INDIAN LUNAR EXPLORATIONS

Presentation to
57th UNCOPUOS STSC
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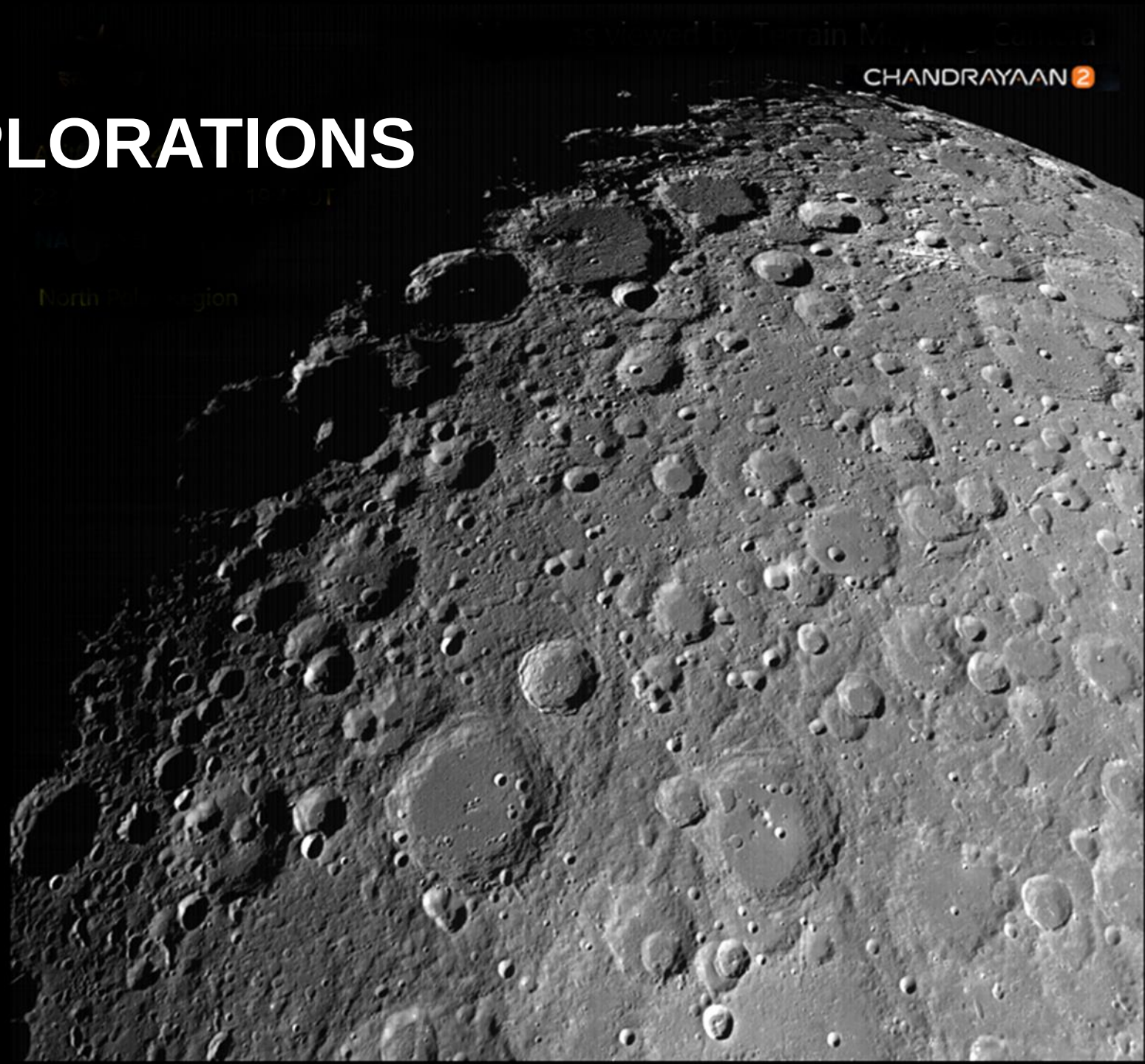


Chandrayaan-1

India's first mission to Moon- Placed in lunar obit on November 8th 2008

Achievements:

Carried eleven scientific instruments built in India, USA, UK, Germany, Sweden and Bulgaria.

First spacecraft to make the most significant discovery of Water(H2O) and Hydroxyl (OH) molecul surface.

ISRO sent a Moon Impact Probe (MIP) to the lunar surface.

PAYLOADS

ISRO PAYLOADS

- TMC: Terrain Mapping Camera (ISRO)
- HySI: Hyper Spectral Imager (ISRO)
- LLRI: Lunar Laser Ranging Instrument (ISRO)
- HEX: High Energy X-ray Spectrometer (ISRO)
- MIP: Moon Impact Probe (ISRO)

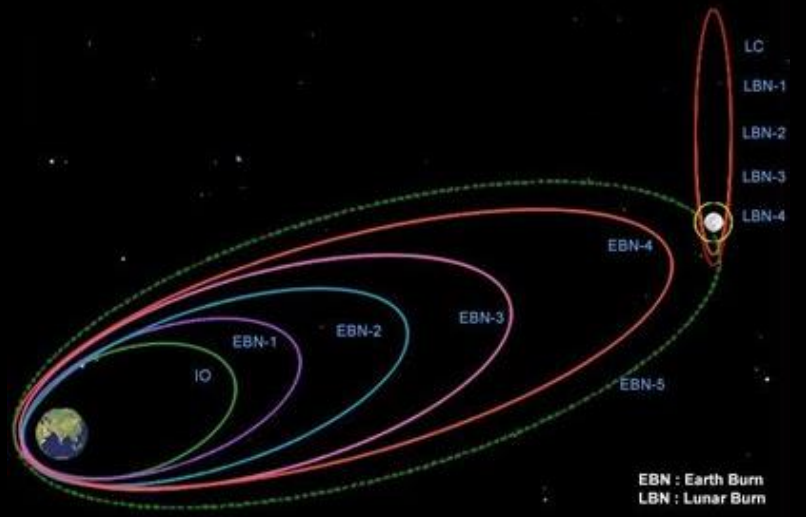
COLLABORATION PAYLOADS

- CIXS: Chandrayaan-1 X-ray Spectrometer (ESA,ISRO)
- SARA: Sub keV Atom Reflecting Analyser (ESA,ISRO)

INTERNATIONAL PAYLOADS

- SIR-2: Near-IR Spectrometer (ESA)
- RADOM: Radiation Dose Monitor (Bulgaria)
- Mini-SAR: Miniature Synthetic Aperture Radar (NASA)
- M3: Moon Mineralogy Mapper (NASA)

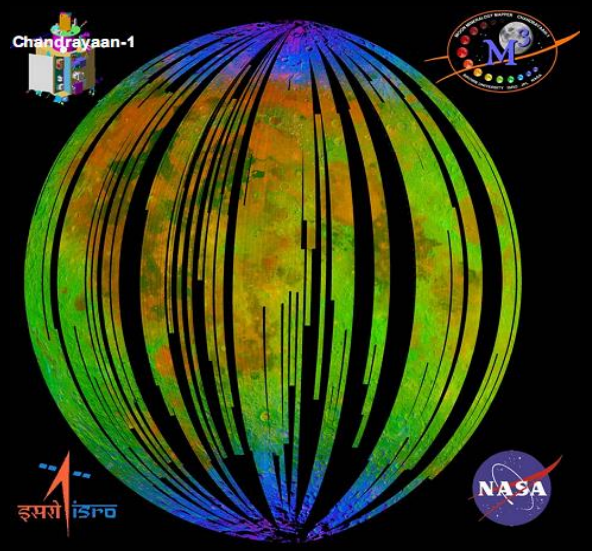
Chandrayaan-1 Mission Profile

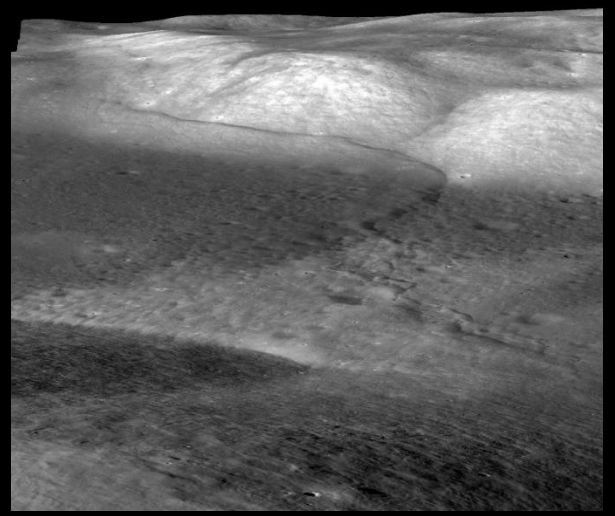


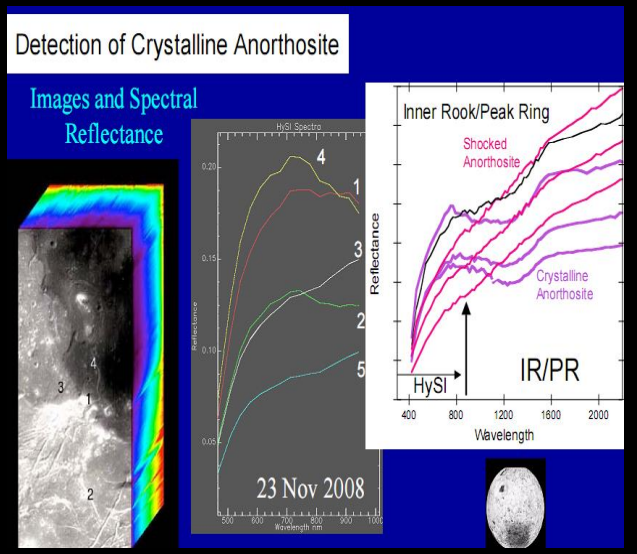
Scientific Achievements of Chandrayaan-1 mission

Chandrayaan-1 successfully carried out study of Moon's Environment & Surface processes. Apart from the significant discovery of water, major findings include:

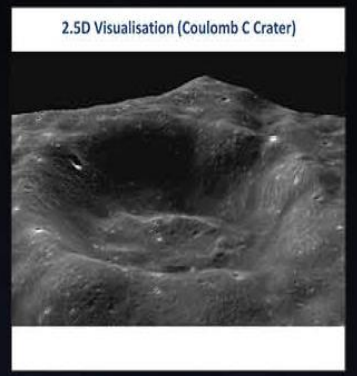
- *A Tenuous but Active Hydrosphere*
- *Volcanically Active & Geologically Dynamic Moon*
- *Established Global Magma Ocean Hypothesis*





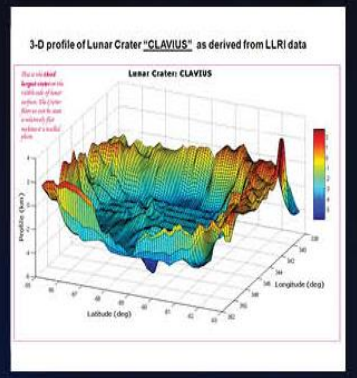


Chandrayaan-1 Payloads –Science

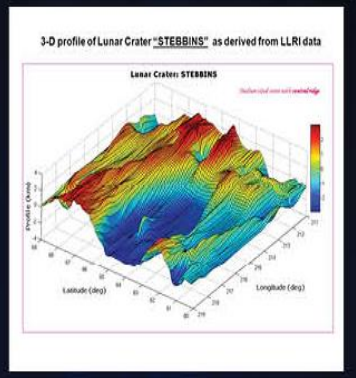


2.5D Visualisation of Coulomb C Crater by TMC

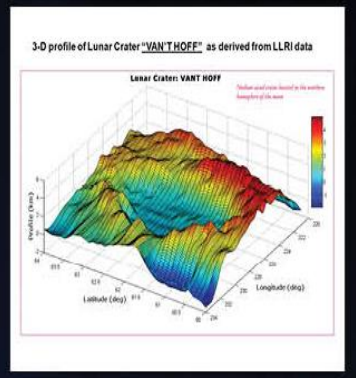
3D - View of Moon generated using TMC imagery of 23 Nov 2008 (Mountain with Height of 400 meter)



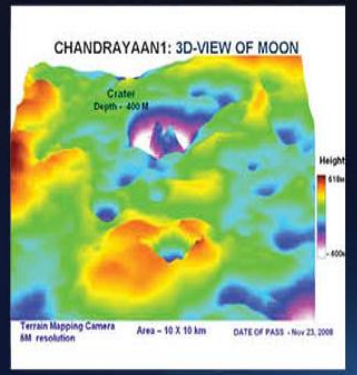
3D - profile of Lunar Crater "CLAVIUS" as derived from LLRI data



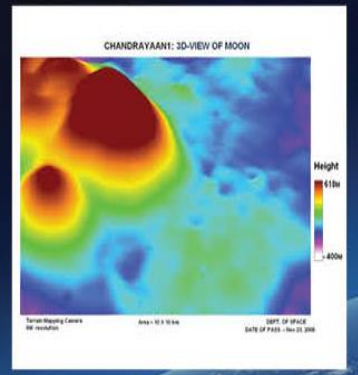
3D - profile of Lunar Crater "STEBBINS" as derived from LLRI data



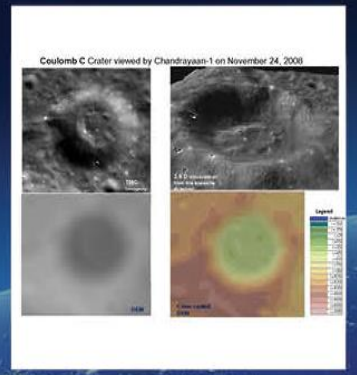
3D - profile of Lunar Crater "VAN'T HOFF" as derived from LLRI data



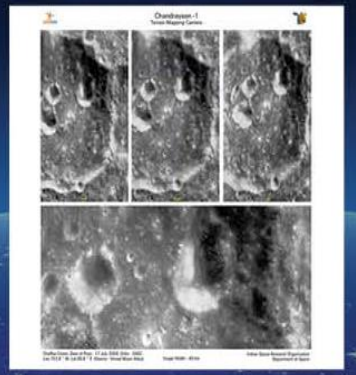
Colour Coded Imagery of Moon generated using TMC imagery of 23 Nov 2008 (Mountain with Height of 400 meter)



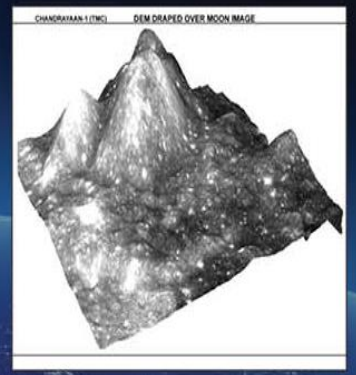
Colour Coded Imagery of Moon generated using TMC imagery of 23 Nov 2008 (Mountain with Height of 618 meter)



Crater Visualisation from TMC Images



Details of Chaffee Crater on the lunar surface as seen by TMC on July 17, 2009

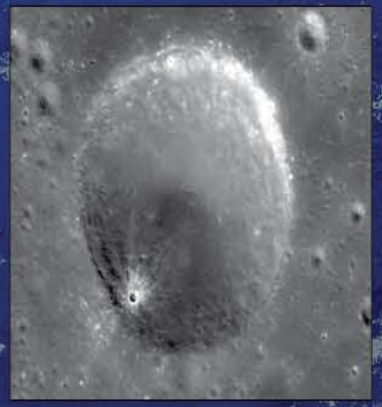


Digital Elevation Model of the lunar surface generated using TMC Imagery

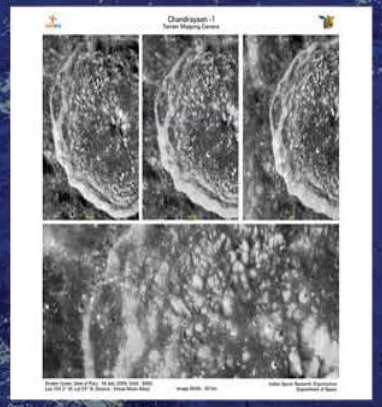
Chandrayaan-1 Payloads –Science Outcome

Earth as viewed by TMC on 29 Oct 2008, Distance ~ 70000 Km from Earth

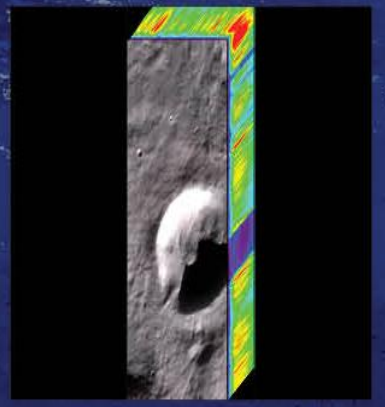
Earth as viewed by TMC on 25 Mar 2009 at 06:13:03 UTC



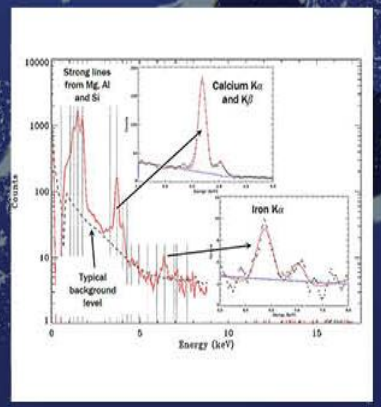
Finer details of a Lunar Crater captured by TMC



Finer details of Dryden Crater on the Moon as seen by TMC on July 18, 2009



Hyper Cube-HySI Data



C1XS - Spectra showing Calcium and Iron Signatures on Moon

Image depicting the details of Leibniz Crater on the Moon as seen by TMC on July 20, 2009

Image showing Craters of different sizes on the Moon as seen by TMC on July 20, 2009

Close up pictures of the Moon's surface taken by Moon Impact Probe (MIP) on November 14, 2008, as it approached it after separating from Chandrayaan-1 spacecraft.

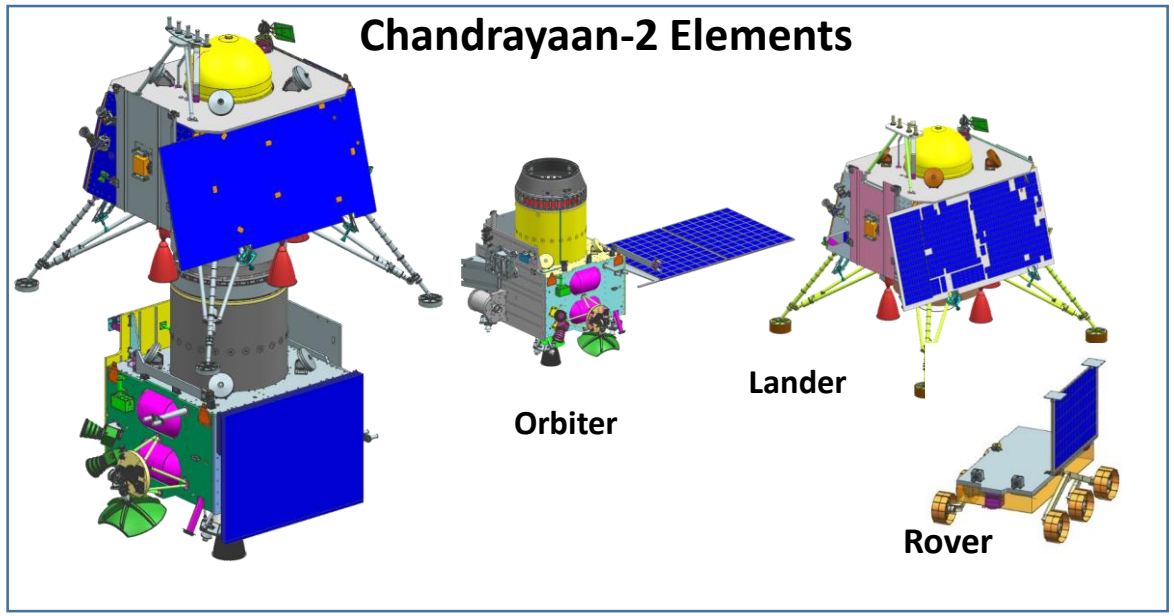
Chandrayaan-2 Overview

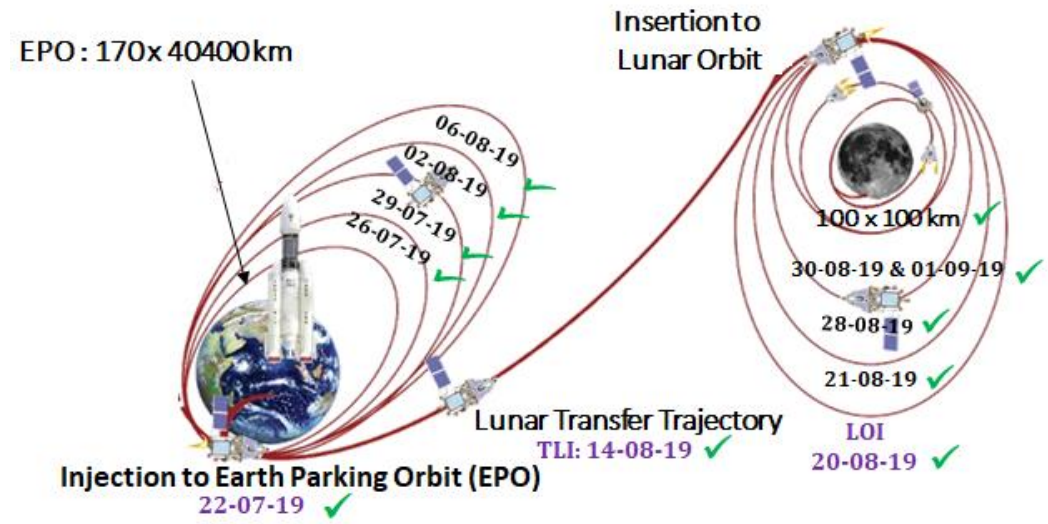
Mission Objectives

To develop and demonstrate the key technologies for end-to-end lunar mission capability, including **soft-landing and roving** on the lunar surface.

To **expand the lunar scientific knowledge** through detailed study of topography, mineralogy, surface chemical composition, thermo-physical characteristics and tenuous lunar atmosphere leading to a better understanding of the origin and evolution of the Moon.

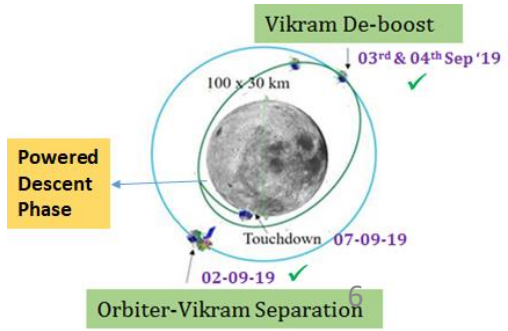
- **Second Indian lunar mission** after Chandrayaan-1
- Launched on the 22nd of July 2019 from ISRO
- Chandrayaan-2 was placed in a Elliptic Parking Orbit (EPO) by ISRO's GSLV MK-III launch vehicle.
- Most complex & scientifically challenging mission undertaken by ISRO



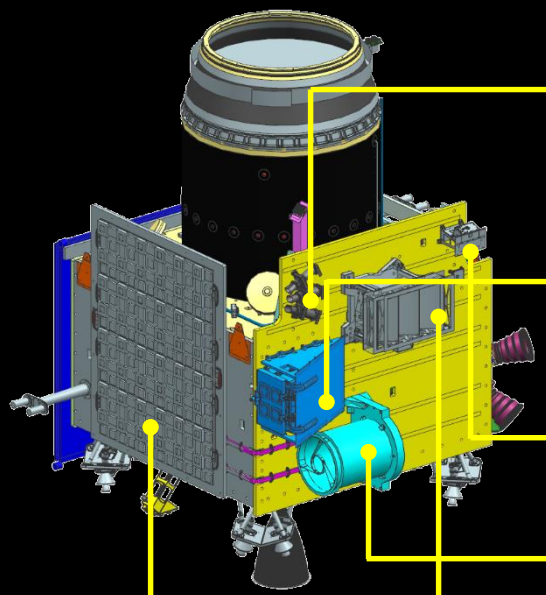


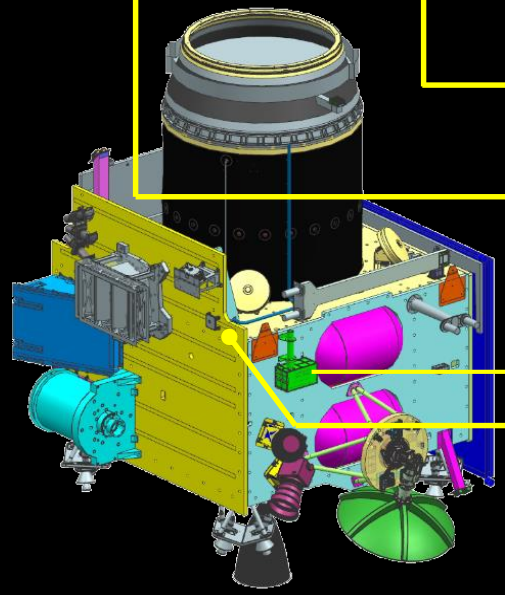
Mission Aspects Achieved

- All the eight, state of the art payload instruments on Orbiter performing well
- Several new technologies demonstrated



Chandrayaan-2 Payloads





ORBITER PAYLOADS

TMC – 2
Terrain Mapping Camera

CLASS
CH2 Large Area Soft X-Ray Spectrometer

XSM
X-Ray Solar Monitor

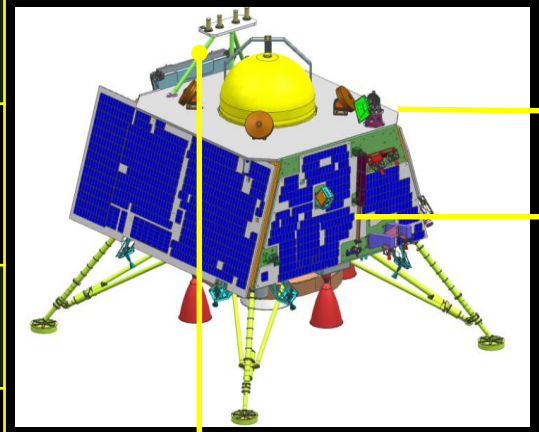
OHRC
Orbiter High Resolution Camera

IIRS
Imaging IR Spectrometer

DUAL FREQUENCY SAR
Synthetic Aperture Radar

CHACE -2
Chandras Atmospheric Composition Explorer

DFRS
Dual Frequency Radio Science Experiment



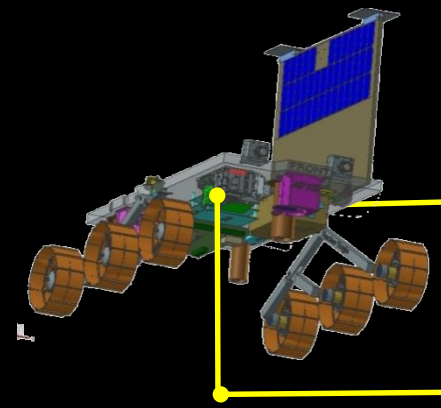
LANDER PAYLOADS

RAMBHA-LP
Langmuir Probe

ChaSTE
Chandra's Surface Thermo Physical Experiment

ILSA
Instrument for Lunar Seismic Activity

LRA –(From NASA-JPL)
Laser Reteroreflector Array



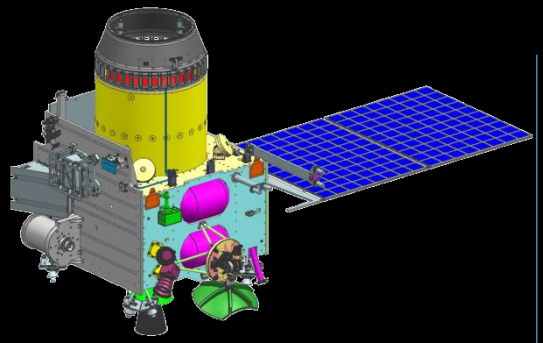
ROVER PAYLOADS

APXS
Alpha Particle X-Ray Spectrometer

LIBS
Laser Induced Breakdown Spectroscope

Chandrayaan-2 Orbiter Payloads – Science Objectives

8 Scientific instruments



- OHRC
- IIRS
- DF SAR
- CLASS
- TMC-2
- XSM
- CHACE-2
- DFRS

Total Payload Mass: 90 kg
Designed Life: 1 Year
Expected Life: 7.5 Years

Science payloads will generate new knowledge about moon

Orbiter Scientific objectives

Investigations on the presence and distribution of water on the surface, subsurface and exosphere

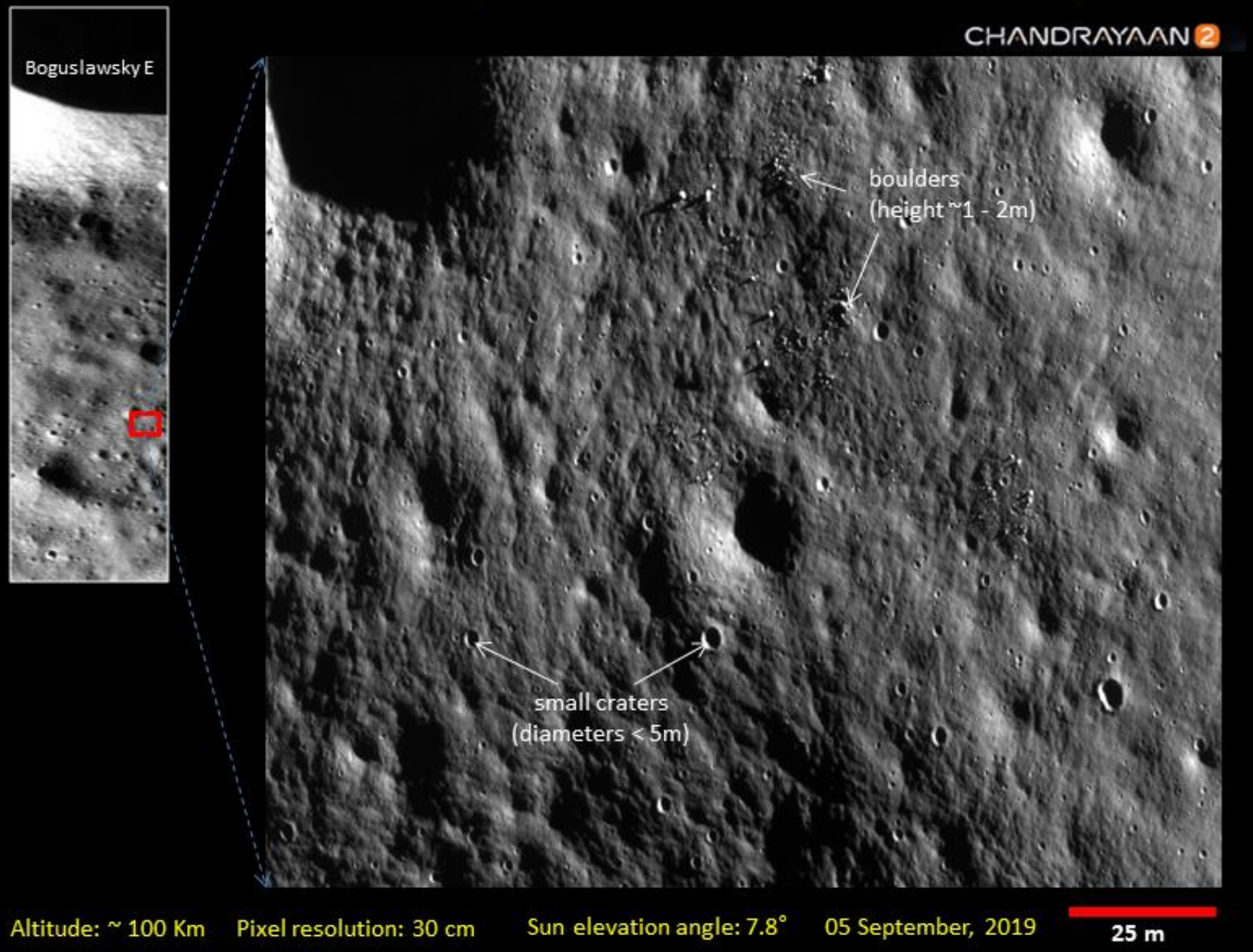
Global mapping of surface mineralogy and chemistry.

Chandrayaan-2 Orbiter Payloads & their Objectives		
Orbiter High Resolution Camera (OHRC)	0.25m Ground Sampling Distance (GSD)	Highest till date
Imaging Infrared Spectrometer (IIRS)	0.8 to 5μm operating wavelength with 250 spectral bands	Unambiguously identify the water and ice signatures and to investigate and identify minerals
Dual Frequency Synthetic Aperture Radar (DF SAR)	Quantification of sub-surface (up to 10m) water and ice in the polar regions	
CH2 Large Area Soft X-Ray Spectrometer (CLASS)	Maps the abundance of the major rock forming elements (Mg, Al, Si, Ca, Ti and Fe) on the lunar surface using the technique of X Ray Fluorescence.	
Terrain Mapping Camera (TMC-2)	Prepares a detailed three dimensional map of the lunar surface.	
X-Ray Solar Monitor (XSM)	Observe the X-rays emitted from the Sun corona and supports CLASS.	
Chandra's Atmospheric Composition Explorer (CHACE -2)	Neutral Mass Spectrometer which will carry out a detailed study of the lunar exosphere.	
Dual Frequency Radio Science Experiment (DFRS)	Measures the Total Electron Content (TEC) of the Lunar ionosphere and its morphology. To study the temporal variations, if any, in the ionospheric plasma density	

Chandrayaan-2 Orbiter : Thematic Investigations - Summary

Water on Moon	•Surface water - IR reflectance spectroscopy - **IIRS** •Subsurface water - **Dual band SAR (L & S)** •Exospheric water - **CHACE-2**
Compositional studies	• Mineralogy - **IIRS** • Chemistry - **CLASS (+ XSM)** • Regolith thickness - **SAR** • Ionospheric studies – Radio Occultation - **DFRS**
Global mapping	• Topography – context – **TMC-2 & OHRC** • 3 Dimensional mapping – **TMC-2** • High resolution images - **OHRC**

Orbiter High Resolution Camera (OHRC) Images



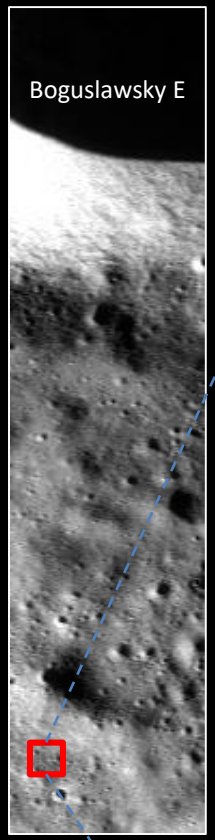
25 cm spatial resolution from 100km orbit; Swath 3km

High resolution images…

Provides sharpest images ever from a lunar orbiter platform.

Center co-ordinates
Lat: 74.623 S
Long: 54.087 E

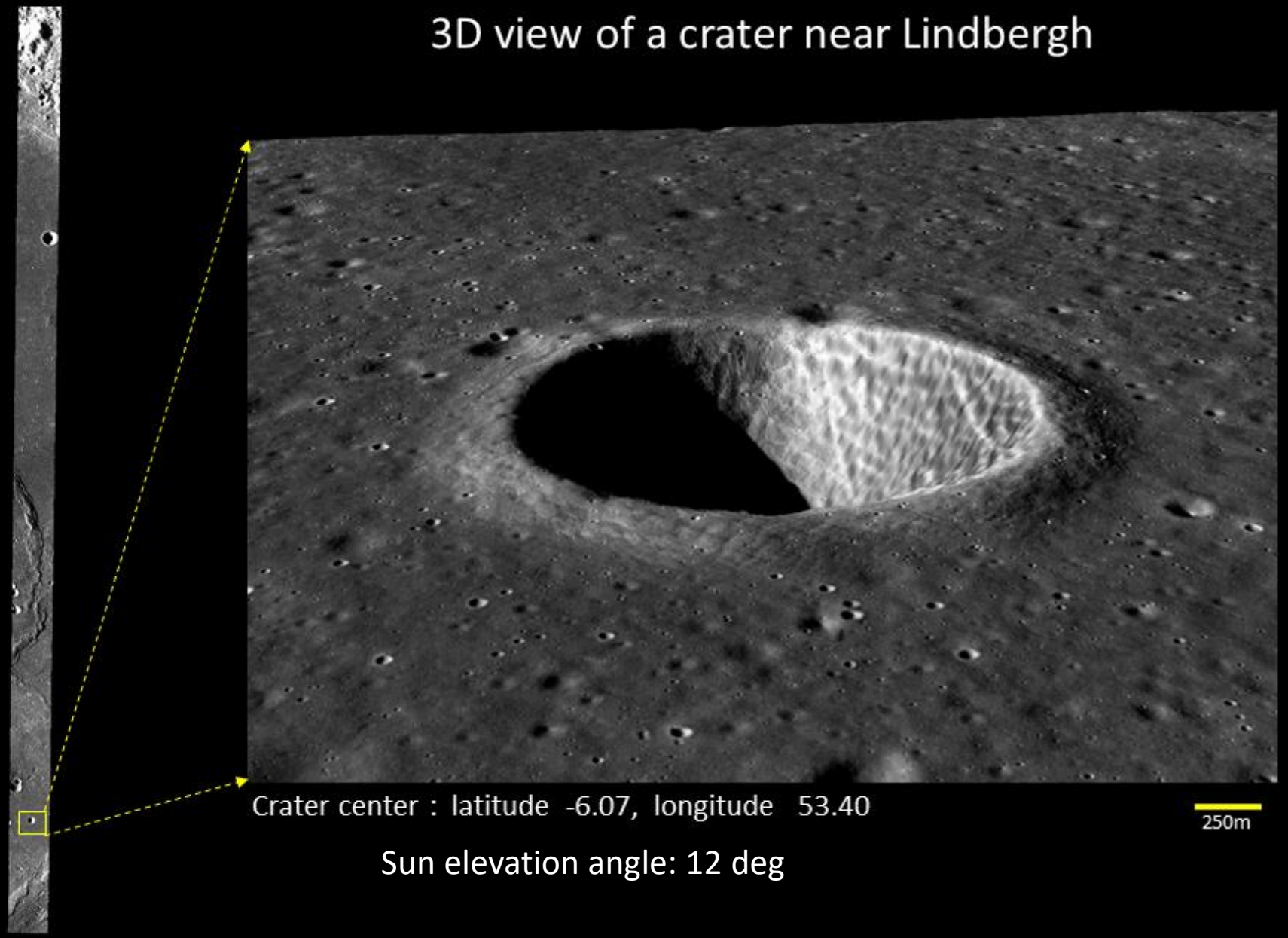
Boulders imaged by OHRC



Altitude: ~ 100 km Pixel resolution: 30 cm Sun elevation angle: 7.8° 05 September, 2019

25 m

Terrain Mapping Camera (TMC-2) Images



0.4 µm to 0.85 µm Panchromatic band

Fore, nadir and aft views.

5m spatial resolution

10m DEMs can be generated.

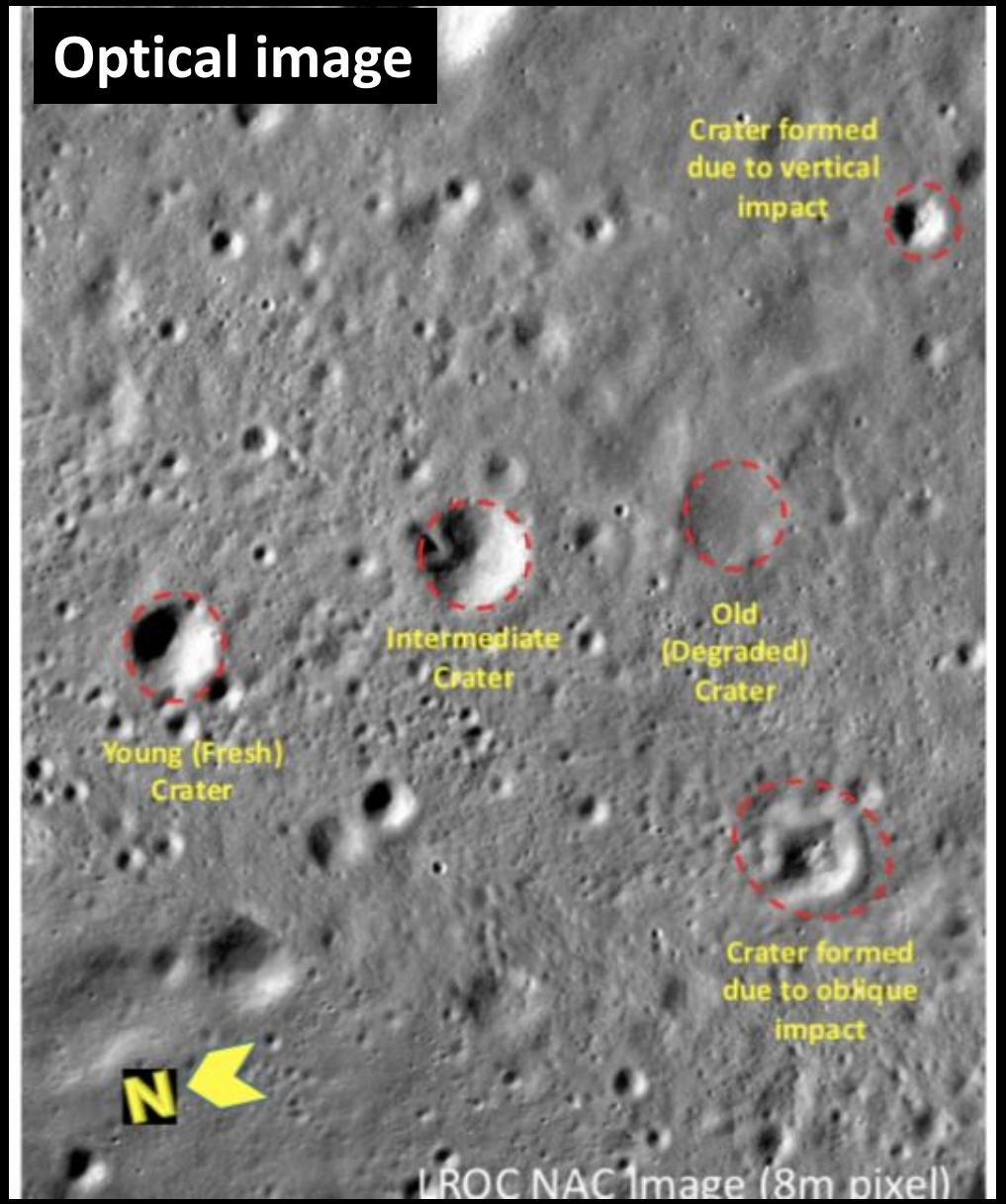
Terrain Mapping Camera (TMC-2) Images

3D view of a Wrinkle ridge near Dorsa Geikie

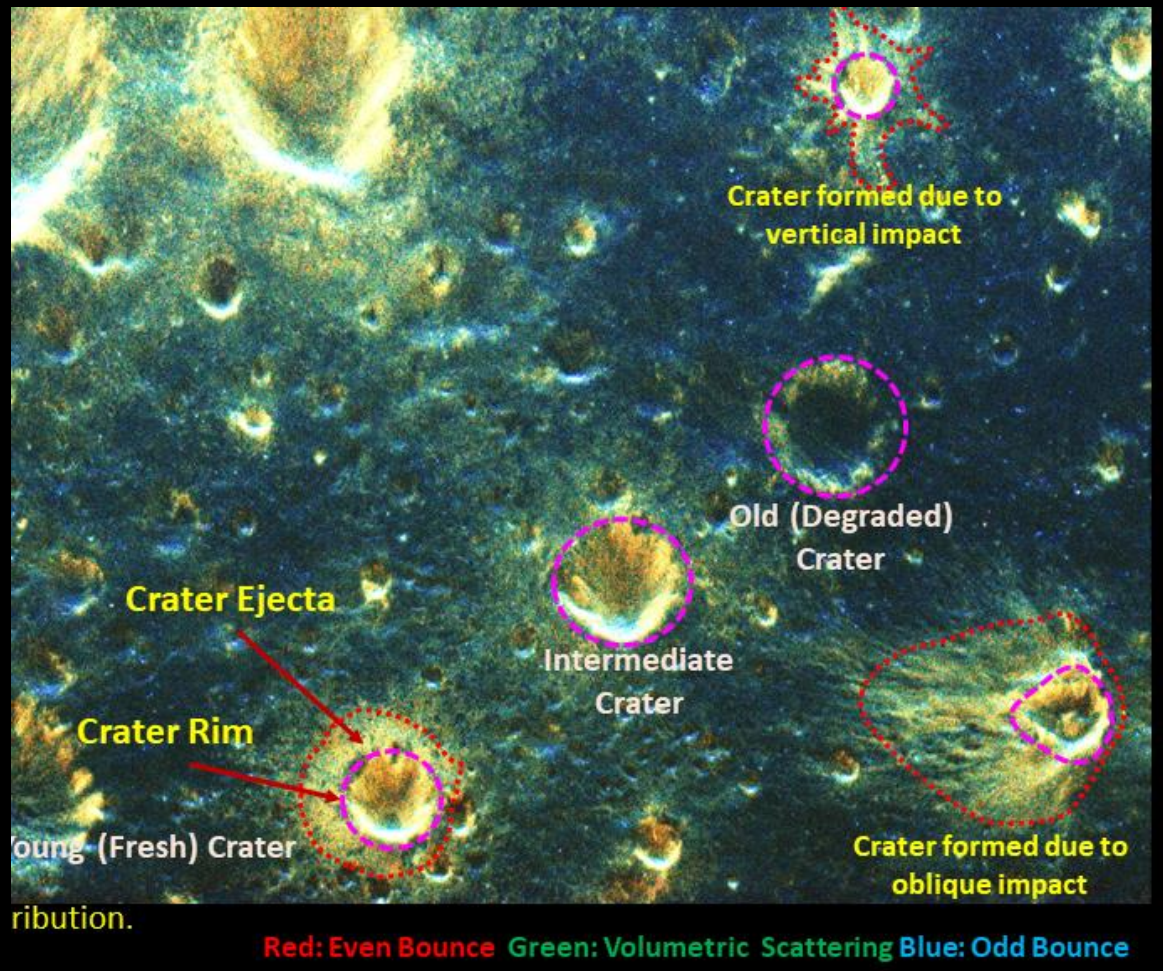
Sun elevation angle: 12 deg

Dual-Frequency Synthetic Aperture Radar (DF-SAR) – L&S bands

Comparison of Optical image and SAR Image

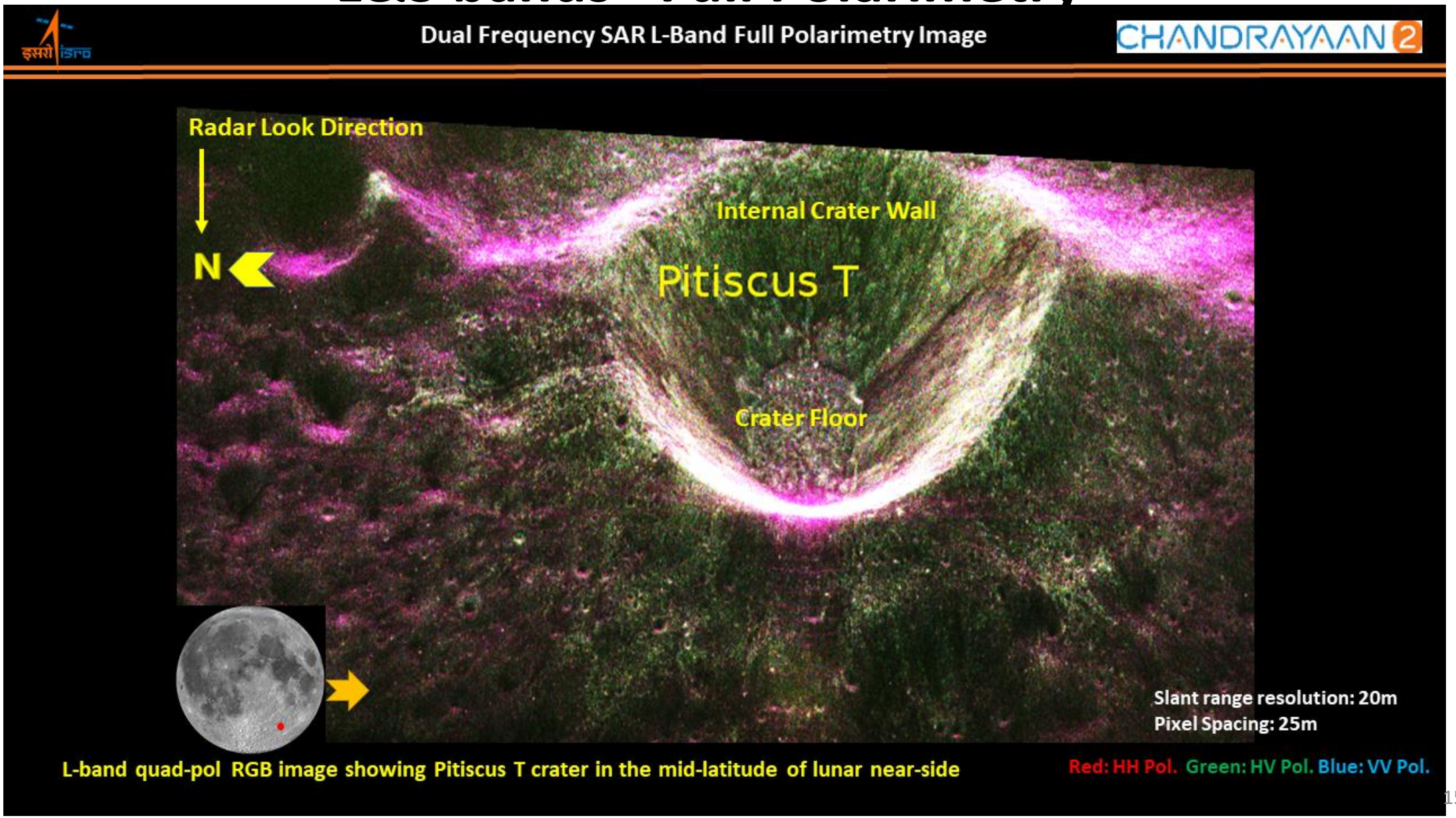


L-band radio SAR image from Ch-2



Craters of different age and origin seen along with their ejecta distribution. Yellowish texture around the crater rims show the ejecta field.

Dual-Frequency Synthetic Aperture Radar (DF-SAR) – L&S bands –Full Polarimetry

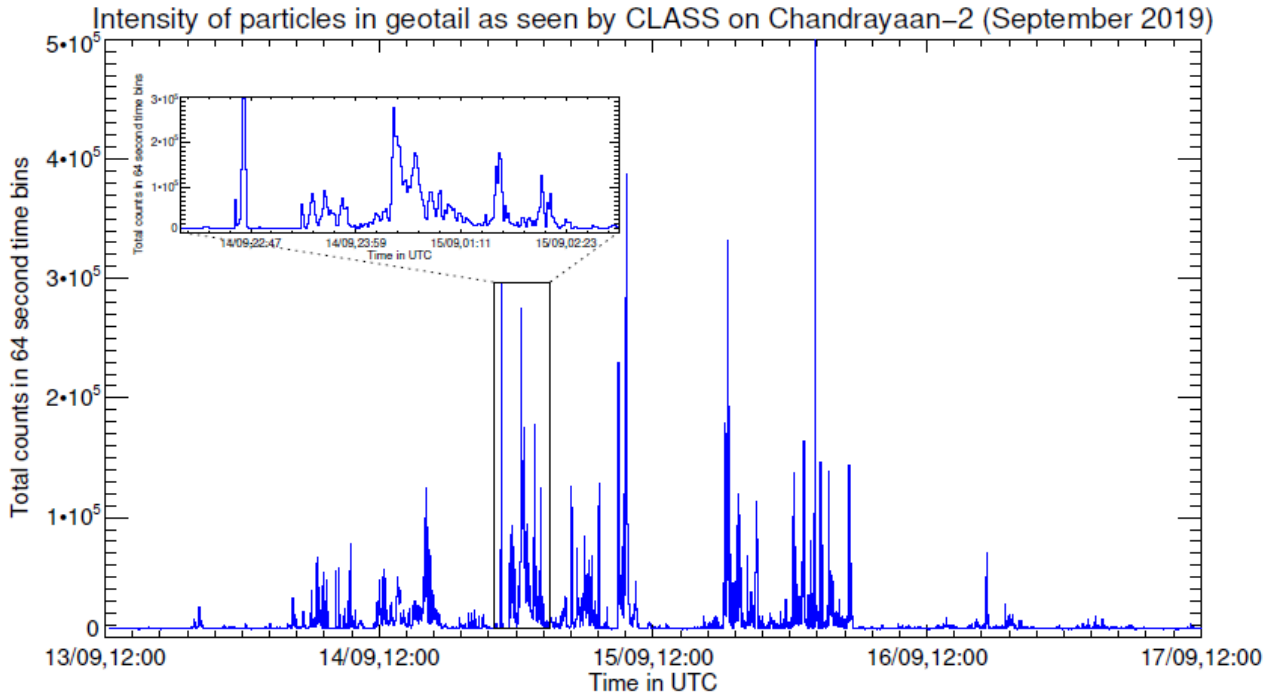


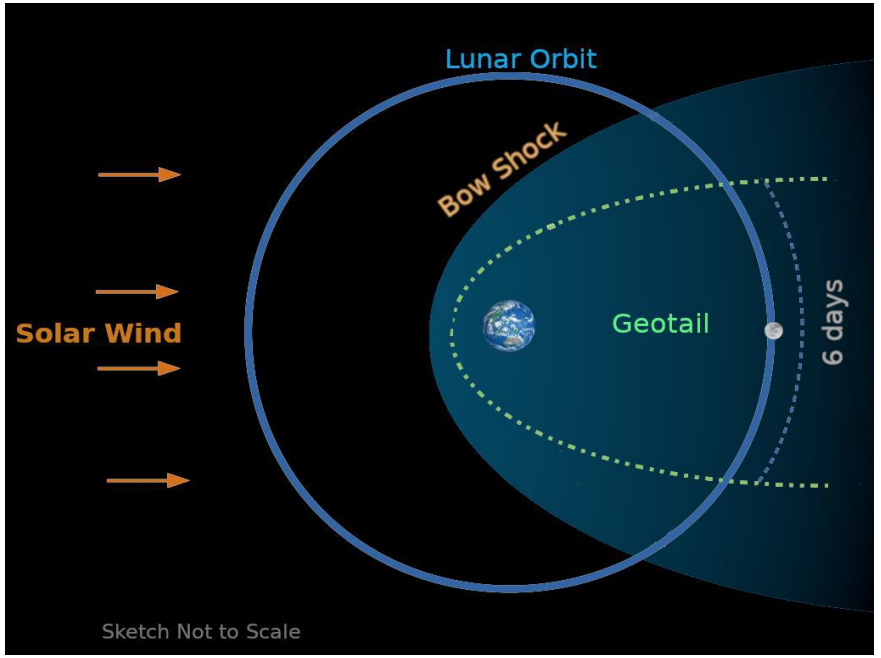
CLASS results…

Studying Earth's extended magnetosphere (geotail)plasma around Moon

Once every 29 days, Moon traverses the geotail for about 6 days centred around full moon.

Ch-2 Large Area Soft X-ray Spectrometer (CLASS) detected charged particles and its intensity variations during its first passage through the geotail during Sep.

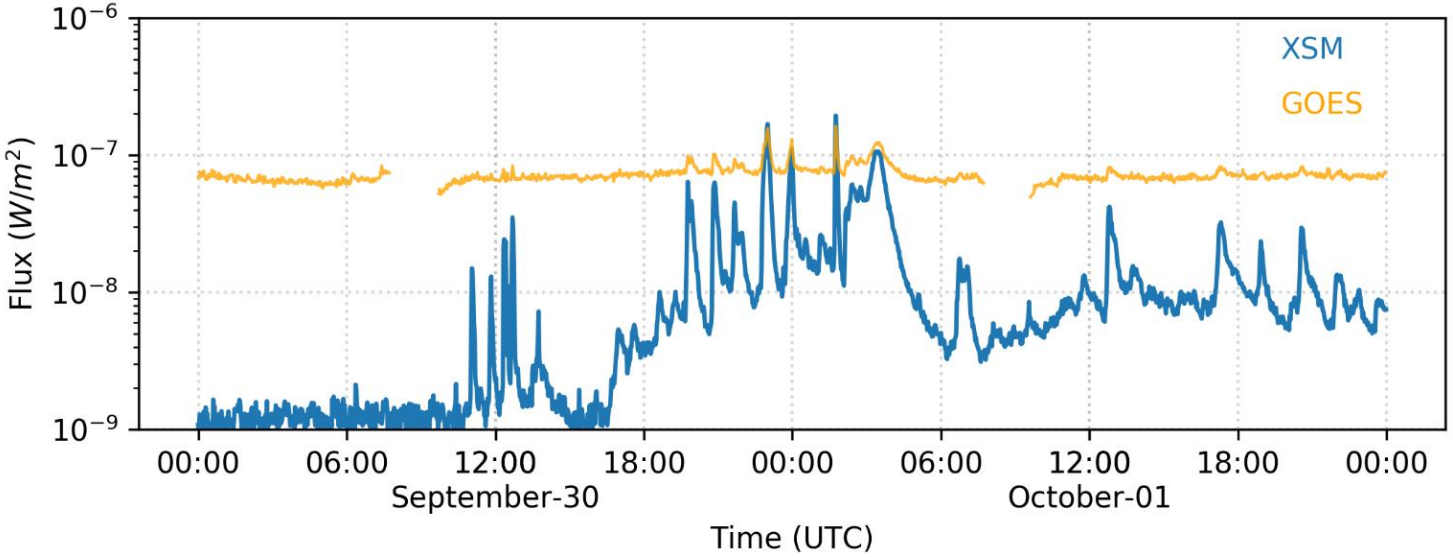




Change in intensity of particle events (believed to be mostly electrons), sometimes as much as 10 times the levels outside the geotail, indicating complex interplay with the magnetic field.

XSM results…

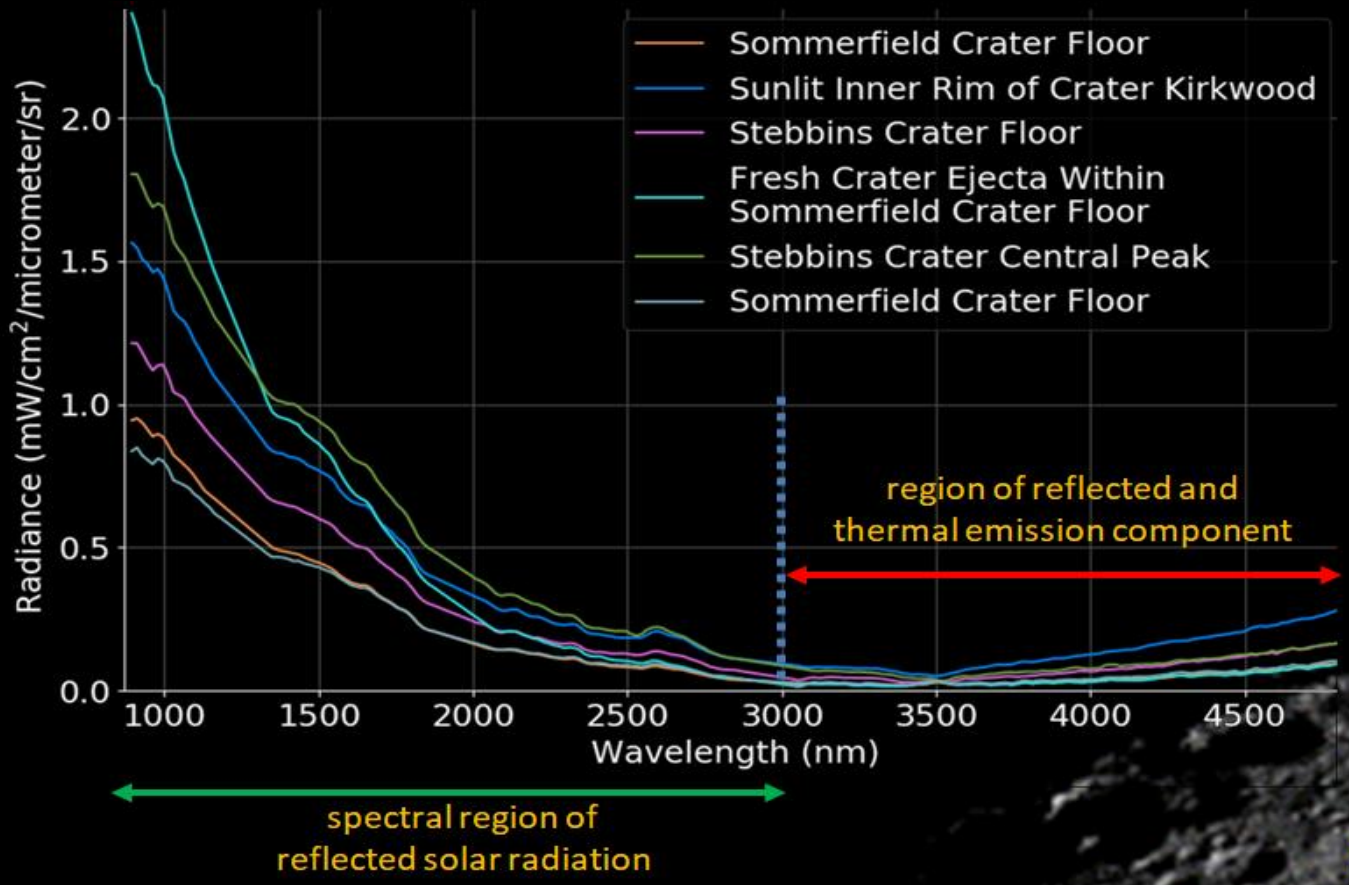
Solar flare observed by the Solar X-ray Monitor



Solar X-ray flux as measured by XSM (in blue) during this period, and for comparison, the flux measured by X-ray sensor on the Geostationary Operational Environmental Satellite (GOES-15) is also shown (in orange), which is considered the standard for solar X-ray intensity measurement.

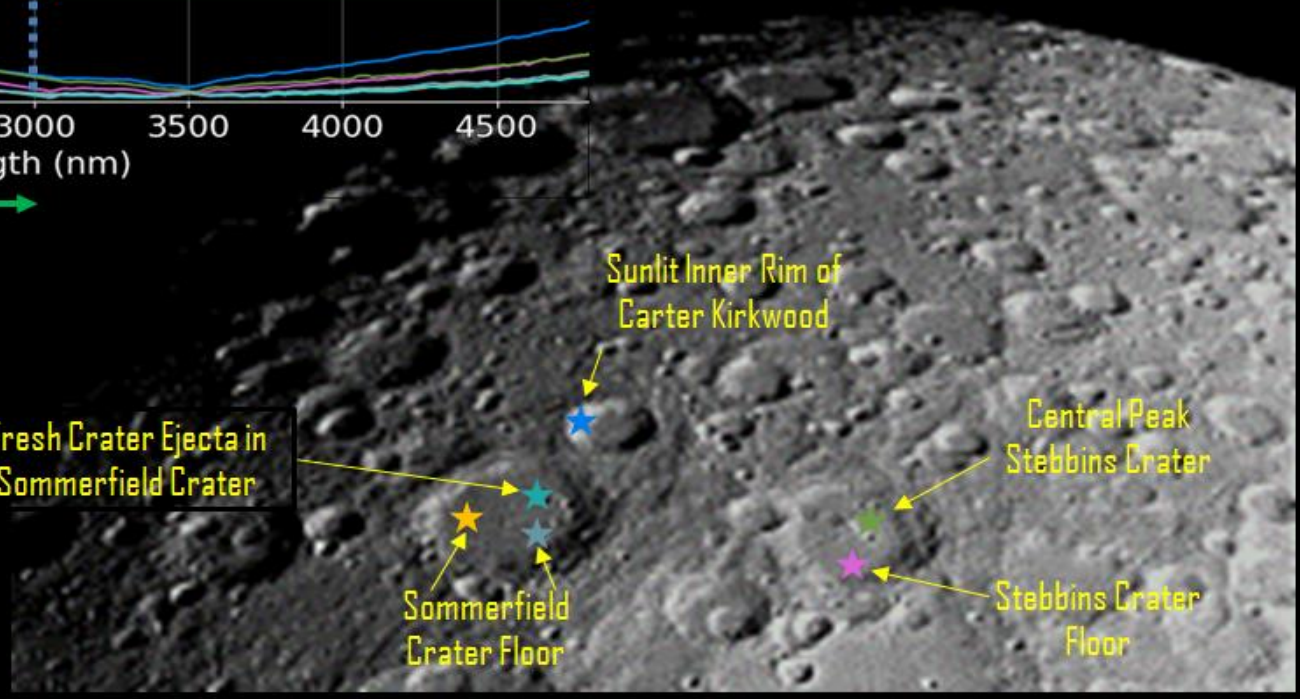
It shows that XSM is able to detect the intensity variations of the Sun much beyond the sensitivity limit of GOES.

Chandrayaan-2 Imaging IR Spectrometer (IIRS) spectral signatures



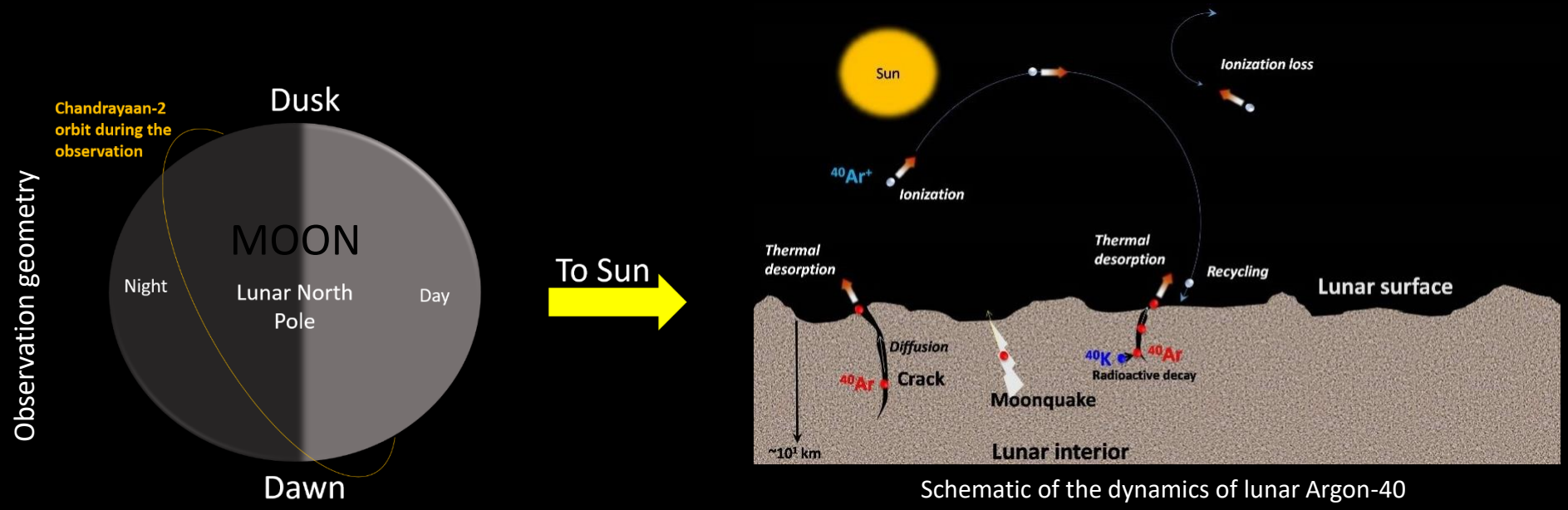
Mapping the lunar surface mineral and volatile composition using signatures in the reflected solar spectrum.

0.8 to 5.0 micron range

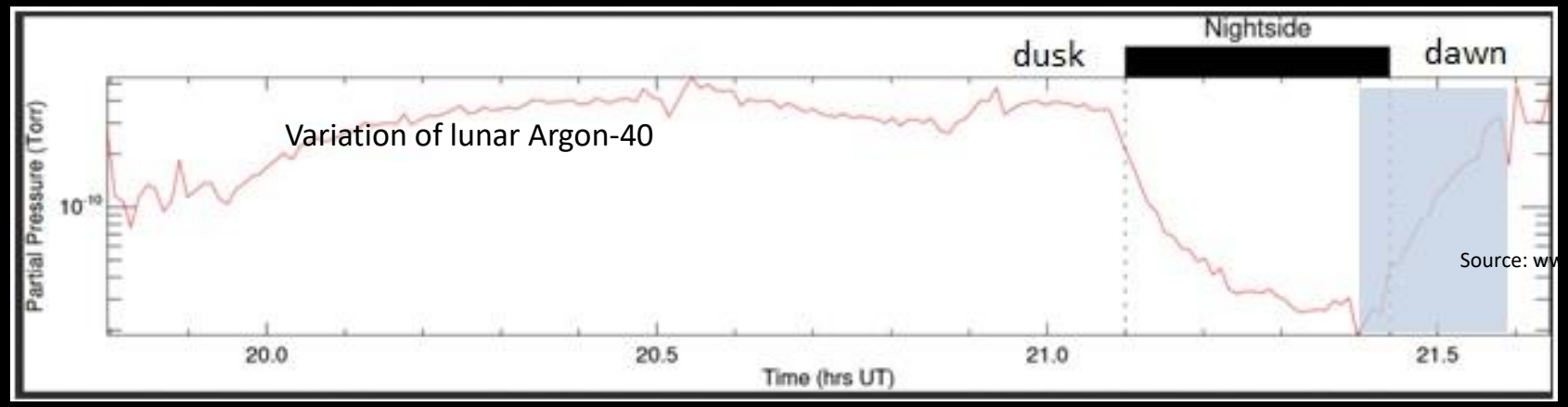


CHANDRAYAAN 2

In Situ Diurnal and Latitudinal Variation of Lunar Argon-40 by **CHACE-2** Mass Spectrometer



Schematic of the dynamics of lunar Argon-40

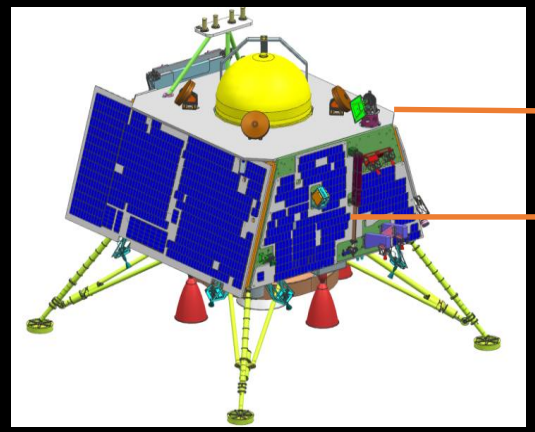


Regular mission observations are in progress

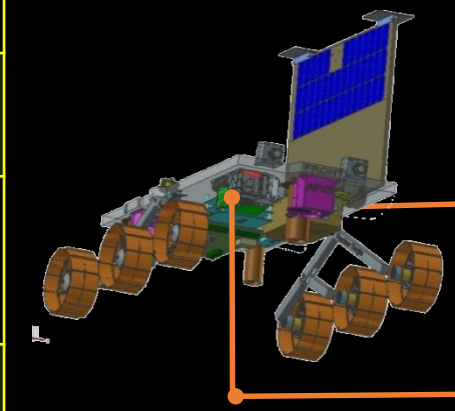
Chandrayaan-3

- Chandrayaan-3 is the follow on mission and it is approved by Government.
- It comprises of a Lander and a Rover with a Propulsion module.
- Activities have initiated and realisation is in progress.

Payloads on Chandrayaan-3



LANDER PAYLOADS
RAMBHA-LP Langmuir Probe
ChaSTE Chandra's Surface Thermo Physical Experiment
ILSA Instrument for Lunar Seismic Activity



ROVER PAYLOADS
APXS Alpha Particle X-Ray Spectrometer
LIBS Laser Induced Breakdown Spectroscope

THANK YOU