Current Journal of Applied Science and Technology

39(43): 43-57, 2020; Article no.CJAST.62772
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Chandrayaan-2: A Memorable Mission Conducted by ISRO

Buddhadev Sarkar[1*] and Pabitra Kumar Mani[1]

[1]Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia 741252, West Bengal, India.

Authors' contributions

This work was carried out in collaboration between both authors. Author BS designed the study, managed the literature searches and wrote the first draft of the manuscript. Author PKM managed the analyses of the study. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2020/v39i4331139
Editor(s):
(1) Dr. Grzegorz Golanski, Czestochowa University of Technology, Poland.
(2) Prof. Samir Kumar Bandyopadhyay, University of Calcutta, India.
(3) Prof. Singiresu S. Rao, University of Miami, USA.
Reviewers:
(1) Anonymous, Colombia.
(2) Mohammed Aboud Kadhim, Middle Technical University, Iraq.
(3) Ilaria Cinelli, Space Generation Advisory Council (SGAC), Austria.
(4) Marcos Cesar Danhoni Neves, State University of Maringá, Brazil.
Complete Peer review History: http://www.sdiarticle4.com/review-history/62772

Mini-review Article

Received 10 October 2020
Accepted 15 December 2020
Published 31 December 2020

ABSTRACT

Aims: The Chandrayaan-2 aims to wave the Indian flag on the dark side (South Pole) of the Moon that had never been rendered by any country before. The mission had conducted to gather more scientific information about the Moon. There were three main components of the Chandrayann-2 spacecraft- an orbiter, a lander, and a rover, means to collect data for the availability of water in the South Pole of the Moon.

Place and Duration of Study: The rover (Pragyan) was designed to operate for one Lunar day that is equivalent to 14 Earth days, whereas the orbiter is assumed to orbit the Moon for seven years instead of the previously planned for just one year.

Overview: The Chandrayaan-2 spacecraft launched by India's heavy-lift rocket Geosynchronous Satellite Launch Vehicle-Mark III (GSLV MKIII) from the Satish Dhawan Space Center launch pad located on Sriharikota island of Andhra Prades. Unlike, Chandrayaan-1, this lunar mission aimed to perform a soft-landing on the South Pole of the Lunar surface and do scientific experiments with the help of the rover (Pragyan).

**Corresponding author: E-mail: buddhas850@gmail.com;*

Reason: The Chandrayaan-1, the first lunar mission of ISRO that detected water molecules on the Moon. The Chandrayaan-2 was a follow-on mission of Chandrayaan-1 to explore the presence of water molecules on the South Pole of the Moon.

Conclusion: Although the orbiter fulfilled all of the command, unfortunately, the lander (Lander) lost its communication at the last moment to touch the Moon's surface softly. Despite that, India again showed its potential in space missions. Chandrayaan- 2 was the most low budget lunar mission ever conducted by any space organization. The developing or even underdeveloped countries may come forward in their space program as ISRO is showing a convenient way in space missions.

Keywords: Chandryaan-2; Moon's South Pole; Payloads; Orbiter; Lander (Vikram); Rover (Pragyaan).

1. INTRODUCTION

Moon is the natural satellite having a direct link with the evolutionary history of our planet [1]. We can learn so much information about our planet only by studying the Moon [2] and space exploration is very much necessary for a better understanding of the Earth [3]. From the time of the Cold War between the U.S. and Soviet Union, the lunar mission came into existence [4]. Luna-1 was the first spacecraft launched by the Soviet Union in January 1959 to study the cosmic radiation and the magnetic fields of the Moon [5]. Although it had successfully escaped the Earth's gravity, but before reaching the Moon's surface lost its communication with the ground control team [5]. Since then various lunar missions were launched by the Soviet Union, but the Ranger mission conducted by NASA between 1961 and 1965 gave the first close-up view of the Moon surface for humankind [6]. Luna-9 was the first spacecraft that landed on the Moon surface in 1966 [7], and after that Luna-10 became the first spacecraft to successfully orbit the Moon [8]. In 1969 NASA make history by sending the first human on the Moon's soil through their Apollo-11 mission [9]. India participated in the race for lunar exploration on October 22, 2008, with the launch of Chandrayaan-1, India's first planetary exploration mission [10]. The spacecraft designed to orbit the Moon at a height of 100 km from the lunar surface for chemical, mineralogical, and photo-geologic mapping of the Moon [10]. India was the first country to detect water molecules on the Moon's surface with the help of ISRO's very first lunar exploration mission (Chandrayaan-1) in 2009 [11]. Both Chandrayaan-1 and MAR's (Mars Orbiter Mission or MOM) missions conducted by ISRO were great winning for India [12]. Chandrayaan-2 was an Indian lunar mission, designed to land on the South Pole of the Moon where no country had ever gone before [13]. Around $150 million had allocated for this mission [14] which was a follow-on mission of Chandrayaan-1, with major up-gradation, made-up of three major components which are Orbiter, Lander ("Vikram"), and Rover (Pragyaan, means 'wisdom'). Heavy-lift rocket Geosynchronous Satellite Launch Vehicle-Mark III (GSLV MKIII) used to launch the 4000 kg Chandrayaan-2 spacecraft from the Satish Dhawan Space Center launch pad on Sriharikota island of Andhra Prades [13]. Unlike Chandrayaan-1, performing a soft landing on the Moon surface and take scientific data with the help of Pragyan (Rover) was the main aim of Chandrayann-2 that would have made India a forth nation (after the Soviet Union, United States, and China) in the world, to mark footprint on the Moon surface [15]. The orbiter is still providing crucial data, and hopefully, it will be under function for the next seven years [13,16].

This paper provides knowledgeable information about the Chandrayaan-2, India's second Moon mission. The mission is about attempting a soft landing on the unexplored side of the Moon. This paper explains the reasons behind the interest in the South Pole and the objectives of Chandrayaan-2. Besides, the timeline of Chandrayaan-2 is provided, along with information about various payloads and their mission functions.

2. BACKGROUND OF LUNAR MISSIONS

The Moon is the closest neighbor of our planet, even though we have very limited information about this natural satellite. Scientists have different arguments about the Moon's origin.

There are four widely accepted theories about the Moon's origin are as follows:

1 ***Fission theory***: At the very initial period Moon was an integral part of the Earth, which separated due to the rotational force of Earth, but the Earth's gravitational force anchored this separated fragment to become our natural satellite [17,18].

2 ***Capture theory***: Moon was not at all a part of the Earth. It came from somewhere in the galaxy several billion years ago, which was just accidentally caught by the Earth's gravitation pull and started to orbit around our planet [19].
3 ***Co-accretion theory***: Earth and the Moon formed independently but from a single cloud of gas [20].
4 ***Giant impact hypothesis***: Scientists believe that a collision between Earth and a giant asteroid breaks off, a segment of Earth billions of years ago, this becomes today's Moon [21].

To finding out which among the hypothesis is more accurately describing the Moon's origin and also to know the Earth's evolution, scientists show their interest in various lunar missions (like Chandrayaan-1 and Chandrayaan-2 mission conducted by ISRO).

3. OBJECTIVES OF CHANDRAYAAN-2

Chandrayaan-2 was a mission nothing like before, which aimed to land on the Moon's unexplored side. The experimental payloads carried by the spacecraft were mean for a detailed study of the Moon [13].

So the main objectives for Chandrayaan-2 were

1. Gather more and more information about the Moon's origin, and find out which among the above theories is describing the Moon's origin preciously [13].
2. Detection of water molecules on the Moon's surface, by ISRO's first lunar mission, needed further study to know the distribution pattern of water, the state of water, and how it can be utilized or extracted. Also, it was the very first attempt made by any country to perform a soft landing on the dark side of the Moon, which will motivate the youth space scientists and technologists [13].
3. To study the surface characteristics and creating a 3D diagram of the Moon, which may help the scientists to understand the location more accurately [13].
4. To examine the density of the electrons on the Moon's ionosphere, which is the uppermost part of the atmosphere and can be ionized by radiation [13].
5. To study the chemical composition of the mineral elements present on the Moon. Also, draw a plan to utilize those elements for a better future for mankind [13].

4. WHY SCIENTISTS SHOWING INTEREST IN THE SOUTH POLE OF THE MOON?

Some points which makes the South Pole special:

1. Moon's South Pole remains in shadow for billions of years, so scientific experiments on this site may bring some new ideas about the Moon's origin and its link with the Earth as this is the virgin part where no country has ever gone before [22].
2. As per scientific studies, scientists are assuming the presence of a huge amount of water (mainly in the form of ice) in the coldest part of the Moon [22].
3. Studies also reported a possibility of containing fossils of the early solar system that are in a cold trap as the South Pole are not been touched by sunlight for billions of years [22].
4. The experience gain by studying the Moon may be useful for future Mars missions [22].
5. The elementary and positional characters of the South Pole make it a pit spot for potential exploration of space [22].

5. HOW CHANDRAYAAN-2 DIFFERENT FROM CHANDRAYAAN-1 MISSION?

Chandrayaan-1 was India's first lunar mission. ISRO successfully launched this spacecraft in 2008 by PSLV-C11 rocket, which was designed to operate for 2 years, but lost communication by working for about a year [10]. The mission was to orbit the Moon at a height of 100 km from the lunar surface for the chemical, mineral, and photo-geological mapping of the Moon with the help of 11 scientific payloads carried by the spacecraft. The discovery of water molecules on the Moon by Chandrayaan-1 was a great achievement for space scientists [23]. Whereas the Chandrayaan-2 is a follow-on mission to the Chandrayaan-1, comprising an Orbiter, Lander (Vikram), and Rover (Pragyaan) [13]. Unlike, Chandrayaan-1, this second lunar mission was designed to attempt a soft landing of Vikram on the lunar surface and deploy a six-wheeled Rover

(Pragyaan) to find water molecule on the darkest side of the Moon. GSLV MK-III M1 launching rocket used for lifting Chandrayaan-2, which contained 14 upgraded payloads compare to Chandrayaan-1 [13].

6. THE SCIENTIFIC PAYLOADS AND THEIR USES, CARRIED BY CHANDRAYAAN-2

Total 14 payloads were installed in the Chandrayaan-2 spacecraft, among them 13 from ISRO and one from NASA. GSLV MKIII M1 launch vehicle (Fig. 1) used to lift out the spacecraft towards the Moon.

6.1 Orbiter Payloads

The weight of the orbiter ('Pragyan') was 2,379 kg and carried 8 among 14 payloads. It had a 1000 W electric power generation capacity and could communicate with Indian Deep Space Network (IDSN) to create a link with the lander ('Vikram') (Fig. 2a). ISRO made it for orbiting the Moon for seven years instead of one year [13].

The payloads associated with the orbiter were as follows:

6.1.1 Terrain Mapping Camera 2 (TMC 2)

To examine the morphological parameters and to map the lunar surface topographically, TMC-2 was installed, which is useful for reconstruction of the lunar geological history and understanding of the volcanic and tectonic processes that have occurred in the past [24].

In the end, the data gathered by TMC 2 is used to provide clues about the evolution of the Moon and to help draw 3D maps of the lunar surface [24].

6.1.2 Chandrayaan-2 Large Area Soft X-ray Spectrometer (CLASS)

CLASS measures the X-ray Fluorescence Spectrometer (XFS) of the Moon, which can detect the X-rays emitted by magnesium, aluminum, silicon, calcium, titanium, iron, and sodium whenever the photon particles of the sun are excited. So it is used to estimate the abundance on the lunar surface of different elements [25].

This instrument was built by the U.R. Rao Satellite Centre, Indian Space Research Organization [25].

6.1.3 Solar X-ray Monitor

It functioned as a CLASS supporter. It was designed to measure the solar radiation intensity in X-ray form emitted from the sun and its corona [26].

A solar X-ray spectrum within the energy range of 1-15 keV had provided and XSM can include high-energy resolution and high-cadence solar X-ray spectrum measurements (full spectrum per second) as an input for CLASS data analysis [26].

The primary objective of the XSM is to provide the incident solar spectrum on the Chandrayaan-2 orbiter for the X-ray fluorescence spectroscopy experiment, which aims to generate lunar surface elemental abundance maps [26].

6.1.4 Orbiter High-Resolution Camera (OHRC)

OHRC had two main goals, firstly to provide high-resolution images of the landing site to ensure the safe landing of the Chandrayaan-2 lander ('Vikram') to prevent any damage. Another objective, owing to its very high potential for imaging the lunar surface at spatial resolution for detail scientific study [27].

High-resolution images can also be used to examine the volcanic location, the tectonic process, and the central peaks of new impact craters [27].

6.1.5 Imaging Infrared Spectrometer (IIRS)

IIRS was a hyperspectral tool detect hydroxyl signature, used to study the mineralogy of the lunar surface [28].

Used to map the lunar minerals and water resources with a higher spectral and spatial resolution, which could help scientists understand the Moon's hydration function, whether it is present as H_2O or OH or in H_2O-ice form [28].

To understand the origin and evolution of the Moon in a geological context, IIRS aims to detect and map the composition of the lunar surface and volatiles [28].

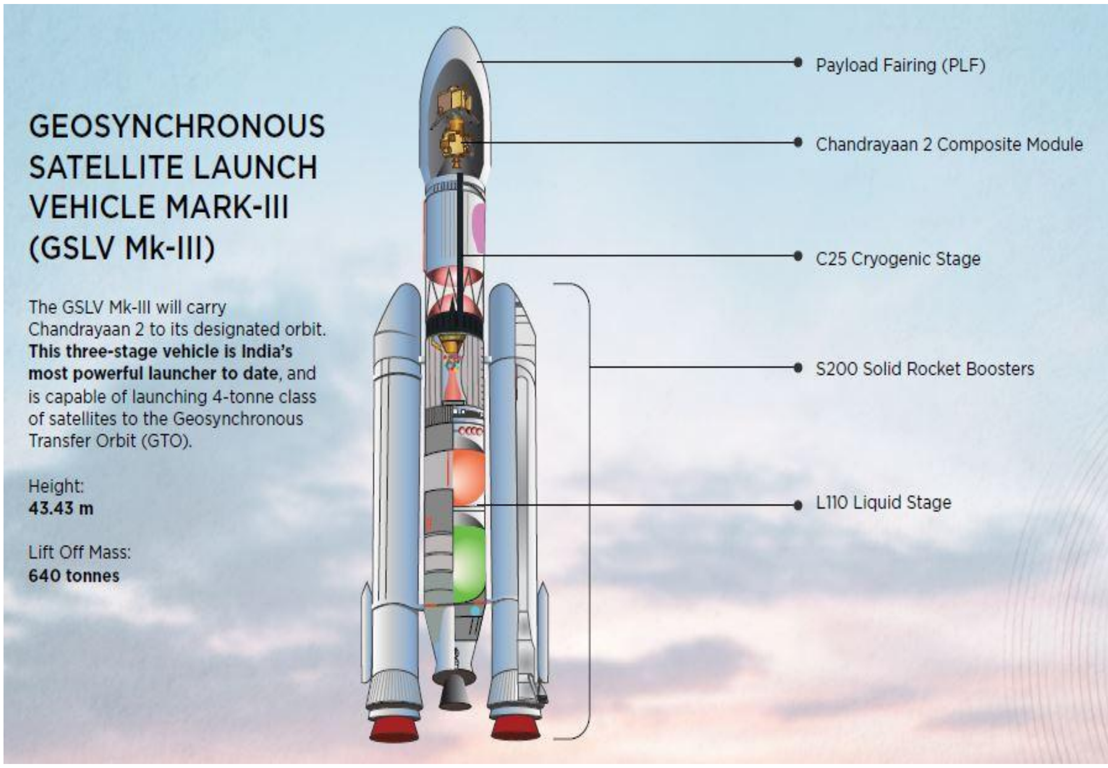

Fig. 1. GSLV MK-III M1 Launch Vehicle used in Chandrayaan-2 mission [29]

6.1.6 Dual Frequency Synthetic Aperture Radar (DFSAR)

The goals of this instrument were:

(i) Study of the processes of geological evolution on the lunar surface, in particular in the Polar Regions, by preparing high-resolution geomorphological maps and mapping the crater floor.
(ii) In the Polar Regions, estimation of water molecules through detection of dielectric constant.
(iii) Estimation of regolith thickness and regional scale distribution using data from dual-frequency radiometer mode.

It was a revised version of the mini SAR S-band used in Chandrayaan-1. The dispersive properties of the dark side may be helpful to scientists for a better understanding of the Moon [30].

6.1.7 Chandrayaan-2 Atmospheric Compositional Explorer 2 (CHACE 2)

CHACE-2 was a Quadrupole Mass Spectrometer (QMA) capable of scanning both long and short-term variations on exospheric density and composition and also could study their mechanisms [31].

In particular, the scientific questions include the diurnal variation and changes in composition during the passage of the Moon through each lunation in the geomagnetic tail region compared to the scenario when the Moon is in the upstream bow shock of the Earth [31].

6.1.8 Dual Frequency Radio Science (DFRS) experiment

The experiment on Dual Frequency Radio Science aboard Chandrayaan-2 used the radio occultation mode communication channel between orbiter and ground to study the temporal evolution of electron density in the lunar ionosphere [32].

The main objectives of this instrument were:

(i) To study the variations in the Moon's ionosphere.

(ii) To explore whether the Moon's ionosphere is ubiquitous or has episodic appearances.
(iii) To confirm the source of ions, whether dusty or molecular, in the lunar ionosphere.

6.2 'Vikram' Payloads

The lander had named 'Vikram' after the name of Dr. Vikram Ambala Sarabhai, known as the Father of the Indian Space Programme. The lander's total weight was 1,471 kg and consisted of 4 payloads, one of which was delivered by NASA. 'Vikram' was designed to carry the rover (Pragyan') with it (Fig. 2b).

The payloads associated with the orbiter were as follows:

6.2.1 Radio Anatomy of Moon Bound Hypersensitive ionosphere and Atmosphere (RAMBHA)

Phenomena such as solar wind, photoelectron sheath, and lunar electromagnetic potential on the surface create a highly dynamic plasma environment for the lunar ionosphere [13].

RAMBHA had designed to collect such in-situ information, which could help the scientists to analyze the ambient electron density in the lunar ionosphere that could evaluate lunar plasma density near the surface under varying solar conditions [13].

6.2.2 Chandra's Surface Thermophysical Experiment (ChaSTE)

ChaSTE developed to measure the vertical gradient of the temperature and the thermal conductivity of the lunar surface [13].

ChaSTE designed for two different modes of operations:

Activity of the active mode in which the fluctuations in temperature over a given period have been measured and the thermal conductivity of the regolith in contact whereas through the passive mode of operation, it was used to continue collecting the in-situ measurements of temperature at different depths.

6.2.3 Instrument for Lunar Seismic Activity (ILSA)

The best geophysical tool for determining the internal structure of a planet is seismology. Seismometers with varying performance parameters are used to conduct seismic experiments, both in terms of sensitivity and bandwidth.

It was a micro-machined high-sensitivity silicon accelerometer used to measure the acceleration of the ground due to lunar quakes. It had the objective to examine the seismicity of the landing site by its two sensors, namely a coarse range sensor and a fine-range sensor [33].

6.2.4 Laser Retroreflector Array (LRA)

This was a NASA instrument carried by Chandryann-2 spacecraft, developed for deriving clues on the lunar interior.

Its primary objective was to accurately calculate the distance between Earth and Moon and also to help in understanding the dynamics of the Earth and the Moon system [13].

6.3 'Pragyan' Payloads

'Pragyan' is an ancient Sanskrit word meaning wisdom. With 50 W of electric power generating capacity, the weight of the rover was 27 kg. It was a robotic 6-wheeled vehicle consisted of 2 payloads (Fig. 2c).

6.3.1 Alpha Particle X-ray Spectrometer (APXS)

Curium (244) metal used in APXS to emit high energy alpha particles, and the X-ray fluorescence spectroscopy technique was mean to use for exciting the lunar surface with the help of X-ray or alpha particles [34].

APXS's primary scientific objective is to determine the basic composition of the South Polar surface in the landing site's surrounding regions as APXS helps to detect major rock-forming elements such as sodium, magnesium, aluminium, silica, calcium, titanium, iron, and also some trace elements like zirconium, strontium, and yttrium [34].

6.3.2 Laser-Induced Breakdown Spectroscope (LIBS)

It was designed for in-situ measurement of the elemental composition of lunar regolith and rocks present on the Moon's surface [35]. So its prime objective was to detect the abundance of various elements on the landing site of the South Pole with the help of a pulsed laser source, a set of optical lenses and mirrors, an aberration-corrected concave holographic grid, and a linear detector [35].

Fig. 2. All the three components of Chandrayaan-2 spacecraft [29]

7. MISSION OPERATION TIMELINE OF CHANDRAYAAN-2

Chandrayaan-2 was a highly complex mission compared to the previous Chandrayaan-1 mission, which brought together Orbiter, Lander and Rover to explore the south pole of the Moon.

Table. 1. Timeline of the CHANDRAYAAN-2 mission during the formulation stage

Date	Progress on the Chandrayaan-2 mission
14th November 2007	ISRO and Roscosmos (Russian space agency) officially agreed to a joint venture for Moon exploration through a soft landing on the Moon's surface. Roscosmos signed to provide the lander and rover, whereas ISRO had the responsibility to provide the orbiter [36].
18th September 2008	The government of India approved the Chandrayaan-2 mission [37].
16th August 2009	The design of the Chandrayaan-2 had completed, and ISRO started working on the prototype [38].
24th January 2010	ISRO successfully conducted the test of Solid Propellant Booster Rocket Stage for GSLV Mk III launch vehicle [39], that latter used for Chandrayaan-2 mission.
30th August 2010	The payloads for the Chandrayaan-2 mission finalized. Initially, there were five payloads for orbiter and two for rover [40].
8th September 2010	ISRO successfully conducted the test of L 110 Liquid Core Stage of GSLV - Mk III [41].
22nd January 2013	Russia backed out from this mission after the Phobos Grunt project crashed. ISRO alone started working on the Chandrayaan-2 mission [42].
18th December 2014	ISRO successfully conducted the first experimental flight test of the GSLV Mk-III launched vehicle and achieved a new milestone [43].

7.1 Operational Stage

28th June 2019

- ISRO successfully completed the assembly of batteries for all stages in GSLV MkIII-M1 launch vehicle [44].

29th June 2019

- The rover ('Pragyan') integrated with the lander ('Vikram'), after successful completion of all the trials. Finally the lander and rover integrated with the orbiter [44].

4th July 2019

- ISRO completed the integration of encapsulated Chandrayaan-2 spacecraft with the GSLV MKIII-M1 launch vehicle [44].

10th July 2019

- All the necessary checks for the Cryogenic and the Liquid stage (L110) control system of the launch vehicle were completed [44].

15th July 2019

- Launch was stopped just one hour before take-off due to a minute technical error [44].

22nd July 2019

- ISRO successfully launched the Chandrayaan-2 spacecraft with the help of the GSLV MkIII-M1 launch vehicle [44].

24th July 2019

- The first Earth bound orbit raising manoeuvre of Chandryaan-2 was performed at 1452 hrs (IST), for only 48 seconds by using an onboard propulsion system to reach the next orbit of 230 X 45163 km [44]

26th July 2019

- For the Chandryaan-2 spacecraft, the second Earth bound orbit elevation manoeuvre was successfully carried out at 0108 hrs (IST) using the onboard propulsion system for a firing time of 883 seconds to achieve an orbit of 251 x 54829 km [44].

29th July 2019

- The third Earth bound orbit raising manoeuvre for Chandryaan-2 spacecraft was performed successfully at 1512 hrs (IST) as planned, by using the onboard propulsion system for a firing duration of 989 seconds and achieved the orbit of 276 x 71792 km [44].

2nd August 2019

- The fourth manoeuvre of the Earth bound orbit raising done by using the onboard propulsion system, firing for 646 seconds at 1527 hrs (IST) as planned, to achieve the orbit of 277 X 89472 km [44].

6th August 2019

- ISRO had successfully conducted the fifth Earth bound orbit raising manoeuvre for Chandryaan-2 spacecraft at 1504 hrs (IST), using the onboard propulsion system for a firing duration of 1041 seconds and the achieved the orbit of 276 x 142975 km. [44].

14th August 2019

- The final Earth bound orbit raising manoeuvre of the Chandrayaan-2 spacecraft was successfully carried out at 02:21 am IST. The liquid engine of the spacecraft fired for about 1,203 seconds, and the Chandrayaan-2 had entered the Lunar Transfer Trajectory. Earlier, the orbit of the spacecraft had progressively increased five times between July 23 and August 06, 2019. [44].

20th August 2019

- The first Lunar Orbit Insertion (LOI) maneuver was successfully conducted by ISRO at 0902 hrs IST for a duration of 1738 seconds. With this, Chandrayaan-2 was successfully inserted into the Lunar orbit and achieved an orbit of 114 km x 18072 km [44]

21st August 2019

- The second Lunar bound orbit maneuver for Chandrayaan-2 spacecraft performed successfully at 1250 hrs IST as planned, using the onboard propulsion system. The spacecraft achieved an orbit of 118 km x 4412 km with the maneuver of 1228 seconds [44].

28th August 2019

- Lunar bound orbit maneuver for Chandrayaan-2 spacecraft performed for the third time at 0904 hrs IST, using an onboard propulsion system with a maneuver duration of 1190 seconds to reach a distance of 179 km x 1412 km [44].

30th August 2019

- ISRO had conducted the fourth Lunar bound orbit maneuver for Chandrayaan-2 at 1818 hrs IST as planned, using the onboard propulsion system, for a duration of 1155 seconds for achieving an orbit of 124 km x 164 km. [44].

1st September 2019

- The last Lunar bound orbit maneuver for Chandrayaan-2 spacecraft performed successfully at 1821 hrs IST as planned, using the onboard propulsion system for a maneuver duration of 52 seconds to achieve 119 km x 127 km [44].

2nd September 2019

- The Vikram Lander successfully separated from the Chandrayaan-2 Orbiter at 1315 hrs (IST) and located in an orbit of 119 km x 127 km. [44].

3rd September 2019

- ISRO carried out the first de-orbiting maneuver for the Chandrayaan-2 spacecraft at 0850 hrs IST as planned, using the onboard propulsion system. The duration of the maneuver was 4 seconds to reach an orbit of 104 km x 128 km [44]

4th September 2019

- The second de-orbiting maneuver of the Chandrayaan-2 spacecraft performed successfully at 0342 hrs IST as planned, using the onboard propulsion system. The maneuver lasted 9 seconds, so the Vikram lander reached an orbit of 35 km x 101 km. In an orbit of 96 km x 125 km the Chandrayaan-2 Orbiter continues to orbit the Moon, and both the orbiter and the lander are normal [44].

7th September 2019

- ISRO lost its communication with 'Vikram' lander just 2 km away from the landing site. It was a heart-breaking moment for all the science and space lovers across the world. Though the orbiter was doing its experiment according to the plan, and ISRO had announced the orbiter is capable of doing its job for the next seven years instead of the planned only for one year [44].

10th September 2019

- ISRO located the Vikram lander by the orbiter of the Chandrayaan-2 but failed to communicate with it yet [44].

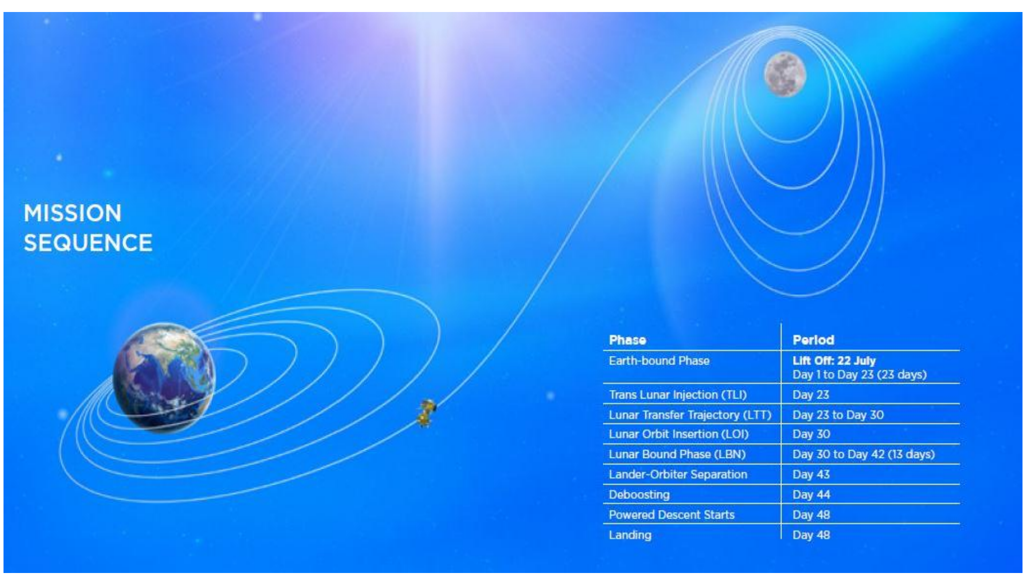

Fig. 3. All the maneuvers made by the Chandrayaan-2 spacecraft [29]

8. 'VIKRAM' WENT SILENT JUST BEFORE FULFILLING INDIA's GREAT SPATIAL MISSIONS

Just before the final touchdown to the lunar surface, 'Vikram' went silent. There were three distinct stages of the soft landing sequence, meaning a gradual deceleration of the spacecraft and its altitude until it reaches close to zero when touching the ground. To do so, 'Vikram' had a cluster of five engines designed to execute different pre-programmed functions. After the rough barking phase, a technical snag occurred, resulting in a drop in the communication link between the lander and the orbiter just 2.1 km above the surface of the Moon. With Vikram's silence, one of the most unforgettable attempts by ISRO to land on the South Pole of the Moon becomes shattered [44].

9. CONCLUSION

The historical attempt by ISRO to land on the South Pole of the Moon ended with an unexpected result. Unlike the Chandrayaan-1, this mission was not only an orbiter mission but performing the soft landing on the Moon surface was the objective. The mission, however, was not a complete failure as Chandrayaan-2's mission still lives with the orbiter that will continue to orbit the Moon. In spacecraft launches since the early 1960s, when the components were assembled by hand and transported by bicycle, the whole world appreciated the fact that ISRO had come a long way. India's very first attempt at making history by being the fourth country to land on the Moon failed, but not the courage. Through this mission, ISRO aims to expand its footprint in space, encourages a new technology of exploration, increase our understanding of the Moon, and also can inspire the future generation in the field of space science. Chandrayaan-2 was the lowest budget lunar mission ever undertaken by any space organization. Both the developing and underdeveloped countries may come forward in their space program as ISRO shows a convenient way in space missions. Let's hope that the orbiter of the Chandrayaan-2 spacecraft can discover something new that can nourish our definition of the Moon, like Chandrayaan-1 found water on the surface of the Moon for the first time.

DISCLAIMER

There is no conflict of interest between the authors and the producers of the products because we do not intend to use these products as an avenue for any dispute, but the advancement of knowledge. The research was also not funded by the producing company, but rather financed by the authors' efforts.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Dr. Tarik Mitran (NRSC-ISRO, Hyderabad, India) for providing necessary guidance. No funding was received for this work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Carballido A. What the moon tells us about Earth. EarthSky; 2015.
   Accessed 18 November 2020.
   Available:https://earthsky.org/space/what-the-moon-can-tell-us-about-earth
2. Yan I. 10 Things: What We Learn About Earth by Studying the Moon. NASA; 2019.
   Accessed 18 November 2020.
   Available:https://solarsystem.nasa.gov/news/812/10-things-what-we-learn-about-earth-by-studying-the-moon/
3. Rosenthal J. Space Exploration: Leaving the Earth to Understand It. Planetary Society; 2016. Accessed 18 November 2020.
   Available: https://www.planetary.org/articles/0513-leaving-earth-to-understand-it
4. Drake N, Howard J. A brief history of moon exploration. National Geographic. 2020. Accessed 18 November 2020.
   Available:https://www.nationalgeographic.com/science/space/space-exploration/moon-exploration/
5. Anonymous. Luna 01. NASA; 2020.
   Accessed 18 November 2020.
   Available:https://solarsystem.nasa.gov/missions/luna-01/in-depth/
6. Anonymous. Ranger Spacecraft. Smithsonian National Air and Space Museum.
   Accessed 18 November 2020.

Available:https://airandspace.si.edu/collection-objects/ranger-spacecraft/nasm_A19770993000
7. Howell E. Luna 9: 1st Soft Landing on the Moon. SPACE.com.
Accessed 18 November 2020.
Available:https://www.space.com/35116-luna-9.html
8. Ivankov A. Luna 10. NASA; 2020.
Accessed 18 November 2020.
Available:https://nssdc.gsfc.nasa.gov/nmc/spacecraft/display.action?id=1966-027A
9. Loff S. Apollo 11 Mission Overview. NASA; 2019.
Accessed 18 November 2020.
Available:https://www.nasa.gov/mission_pages/apollo/missions/apollo11.html
10. Anonymous. Chandrayaan-1. Department of Space, ISRO; 2008.
Accessed 18 November 2020.
Available:https://www.isro.gov.in/Spacecraft/chandrayaan-1
11. Anonymous. Chandrayaan-1 / Moon Impact Probe. NASA; 2019.
Accessed 18 November 2020.
Available:https://solarsystem.nasa.gov/missions/chandrayaan-1/in-depth/
12. Thekkethil D. 5 achievements by ISRO that India is proud of. The American Bazaar; 2016.
Accessed 18 November 2020.
Available:https://www.americanbazaaronline.com/2016/04/28/5-achievements-by-isro-that-india-is-proud-of-410885/
13. Anonymous. Chandrayaan-2. Department of Space, ISRO.
Accessed 18 November 2020.
Available:https://www.isro.gov.in/chandrayaan2-mission
14. Anonymous. Chandrayaan-2: The grand ambitions of India's second Moon mission. BBC News; 2019.
Accessed 19 November 2020.
Available:https://www.bbc.com/news/world-asia-india-49589850#:~:text=Costing%20%24150%20million%2C%20Chandrayaan%2D2,on%20the%20parched%20lunar%20surface
15. Bartels M, Weitering H. India Loses Contact with Vikram Lander During Historic Moon Landing Attempt. SPACE.com; 2019.
Accessed 19 November 2020.
Available:https://www.space.com/india-loses-contact-with-vikram-moon-lander-chandrayaan-2.html
16. Available:https://www.isro.gov.in/chandrayaan2-latest-updates
https://www.bbc.com/news/world-asia-india-49589850#:~:text=Costing%20%24150%20million%2C%20Chandrayaan%2D2,on%20the%20parched%20lunar%20surface
17. Darwin SGH. On the Precession of a Viscous Spheroid. Nature. 1878;18:580-582.
Available:https://doi.org/10.1038/018580a0
18. Wise DU. Origin of the Moon by Fission. In: Marsden, BG. Cameron, AGW, editors. The Earth-Moon System. Springer, Boston, MA; 1966.
Available:https://doi.org/10.1007/978-1-4684-8401-4_14
19. Singer SF. Origin of the moon by capture. In: Origin of the moon; Proceedings of the Conference, Kona, HI, October 13-16, 1984 (A86-46974 22-91). Houston, TX, Lunar and Planetary Institute. 1986;471-485.
20. Ruskol EL. The Origin of the Moon. III. Some Aspects of the Dynamics of the Circumterrestrial Swarm Sov Astron. 1972;15(4):646-654.
Available:http://articles.adsabs.harvard.edu/full/seri/SvA../0015//0000646.000.html
21. Hartmann WK, Davis DR. Satellite-sized planetesimals and lunar origin. Icarus. 1975;24(4):504-515.
Available:https://doi.org/10.1016/0019-1035(75)90070-6
22. Dunbar B. Moon’s South Pole in NASA’s Landing Sites. NASA; 2019.
Accessed 19 November 2020.
Available:https://www.nasa.gov/feature/moon-s-south-pole-in-nasa-s-landing-sites
23. Anonymous. Results from Chandrayaan-1 Mission. Vikram Sarabhai Space Centre; 2017. Accessed 21 November 2020.
Available:https://www.vssc.gov.in/VSSC/index.php/results-from-chandrayaan-1-mission
24. Chowdhury AR, Patel VD, Joshi SR, Arya AS, Kumar A, Paul S, et all. Terrain Mapping Camera-2 onboard Chandrayaan-2 Orbiter. Curr Sci. 2020;118(4):566-572.
25. Radhakrishna V, Tyagi A, Narendranath S, Vadodariya K, Yadav R, Singh B, et al. Chandrayaan-2 Large Area Soft X-ray

Spectrometer. Curr Sci. 2020;118(2):219-225.

26. Mithun NPS, Vadawale SV, Sarkar A, Shanmugam M, Patel AR, Mondal B, et al. Solar X-Ray Monitor on Board the Chandrayaan-2 Orbiter: In-Flight Performance and Science Prospects. Sol Phys. 2020;295(139).
Available:https://doi.org/10.1007/s11207-020-01712-1
27. Chowdhury AR, Saxena M, Kumar A, Joshi SR, Amitabh AD, Dagar A, et al. Orbiter High-Resolution Camera onboard Chandrayaan-2 Orbiter. Curr Sci. 2019;117(7):560-565.
28. Chowdhury AR, Banerjee A, Joshi SR, Dutta M, Kumar A, Bhattacharya S, et al. Imaging Infrared Spectrometer onboard Chandrayaan-2 Orbiter. Curr Sci. 2020;118(3):368-375.
29. Anonymous. Launch Kit at a glance. Department of Space, ISRO; 2008.
Accessed 19 November 2020.
Available:https://www.isro.gov.in/gslv-mk-iii-m1-chandrayaan-2-mission/launch-kit-glance
30. Putrevu D, Trivedi S, Das A, Pandey D, Mehrotra P, Garg SK, et al. L-and S-band Polarimetric Synthetic Aperture Radar on Chandrayaan-2 mission. Curr Sci. 2020;118(2):226-233.
31. Das TP, Thampi SV, Dhanya MB, Naik N, Sreelatha P, Pradeepkumar P, et al. Chandra's Atmospheric Composition Explorer-2 onboard Chandrayaan-2 to study the lunar neutral exosphere. Curr Sci. 2020;118(2):202-209.
32. Choudhary RK, Bindu KR, Harshit K, Karkara R, Ambili KM, Pant TK, et al. Dual Frequency Radio Science experiment onboard Chandrayaan-2: a radio occultation technique to study temporal and spatial variations in the surface-bound ionosphere of the Moon. Curr Sci. 2020;118(2):210-218
33. John J, Thamarai V, Mehra MM, Choudhary T, Giridhar MS, Jambhalikar A, et al. Instrument for Lunar Seismic Activity Studies on Chandrayaan-2 Lander. Curr Sci. 2020;118(3):376-382.
34. Shanmugam M, Vadawale SV, Patel AR, Mithun NPS, Adalaja HK, Ladiya, T, et al. Alpha Particle X-Ray Spectrometer (APXS) On-board Chandrayaan-2 Rover. Curr Sci. 2020;118(1):53-61.
35. Laxmiprasad AS, Sridhar RVLN, Goswami A, Lohar KA, Rao MVH, Shila KV, et al. Laser Induced Breakdown Spectroscope on Chandrayaan-2 Rover: a miniaturized mid-UV to visible active spectrometer for lunar surface chemistry studies. Curr Sci. 2020;118(4):573-581.
36. Anonymous. India and Russia Sign an Agreement on Chandrayaan-2. Department of Space, ISRO; 2007.
Accessed 20 November 2020.
Available:https://www.isro.gov.in/update/14-nov-2007/india-and-russia-sign-agreement-chandrayaan-2
37. Anonymous. Chandrayaan-2: Expanding the boundaries of human knowledge. Department of Space, ISRO.
Accessed 20 November 2020.
Available: https://www.isro.gov.in/chandrayaan2-home-0
38. Anonymous. India completes design of Chandrayaan-2. The Hindu; 2009.
Accessed 21 November 2020.
Available:https://www.thehindu.com/sci-tech/technology/India-completes-design-of-Chandrayaan-2/article16877784.ece
39. Anonymous. Successful static testing of Solid Propellant Booster Rocket Stage S200 for GSLV Mk III Launch Vehicle. Department of Space, ISRO; 2010.
Accessed 21 November 2020.
Available:https://www.isro.gov.in/update/24-jan-2010/successful-static-testing-of-solid-propellant-booster-rocket-stage-s200-gslv-mk
40. Anonymous. Payloads for Chandrayaan-2 Mission Finalised. Department of Space, ISRO; 2010.
Accessed 21 November 2020.
Available:https://www.isro.gov.in/update/30-aug-2010/payloads-chandrayaan-2-mission-finalised
41. Anonymous. Successful Static Testing of L 110 Liquid Core Stage of GSLV - Mk III. Department of Space, ISRO; 2010.
Accessed 21 November 2020.
Available:https://www.isro.gov.in/update/08-sep-2010/successful-static-testing-of-l-110-liquid-core-stage-of-gslv-mk-iii
42. Ramachandran R. Chandrayaan-2: India to go it alone. The Hindu; 2013.
Accessed 22 November 2020.

Available:https://www.thehindu.com/news/national/chandrayaan2-india-to-go-it-alone/article4329844.ece

43. Anonymous. First Experimental Flight of India's Next Generation Launch Vehicle GSLV Mk-III Successful. Department of Space, ISRO; 2014.
Accessed 22 November 2020.
Available:https://www.isro.gov.in/update/18-dec-2014/first-experimental-flight-of-indias-next-generation-launch-vehicle-gslv-mk-iii

44. Anonymous. Chandrayaan-2: Latest Updates. Department of Space, ISRO.
Accessed 22 November 2020.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/62772