CHANDRAYAAN-2: India's 2nd Lunar Exploration Mission

Hemant Khati, Devender Sharma
Department of Aeronautical Engineering,
Manav Rachna International Institute of Research and Studies,
Faridabad, India

***Abstract*:- Chandrayaan-2 was a great achievement for India and the mankind and it made a history as 1st mission in the world which was projected on the southern pole of moon. This region always remains in darkness and temperature is extreme cold there and these two things are most dangerous and affect negatively on mission. Therefore it was very challenging mission for India and entire world was curious about its success. Its budget was 9.62 billion Indian rupees and it is the most expansive space mission of India till now. Chadrayaan-2 consisted of 3 parts; Orbiter, Lander and Rover. This mission was launched in 2019. In this mission, Orbiter was successful its mission to reach in moon's orbit but unfortunately communication was lost with Lander which causes Lander did not perform well and it crashed along Pragyan rover and other sciencetific equipments. This paper presents a detailed review about Mission Chandrayaan-2 and its landing failure.**

INTRODUCTION

Chandrayaaan -2 was the second lunar mission of India which was launched on 22 July 2019 form satish dhawan space centre by GSLV MK-3 rocket. It was most important & anticipated mission for India and world both because chandrayaan-2 had to land on south polar region of moon where no one has reached yet. Its primary objects were to understand the dark side of moon, mapping of lunar surface and to find the presence of water on South Pole.

Total cost of this mission was approx 9.78 billion Indian rupees. It was most costly mission ever in Indian space history. Chandrayaan-2 was made up of 3 part; Orbiter, VIKRAM Lander and PRAGYAN Rover. But it was not completely successful mission because lander crash landed on the lunar surface with rover.

1. 1st space mission to conduct soft landing on the moon's South Polar Region.
2. 1st Indian mission in which it attempts a soft landing on the lunar surface with home-grown technology.

OBJECTIVES

1. To understand the history of our solar system & moon.
2. Origin and evolution of moon

South Pole is greater than the North Pole & here lunar surface area remains in shadow & there is a higher probability of the presence of water & fossil records because it is the coldest place on the moon & generally this always remains in shadow. South Pole has craters that are extremely cold and contain fossil record.

Chandrayaan-1 got the presence of water molecules on the lunar surface in 2012 which was confirmed later by LRO (NASA). Therefore chandrayaan-2 is a second lunar mission of India which will further study on the lunar surface of south region related to water presence, mapping of the moon, elemental study.

CHALLENGES OF MOON LANDING

There are various challenges in moon landing like; trajectory accuracy, communication with deep space network, extreme cold & hot temperature variation, lunar dust, lumpy gravity, soft landing etc. some of the challenges involved in moon landing are mentioned here.

COMMUNICATION WITH DEEP SPACE NETWORK

Communication to the satellite from the ground station is very important. It helps to control satellite during mission, send commands and new updates, give satellite location and its path, firing rocket engine and thruster. Indian deep space network is located at byalalu near the bangluru (Karnataka). Usually most of the time lack of communication is responsible for the mission failure (ISRO, 2019a).

SOFT LANDING

Soft landing was the main challenge in this mission and it was first time for india attempt a soft landing on lunar surface. The soft landing was executed by performing the rough braking and fine braking maneuvers by firing the onboard engines and it takes extreme precision. Lander was also capable to absorb shock impact without damaging onboard payload and systems (ISRO, 2019a).

EXTREME TEMPERATURE

There is no atmosphere on moon which causes temperature variation is extreme. It takes 27.5 days to complete one rotation around its axis and also around the earth. Due to its rotation one side of moon remains 13.6 day in light which is called lunar day and another part remains in darkness for 13.6 days which is called lunar night. During the lunar day temperature can reach 260 F and in lunar night it can reach -280 F (ISRO, 2019a).

CONFIGURATION OF CHANDRAYAAN-2

Chandrayaan 2 was launched by GSLV MK 3 from Satish Dhawan Space Centre and its lift mass was 3850 kg approx. It consisted of Lunar Orbiter, Vikram Lander, and Pragyan Rover. Budget of chandrayaan 2 mission was 9.78 billion rupees. In which, 6 billion was allotted for space vehicle and 3.75 billion for rocket (GSLV MK 3).

ORBITER

From September 2019, the Chandrayaan-2 orbiter was orbiting in polar orbit of the moon at an altitude of

100 km. It carries eight scientific instruments; two of which are advanced versions of those flown on Chandrayaan-1. The approximate launch mass was 2,379 kg. The Orbiter High Resolution Camera (OHRC) organized high-resolution observations of the landing site before to separation of the lander from the orbiter. The structure of orbiter was manufactured by Hindustan Aeronautics Limited and delivered to ISRO Satellite Centre on 22 June 2015 (isro.gov.in)
Chandrayaan 2 Orbiter can communicate with Indian Deep Space Network (IDSN) at Byalalu as well as the Vikram Lander. Its mission life is seven years which was planned first one year.

- Dimensions: 3.2 × 5.8 × 2.2 m
- Gross lift-off mass: 2,379 kg (5,245 lb)
- Propellant mass: 1,697 kg (3,741 lb)
- Dry mass: 682 kg (1,504 lb)
- Electric power generation capacity- 1000 Wt.
- Life- 7 years

VIKRAM LANDER

The Lander of Chandrayaan-2 was named Vikram after Dr Vikram A. Sarabhai, who was the Father of the Indian Space Programme. It was designed to operate for one lunar day, which is similar to about 14 Earth days (Annadurai, 2017).

The preliminary configuration analysis of the lander was completed in 2013 by the Space Applications Centre (SAC) in Ahmedabad. The lander's propulsion system has eight 50 N thrusters to attitude control and five 800 N (180 lb_f) liquid main engines derived from ISRO's 440 N liquid Apogee Motor. Initially, the lander design used four main liquid engines, but a centrally mounted engine was added later to handle new requirements of having to orbit the Moon before landing. The additional engine was expected to attenuate upward draft of lunar dust during the soft landing. The Lander was designed to safely land on slopes up to 12°.

Some associated technologies include a high resolution camera, Laser Altimeter (LASA), Lander Horizontal Velocity Camera (LHVC), Lander Position Detection Camera (LPDC), Lander Hazard Detection Avoidance Camera (LHDAC), an 800 N throttle able liquid main engine, attitude thrusters, Laser Inertial Reference & Accelerometer Package (LIRAP), Ka band radio altimeters (KaRA), and the software needed to run these components.

- Dimensions: 2.54 × 2 × 1.2 m
- Power generation capability: 650 W
- Gross lift-off mass: 1,471 kg (3,243 lb)
- Propellant mass: 845 kg (1,863 lb)
- Dry mass: 626 kg (1,380 lb)
- Mission duration: 14 days (one lunar day)

ROVER

The mission rover is known as Pragyan which means in Sanskrit is 'wisdome'. It had mass of 27 kg (60 lb) and it was a 6 wheeled rover operated by solar power. Its design was focused to run 500 meters on the lunar surface with the speed of 1 cm per second. Orbiter was the bridge between pragyan and ISRO command centre in this mission. It was not capable to directly contact with ground station (isro.gov.in)

- Stereoscopic camera-based 3D vision:
  two 1 megapixel, monochromatic NAVCAMs are mounted in front of the rover to provide the ground control team a 3D view of the surrounding lunar surface, and help in path-planning by developing a digital elevation model of the terrain. IIT Kanpur collaborated to the development of the subsystems for light-based map generation and motion planning for the rover.

- Control and motor dynamics:
  The rover uses a rocker-bogie suspension system and runs on six wheels, each driven by individual brushless D C electric motor. Steering is managed by differential speed of the wheels or skid steering.

The expected mission life of Pragyan rover was one lunar day, which is equal to 14 Earth days. Its electronic systems were not designed to function in extreme dark and cold lunar night.

- Dimensions: 0.9 × 0.75 × 0.85 m
- Travel speed: 1 cm/sec.
- Power: 50 Wt
- Mission duration: 14 days (one lunar day)

FAILURE OF VIKRAM

On 16 November 2019, the Failure Analysis Committee released its report to the Space Commission, concluding that the crash was caused by a software glitch. It was unexpected event because software was functioning well during the trial period. The lander completed successfully its phase one of landing, in which from an altitude of 30 km to 7.4 km over the Moon surface the velocity of vehicle was reduced from 1,683 m/s to 146 m/s. But unfortunately velocity reduction during the second phase of descent was more than the calculation. Which causes actual calculation and condition were beyond the designed parameters of on-board software and Vikram had to apply rough landing. Then it was crashed and found approximately 500 meters of the intended landing site. The impact of the crash damaged its on board system and communication which made it helpless.

PAYLOAD

ISRO selected 8 state of the art instruments for orbiter, four for the lander and 2 instruments for rover.

PAYLOAD CARRIED BY ORBITER

- Terrain Mapping Camera 2 (TMC-2), which is used to map the lunar surface in three dimensions using two on-board cameras. A predecessor instrument called TMC flew on Chandrayaan-1(ISRO, 2019c).

- Collimated Large Array Soft X-ray Spectrometer (CLASS), which is designed to map the abundance of minerals on the surface. It is the successor of CIXS flew on Chandrayaan-1(Narendranath et al., 2014).
- Solar X-ray Monitor (XSM), which monitors the emissions of solar X-rays (Vadawale et al., 2014).
- Chandra's Atmospheric Composition Explorer (ChACE-2) is a neutral mass spectrometer which is successor instrument of CHACE-1 flew on Chandrayaan-1's Moon Impact Probe (Bhardwaj et al., 2016).
- Synthetic Aperture Radar (SAR), which is used for mapping the surface in radio waves. It is basically design on Chandrayaan-1's MiniSAR (Putrevu et al., 2016).
- Imaging Infra-Red Spectrometer (IIRS), which measures the abundance of water/hydroxyl on the surface.
- Orbiter High Resolution Camera (OHRC) to scrutinize the surface, specially the landing site of the Lander and rover (ISRO, 2019c).
- DFRS (Dual Frequency Radio Science), to study temporal evolution of electron density in the lunar surface (space.com, 2019)

The Lander's instruments:

- Instrument for Lunar Seismic Activity (ILSA), to examine for moonquakes (space.com, 2019)
- Chandra's Surface Thermo physical Experiment (ChaSTE), for inspection of surface's thermal properties (space.com, 2019)
- Radio Anatomy of Moon Bound Hypersensitive ionosphere and Atmosphere (RAMBHA-Langmuir Probe), to study the plasma density on the surface (Manju, 2016).

PAYLOAD CARRIED BY ROVER

Pragyan also carried two scientific instruments which were designed to scrutinize the composition of the moon's surface: the Laser-Induced Breakdown Spectroscope (LIBS) and the Alpha Particle X-Ray Spectrometer (APXS) (Shanmugam et al., 2014).

ROCKET

GSLV MK III was used to carry Chandrayaan-2 spacecraft to its destination. It is a three-stage heavy lift indigenous cryogenic launch vehicle developed by ISRO. It has two solid strap-ons, a core liquid booster and a cryogenic upper stage system.

GSLV Mk III is designed to launch 4 ton class of satellites into Geosynchronous Transfer Orbit (GTO) or about 10 tons to Low Earth Orbit (LEO). It is about twice the capability of the GSLV Mk II.

The two strap-on motors of GSLV Mk III are situated on either side of its core liquid booster. Known as 'S200', each carries 205 tons of composite solid propellant and their ignition results in vehicle lift-off. These S200 motors operate for 140 seconds. During strap-ons working phase, the two clustered Vikas liquid Engines of L110 liquid core booster ignites for 114 sec after lift -off to further increment the thrust of the vehicle. These two engines continue to operate after the separation of the strap-ons at about 140 seconds after lift -off.

The first orbital flight of GSLV Mk III, the GSLV-Mk III-D1 successfully launched and placed GSAT-19 satellite to a geostationary transfer orbit (GTO) on June 05, 2017 from SDSC SHAR, Sriharikota (isro.gov.in)

- Vehicle Diameter: 4.0 m
- Height: 43.43 m
- Heat Shield (Payload Fairing) Diameter: 5.0 m
- Lift Off Mass: 640 tones
- Number of Stages: 3

MISSION PROFILE

Phase	Date	Event	Detail	Result	
				Apogee / Aposelene	Perigee / Periselene
Geocentric phase	22 July 2019 09:13:12 UTC	Launch	Burn time: 16 min 14 sec	45,475 km (28,257 mi)	169.7 km (105.4 mi)
	24 July 2019 09:22 UTC	1st orbit-raising maneuver	Burn time: 48 sec	45,163 km (28,063 mi)	230 km (140 mi)
	25 July 2019 19:38 UTC	2nd orbit-raising maneuver	Burn time: 883 sec	54,829 km (34,069 mi)	251 km (156 mi)
	29 July 2019 09:42 UTC	3rd orbit-raising maneuver	Burn time: 989 sec	71,792 km (44,609 mi)	276 km (171.5 mi)
	2 August 2019 09:57 UTC	4th orbit-raising maneuver	Burn time: 646 sec	89,472 km (55,595 mi)	277 km (172 mi)
	6 August 2019 09:34 UTC	5th orbit-raising maneuver	Burn time: 1041 sec	142,975 km (88,841 mi)	276 km (171 mi)
	13 August 2019 20:51 UTC	Trans lunar Injection	Burn time: 1203 sec	—	—
Selenocentric phase	20 August 2019 03:32 UTC	Lunar orbit insertion 1st lunar bound maneuver	Burn time: 1738 sec	18,072 km (11,229 mi)	114 km (71 mi)
	21 August 2019 07:20 UTC	2nd lunar bound maneuver	Burn time: 1228 sec	4,412 km (2,741 mi)	118 km (73 mi)

	28 August 2019 03:34 UTC	3rd lunar bound maneuver	Burn time: 1190 sec	1,412 km (877 mi)	179 km (111 mi)
	30 August 2019 12:48 UTC	4th lunar bound maneuver	Burn time: 1155 sec	164 km (102 mi)	124 km (77 mi)
	1 September 2019 12:51 UTC	5th lunar bound maneuver	Burn time: 52 sec	127 km (79 mi)	119 km (74 mi)
Vikram lunar landing	2 September 2019 7:45 UTC	Vikram separation	—	127 km (79 mi)	119 km (74 mi)
	3 September 2019 3:20 UTC	1st deorbit burn	Burn time: 4 sec	128 km (80 mi)	104 km (65 mi)
	3 September 2019 22:12 UTC	2nd deorbit burn	Burn time: 9 sec	101 km (63 mi)	35 km (22 mi)
	6 September 2019 20:08 UTC	Powered descent	Burn time: 15 min	Landing (planned)	Landing (planned)
	6 September 2019 20:23 UTC	Vikram landing	Trajectory deviation started at 2.1 km altitude, telemetry was lost seconds before touchdown.[28][122]	Lost upon crash landing.	
	7 September 2019 00:00 UTC−01:00 UTC (planned)	Pragyan rover deployment	Lander failure, rover was not deployed.	—	—

(Chandrayaan-2, Wikipedia)

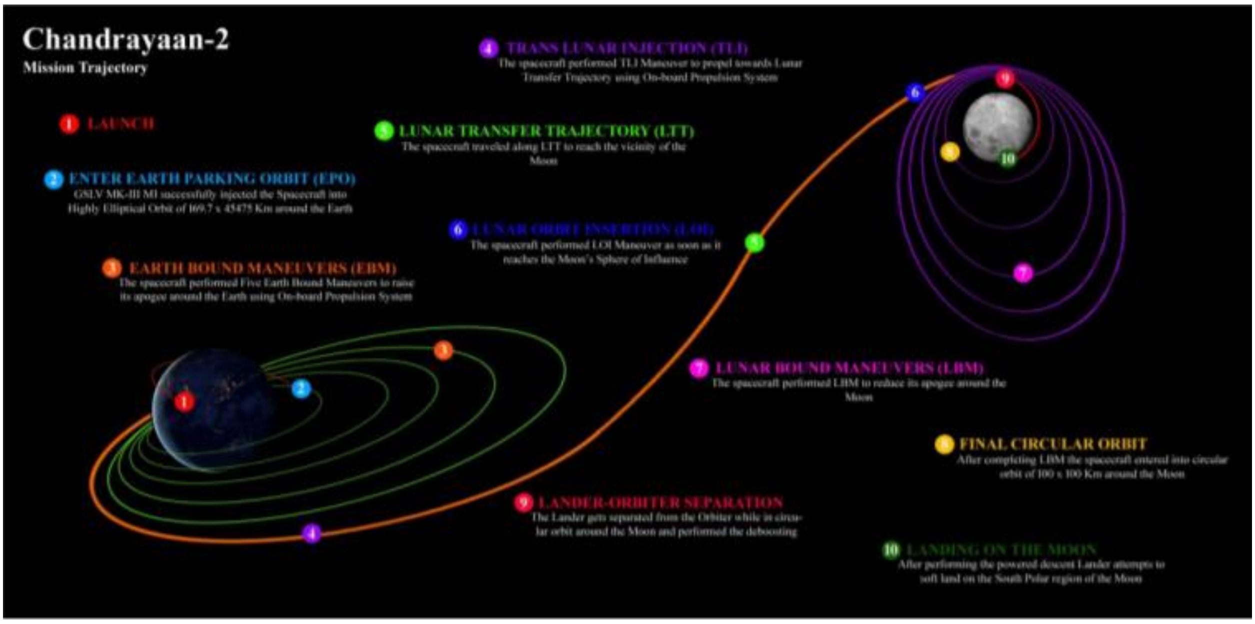

Figure 1 : Mission trajectory for chandrayaan-2 spacecraft (Credit – ISRO)

CONCLUSION

This paper provides a detailed information and analysis of chandrayaan-2. It was a nation pride mission for India and it was the first time in the world when a nation launched mission to reach South Pole of the moon. Unfortunately landing on the moon of VIKRAM rover was not successful but this project achieved its 95 % success and objectives according to ISRO. Now ISRO has planned a new landing mission on the lunar surface with Chandrayaan-3.

FUTURE ADVANCEMENT

In November 2019, ISRO officials confirmed news about a new lunar Lander mission is being studied for launch in November 2020. New project is known as Chandrayaan-3 and it would be a re-attempt to achieve the landing capabilities on lunar surface. This Lunar Polar Exploration Mission is a joint venture of India with Japan which in 2024. In this mission, there would be no orbiter launching in lunar orbit. The proposed spacecraft would have a detachable propulsion system, a Lander and a rover.

REFERENCES

[1] www.isro.gov.in
[2] Space.com
[3] Launch Kit of GSLV Mk III M1 Chandrayaan-2
[4] "Chandrayaan-3: Second bid to land on Moon by November 2020 | India News - Times of India"
[5] Annadurai, M., 2017. Chandrayaan-2: Lunar orbiter and lander mission. Proceedings of the 10th IAA Symposium on The Future of Space Exploration: Towards the Moon Village and Beyond, (MVB' 17), Torino, Italy.

[6] Bhardwaj, A., Das, T.P., S.V.P. Mohankumar and S.V. Thampi, 2016. CHACE-2 mass spectrometer aboard chandrayaan-2 orbiter to study the lunar neutral exosphere. Proceedings of the 19th National Space Science Symposium (SSS' 16), At Space Physics Laboratory, Thiruvananthapuram, India.
[7] ISRO, 2019a. The challenges of a moon landing. Department of Space, Indian Space Research Organisation (ISRO).
[8] ISRO, 2019c. Launch Kit at a glance. Department of Space, Indian Space Research Organisation (ISRO).
[9] Manju, G., 2016. RAMBHA Langmuir Probe (LP) Payload onboard chandrayaan-2 lander: Design and development. Proceedings of the 19th National Space Science Symposium, (SSS' 16), Thiruvananthapuram, India.
[10] Putrevu, D., A. Das, J.G. Vachhani, S. Trivedi and T. Misra, 2016. Chandrayaan-2 dual-frequency SAR: Further investigation into lunar water and regolith. Adv. Space Res., 57: 627-646. DOI: 10.1016/j.asr.2015.10.029
[11] Shanmugam, M., S.V.S. Murty, Y.B. Acharya, S.K. Goyal and A.R. Patel et al., 2014. Alpha Particle Xray Spectrometer (APXS) on-board chandrayaan-2 rover. Adv. Space Res., 54: 1974-1984. DOI: 10.1016/j.asr.2013.03.011
[12] Vadawale, S.V., M. Shanmugam, Y.B. Acharya, A.R. Patel and S.K. Goyal et al., 2014. Solar X-ray Monitor (XSM) on-board Chandrayaan-2 Orbiter. Adv. Space Res., 54: 2021-2028. DOI: 10.1016/j.asr.2013.06.002