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Journey of Chandrayaan Missions

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Abstract: ***The upcoming lunar probe mission of India is Chandrayaan 3 and its launching to the moon will be a very big study for every citizen of the world. Chandrayaan 2 was known as a highly complex mission, as it consists of three vehicles Lander, rover and orbiter. Lander and rover aims of exploring South Pole of the moon. The term Chandra means moon, yaan means ship that means it signifies a moon craft which explore various diversities on moon surface 95% mission was completed but due to few challenges rover did not explore the surface due to technical issue. Chandrayaan 3 mission is announced to launch in 2021 by ISRO. Chandrayaan-3's configuration will be similar to that of its predecessor, the Chandrayaan-2. This means that the Chandrayaan-3 will also have a Lander and a rover with a propulsion module.***

Keywords: Chandrayaan mission, Lander, rover, orbiter

1. Introduction

The idea of exploring lunar surface was come to existence when an American scientist Neil Armstrong successfully completed the first mission named Apollo 11 on moon in 1969. There are various theories about how the Moon was created, but recent evidence indicates that it was formed when a huge collision tore a chunk of the Earth away. Astronomers believe that the moon was formed about 4.6 billion years ago when the earth was hit by another body larger than the present Moon. A lunar program initiative at ISRO was started by K. Kasturirangan, Chairman of ISRO in 1999. The Chandrayaan mission was announced by the Prime Minister of India, Mr. Atal Bihari Vajpayee, on August 15, 2003 (Independence Day) as a goal of India's Space Program. Finally the journey of lunar probe missions started by ISRO in 2008 when first mission was launched Chandrayaan 1. Chandrayaan-1 was the first Indian Lunar probe under Chandrayaan programme. It was launched by the Indian Space Research organization in October 2008 and operated until August 2009 from Satish Dhawan space centre, Sriharikota. The Chandrayaan-1 mission represents also an important step forward in U. S.-India space ties. On May 9, 2006, a MOU was signed between ISRO and NASA in Bangalore, India, to include two NASA instruments (Mini-SAR and M^3) on the Chandrayaan-1 spacecraft. Chandrayaan-2 was India's second mission to the moon, and was a follow-up mission from the Chandrayaan 1 mission. It was launched for confirming the presence of water/hydroxyl on the moon in 2009. Chandrayaan-2 launched from the Satish Dhawan Space Center in Sriharikota, India. Chandrayaan 2 consists of 3 main vehicles rover, orbiter and Lander. The functionality of orbiter was done successfully but rover and Lander were not able to perform their operations successfully. Launch system is the vehicle which put the spacecraft in orbit around the earth or on an escape trajectory to a planet [1]. To complete the journey of Chandrayaan 2, new lunar mission on Chandrayaan named as Chandrayaan 3 is now introduced by ISRO. Chandrayaan 3 will be a repeat mission of Chandrayaan 2 and will only include Lander and rover but will not have orbiter. Chandrayaan mission type is Lunar Lander and rover which is going to launch in 2021. From these missions it was set Moon based on astronomical, physical, chemical, isotopic, geological and geochronological data. It is important to understand some of the important questions from moon surface for further exploration [1]. Payload is the set of instruments that perform the mission. The functions of tracking and data systems are i) receive the downlink and relay it to mission operations and ii) uplink commands to the spacecraft.

2. Objectives of the Lunar Mission

Main objectives of Lunar mission is to explore the untouched surface of moon and to provide high resolution mineralogical and chemical imaging of the global surface of the moon, with stereographic coverage of the most of the moon's surface with 5m resolution. CHANDRAYAAN-1 is a remote sensing satellite for high resolution photogeological, chemical and mineralogical mapping of the Moon [1]. It provides new penetration in understanding the moon's origin and evolution. Chandrayaan 1 also plays an important role in the discovery of water molecules on the moon. Chandrayaan 1 was India's first deep space mission. Among its suite of instruments, it carried NASA's Moon mineralogy, Mapper, and imaging spectrometer helped confirm the discovery of water locked in minerals on the moon. The orbiter also released an impactor that was deliberately crashed into the Moon, releasing debris that was analyzed by the orbiting spacecraft's. To test the impact of a sub-satellite on the lunar surface for its future soft-landing missions.

3. Instrumentation and its running up

Chandrayaan-1 was equipped with many instruments listed or named as impact probe, which housed three additional instruments. The results obtained by four instruments viz. Chandra's Altitudinal Composition Explorer, Moon Mineral Mapper (M^3), SWIM (Solar Wind Monitor) and Mini-SAR (Miniature Synthetic Aperture Radar) gave an insight into an active hydrosphere, with several complex processes operating between lunar surface and its environment. These inferences are based on identification of H, OH, H_2O, CO_2, Ar etc. in the lunar atmosphere. The weight of spacecraft is 1380 kilograms. The Launch vehicle was PSLV XL C11. Among its suite of instruments, it also carries NASA's Moon mineralogy Mapper, and imaging spectrometer helped confirm the discovery of water locked in minerals on the

moon. To focus on some key issues in lunar science which can be addressed by chemical, mineralogical and topographic mapping [1]. The orbiter also released an impactor that was deliberately crashed into the Moon, releasing debris that was analyzed by the orbiting spacecraft's. The Scientific instruments used are Terrain Mapping Camera (TMC), Hyper Spectral Imager (HySI), Lunar Laser Ranging Instrument (LLRI), High Energy X-ray Spectrometer (HEX), Chandrayaan-1 X-ray Spectrometer (CIXS), Near Infrared Spectrometer (SIR-2), Sub Kev Atom Reflecting Analyzer (SARA), Miniature Synthetic Aperture Radar (Mini SAR), NASA's Moon Mineralogy Mapper (M3), Radiation Dose Monitor (RADOM) and Moon Impact Probe (MIP**)** are Radar Altimeter, Video Imaging System, Chandra's Altitudinal Composition Explorer (Mass Spectrometer) (CHASE) [3]. Due to high temperature, Chandrayaan-1 one scientific instrument got fail at one time. There was a star sensor failure in Chandrayaan-1 after nine months of operation in lunar orbit. Again a backup sensor also failed after sometime, which results inoperable the spacecraft's primary attitude control system. Instead, controllers used a mechanical gyroscope system to maintain proper attitude. Last contact with Chandrayaan-1 was at 20: 00 UT Aug.28, 2009. This was short of the spacecraft's planned two-year lifetime, although ISRO noted that at least 95% of its mission objectives had been accomplished by then. To identify craters having plenty of water-ice deposits, different approaches have been applied. The Mini-SAR instrument acquired more than 300 image strips of the Moon, covering more than 90% of both Polar Regions [5].

Result obtain from Chandrayaan 1

The results obtained by the mission established (i) A tenuous but active hydrosphere (ii) Volcanically active and geologically dynamic Moon and (iii) Global melting of Moon's surface regions and formation of Magma Ocean early in the history of Moon.

End of Chandrayaan1 Mission

Chandrayaan 1 mission came to an end when there was a failure of the power supply due to overheating. Perhaps Chandrayaan-1's most important finding was related to the question of water on the Moon. In September 2009, the American M3 published the result collected by scientists which had detected absorption features on the polar regions of the surface of the Moon usually linked to hydroxyl and/ or water-bearing molecules. This finding was followed in August 2013 by an announcement of evidence of water molecules locked in mineral grains on the surface of the Moon magmatic water, or water that originates from deep in the Moon's interior. Magmatic water had been found in samples returned by Apollo astronauts but not from lunar orbit until the operation of the M3 instrument. Although Cassini, during its flyby of the Moon in August 1999, had detected (using its VIMS instrument) water molecules and hydroxyl. The Lunar probe worked for 312 days on the lunar surface. The estimated cost of this project cost was Rs.386 Crore or US$60 million. Again after the launch of Chandrayaan 1, the launch of Chandrayaan mission 2 has been started.

Figure 1: Chandrayaan Landing Orbiter, Lander and Rover on moon surface

Chandrayaan 2

During the Sept.6 moon landing attempt, ISRO officials as the probe was just 1.3 miles (2.1 kilometers) above the lunar surface. Officials have been unable to reach the Lander since losing contact on Sept.6. Basically, the requirement of the Lander includes communication, Landing area shape, topography and sunlit area. For analyzing the landing site of chandryaan-2 we are using the data of LOLA which is one of the payloads onboard Lunar Reconnaissance Orbiter (LRO). The Lunar Orbiter Laser Altimeter (LOLA) is an instrument designed to assist in the selection of landing sites on the Moon for future robotic and human exploration [3].

ISRO has confirmed that all the instruments on board the orbiter are working well, despite the apparent crash-landing of the Lander. The current orbiter carries eight different instruments and Indian scientists are already poring over some of the mission's very first science data first science data. On Oct.4, ISRO released photos the orbiter's High Resolution Camera took on Sept.5 of a crater called Boguslawsky E, located near the lunar South Pole. Earth is always having history linking with moon. From these records we will understand the origin of moon. Extensive mapping of lunar surface to study variations in lunar surface to study variations in lunar surface were essential to track the record of the origin and evolution of the moon. Water molecules evidence was discovered by Chandrayaan-1. It also required further studies on the extent of water molecule distribution on the surface, below the surface and in the lunar exosphere to address the origin of water on Moon. Further the South Pole exploration is important for lunar surface. The Lunar South pole is especially more interesting because of the lunar surface area that remains in shadow is much larger than that at North Pole. There could be a possibility of presence of water in permanently shadowed areas around it. In addition, South Pole region has craters that are cold traps and contain a fossil record of the early Solar System.

Figure 2: Chandrayaan 2

Chandrayaan 2 has launched three main vehicles for the study of lunar surface named as orbiter, Lander and rover. All three have different purposes and functions.

Objectives of Chandrayaan 2

Lunar Regolith is a layer of loose, heterogeneous material covering solid rock. It includes dust, soil, broken rock, and other related materials [5]. The day time temperatures are fairly straight forward to calculate but night time temperatures are a function how well the heat is transferred into and out of the regolith, and the internal heat generation of moon.

Orbiter: Orbiter is one of the vehicle of Chandrayaan 2 has a weight of 2, 379 kg and electric power generation capability is 1, 000 W Chandrayaan 2 orbiter is capable of communicating with Indian Deep Space Network (IDSN) at Byalalu as well as vikram lander. The Precise launch and mission management has ensured a mission life of almost seven years instead of the planned one year. The mission would carry five instruments on the orbiter. The payloads of the orbit [3]

1. Large Area Soft X-ray Spectrometer (CLASS)
2. L and S band Synthetic Aperture Radar
3. Imaging IR Spectrometer (IIRS)
4. Neutral Mass Spectrometer (ChACE-2)
5. Terrain Mapping Camera-2 (TMC-2)

Figure 3: Orbiter of Chandrayaan 2 mission

Lander: The second vehicle of Chandrayaan 2 was lander has a weight of 1, 471 kg and Electric power generation capability of 650 W. The lander of Chandrayaan 2 was named Vikram after A great scientist Dr. Vikram Sarabhai, the father of Indian Space program. It was designed to function for a lunar day, which is equivalent to a 14 days.

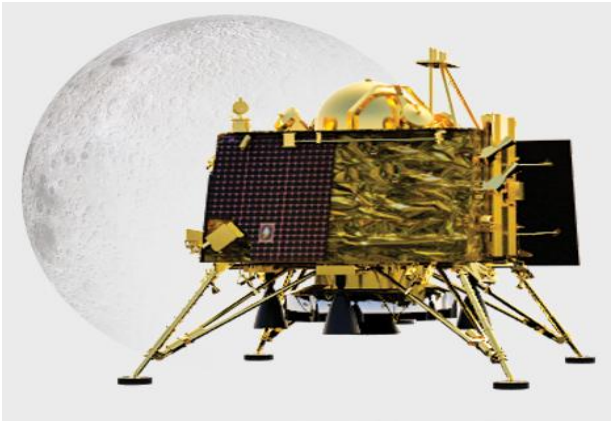

Figure 4: Lander of Chandrayaan 2 Mission

Rover: Rover is the third vehicle carried by Chandrayaan 2 also named as pragyan. Its weight was 27 Kg and electric power generation capability is 50 W. Chandrayaan 2's rover was a six wheeled robotic vehicle named as pragyan which translates wisdom in Sanskrit. The primary objectives of the **Chandrayaan-2** lander were to demonstrate the ability to soft-land on the lunar surface and operate a robotic **rover** on the surface. Scientific goals include orbital studies of lunar topography, mineralogy, elemental abundance, the lunar exosphere, and signatures of hydroxyl and water ice. Rover will carry are as follows

Laser induced Breakdown Spectroscope (LIBS)
Alpha Particle Induced X-ray Spectroscope (APIXS).

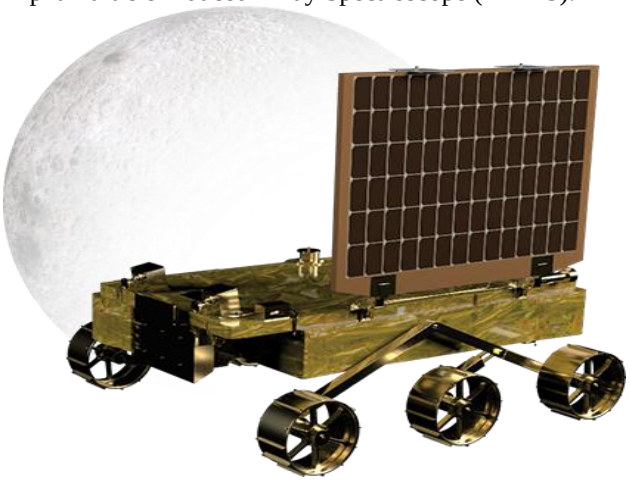

Figure 5: Rover of Chandrayaan 2 Mission

4. Development and Science

Initially The Chandrayaan 2 mission was planned between India and Russia. Both the ISRO and Russian Agency signed an agreement in 2007 to launch the orbiter and lander in 2013. Russia later pulled out of the agreement, however, according to the Russian lander's construction was delayed after the December 2011 failure of Roscosmos' Phobos-Grunt mission to the Martian moon of Phobos, the report stated. Russia cited financial issues and pulled out of Chandrayaan-2 altogether. Later on it was also come into notification that NASA and ESA were interested to join Chandrayaan mission but ISRO carried it by its own. The goal of the Chandrayaan-2 orbiter was to circle the moon and provide information about its surface, ISRO stated previously. "The payloads will collect scientific information on lunar topography, mineralogy, elemental abundance,

lunar exosphere and signatures of hydroxyl and water-ice, " The mission was also supposed to send a small, 20-kilogram (44 lbs.), six-wheeled rover to the surface that could move semi-autonomously, examining the lunar regolith's composition.

Instruments used to carried out the Mission were

The lander's instruments are

- Instrument for Lunar Seismic Activity (ILSA), to look for moonquakes.
- Chandra's Surface Thermophysical Experiment (ChaSTE), to examine the surface's thermal properties.
- Radio Anatomy of Moon Bound Hypersensitive ionosphere and Atmosphere (RAMBHA-Langmuir Probe), to look at plasma density on the surface.

The rover also carried two science instruments designed to look at the composition of the moon's surface that are the Laser-Induced Breakdown Spectroscope (LIBS) and the Alpha Particle X-Ray Spectrometer (APXS).

Objectives of Chandrayaan 2

(1) Terrain Mapping Camera 2 (TMC-2), which will map the lunar surface in three dimensions using two on-board cameras. A predecessor instrument called TMC flew on Chandrayaan-1.
(2) Collimated Large Array Soft X-ray Spectrometer (CLASS), which will map the abundance of minerals on the surface. A predecessor instrument called CIXS (sometimes written as C1XS) flew on Chandrayaan-1.
(3) Solar X-ray Monitor (XSM), which looks at emissions of solar X-rays.
(4) Chandra's Atmospheric Composition Explorer (ChACE-2), which is a neutral mass spectrometer. A predecessor instrument called CHACE flew on Chandrayaan-1's Moon Impact Probe.
(5) Synthetic Aperture Radar (SAR), which will map the surface in radio waves. Some of its design is based on Chandrayaan-1's MiniSAR.
(6) Imaging Infra-Red Spectrometer (IIRS), which will measure the abundance of water/hydroxyl on the surface.
(7) Orbiter High Resolution Camera (OHRC) to examine the surface, particularly the landing site of the Lander and rover. [3]

Landing near the pole

Chandrayaan-2's Lander and rover were about to land on locations near about 600 km (375 miles) from the South Pole. First time in the history any mission touched down so far from the equator. ISRO planned to use the experience for more challenging missions in the future, such as touching down on an asteroid or Mars, or sending a spacecraft to Venus. The Lander was expected to last about one lunar day, or 14 Earth-days, and it was unclear if it would revive after falling into the darkness of a lunar night and ISRO will have to wait until another mission to find out.

On Sept.6, 2019 K. Sivan, the director of ISRO, confirmed that communication had been lost with the Chandrayaan-2 Vikram Lander.

"Vikram Lander descent was as planned and normal performance was observed up to an altitude of 2.1 kilometers that is 3.1 miles. “Subsequently the communications from the Lander to the ground station was lost. The data is being analyzed. "

It was not clearly explained when ISRO would be able to provide updates about the fate of the Vikram Lander. According to the data shown during the descent maneuver, the lowest altitude reported back to Earth was 0.2 miles (0.33 km) above the lunar surface.

A plot comparing live data received to the mission's trajectory suggested that Vikram was about 0.6 miles (1 km) horizontally off-track from the targeted landing site when communications stopped.

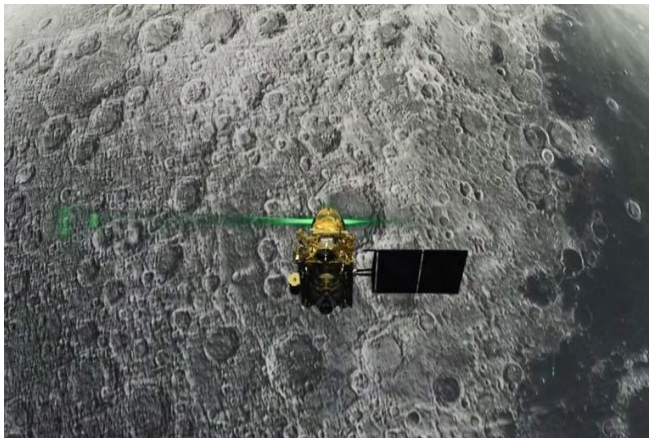

Figure 6: Last minute software glitch leds to failure of Chandrayaan 2 mission

The image above shown is a last-minute software glitch led to the failure of the Chandrayaan 2 mission. The lander named as Vikram used for the Chandrayaan 2 mission, crashed on the moon after ground stations lost communication with it. The contact was lost after the lander descended to 2.1km.

The Indian Space Research Organization (ISRO) designed Chandrayaan 2 to soft-land a probe on the moon, but the Vikram Lander lost control 500m short of the lunar surface and crashed. Efforts are on to locate the Lander that was supposed to analyse the moon's terrain and send back data for 14 days. The glitch was unexpected since the software was functioning well throughout the trial period.

The proper interpretation of hydration feature through spectral analysis is significant as it provides important inputs regarding geology and geophysics of the mantle in terms of their mineralogy, chemical composition, and rheology and solar–wind interaction. This is also significant for future planetary exploration for resource utilization. The thermal stability of these hydration features depends upon how they interact with one another, with the surface and their environment at particular temperature range and therefore provides important clues about their origin and evolution.

Findings of Chandrayaan 2

The Instruments of Chandrayaan 2 mission have gathered new information about moon and its environment.

The Chandrayaan-2 mission, which was lost after it hard landed on the dark side of the Moon in 2019, remains active in the form of its orbiter hovering over the Moon. Scientists used the Solar X-ray Monitor (XSM) onboard Chandrayaan-2 in September 2019 to study the Sun.

- The primary objective of Chandrayaan 2 was to demonstrate the ability to soft-land on the lunar surface and operate a robotic rover on the surface.
- The mission consisted of an Orbiter of the Moon, Vikram (after Vikram Sarabhai) the lander and Pragyan (wisdom) the rover, all equipped with scientific instruments to study the moon.
- Many precious elements for eglike magnesium, aluminum, silicon, calcium, titanium, iron etc.

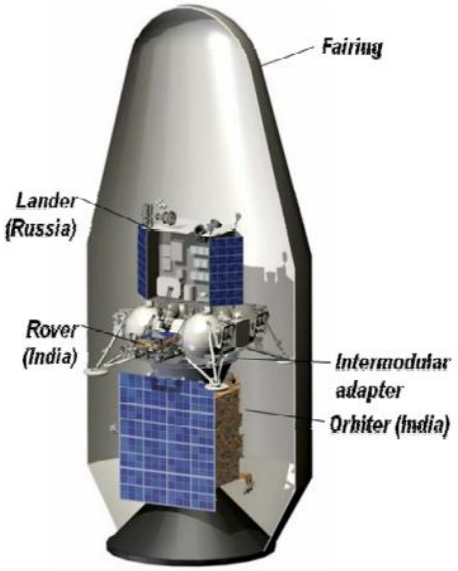

Figure 7: Lander, orbiter and rover configuration

Chandrayaan 3

Chandrayaan II deviated from its path and wasn't able to make a soft landing. To finish the objectives set for Chandrayaan II, Chandrayaan III is slated to be launched by 2022. Chandrayaan III will have a different design from the Chandrayaan II. It will have a lander and rover like that of Chandrayaan II but no orbiter will be present with Lander and rover.

With the aim of again exploring the moon surface ISRO has announced the next Moon mission that is Chandrayaan-3. It would have a "similar configuration" to the previous mission which would only include a Lander and a rover because India already has a working orbiter at the moon. An unnamed scientist new Lander would have stronger legs to allow the spacecraft to withstand touching the surface at a higher velocity during landing.

"It is essential to carry out detailed analysis on the changes for improving the Lander system considering the recommendations of both the expert committee of Chandrayaan 2 and the recommendations which could not be implemented due to the advanced stage of Chandrayaan 2 flight preparation.

Figure 8: ISRO geared up for Chandrayaan 3 mission

The launch will be performed using the GSLV Mk III rocket. GSLV Mark 3 (GSLV Mk III) is a three-stage heavy-lift launch vehicle that was also used for launching the Chandrayaan 2 in 2019. It consists of a core liquid booster (L110), two solid rocket boosters (S200) on each side and a cryogenic upper stage (C25). India's biggest cryogenic engine CE-20 powers the upper stage. Two Vikas engines that burn 110t of fuel power the core stage.

- The realization of Chandrayaan-3 involves various processes, including finalization of configuration, subsystem realization (manufacturing), integration, spacecraft-level detailed testing and a number of special tests to evaluate the systems performance on Earth.
- The findings pave the path for adding knowledge about the magmatic evolution of the Moon, its nebular conditions and much more.

5. Conclusion

From Chandrayaan 1 mission there is direct detection of water in its vapour phase in the tenuous lunar environment. This *in situ* measurements carried out by the Chandra's Altitudinal Composition Explorer (CHACE) payload, onboard the Moon Impact Probe (MIP) of Chandrayaan I mission indicates the presence of water on the surface of the moon in form of ice at higher lunar latitudes inferred from IR absorption spectroscopy, (especially that of OH), by the Moon Mineralogy Mapper (M^3) of Chandrayaan I [6]. GSLV MkIII, chosen to launch Chandrayaan-2 spacecraft, is a three-stage heavy lift launch vehicle developed by ISRO

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