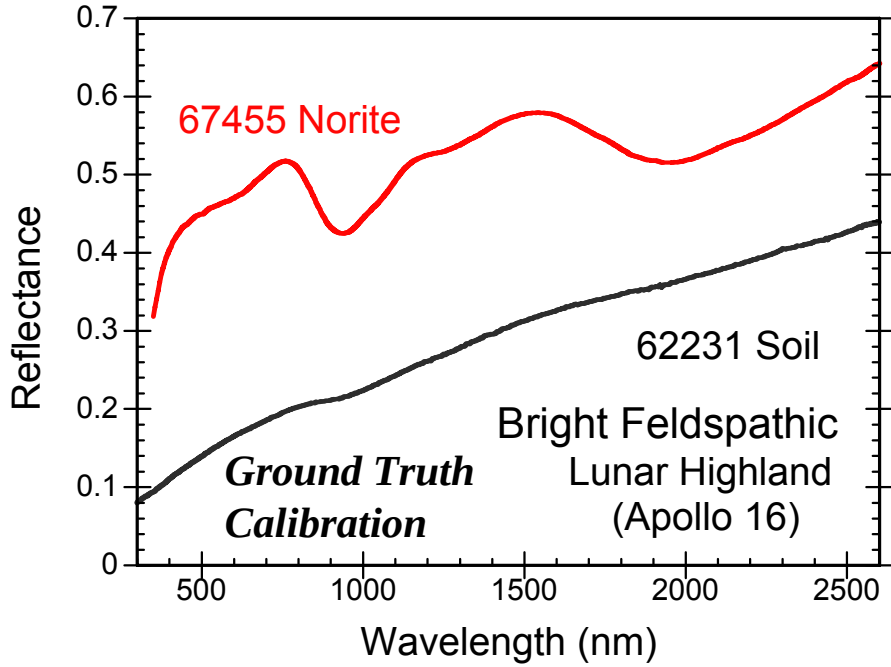
4.5 Gyr ago

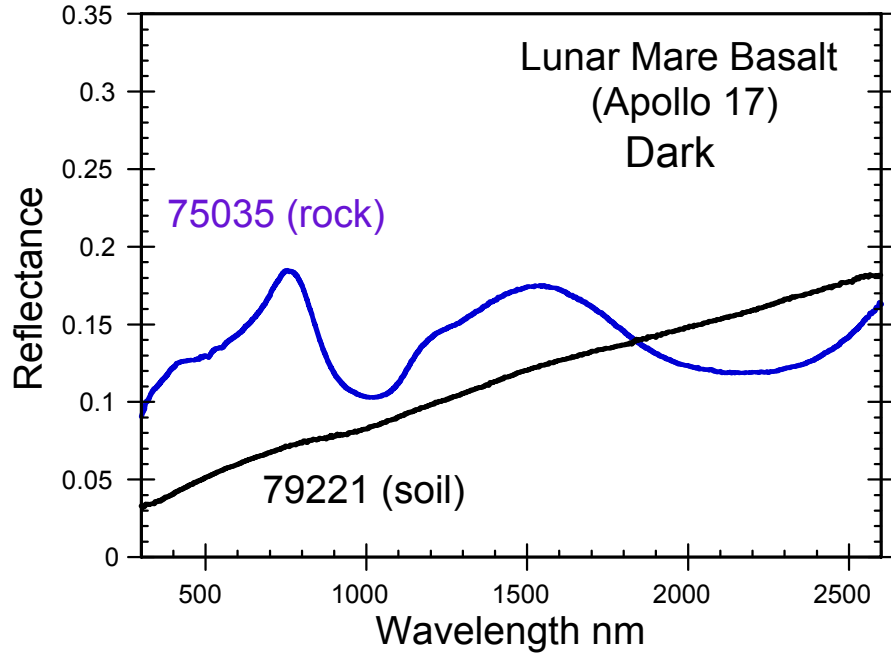


Present

Lunar Minerals Exhibit Highly Diagnostic Absorption Bands



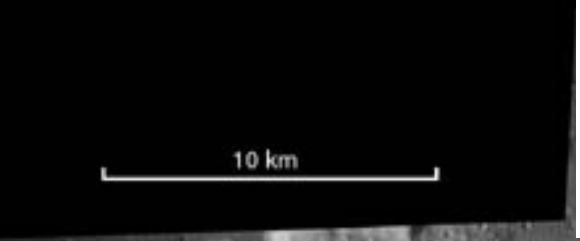




High spectral resolution reflectance spectra across the near-infrared are required to capture characteristic absorptions of lunar materials.

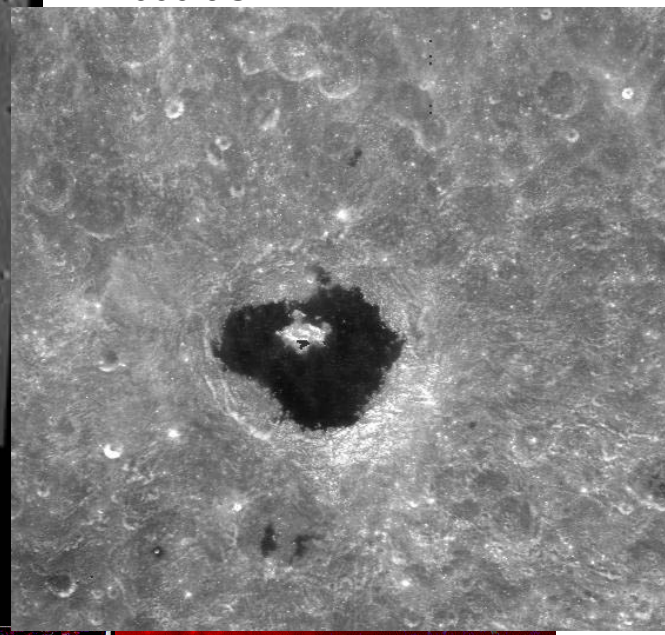
Mineralogy + Spatial information is Key.
Tsiolkovsky: A Farside Pluton?

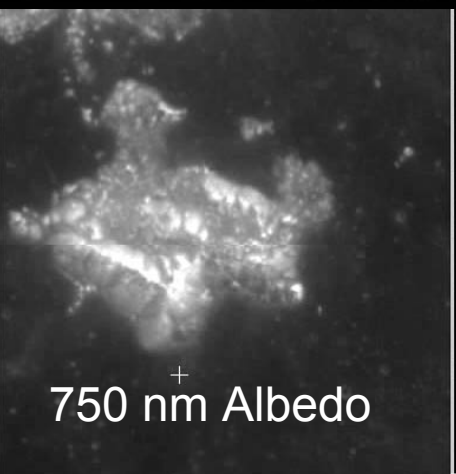
Olivine? + Anorthosite Central Peaks



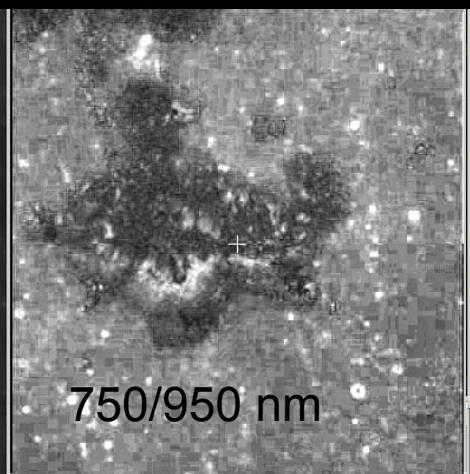
Central peak material was originally at ~20 Km depth.

Pieters and Tompkins
1999 JGR

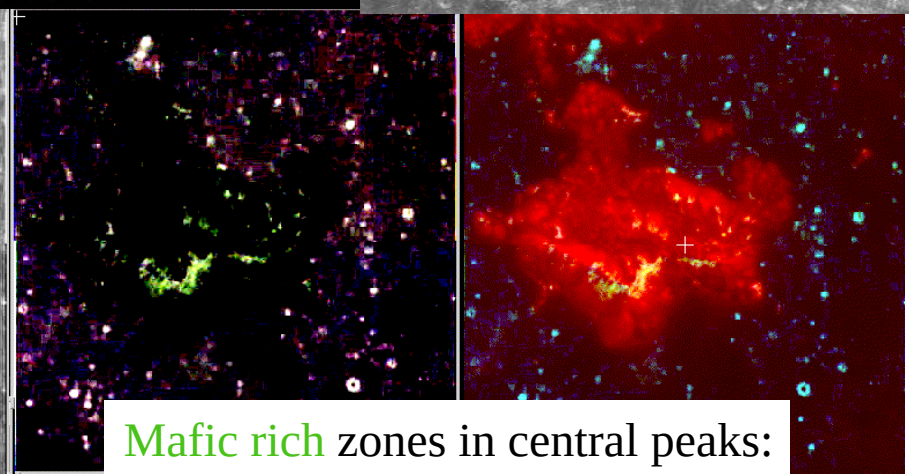




750 nm Albedo



750/950 nm



Mafic rich zones in central peaks:

M3 Science Goals:
Mineralogy and Resources

- Origin and Evolution of the lunar crust and mantle.
  - Evaluate primary crustal components and their distribution across the highlands.
  - Characterize the diversity and extent of different types of basaltic volcanism.
  - Map fresh craters to assess abundance of small impacts in the recent past.
- Identify and assess deposits containing volatiles.
- Identify and evaluate concentrations of unusual/unexpected minerals.

Mini-RF Organization, Science and Resource Evaluation Objectives

- Mini-RF is a suite of radar instruments funded by NASA (SOMD & ESMD) and DoD. Mini-RF on Chandrayaan-1 is built by Raytheon with BAE & Surrey Satellites. Naval Air Warfare Center is the executing agent, with APL providing instrument Science Operations Center, backup ground station and science and programmatic support.

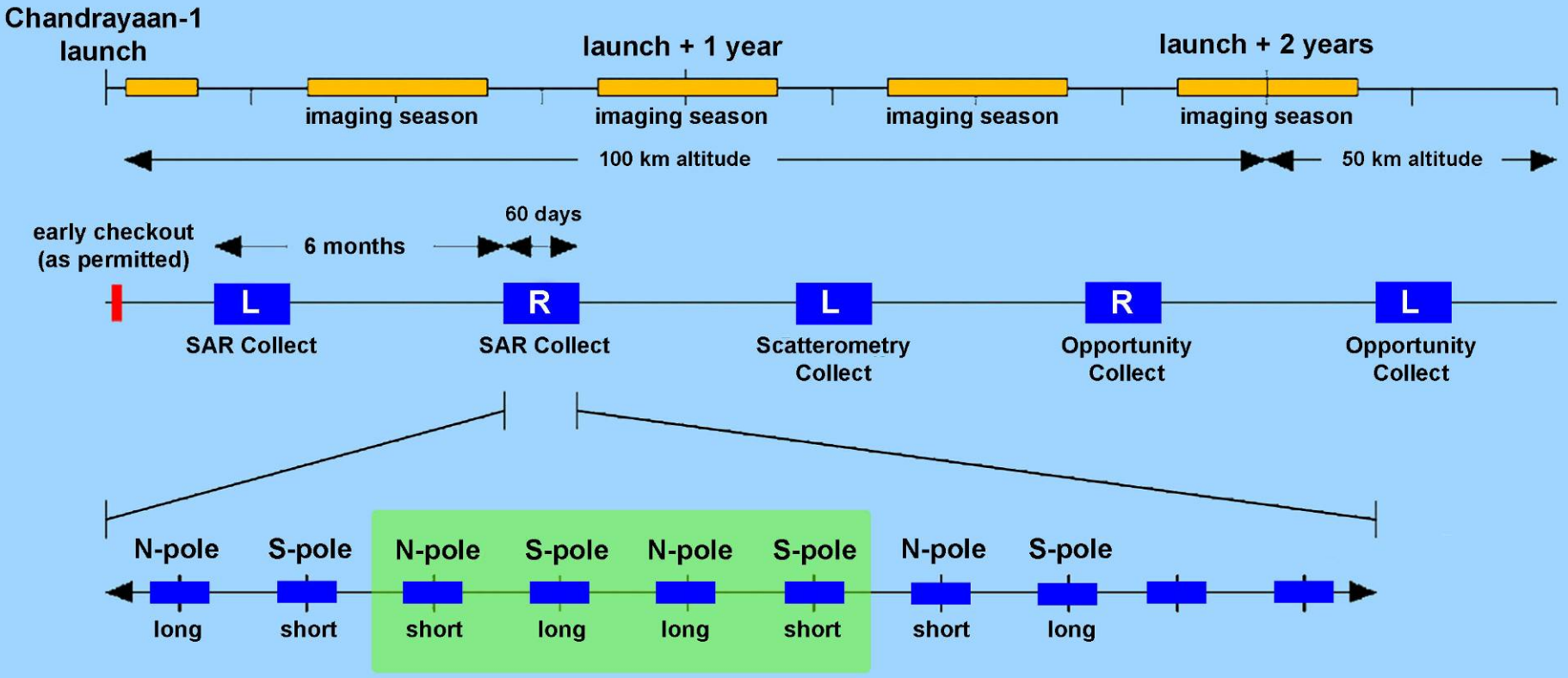
- Search for areas near the lunar poles that have the anomalous radar reflectivity signatures (***high radar albedo and Circular Polarization Ratios***) that differentiate volumetric water-ice deposits from more typical lunar surfaces
- Map the morphology of permanently dark regions near the poles

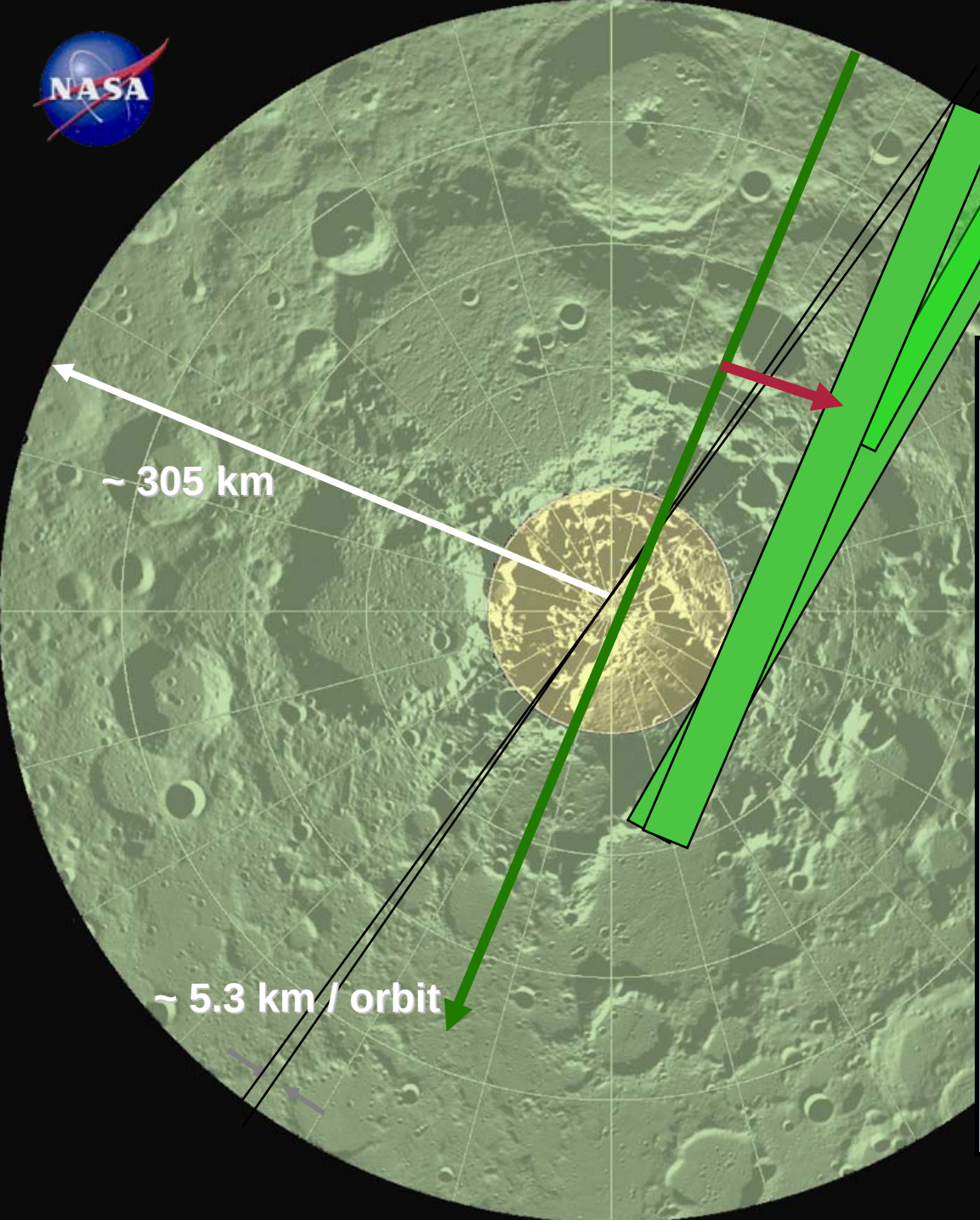
Top-level Radar Overview

Parameter	*Chandrayaan-1*	*LRO*
• **Frequency**	**S-band**	S-band and X-band
• **Polarization**	***Tx*** **RCP**	
	Rx **Two orthogonal polarizations, coherently**	
• **Scatterometry**	**S-band**	(none)
• **Imager**	**Regional maps**	Site-specific selections
• **Resolution (m/pixel)**	**75**	75, 7.5 azimuth x 15 range
• **Looks**	**16**	16 or 8
• **Swath (km)**	**8**	6 or 4
• **Altitude (km)**	**100**	50
• **Incidence**	**33°**	45°
• **Interferometry**	**No**	**Yes: experimental**

Operational Strategy

Measurement Timeline

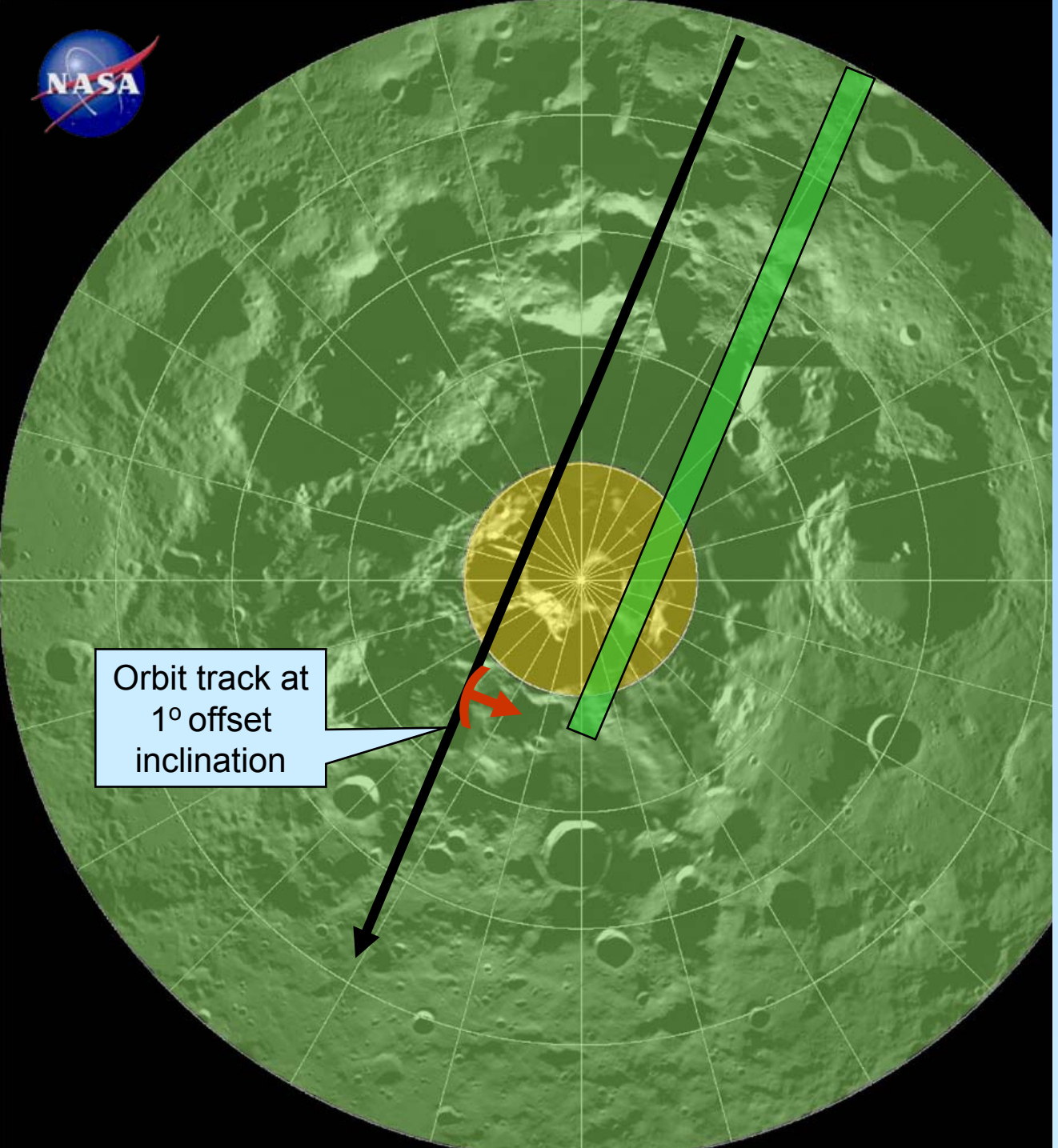




SAR Mapping

Chandrayaan-1

- Mosaic assembled from a sequence of ~338 orbit strips
- Swath width 8 km
- Alternate long and short passes. 2 Gbits / orbit
- Near-range minimum is set by 33° incidence & altitude => near-polar image gap

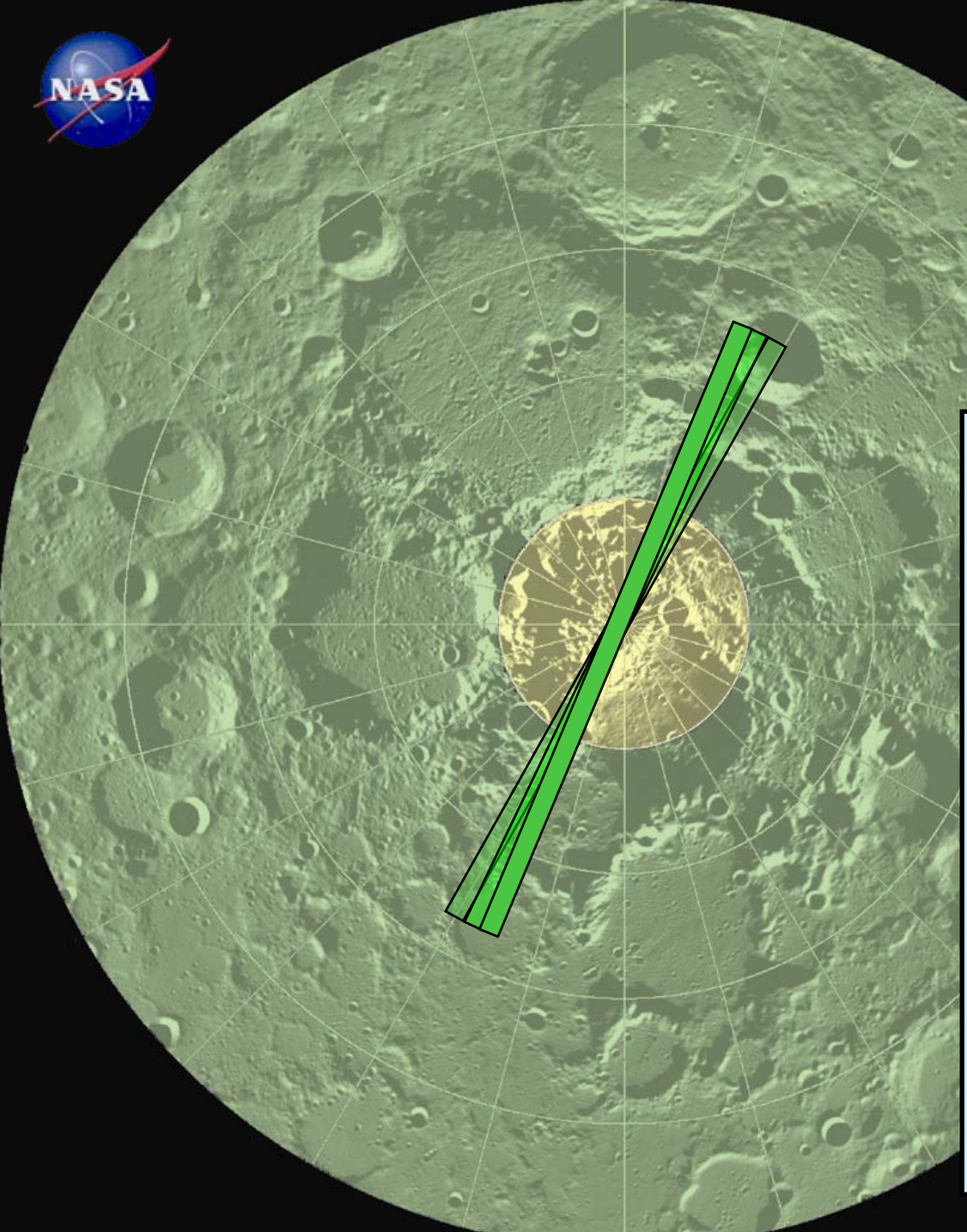


Optimal Orbits

Twice a month Chandrayaan-1 has a 91° orbit

50% of these will be in the correct look geometry

Can collect data over key areas in the nominal SAR gap



Scatterometry

- *Fill in polar gap: 85°-90°-85°*
- *Swath Width: 10 km*
- *Instrument operated in nadir direction*
- *523 Mbits per strip (1047 Mbits / orbit)*
- *Full polar mosaic acquired over 14 days*

Lunar (Polar) Mapping

Chandrayaan-1 data products

- Initial products
  - **Geolocated strips, complex multi-look SAR data (35° incidence, *H, V + cross product*)**
  - **Along-track scatterometer profiles (0° incidence, >85° latitude)**
- Intermediate products
  - **SAR image mosaics >80° latitude, both right and left looking**
  - **Stokes parameter maps**
    - **Derived same-sense, opposite-sense polarization, albedo maps**
    - **Left-side and right-side looking**
  - **Scatterometry mosaics (*four per pole*, >85° latitude)**
    - **Fill in near-pole mean reflectivity data**
    - **Lower-resolution, average reflectivity, vertical incidence**
- Final products
  - **Maps to indicate size and location of likely water-ice deposits**
  - **Maps of areas having anomalous reflectivity**
  - **All Mini-RF data archived to the NASA PDS.**

Chandrayaan-1 Mission

The Present Status:

- *PDR of ALL payloads and CDR of several instruments are over.*
- *The second meeting of Chandrayaan-1 Science Team (comprising of ALL PIs) took place in September, 2006*
- *Spacecraft CDR will be held in a few months time*
- *Schedule launch of Chandrayaan-1 in early 2008 as planned*

Other Developments:

Network consisting of 18m (ready & tested) and 32m antennas will be ready for the mission

A National Space Science Data Center is being set up to receive and archive the Chandrayaan-1 data

Data access for PI and teams, and other interested scientists have been drawn up