

Developments of the Indian Lunar Mission and the Research Works Carried Out on the Moon

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Abstract— This paper gives the developments of the Indian lunar mission and the research works carried out on the moon. Chandrayaan-3, the latest mission in India's lunar exploration program by ISRO, follows the successes of Chandrayaan-1 and Chandrayaan-2. The mission aims to demonstrate safe landing and roving on the lunar surface, focusing on the south pole region. Utilizing advanced technology, including lunar lander and rovers, Chandrayaan-3 seeks to enhance our understanding of the Moon's geological and mineralogical features. Objectives include analyzing lunar soil, mapping surface composition, and studying the Moon's exosphere. This mission represents a significant step forward in India's lunar exploration, contributing to global lunar exploration efforts and bolstering India's position in space exploration. The entire work that is being presented in this paper is the data that was available on the internet, ISRO website, news channels & papers, etc... & is just a review article about the Chandrayan Mission – 3.0.

Index Terms— Chandrayaan-3, lunar south pole, geological, moon's exosphere, lander, rover.

I. INTRODUCTION

Chandrayaan-3 is the third instalment in India's ambitious lunar exploration program, stands as a testament to the nation's commitment to unraveling the mysteries of Earth's celestial companion. Building on the successes and lessons learned from Chandrayaan-1 and Chandrayaan-2, this upcoming mission heralds a new chapter in lunar exploration, focusing on the uncharted territory of the Moon's south pole. With advancements in technology and a refined scientific agenda, Chandrayaan-3 is poised to make significant contributions to our understanding of lunar geology, mineralogy, and the broader cosmic landscape. This mission not only represents a crucial step in India's space exploration journey but also underscores the nation's dedication to pushing the boundaries of scientific discovery on an international scale [1]-[7].

II. LITERATURE SURVEY

Paper: "Chandrayaan-3 and other moon missions: An Update and Review" [1]-[7]

Authors: Som Biswas and Srirupa Biswas

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The paper provides a detailed overview of the Chandrayaan-3 mission and its objectives. It also discusses the scientific instruments on board the lander and rover, which are designed to conduct in-situ experiments on the lunar surface.

Advantages: Demonstrates end-to-end capability in safe landing and roving on the lunar surface and provides valuable insights into the Moon's origins and evolution and also helps scientists to better understand the potential for resources on the Moon.

Applications: Helps scientists to better understand the potential for resources on the Moonhydroxyl and water ice experiments on the lunar surface Conducts novel spectro-polarimetric studies of Earth from lunar orbit

III. BLOCK-DIAGRAM & FLOW-CHART

Diagram of lander and rover is shown in the figure 1. The spacecraft lander is a protective "shell" that houses the rover and protects it, along with the airbags, from the forces of impact. The lander is a strong, lightweight structure, consisting of a base and three sides "petals" in the shape of a tetrahedron (pyramid-shaped). The Lander structure consists of beams and sheets that are made from a "composite" material. Composites such as fiberglass are made of strong fibers or fabrics that are stiffened with glue, or "matrix". The lander beams are made out of carbon-based layers of graphite fiber woven into a fabric, creating a material that is lighter than aluminum and more rigid than steel. Titanium fittings are bonded (glued and fitted) onto the lander beams to allow it to be bolted together. The Rover is held inside the lander with bolts and special nuts that are released after landing with small explosives [1]-[7].

IV. LANDER DESIGN FOR TURNING THE ROVER UPRIGHT

The Mars lander, with three hinged petals connected to a tetrahedral base, employs powerful motors on each petal to ensure the rover can be placed upright regardless of the landing orientation. Weighing about 530 kilograms (1,200 pounds on Earth, 437 pounds on Mars), the rover utilizes accelerometers to detect gravity's pull on Mars. The rover's computer commands the correct petal to open, ensuring a stable position. If outer petals land on rocks, the middle petal acts as a bridge, creating a flat surface. Earth's flight team can then send commands to adjust petals for a safer rover descent onto moon surface, whose data is given in Table 1.

V. ROVER MODULE

The rover has following parts [1]-[7]:

TABLE 1. SPECIFICATIONS OF THE LANDER & ROVER [1]-[7]

Body	A structure that protects the rovers' "Vital organs"
Brains	Computers to process information
Temperature controls	Internal heaters, a layer of insulation and more
Neck and head	A mast for the cameras to give the rovers a human-scale view
Eye	Cameras and instruments that give the rovers information about their environment
Arm	A way to extend its reach
Wheels	Parts for mobility
Energy	Batteries and solar panels
Communications	Antennas for "Speaking" And "Listening"

Chandrayaan-3 comprises an indigenous Lander module (LM), Propulsion module (PM), and a Rover, aiming to develop and demonstrate technologies for interplanetary missions. The Lander, equipped with scientific payloads, will soft land on the lunar surface, deploying the Rover for in-situ chemical analysis. The PM facilitates the LM's journey from launch vehicle injection to lunar orbit, with an additional scientific payload. The chosen launcher is LVM3 M4, placing the module in an Elliptic Parking Orbit. Mission objectives include demonstrating safe lunar landing, rover mobility, and conducting in-situ scientific experiments. The Lander incorporates advanced

technologies such as altimeters, velocimeters, inertial measurement, propulsion systems, navigation, guidance, and hazard detection for mission success [1]-[7].

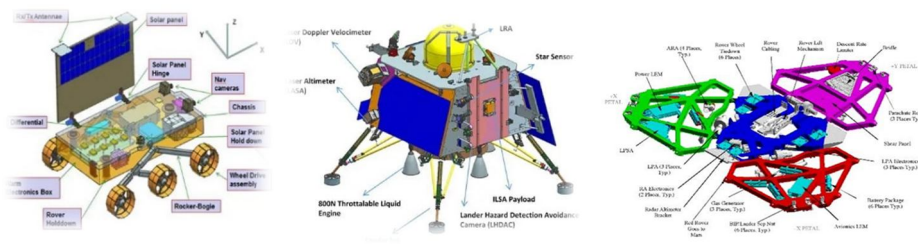


Figure 1. Block diagram of the lander & rover

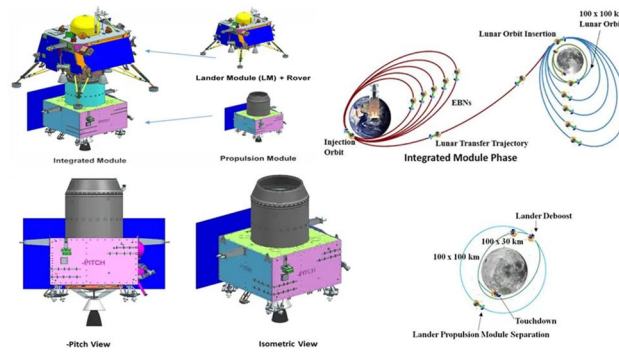


Figure 2. Pictorial representation of the rover / Trajectory profile of the Chandrayaan-3.0 / Trajectory profile of the Chandrayaan-3.0

VI. PROPULSION MODULE

The propulsion module carried the lander and rover configuration till the 100 km lunar orbit. Other than carrying the Lander Module, it also has a scientific payload called Spectro-polarimetry of Habitable Planet Earth (SHAPE). The SHAPE payload will conduct novel spectro-polarimetric studies of Earth from lunar orbit. It will look for smaller planets that could be habitable in the reflected light. Figure 2 gives the pictorial representation of the rover / Trajectory profile of the Chandrayaan-3.0 / Trajectory profile of Chandrayaan-3.0.

VII. LANDER MODULE

The Lander Module of Chandrayaan-3 consists of the Lander (Vikram) and the Rover (Pragyan). The Lander executed a soft landing using the Automatic Landing Sequence (ALS), employing thrusters to control speed, direction, and landing site positioning. Following the historic touchdown, the Rover descended to the lunar surface to conduct in-situ chemical analysis during its mission lifespan. The mission's total duration, covering both the Lander and Rover, spans one lunar day, equivalent to 14 Earth days. Both components are equipped with scientific payloads, enabling experiments and studies on the lunar surface to advance our understanding of the Moon's composition and characteristics [1]-[7].

VIII. METHODOLOGY & THE DESIGN PROCESS

Chandrayaan-3 consists of Lander and Rover configuration. It was launched by LVM3 from SDSC SHAR, Sriharikota. The propulsion module carried the lander and rover configuration till 100 km lunar orbit. The propulsion module has Spectro-polarimetry of Habitable Planet Earth (SHAPE) payload to study the spectral and Polari metric measurements of Earth from the lunar orbit [1]-[7].

IX. ROBOT SPECIFICATIONS, SENSOR USED & AI CONCEPTS

Chandrayaan-3 is a follow-on mission to Chandrayaan-2 to demonstrate end-to-end capability in safe landing and roving on the lunar surface. It consists of Lander and Rover configuration. It will be launched by LVM3 from SDSC SHAR, Sriharikota. The propulsion module will carry the lander and rover configuration till 100 km lunar

orbit. The propulsion module has Spectro-polarimetry of Habitable Planet Earth (SHAPE) payload to study the spectral and Polarimetric measurements of Earth from the lunar orbit [1]-[7].

Lander payloads: Chandra's Surface Thermophysical Experiment (ChaSTE) to measure the thermal conductivity and temperature; Instrument for Lunar Seismic Activity (ILSA) for measuring the seismicity around the landing site; Langmuir Probe (LP) to estimate the plasma density and its variations. A passive Laser Retroreflector Array from NASA is accommodated for lunar laser ranging studies [1]-[7].

Rover payloads: Alpha Particle X-ray Spectrometer (APXS) and Laser Induced Breakdown Spectroscopy (LIBS) for deriving the elemental composition in the vicinity of landing site. Chandrayaan-3, consisting of a Propulsion module, Lander, and Rover, utilizes advanced sensors to enhance lunar exploration. The propulsion module facilitates transport to a 100 km lunar orbit and carries the Spectro-polarimetry of Habitable Planet Earth (SHAPE) payload for studying Earth remotely [1]-[7].

The Vikram Lander is equipped with various sensors:

1. Laser Inertial Referencing and Accelerometer Package (LIRAP)
2. Lander Position Detection Camera (LPDC)
3. Lander Hazard Detection and Avoidance Camera (LHDAC)
4. Laser Altimeter (LASA)
5. Laser Doppler Velocimeter (LDV)
6. Lander Horizontal Velocity Camera (LHVC)
7. Micro star sensor

These sensors play critical roles in navigation, hazard detection, and data collection, enabling precise soft landings, rover deployment, and in-situ chemical analysis on the lunar surface. The integration of sophisticated sensor technologies enhances Chandrayaan-3's ability to explore and gather valuable data during its mission.

X. WORKING PHASES & ORDER OF MISSIONS [7]

The Chandrayaan -3 mission comprised three primary phases.

Earth Centric Phase, Phase 01

Lunar Transfer Phase, Phase 02

Centric Phase of the Moon, Phase 03

XI. PHASES OF EARTH CENTRICITY [1]-[7]

- This stage includes the time spent testing the vehicle and launching the spacecraft.
- Pre-launch Stage: It consists of test launches, testing cycles, and launch preparation.
- Phase of Launch and Ascent: Launched from the Satish Dhawan Space Centre Second Launch Pad in Sriharikota, Andhra Pradesh, India, the Chandrayaan-3 spacecraft reached an Earth parking orbit with a perigee of 170 km and an apogee of 36500 km on July 14, 2023, at 09:05 UTC. The LVM3-M4 rocket carried the rocket during launch.
- Phase of Earthbound Manoeuvre: It consisted of five movements with varying apogees and perigees that were Earthbound.
 - 1) The Earthbound Manoeuvre I: July 15, 2023
 - 2) The Earthbound Manoeuvre II: July 17, 2023
 - 3) The Earthbound Manoeuvre III: July 18, 2023
 - 4) The Earthbound Manoeuvre IV: July 20, 2023
 - 5) The Earthbound Manoeuvre V: July 25, 2023

A. Lunar transfer phase [1]-[7]

On July 31, 2023, a sequence of Earthbound manoeuvres was carried out to place the Chandrayaan 3 in a trans-lunar injection orbit.

B. Centric phase of moon [1]-[7]

- Phase 3 of the Lunar Orbit Insertion Phase (LOI):
- On August 5, ISRO carried out a Lunar insertion [LOI], effectively putting the Chandrayaan-3 spacecraft into an orbit around the moon. From the ISRO Telemetry, Tracking, and Command Network in Bengaluru, the LOI operation was conducted.
- Phase 4 is the Moon-bound Manoeuvre

- Phase-5 is PM and Lunar Module Separation
- Phase 6 involves De-boost Phase
- Phase 7 comprises of Pre-landing Phase
- Phase 8 is the Landing Phase:
- On August 23, at 6:04 p.m., India's Moon mission Chandrayaan-3 made history by landing successfully on the moon. India becomes the first nation to have ever accomplished a "soft landing" on the Moon's south pole after the Lander successfully completes the mission. Then, from the Lander, sprang a rover.

XIII. MOST IMPORTANT STAGE – SOFT LANDING [8]

The soft landing of the lander, a highly important mission phase, was one of the primary goals of Chandrayan-3. To land softly is to do it at a regulated, gentle speed so as to avoid damaging a spacecraft. On August 23, as the Chandrayaan-3 Lander entered the last 15 minutes of its mission to make a soft landing on the Moon, it executed a crucial technical manoeuvre: it changed from a high-speed horizontal to a vertical position to enable a gentle descent to the surface [1]-[7].

XII. HOW ARE COLLECTED DATA TRANSMITTED ?

Chandrayaan-3 employs remote sensing techniques to study the Moon, using instruments on the spacecraft that capture signals reflected or emitted by the lunar surface. Instruments like the Laser Induced Breakdown Spectroscope (LIBS) and Alpha Particular X-ray Spectrum (APXS) analyze lunar rocks and soil composition without physical contact. For communication, Chandrayaan-3 features a two-way communication system with radio wave transmitters and receivers. As the rovers and landers explore the Moon, they collect data, which is transmitted via radio waves to Earth's large antennas at ground stations. Scientists analyze this data to understand lunar features and mission status. In turn, scientists on Earth use the same communication system to send commands to the spacecraft, encoded in radio signals, directing operations such as rover movement or instrument activation. Key discoveries and surface operations on the Moon are facilitated by this communication system, allowing scientists to remotely guide the spacecraft and interpret data, enhancing our understanding of lunar features and geology. The sensors & the robot on moon is shown in Fig. 4 [9].



Figure 4. Chandrayan Mission Photos on Moon

XII. DISCOVERIES ON THE LUNAR SURFACE [1]-[7]

1. Presence of Sulphur [10]

- Pragyan rover confirmed the presence of sulphur on the lunar surface.
- Laser-Induced Breakdown Spectroscopy identified elements, including sulphur, through plasma analysis produced by powerful laser pulses.

2. Lunar Surface Temperature Measured [12]:

- The Thermophysical Experiment (ChaSTE) payload on Vikram lander measured lunar topsoil temperature.
- Temperature profile showed a decrease of approximately 140 degrees Fahrenheit at a depth of 3 inches.

3. 4-Meter-Diameter Crater Discovery [13]:

- Chandrayaan-3 Rover encountered a 4-meter-diameter crater on August 27.
- The Rover adjusted its route for safety after ISRO commanded it to retrace.

4. Additional Elements Discovered [14]:

- Pragyan identified aluminium, calcium, iron, chromium, titanium, manganese, silicon, and oxygen.
- ISRO is exploring the presence of hydrogen, crucial for potential water mining on the Moon.

5. Possible Seismic Event [15]:

- Vikram lander's Instrument for Lunar Seismic Activity (ILSA) detected a seismic event.
- The event suggested a potential moonquake.

6. First Measurement of Moon's Ionosphere [16]:

- Langmuir probe on Vikram lander measured temperature and density of the moon's ionosphere for the first time.
- Significant data for understanding lunar atmospheric conditions.

7. Rover's Conclusion and Sleep Mode:

- Pragyan rover completed its tasks by September 3 and entered sleep mode.
- Data collected transmitted to Earth.
- Lander and rover designed for a lunar daylight period, not equipped for prolonged nighttime temperatures.

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