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**
- 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 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)
**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
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

<table>
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<tr>
<th>Fore Viewing</th>
<th>Nadir Viewing</th>
<th>Aft Viewing</th>
</tr>
</thead>
</table>

[Diagram showing viewing angles and instrument configuration]
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**

- **Flight Direction**

- **Detection Array Area**

- **Spectral Dimension (\(\lambda\))**

- **Wedge Filter**

- **Objective**

400-900 nm, 32 bands, resolution 80 m
Compact Imaging X-ray Spectrometer (CIXS)

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

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

New generation Swept-charge X-ray Detector

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

[Ca, Ti, Fe : Solar Flare time]
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

**Basic Features**

- **Detector:** Cd-Zn-Te Array
- **Effective Area:** 100 cm²
- **Energy Range:** 20-250 keV
- **Energy Resolution:** ≤6% @ 60 keV
- **FOV:** 40km x 40km
- **Active Anticoincidence Shielding:** CsI(Tl)+PMT
- **Collimator:** Tantalum
- **Weight:** 15 kg
- **Power:** 23 W

**Developed by Physical Research Laboratory & ISRO Satellite Center**
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

\[ ^{226}\text{Ra} \quad 1622\text{y} \]
\[ \alpha \]
\[ ^{222}\text{Rn} (\gamma) \quad 3.8\text{d (gas)} \]
\[ \alpha \]
\[ ^{218}\text{Po} \quad 3.05\text{m} \]
\[ \alpha \]
\[ ^{214}\text{Pb} \quad 23.8\text{m} \]
\[ ^{214}\text{Bi} \quad 19.7\text{m} \]
\[ ^{214}\text{Po} \quad 1.6\times10^{-4}\text{s} \]
\[ \alpha \]
\[ ^{210}\text{Pb} (\gamma) \quad 22.3\text{y \ paint} \]
\[ \alpha \]
\[ ^{210}\text{Bi} \quad 5.01\text{d} \]
\[ ^{210}\text{Po} \quad 138\text{d} \]
\[ \alpha \]

Water on Moon:
Movement of volatile \(^{222}\text{Rn}\) to permanently shadowed polar regions using \(^{210}\text{Pb}\) (46 keV) as tracer
## Payload Configuration & Details

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

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

- **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
## 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

<table>
<thead>
<tr>
<th>Basic Science Objective</th>
<th>Imaging of:</th>
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<tr>
<td></td>
<td>(i) Moon’s surface composition</td>
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<td></td>
<td>(ii) lunar surface magnetic anomalies</td>
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### 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
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
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)
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°
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