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CHANDRAYAAN

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Abstract: This article gives a brief of India's Moon Missions launched so far in terms of its Objectives, Payloads and the mission operation details. The summary of the outcome of each mission is also discussed.

I. INTRODUCTION

The exploration of space began as early as 1957 with USSR launching Sputnik satellite. This was followed by rapid development of technology which enabled realisation of launchers to not only launch advanced satellites for telecommunications, remote sensing but also for deep space missions. Many experimental missions finally led to the development of International Space Station.

The USA took to manned Missions to Moon during 1965-72 periods with the launch of Apollo Missions (Apollo 11 landed the first Man on Moon in 1969).Some of the Missions brought rock samples to earth for scientific study of the moon.

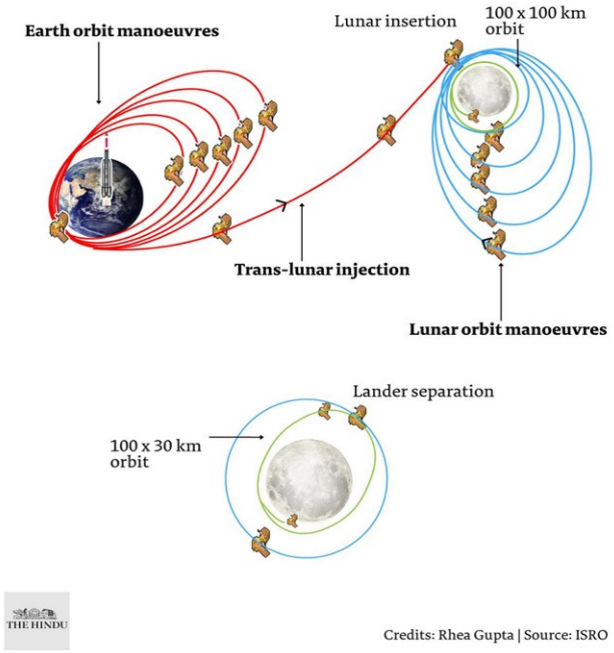
II. CHANDRAYAAN MISSION

The Chandrayaan Mission is the Indian attempt of Lunar exploration to understand the challenges of Lunar mission, encompassing the build of the craft, design of the mission and its operations, landing on the moon and survival in its environment.

The first Chandrayaan Mission placed a Spacecraft around the lunar polar orbit of 100 by 100 Km. It carried several payloads to send useful pictures to earth for analysis by scientific community. This Mission also had a MOON IMPACT PROBE (MIP) which was released from the Orbiter on ground command. The MIP was to study for the later aim of soft landing on the Moon. The major discovery from this mission was the establishment of the presence of water on the moon.

The Weather on moon is completely different from that of earth. The lunar climate is dominated by temperature swings of hundreds of degrees, rocks of all sizes and particles from the sun and beyond. Lunar soil is very dusty and create a dust storm by the use of rocket thruster flumes. The gravity on moon is also less than that on Earth. Hence the Lunar lander and its subsystems have to be designed and tested for these environmental conditions.

The Mission is challenging both in launch phase as well as after the attainment of the proposed lunar orbit as the earth bound orbit is successively raised to around 4 lakh km. The spacecraft has to leave the earth gravity and be inserted into lunar gravitational field with several manoeuvres and finally place the satellite or the orbiter in the required lunar polar orbit. **Refer to the picture below. Fig 1**



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Advanced Moon Missions carry modules called Lander and Rover to land on the moon for detailed exploration.

III. A BRIEF SUMMARY OF CHANDRAYAAN MISSIONS

3.1.1 Chandrayaan – 1

Chandrayaan-1 was India's first spacecraft launched to explore the Moon using India's PSLV. This Spacecraft which weighed 1380 kg, with a power generation capability of 700 W, lifted off from Indian Spaceport at Sriharikota on 22nd October 2008. As stated this Mission was to probe the Moon from a distance of 100 Kms with its Payloads. The mission designed to last for two years ended in less than a year but it mapped about 95% of the moon's surface. On 29 August 2009 radio signals from Chandrayaan-1 were lost. **Chandrayaan unambiguously proved the presence of water on moon.** That is considered as a major achievement of this Mission.

The other major Mission Objectives realised were –

(1) Design, develop, launch and orbit a spacecraft around the Moon using an Indian-made rocket,

(2) Conduct scientific experiments using instruments on the spacecraft,

(3) Chemical and Mineralogical mapping of the entire lunar surface at high spatial resolution, particularly the elements Magnesium, Aluminium, Silicon, Calcium, Iron, Titanium, Radon, Uranium, and Thorium,

(4) Enhance the scientific knowledge, (5) Test the impact of a probe (Moon Impact Probe – MIP) on the surface of the Moon to help prepare for future soft-landing missions

3.1.2 Chandrayaan-2

On July 22, 2019, India successfully launched Chandrayaan-2, the second mission to the moon. This Mission had an ambitious plan of landing on the Moon surface. Twenty-two days later on August 14, after a series of orbit raising manoeuvres, the spacecraft finally escaped the earth's gravity and followed a path towards the moon. Six days later, Chandrayaan-2 was successfully inserted into lunar orbit. Finally, on September 2, the Vikram lander separated from the Orbiter, performed two de-orbit manoeuvres. On September 6th , the descent to the moon's surface began. The descent went as planned up to an altitude of about 2 km from the Moon's surface before communication from the lander to the ground stations was lost. The VIKRAM lander had apparently crash-landed on the Moon. The initial descent was considered to be within the mission parameters, but the lander's trajectory appears to have deviated at about 2 km above the Lunar surface. The telemetry readings indicated that the final vertical velocity was most probably higher than expected. Later it was confirmed to be "it must have been a hard landing". Analysis of the Doppler data suggests that the loss of signal coincided with the lander impacting the lunar surface at a velocity of nearly 50 m/s (180 km/h), as opposed to an ideal 2 m/s (7.2 km/h) touchdown velocity. In 16 November 2019, the Failure Analysis Committee released its report to the Space Commission, concluding that the crash was caused by a software glitch.

Chandrayaan#2 had the orbiter part of the mission orbiting around the Moon. It had eight scientific instruments, They remain operational, and will continue its mission to study the Moon.

3.1.3 Chandrayaan-3 (14 July 2023 -)

Chandrayaan-3 is a follow-on mission to Chandrayaan-2 to demonstrate end-to-end capability in soft & safe landing and roving on the lunar surface. It consists of Propulsion, Lander and Rover configuration.

It was launched by India's own GSLV Mk III M4 Rocket from Sriharikota on July 14, 2023.

3.1.3.1 Modules of Chandrayaan -3

Propulsion module carry the lander and rover configuration till 100km lunar orbit. The propulsion

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module has Spectro-polarimetry of Habitable Planet Earth (SHAPE) payload to study the spectral and polarimetric measurements of Earth from the lunar orbit.

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 Retro reflector Array from NASA is accommodated for lunar laser ranging studies.

Rover payloads: Alpha Particle X-ray Spectrometer (APXS) and Laser Induced Breakdown Spectroscope (LIBS) for deriving the elemental composition in the vicinity of landing site.

Fig 2: The Image below provides the composite of the Propulsion Module, the Lander.

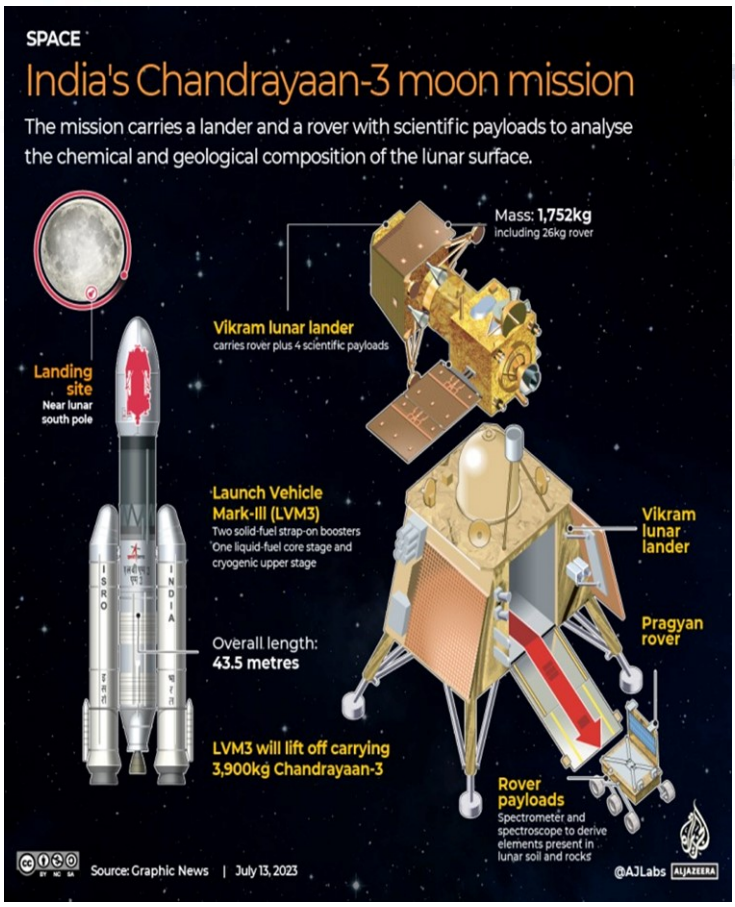

Fig 3: The Image below gives an idea of the Rover on the Lunar surface

3.1.3.2 Why Propulsion Module instead of Orbiter.

Orbiter of Chandrayaan-2 is still functional, therefore replication of the previous sensor suite is not required. Main function of this module is to carry the lander from launch vehicle injection till the final lunar orbit. It will also function as the communications relay while utilizing the Chandrayaan-2 orbiter as a backup.

3.1.3.3 Major Modifications in Chandrayaan#3 Mission

Reinforced Legs in the Lander Module

Reinforcement corresponds to increased tolerance in landing velocity from 2m/s to 3m/s. Lander will be

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able to meet objectives even if landing conditions are not optimal. In case of a crash, the legs will not suffer much damage.

Increased Fuel Capacity on the Lander
Fuel margin on the lander can handle unplanned disruptions in the mission profile. Chandrayaan-3 lander is approximately 250+ kg heavier

Laser Doppler Velocimeter (LDV)
This new instrument will provide crucial information about the lunar terrain
The LDV will measure the velocity and distance of the lander from the lunar surface during descent. This information is critical for a successful soft landing.

Increased Solar Panel Area on Lander
Larger surface area occupied by solar panels on all sides. Adequate power generation ensured even in case of landing orientation not directly facing the sun. Increased battery capacity as well to mitigate weaker solar power generation.

Lander Hazard Detection and Avoidance Cameras
Two LHDAC on Chandrayaan-3 as compared to one on Chandrayaan-2.
Two additional small cameras on the rear side.
Increased Field of View for hazard detection and avoidance.
Central Engine Removed
Four engines instead-of five for better operational efficiency.
Multiple simulations and tests were carried-out to understand the dust blowback issue.
Two engines are used simultaneously to assist in landing as mass is higher compared to Chandrayaan-2

Additional TTC Antennas are provided to take care of additional margins.

Software Upgrade and Robustness
Software can now handle multiple failure scenarios such as engine disruptions, thrust disruptions, and sensor failures.

Improvement over earlier software which could have played a part in the Chandrayaan-2 landing sequence issue.

Increased Simulations and Testing. Major focus on rigorous testing which is much more than that done for the previous mission. Tests include autonomous flights, helicopter flights, crane-mode landing simulations, etc.

On 17 August, the lander module separated from the propulsion module and soon after began its descent to the surface. On 23 August, ISRO confirmed that Chandrayaan-3's lander had successfully touched down in the Moon's southern polar region as planned. India's moon lander is the first to study the lunar South Pole region up close.

3.1.3.4 The Five scientific discoveries.

1. Presence of sulphur
The rover fired intense laser pulses at the lunar surface with its Laser-Induced Breakdown Spectroscopy instrument. The laser then generated a hot, bright plasma. Scientists then study the light from that plasma to identify the various elements in the sample, like sulfur.

2. Other elements found on the surface
It's not just sulfur — in preliminary analyses, Pragyan has also detected the presence of aluminum, calcium, iron, chromium, and titanium. And ISRO said that it's also hunting for the presence of hydrogen.

3. A potential moonquake
Three days after landing on the moon, the Instrument for Lunar Seismic Activity (ILSA) payload on the Vikram lander detected the rumblings could be evidence of moonquake.

4. Temperature changes underground
Vikram has also measured the soil temperature near the lunar South Pole both on the surface and

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underground, for the first time. The probe measured 3 inches into the soil, and found it was about 140 degrees F colder than at the surface.

5. First measurement of the moon's ionosphere

Another device on the Vikram lander called the Langmuir probe, which helps characterize plasma, has been able to measure the density and temperature of the moon's ionosphere

A week after ISRO's historic Moon Mission, Chandrayaan 3 has already made some significant progress in its work and has confirmed the presence of sulphur, aluminium, calcium, iron, chromium, titanium, manganese, oxygen and silicon on the lunar surface near the south pole. ISRO has released a chart showing the presence of these elements at various ranges corresponding to the wavelength. List of elements Chandrayaan 3 found on the moon: Aluminum (Al), sulphur (S), calcium (Ca), iron (Fe), chromium (Cr), titanium (Ti), manganese (Mn), silicon (Si), and oxygen (O). The findings are significant because if Chandrayaan 3 finds the hydrogen that it is searching for, then it will be a step further in the search for water on the moon for the first time.

IV. CONCLUSIONS AND FUTURE PLANS

In conclusion India's Moon Mission series have successfully completed its mission objectives but for Chandrayaan 2 missed the last leg of Soft landing on the Moon South Pole.

Chandrayaan 1 has proved the scientific community about presence of water unamibiqusely along with the complete mapping of Moon's surface due to the chosen Polar Orbit first time.

Chandrayaan 2 Orbiter module is successfully orbiting Moon in a near circular orbit of 100 km and providing valuable data to Scientific Community.

Landing on the South Pole of Moon was missed and lost the telecommunication in the last few minutes.

Chandrayaan 3 has completed its objectives of Soft Landing on the South Pole of Moon for the first time successfully along with the prediction of temperature variations on the surface and possible minerals present.

Chandrayaan series is going to continue in further exploring the Moon by way of bringing back samples from Moon. This involves newer challenges to be accomplished.

Swanirman Sunirmit
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