A Study on Mission to Moon Exploration through Chandrayaan-2

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***Abstract*- The moon is the closest cosmic body at which space discovery can be attempted and documented. Moon provides the best linkage to Earth's early history. It offers an undisturbed historical record of the inner solar system environment. This paper is to give an insight into the various lunar expeditions-especially Chandrayaan-2 which attempted to soft-land the lander-Vikram and rover-Pragyan close to the lunar south pole.**

***Index terms*- Chandrayaan-2, Orbiter, Rover, lander-Vikram, Hovering, Crater, South Pole.**

I.INTRODUCTION

Moon –A Good space for exploration!
Some good reasons why humans should explore moon are:

1. Exploring moon-our nearest heavenly body, doesn't cost as much as interplanetary missions
2. It is possible with our current technology and resources.
3. Moon is a storehouse of valuable resources which are found in earth in negligible amounts. For example rare isotope of Helium, He-3 which is extremely rare in Earth is found in considerable amounts in the lunar surface.
4. Colonizing the moon is the first step of human race in becoming an interplanetary civilization.
5. Moon can be used a launch base, where powerful rockets in the near-future can be launched with less expense of energy due to lower acceleration due to gravitation on lunar surface.

II. INDIA'S PAST LUNAR MISSONS

The Indian Space Research Organization is undoubtedly one of the world's most technologically advanced space agencies. Even though its budget is just a fraction of what NASA gets, the space agency has proven that innovative technology can help to achieve the same objectives at a much lower cost.
ISRO's Chandrayaan mission is one such example. Launched in October of 2008, it was India's first mission to the moon. The launch of Chandrayaan-1 marked the start of India's first-ever lunar program.

III.CHANDRAYAAN-1

Chandrayaan 1 was launched on 22 October 2008 from Satish Dhawan Space Centre, Sriharikota. It used the indigenously developed Polar Satellite Launch Vehicle (PSLV-XL) rocket. The spacecraft successfully entered the lunar orbit on 8 November 2008 and just six days later, released its Moon Impact Probe. The Moon Impact Probe crashed near the Shackleton crater on the same day, due to failure of star tracking sensors. The Impact Probe crashed in such a way that the subsurface lunar soil could be analyzed for traces of ice.

Hovering just 100 km above the Moon's surface, Chandrayaan-1 took numerous high-resolution images of the Moon's topography. It also performed mineralogical mapping and scoured the surface for any radioactive elements.

One of the mission's major achievements was the discovery of a large number of water molecules present in the Moon's soil. The mission cost a mere $56 million and gave us crucial information about the Moon's surface. It also discovered water ice on lunar South pole, which could be used for drinking and other purposes.

Figure 1. PSLV C11 carrying Chandrayaan-1

IV. CHANDRAYAAN-2

Chandrayaan-1 was expected to last for two years. But numerous technical issues such as failure of the star sensors and inadequate thermal shielding shortened the lifespan of the spacecraft to just 312 days.

However, 95% of the mission objectives were already achieved. The project was a huge step forward not only for ISRO but also for the world. It paved the way for future lunar explorations.

It gave ISRO a good kick start for its next mission Chandrayaan-2.

A. Objective

1. To soft land on the lunar South Pole, which is considered as one of the coldest places on our solar system.
2. To explore for lunar water near the polar region.
3. To map and study the variations in lunar surface composition and perform chemical analysis of the soil.

B. Cost and manufacture

The entire Chandrayaan-2 mission cost approximately $141 million. Chandrayaan-2 is the country's first time mission using self-manufactured components and design vehicles.

C. Design

The mission was launched on a Geosynchronous Satellite Launch Vehicle Mark III (GSLV Mk III) with an approximate lift-off mass of 3,850 kg (8,490 lb) from Satish Dhawan Space Centre on Sriharikota Island. As of June 2019, the mission has an allocated cost of $ 9.78 billion (approximately US$141 million) which includes $ 6 billion for space segment and $ 3.75 billion as launch costs on GSLV Mk III. Chandrayaan-2 stack was initially put in an Earth parking orbit of 170 km perigee and 40,400 km apogee by the launch vehicle.

D. Orbiter, lander and rover of Chandrayaan-2

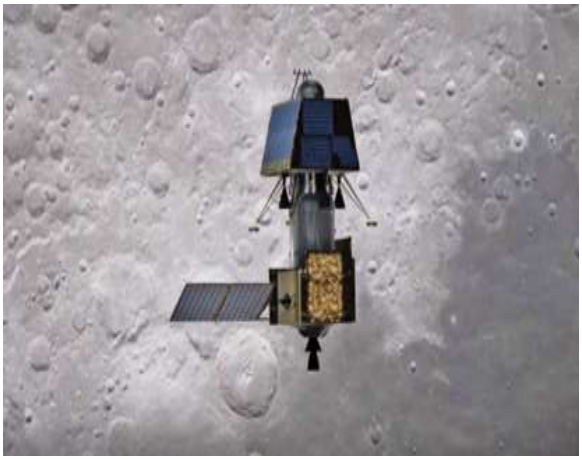

Figure 2. Chandrayaan-2 orbiter

The orbiter will orbit around the moon at a distance of 100 km. It has been sent with 5 payloads. At launch, the orbiter weighed 1400 kg. The life span of the orbiter is 1 year. The orbiter will be hovering over the moon at a distance of 100km and performing passive experiments like its predecessor.

E. Lander (Vikram)

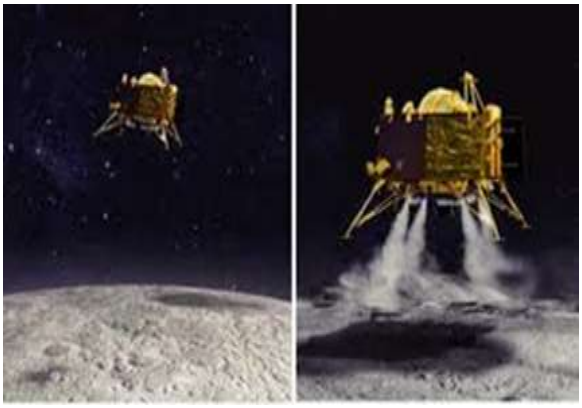

Figure 3. Vikram lander

It was designed to work for one lunar day i.e. about 14 earth days. Vikram can communicate with the orbiter, rover and the space center too. It carried the lunar rover named Pragyan.

F. Rover (Pragyan)

Figure 4. Pragyan rover

The rover of Chandrayaan-2 weighs 27 kg and works with solar energy. It is a robot vehicle with 6 wheels and can travel up to 500 m. It can communicate with the lander only. Its aim is to explore the surface of the moon, take samples of the soil and surface, do analysis and send data to the orbiter which will then relay it to the earth. It was expected that the rover will operate for 14 days but the duration may vary since Pragyan uses solar power to keep itself up.

V. WHAT WAS EXPECTED TO HAPPEN?

"After launch, Chandrayaan-2 will initially reside in a highly elliptical, temporary "parking" orbit, with its lowest point just 170 kilometers above Earth and its highest point more than 40,000 kilometers overhead.
From there, a series of rocket-engine burns will push the outermost edge of the spacecraft's orbit to even greater distances, finally allowing Chandrayaan-2 to be captured by the moon's gravity.
Then further maneuvers will place the spacecraft into a circular orbit 100 kilometers over the lunar surface in early September. Following the separation of the Vikram-lander from the orbiter, the lander will set out for a target site situated between the south-polar
Finally, if all goes well, the Pragyan rover will roll onto the lunar surface at an average speed of one centimeter per second to traverse a distance of 500 meters. The Chandrayaan-2 orbiter is planned to operate around the moon for a full year, conducting scientific reconnaissance and also serving as a communications relay.
Down on the surface, the lander and rover alike are intended to survive for just one lunar day, which is equivalent to 14 Earth days." These were the series of events that were expected to happen with Chandrayaan-2.

VI. WHAT HAPPENED ACTUALLY?

A. Launch

Chandrayaan-2 launch was initially scheduled for 15 July 2019 at 02:51 IST local time. However, the launch was aborted 56 minutes and 24 seconds before launch due to a technical glitch, so it was rescheduled to 22 July 2019. Unconfirmed reports later cited a leak in the nipple joint of a helium gas bottle as the cause of cancellation.
Finally Chandrayaan-2 was launched on board the GSLV MK III M1 launch vehicle on 22 July 2019 at 09:13 UTC (14:43 IST) with better-than-expected apogee.

B. Geocentric phase

After being placed into the parking orbit by the launch vehicle, the Chandrayaan-2 spacecraft stack gradually raised its orbit using on-board propulsion over 22 days. In this phase, one perigee-raising and five apogee-raising burns were performed to reach a highly eccentric orbit followed by trans-lunar injection on 13 August 2019.

C. Selenocentric phase

After 29 days from its launch, the Chandrayaan-2 spacecraft stack entered lunar orbit on 20 August 2019 after performing a lunar orbit insertion burn. The three-spacecraft stack was placed into an elliptical orbit that passes over the polar regions of the Moon. By 1 September 2019 this elliptical orbit was made nearly circular followed by separation of Vikram-lander from the orbiter on 2 September 2019.

D. Planned landing site

The flat highland between craters Manzinus C and Simpelius N was the planned landing zone for the Vikram-lander
Two landing sites were selected. The prime landing site was 600 km (370 mi) from the South pole and the alternate landing site was a little closer to it. The

prime site is on a high plain between the craters Manzinus C and Simpelius N, on the near side of the Moon.

E. Loss of Vikram

On 7 September 2019, the lander, Vikram tried to make a soft landing on the moon but when it was 2 kms away from the surface, the ISRO lost contact with Vikram.

Many efforts were made to restore communication but the efforts were not fruitful. The rover was not able to come out of the lander and thus, it cannot gather important information related to the Moon. Due to this, the data that was supposed to be collected by Vikram and Pragyaan cannot be collected.

VII. WHAT WENT WRONG?

When the countdown began, the lander was moving at a velocity of 1,640 metres per second. The first phase of descent was performed nominally from an altitude of 30 km to 7.4 km above Moon's surface and velocity was reduced from 1,683 metre per second to 146 metre per second.

During the second phase of descent, the reduction in velocity was more than the designed value. Due to this deviation, the initial conditions at the start of the fine braking phase were beyond the designed parameters. As a result, Vikram hard-landed within 500 metre of the designated landing site.

Scientists say it appeared to be moving as planned during the first two phases of deceleration, known as the rough braking and fine braking operations. It was during the final stage, known as the "hovering" stage that the problem occurred.

Some important reasons that they pointed out were:

- The problem could have been with the lander's central engine.
- The gravity on the moon would have made it fall somewhat more rapidly.
- The central engine would not have produced the thrust that is required and therefore the deceleration was no longer what it was supposed to be.
- The other possibility may be that while landing at a higher speed, a lot of dust to rises that also shakes up the spacecraft because of the gravitational pull.

VIII. FAILURE EXPLANATION BY ISRO

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. Phase one of descent from an altitude of 30 km to 7.4 km above the Moon's surface went as intended with velocity being reduced from 1,683 m/s to 146 m/s. But velocity reduction during the second phase of descent was more than expected.

This deviation from nominal was beyond the designed parameters of on-board software, causing Vikram to land hard, though it managed to impact relatively near the intended landing site.

A. Vikram's impact site

Vikram's impact site was located using the debris from the spacecraft in pictures released by NASA. While initially estimated to be within 500 meters of the intended landing site, best-guess estimates from satellite imagery indicate initial impact about 600 m away. The spacecraft shattered upon impact, with debris scattered over almost two dozen locations in an area spanning kilometres.

IX. CHANDRAYAAN-2: EVERYTHING IS NOT LOST

That was a precise launch, the orbiter was maneuvered as anticipated which is a major part of the success is and even the lander passed through all the three phases except that in the last phase it did not function as per the expectations

The mission has achieved a 95% success with the placement of the orbiter in the moon's orbit. Only 5 per cent of the mission has been lost - Vikram, the lander, and Pragyan, the rover. The remaining 95 per cent, that is the Chandrayaan-2 orbiter, is orbiting the moon successfully.

The 2379-kg orbiter, with a designed mission life of one year, carries eight scientific payloads for mapping the lunar surface and studies the exosphere (outer atmosphere) of the Moon.

Luckily, the life of the orbiter has got enhanced from one year to seven years because a lot of fuel was not consumed. It could transmit data for seven years and

we can now rely on data received from the orbiter for future lunar expeditions.

X.MISSION REPEAT : CHANDRAYAAN-3

In November 2019, ISRO officials stated that a new lunar lander mission Chandrayaan-3 is being studied for launch in 2021; and it would be a re-attempt to demonstrate the landing capabilities needed for the Lunar Polar Exploration Mission. This re-attempt would not include launching an orbiter. The proposed configuration would have a detachable propulsion module, a lander and a rover.

XI.CONCLUSION

Even if the mission ends up with a minimum of 5% failure, ISRO will have a lot to learn from its experiences, motivating it to do better in the future. Even though ISRO lacks the resources and money compared to what NASA gets, it is continually proving its dominance in the world with its innovative cost-effective solutions. This "Hard landing" may also pave the way for future Indian missions to land on Mars, and open up the possibility of India sending astronauts into space.

Chandrayaan-2 has made an attempt to foster a new age of discovery, increase our understanding of space, stimulate the advancement of technology, promote global alliances, and inspire a future generation of explorers and scientists.

Let us hope that Chandrayaan-3 fulfill all our expectations and take human kind a little forward towards Space.

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