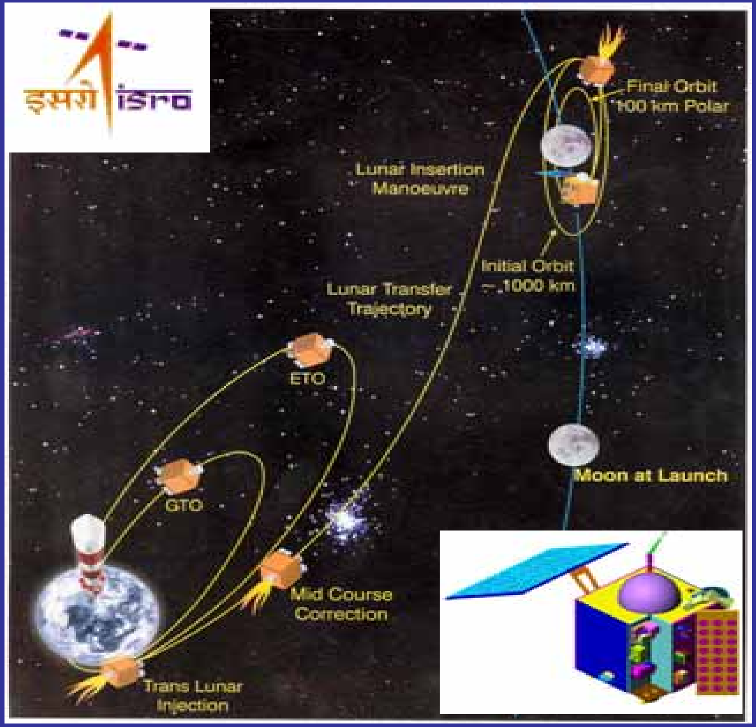
Chandrayaan Mission Objectives and future lunar programs



Paul Spudis, channeling J. N. Goswami

Principal Scientist, Chandrayaan-1 Mission

The Clementine & Lunar Prospector Missions to Moon raised

New Questions about the Evolution of Moon

I. Origin of the Moon: Chance or Destiny?

II. Melting of the Moon: The Magma Ocean Hypothesis

III. The bulk chemistry of Moon, particularly the abundance of iron, magnesium and uranium

IV. Lunar asymmetries & formation of SPA basin

V. The nature and structure of the lunar crust and mantle

VI. Water on Moon and the nature of Volatile transport

And, the List is growing……..

Understanding the origin and Evolution of the Moon

Physical Properties of the Moon

The bulk chemistry of Moon

Topography

Gravity

Magnetic Field

Radiation Environment

Nature of the Lunar Crust

The lunar far side: rock types, chemistry

Special Regions of Interest:

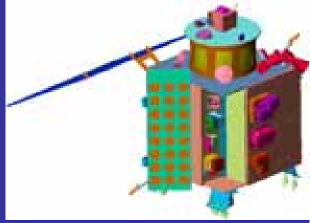
Polar Regions ,

South Pole-Aitken Basin Region,

Selected Basins and Craters as windows into the crust

Nature of the Magma Ocean and Lunar Interior

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



Objectives of the Chandrayaan-1 Mission

Simultaneous Mineralogical, Chemical and Photogeological Mapping at resolutions better than previous and currently planned lunar missions

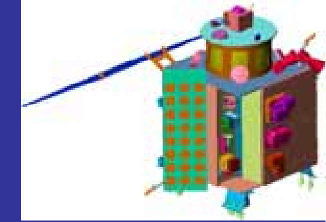
Direct estimation of lunar surface concentration of the elements Mg, Al, Si, Ca, Ti and Fe with high spatial resolution (20 km)

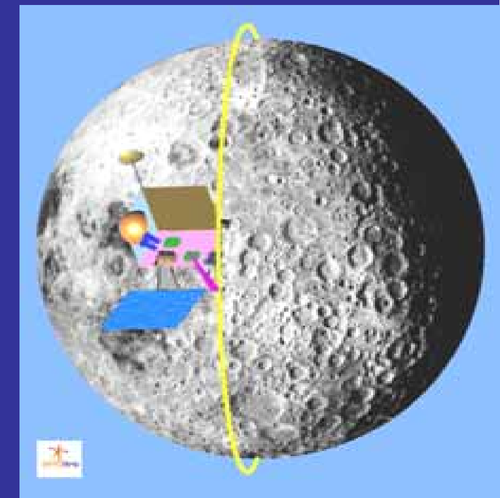
High resolution UV-VIS-NIR mapping of the lunar surface to identify mineralogy and selected elements (Fe, Al, Mg, Ti)

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 Mission

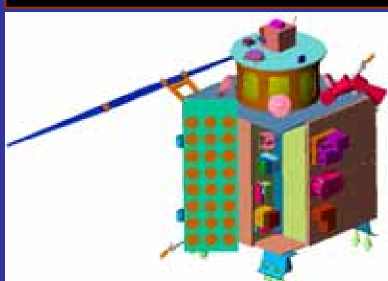




Configuration : 100 km polar orbiter

Observation Period : 2 years

Baseline Payloads:



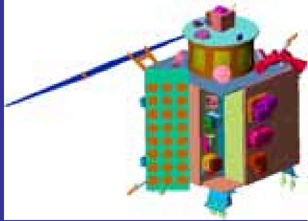
Hyper Spectral Imager (HySI) (0.4-0.9µm)

Terrain Mapping Camera (TMC)

Laser Ranging (LLRI)

High energy X-γ ray spectrometer (HEX) (10-200KeV)

Moon Impact Probe (MIP), camera and altimeter hard lander



Imaging Payloads on Chandrayaan-1

I. Terrain Mapping Camera (TMC)

Stereoscopic instrument in Panchromatic band for ***3D Topographic mapping*** *with high spatial and altitude resolution.*

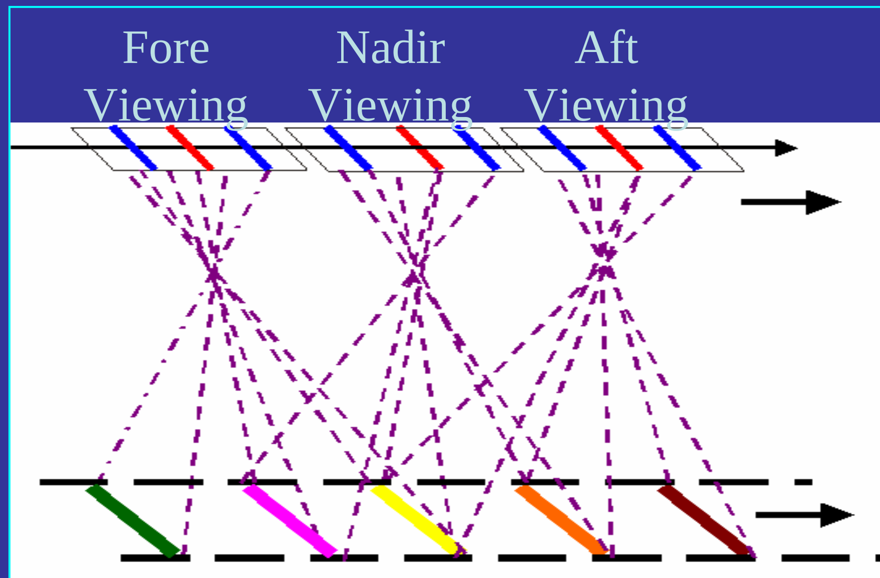
II. Hyper Spectral Imager (HySI)

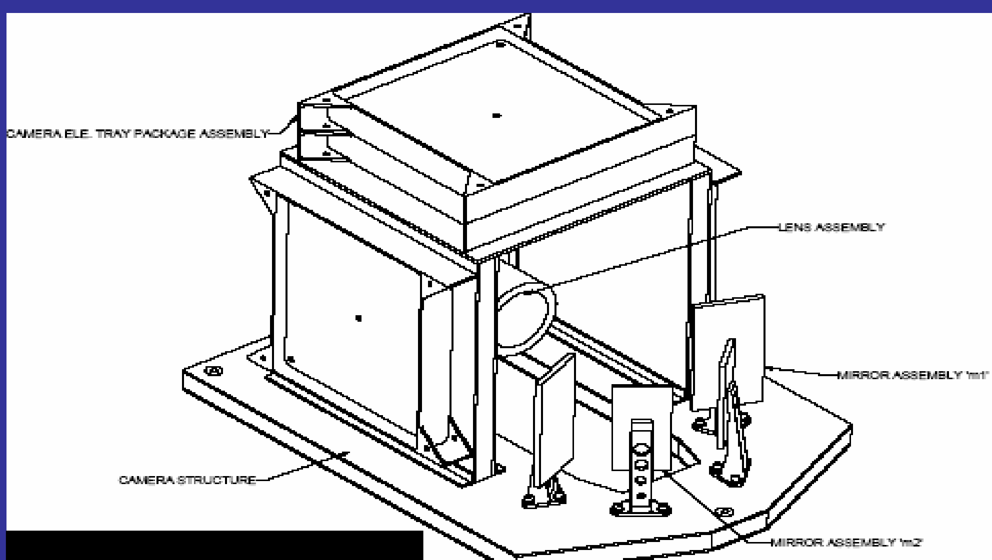
Imager for ***Mineralogical mapping*** *in UV-VIS-NIR with high spectral resolution.*

[Designed and Fabricated at the Space Application Center, ISRO]

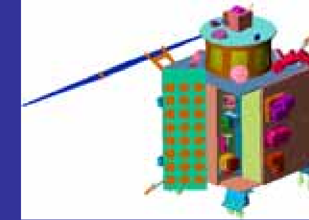
Chandrayaan-1 Mission

TMC concept & Instrument configuration





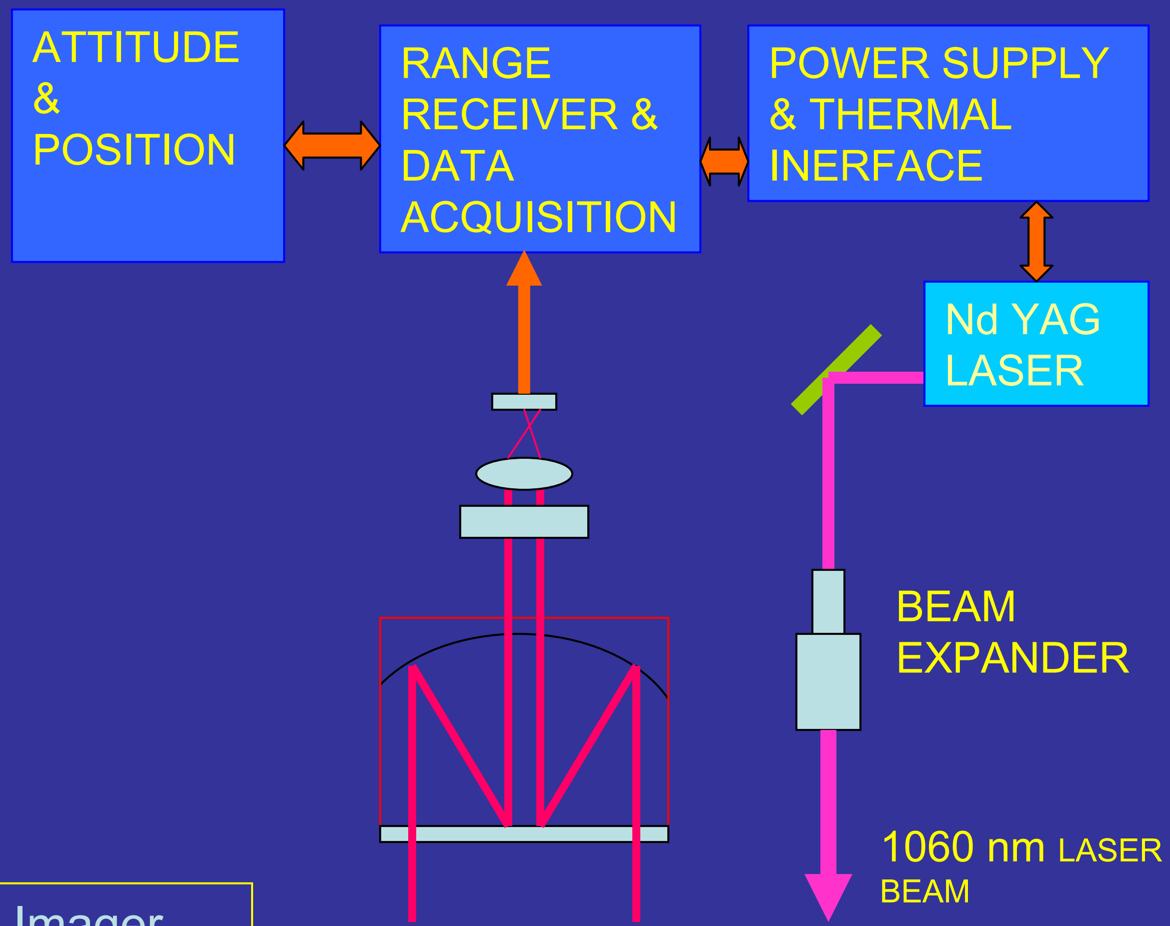
Chandrayaan-1 Mission

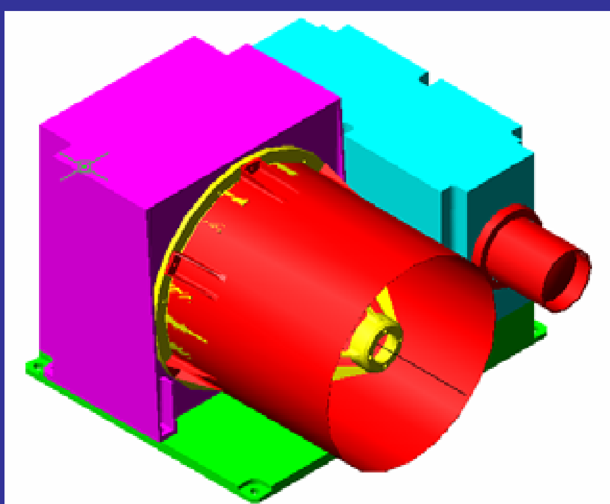


Lunar Laser Ranging Instrument

Primary Objective:

Determine Global Topographic Figure of Moon



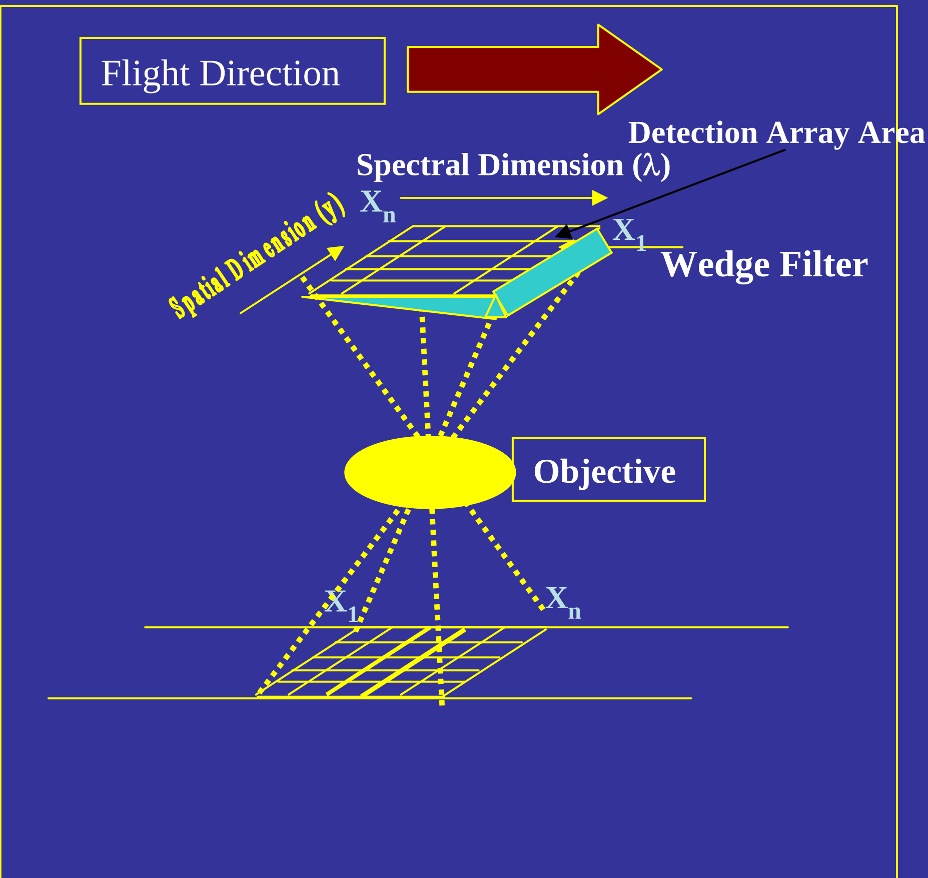


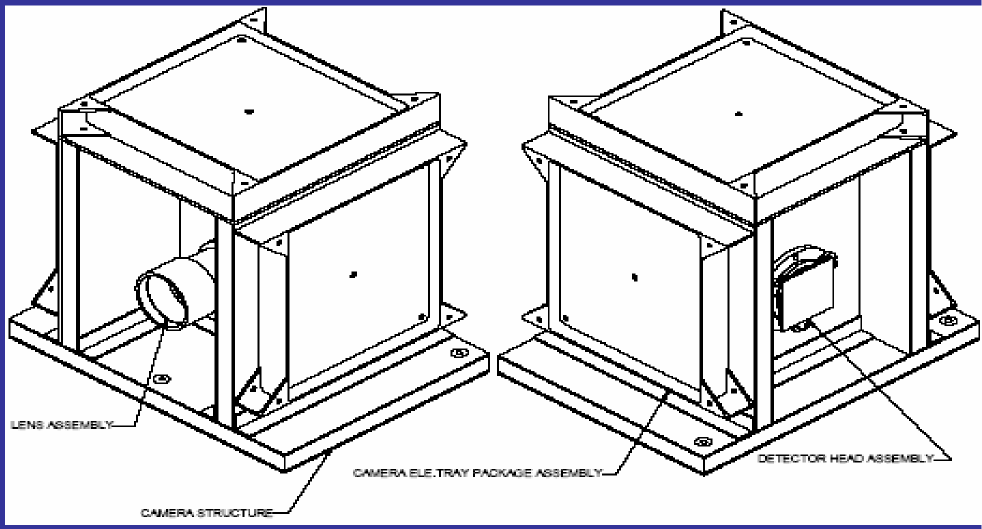
- Supplement TMC and HySI Imager
- Improved model of lunar gravity field

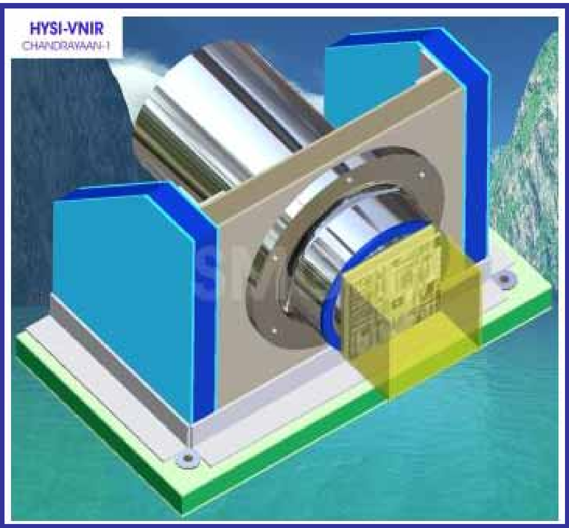
Developed at LEOS, ISRO

Chandrayaan-1 Mission

HySI concept & Instrument configuration

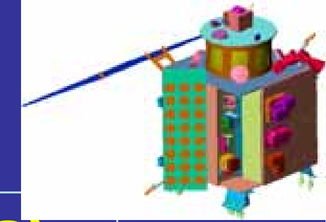






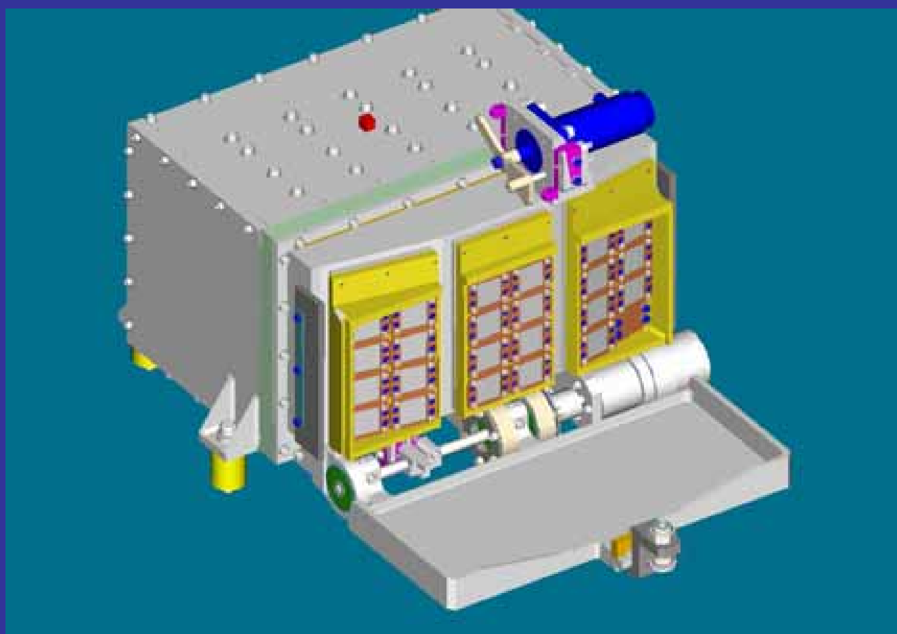
400-900 nm, 32 bands, resolution 80 m

Chandrayaan-1 Mission



Compact Imaging X-ray Spectrometer (CIXS)

A modified version of D-CIXS, the Low Energy X-ray Spectrometer, flown on SMART-1



New generation Swept-charge X-ray Detector

Chemical (Elemental) Mapping of Lunar Surface based on Solar X-ray induced fluorescence emission

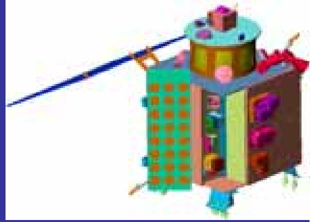
[Mg, Al, Si : Solar quiet time]

Ca, Ti, Fe : Solar Flare time]

High resolution mapping of Fe and estimation of Mg#

P. I. Prof. Manuel Grande,
Rutherford Appleton Laboratory, UK

Indian Co-I : Dr. P. Sreekumar, ISAC

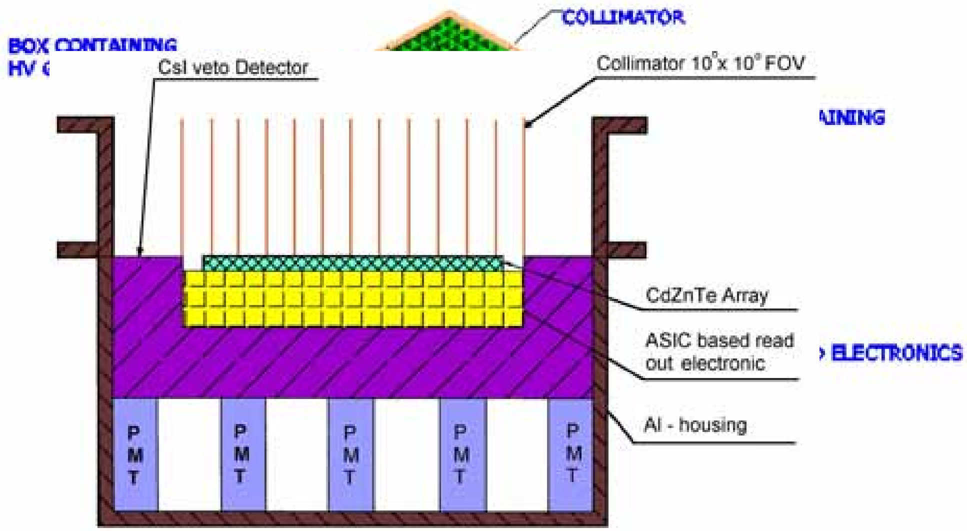


Chandrayaan-1 Mission

High Energy X- γ Ray (HEX) PAYLOAD

- **Volatile Transport on Moon through detection of 46.5 keV line from Pb-210**
- **Th and U map of Polar and U-Th-rich regions**

High Energy X- γ Ray Spectrometer (10-200 KeV)



CdZnTe Array Detector with Collimator

Developed by Physical Research Laboratory & ISRO Satellite Center

Basic Features

Detector: Cd-Zn-Te Array

Effective Area: 100 cm^2

Energy Range: 20-250 keV

Energy Resolution: $\leq$6% @ 60 keV

FOV: 40km x 40km

Active Anticoincidence Shielding: CsI(TI)+PMT

Collimator: Tantalum

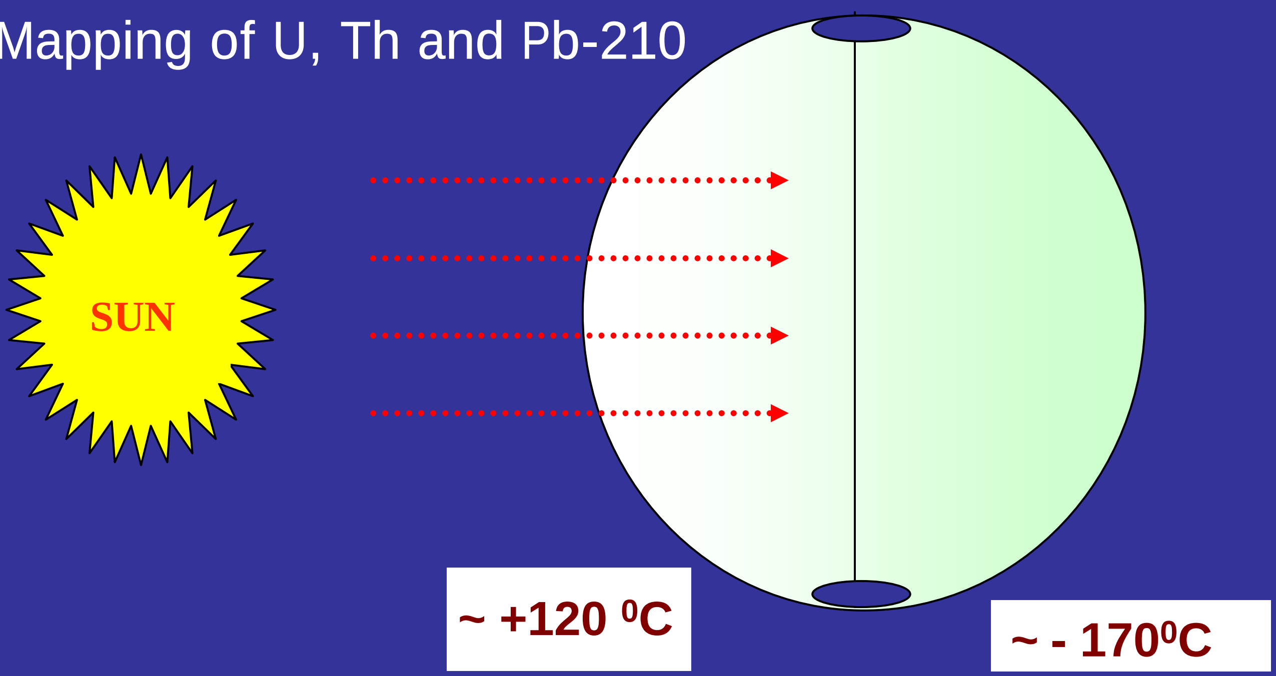
Weight: 15 kg

Power: 23 W

High Energy X- γ Ray (HEX)

First attempt to detect low-energy (20-250 keV) gamma ray emission from a planetary surface

Mapping of U, Th and Pb-210



Source: U-238 in Moon

↓

^{226}Ra 1622y

↓ α

^{222}Rn (γ) 3.8d (gas)

↓ α

^{218}Po 3.05m

↓ α

^{214}Pb 23.8m

↓

^{214}Bi 19.7m

↓

^{214}Po 1.6x10^{-4}s

↓ α

^{210}Pb (γ) 22.3y paint

↓

^{210}Bi 5.01d

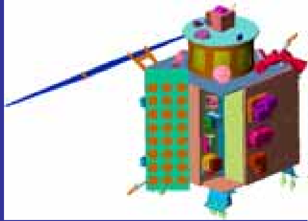
^{210}Po 138d

α ^{206}Pb

↓

Water on Moon:

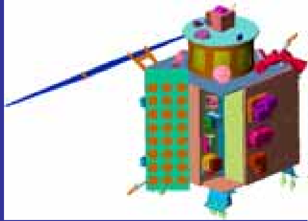
Movement of volatile (^{222}Rn) to permanently shadowed polar regions using ^{210}Pb (46 keV) as tracer



Chandrayaan-1 Mission

Payload Configuration & Details

Payload	Configuration	Range	Resolution	Objective
Hyper Spectral Imager (HySI)	Wedge filter pixelated imager	0.4-0.9 µm	Spatial - 80m Spectral-15nm 32 channels	Mineralogical mapping
Terrain Mapping Camera (TMC)	Three stereo cameras with pixelated imagers	Panchrom -atic; 20 km swath	Spatial - 5m Vertical - 5m	High resolution Atlas of the whole moon
Laser ranging (LLRI)	Pulsed Nd-Yag laser	1064 nm	Vertical - 10 m or better	Topography & Gravity model
Compact X-ray Spectrometer (CIXS)	X-ray SCXD type detector 25 sq. cm area	0.5-10 keV	20 km	Elemental mapping Si, Al, Mg, Ca, Fe, Ti
High energy X-ray spectrometer (HEX)	CdZnTe detector 100 sq. cm. area	10-200 keV	40 km	^{210}Pb, Volatile transport
Solar X-ray Monitor (SXM)	Si-Pin Diode 2 or 3 detectors viewing orthogonally	2-10 keV		Solar X-ray flux monitoring



Chandrayaan-1 Mission

A new era of International Cooperation

Based on science objectives and spacecraft resources, several proposals were accepted from international community; they 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)

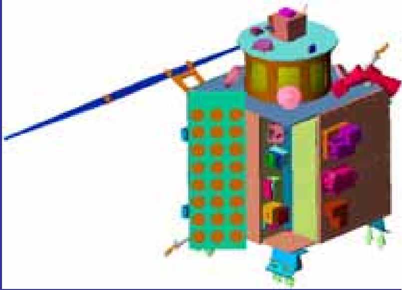
II. An experiment to detect neutral atoms (SARA)

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

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

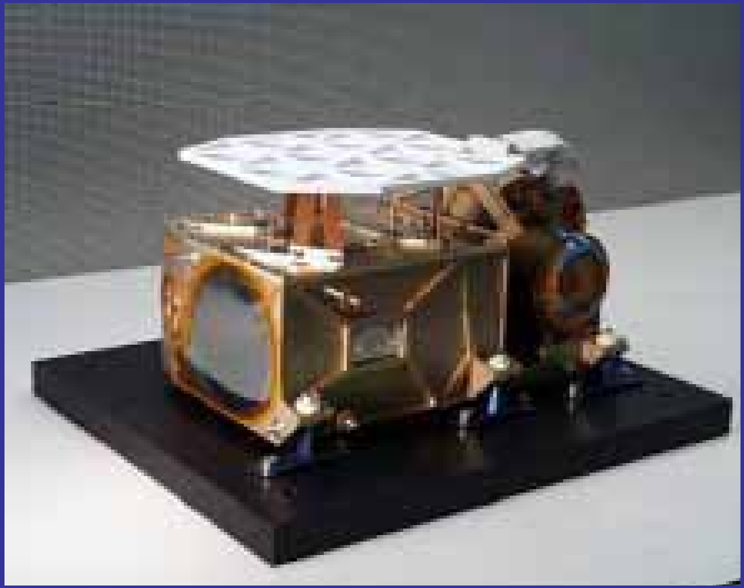
There will be Indian collaboration in analyzing data from all these experiments

Chandrayaan-1 Mission (AO Payloads)



SIR-2: A Near-infrared Spectrometer

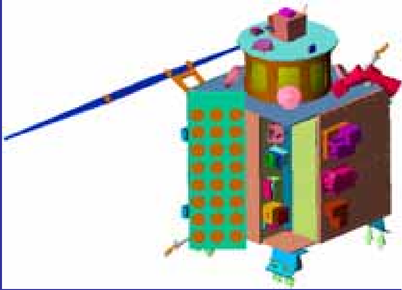
P. I. Dr. Urs Mall,
Max-Planck Institute for Solar System Research
Katlenburg-Lindau, Germany



The first version of SIR orbited the Moon onboard ESA SMART-1 Mission

Spot spectrometer 1.11 milliradian FOV (~110 m surface spot size from 100 km orbit)

930-2400 nm spectral range with 6 nm spectral resolution

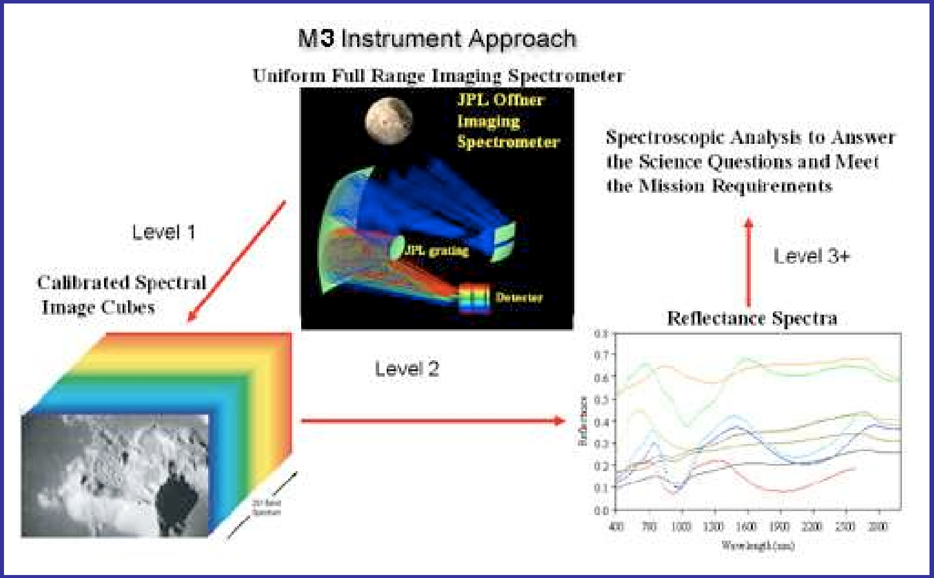


Chandrayaan-1 Mission (AO Payloads)

Moon Mineralogy Mapper

An Imager in VIS-NIR band

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

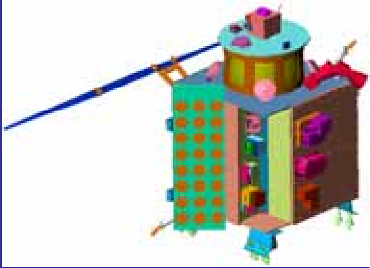


700 to 3000 nm range
Sampling : 10 nanometers
Spatial resolution: 70 m/pixel [from 100 km orbit]
Field of View: 40 km [from 100 km orbit]
Weight: ~7 kg
Power average: ~13 W

Mineral Mapping of Lunar Surface

This Instrument, together with SIR-2, HySI, CIXS and SARA, provide detailed mapping of surface composition of the Moon

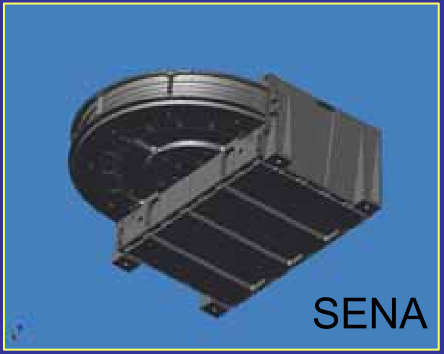
Chandrayaan-1 Mission (AO Payloads)

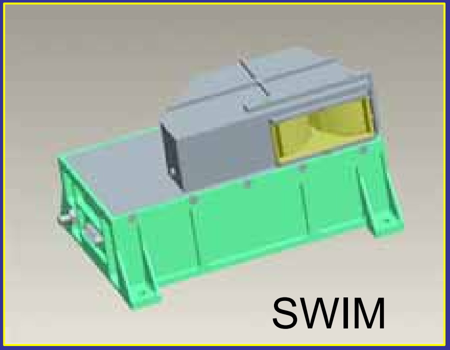


SARA: Sub-KeV Atom Reflecting Analyzer

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*

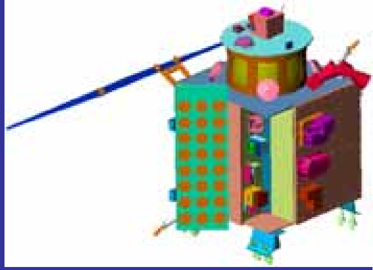




Anticipated Highlights:

- Surface composition of permanently shadowed areas and complement data from other payloads on surface composition
- Surface magnetic anomalies: magnitudes and plausible causes

Chandrayaan-1 Mission (AO Payloads)



RADOM: Radiation characterization

Bulgarian Academy of Sciences

Basic Science Objective : *Characterization of lunar radiation environment and efficacy of shielding effects by lunar materials*

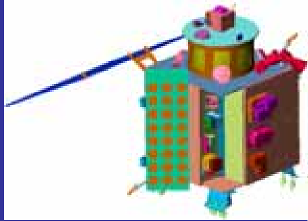
Anticipated Highlights:

Particle flux, deposited energy spectrum, accumulated absorbed dose rates in Lunar orbit

Estimate dose around Moon at different altitudes and latitudes

Evaluate the shielding characteristics (if any) of the near-Moon environment towards galactic and solar cosmic radiation and solar particle events

Chandrayaan-1 Mission (AO Payloads)



Mini-SAR: A Miniature Synthetic Aperture Radar

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

Basic Science Objective: Map terrain of lunar poles and determine surface scattering properties of deposits to search for ice in the permanently shadowed regions of the poles

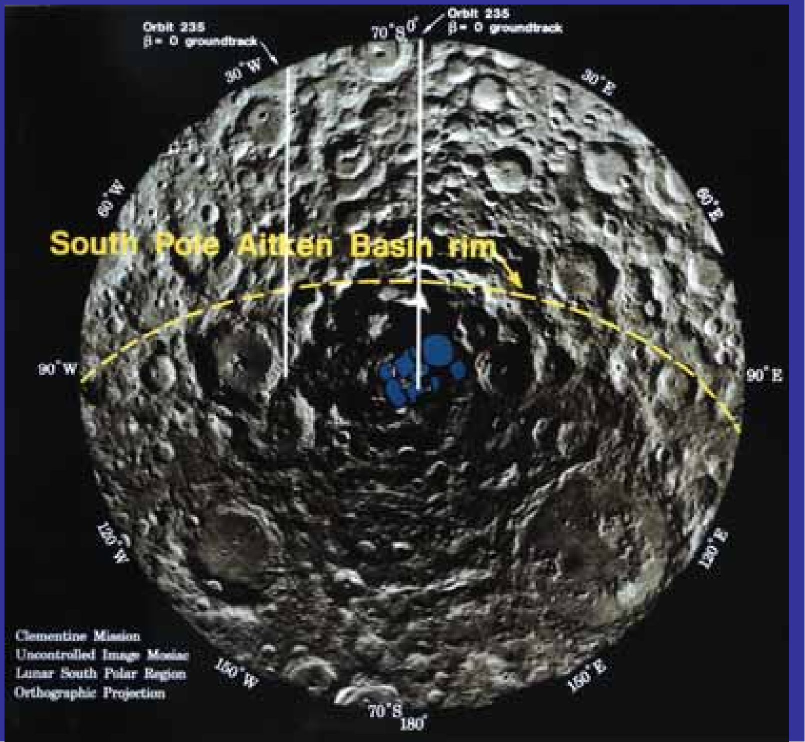
Uses unique hybrid architecture to reconstruct Stokes matrix scattering parameters

Clementine Mission

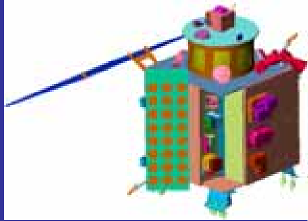
Radar reflections mimicking volume-scattering behavior of ICE

Prospector Mission

Neutron Spectrometer suggests presence of excess hydrogen (water?) in polar regions



Chandrayaan-1 Mission



Salient features of Chandrayaan-1 Mission

High resolution Global Chemical Mapping

Elemental mapping of the moon (Mg, Al, Si, Ca, Ti and Fe) using both X-ray Fluorescence and UV-VIS-IR spectroscopy;

First set of detail data for Fe (from XRF) and mineralogy (IR region)

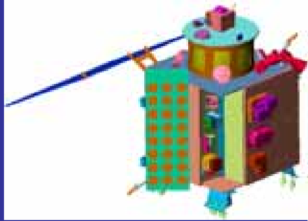
Timing of the mission: Mid-level to high level of solar flare activity

Prospector data for Fe from gamma-ray observation suffers from low spatial resolution (150 km) and Al interference

The Mg* [Mg/(Mg+Fe)] is one of the MOST IMPORTANT diagnostic parameters to understand lunar bulk composition

LEX, HySI, SIR-2, MMM (also SARA; shaded area)

Chandrayaan-1 Mission



Salient features of Chandrayaan-1 Mission

High resolution global topographic map of the Moon

3D mapping with spatial resolution of 5 meter : TMC and LLRI - Study of small (10-100 m) features [e.g., crater distributions on Moon]

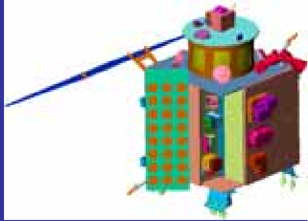
First attempt to detect emission of low energy (<300keV) gamma-rays from a planetary surface (HEX) & detailed study of the permanently shadowed polar regions

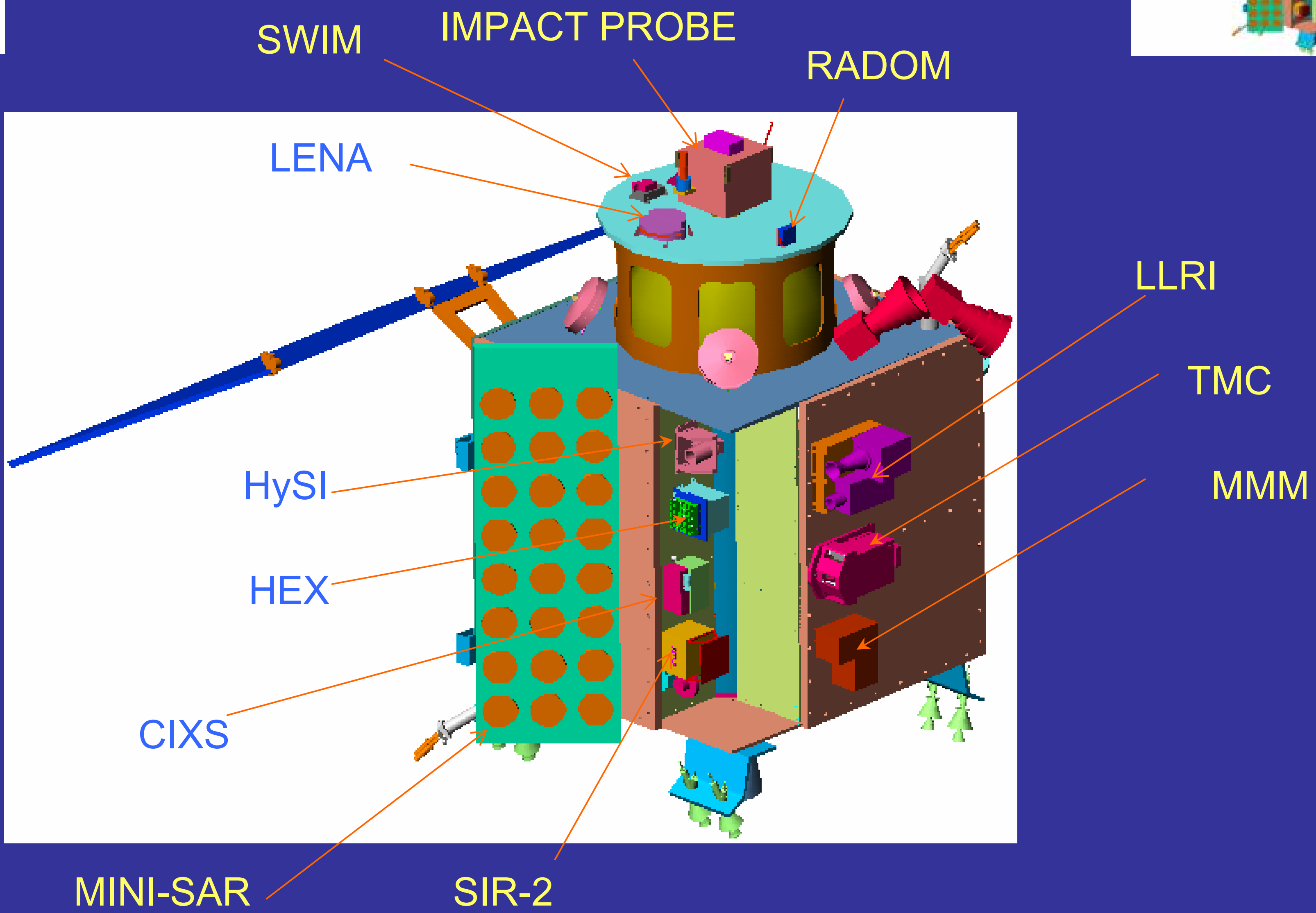
Volatile Transport on Moon:
Enhanced Pb-210 emission in such region (HEX)

Water on Moon in shadowed polar regions via volatile transport:
Detection, mapping, and study using mini-SAR

Magnetic anomaly and composition of shaded area (SARA)

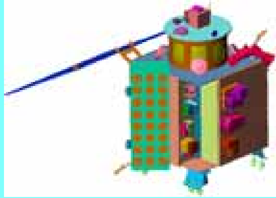
Chandrayaan-1 Mission

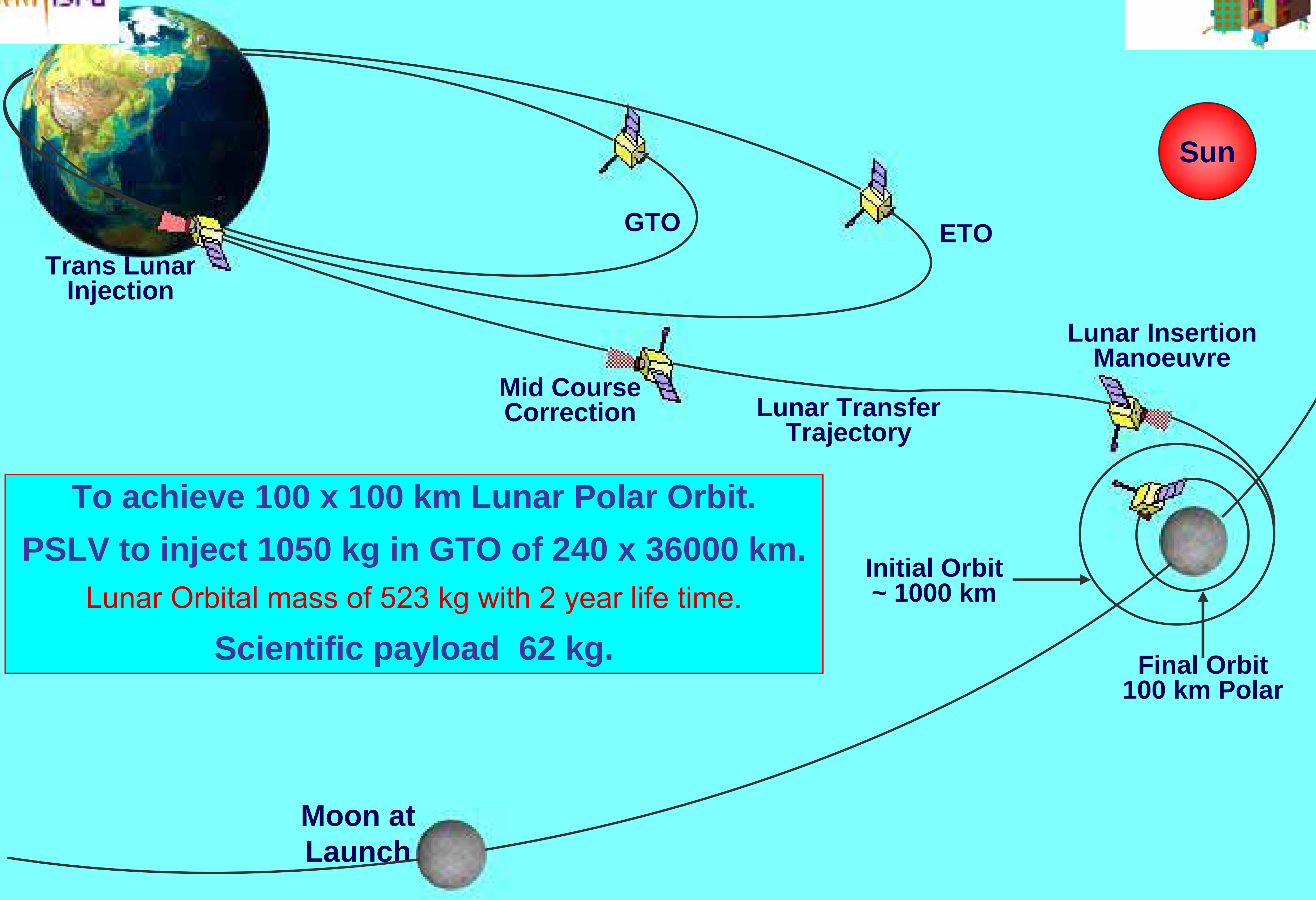




PAY LOAD ACCOMMODATION

Chandrayaan-1 Mission





To achieve 100 x 100 km Lunar Polar Orbit.

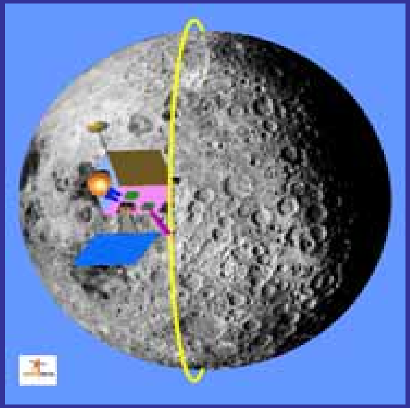
PSLV to inject 1050 kg in GTO of 240 x 36000 km.

Lunar Orbital mass of 523 kg with 2 year life time.

Scientific payload 62 kg.

Launch Of Chandrayaan – I by PSLV

(Target Date: April, 2008)

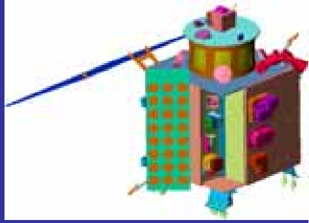


Altitude = 100km;

Inclination = 90^o

Period = 117.6 min.

Track Repeat = 28 days



Chandrayaan-1 Mission

Instrument Calibration: Laboratory Calibration to cover ALL aspects. Additional Calibration during Tran lunar cruise as well as in lunar orbit, if needed

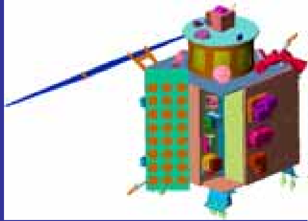
A National Science Data Center will be established to host data from Chandrayaan-1 and other Science Missions (e.g., ASTROSAT-1); Instrument Specific Software Packages for generation of Data Products and Analysis will be available at the Data Center

Spacecraft and Instrument data will be available to PI and Team on real time

Final Data Products and format for archiving have been formulated

Data sharing between various PI groups for enhancing Science return

Chandrayaan 2



- Proposed launch 2010-2011
- Orbital spacecraft and surface rover
- Rover 30-100 kg; semi-hard or soft landing
- Solar powered; may be designed to hibernate during lunar night for a second two weeks of operation
- Instruments TBD, but will conduct compositional analysis of surface materials