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Another Journey to the Moon Begins with Chandrayaan-3

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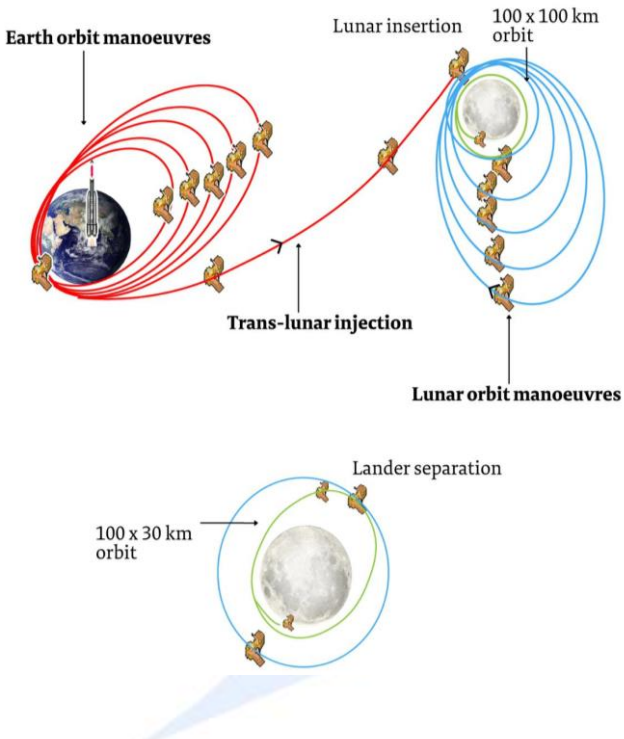
The launch of Chandrayaan-3 aboard Launch Vehicle Mark-3 (LVM-3) from Sriharikota on July 14, 2023, is much more than a spectacular show of rocketry. The scenes of joy, celebrations, and emotional moments that were witnessed from the launch control centre were the result of years of hard work and redemption from failure after the Chandrayaan-2 lander was lost in 2019. The Indian Space Research Organisation (ISRO) entered a 'zero-error syndrome' after the loss of Chandrayaan-2. For Chandrayaan-3, all efforts were made to ensure that errors that had been witnessed in previous missions were not repeated. To ensure this, a fail-safe model has been adopted by expanding the margins of tolerance to include risks that are likely to be encountered during the mission. These are highly complex missions. The only countries to have been successful in soft-landing on the Moon are the US, Russia, and China. India, Israel, and Japan have attempted Moon landings but have not been successful yet.

India's tryst with the Moon began 15 years ago with its first Moon mission, Chandrayaan-1, in 2008. Though Chandrayaan-1 was only an orbiter, it became popular for having done the first and most detailed analysis of the lunar surface for tracing water. It also established the presence of an atmosphere around the Moon. The outcomes of Chandrayaan-1 were remarkable and were applauded by NASA, the US space research organisation. Chandrayaan-2, India's second Moon mission, which launched in 2019, was different. It had an orbiter, a lander, and a rover. The mission was promising, and everything went seamlessly until the landing phase when the lander crashed on the Moon's surface due to inadequate deceleration. The orbiter, however, continues to orbit the Moon and has been sending images back to Earth.[1] Chandrayaan-2 mission has been partially successful as the dynamics of reaching the Moon orbit and separation of the lander from the orbiter, as well as the descent phase of the lander, was flawlessly executed, and normal performance was observed till the lander reached an altitude of 2.1 km from the lunar surface. The orbiter is said to have a very high-resolution camera (0.3 m) and is expected to be active for around seven years.[2]

The mechanics of Chandrayaan-3 will be a repeat of its predecessor as a follow-on mission. Although it has no orbiter of its own, it will make use of the Chandrayaan-2 orbiter for relaying and communicating with the Earth station. The objective is to demonstrate the end-to-end capability of Earth-to-Moon transfer, landing, and roving on the lunar surface. This will be a precursor to all lunar missions in the future. The landing site was selected at the south pole of the Moon, a place yet to be explored. The lander is carrying four payloads, while the rover is carrying two payloads for conducting experiments on the Moon and its atmosphere. Chief among these are the instruments to measure near-surface plasma density and thermal properties and the instruments to assess the seismic activity at the landing zone. Instruments on the rover would do a qualitative and quantitative analysis of minerals on the Lunar surface, including an assessment of their chemical composition.[3]

A journey to the Moon should normally take four to seven days, as was the case with the Apollo lunar landing missions of the US, which flew between 1968-1972. They used the powerful Saturn rockets, which could inject the spacecraft into lunar orbits in much lesser timeframes and cover a distance of around 3,84,000 km, one way to the Moon.[4] Chandrayaan-3, however, has been launched on the LVM-3[5] rocket, which inserted the spacecraft into a much lower elliptical earth orbit that will take around 40 days to reach the Moon through a series of orbit-raising manoeuvres leading to a lunar orbit insertion. The soft landing on the Moon is likely to be attempted on August 23, 2023.[6]

Figure 1: Chandrayaan 3's path to Moon



Source: "Chandrayaan-3 | What it takes to soft-land on the moon," *The Hindu*, July 14, 2023, https://www.thehindu.com/news/national/chandrayaan-3-what-it-takes-to-soft-land-on-the-moon/article67045114.ece. Accessed on July 21, 2023

The Chandrayaan-3 mission has four phases, which include the Earth orbit phase, the Lunar orbit insertion phase, the Lunar landing phase, and the Lunar exploration phase. Though each phase has its own complexities and requires precise manoeuvres, the Lunar landing phase is the most critical one. Most unknowns are likely to occur in this landing phase as compared to the other phases. It was in this landing phase that the Chandrayaan-2 was lost. ISRO scientists have taken great care in incorporating the lessons learnt from the Chandrayaan-2 mission. Changes have been made in the Vikram lander module by strengthening the legs to withstand higher landing forces. The other changes include a higher fuel capacity to cater to repeated attempts at landing or moving to alternate landing sites and the inclusion of a laser Doppler instrument for more accurate velocity and altitude measurements. The lander engine software and design have also been modified to have more

tolerance to variations and disruptions. The spacecraft will have the capability to autonomously select a suitable landing site within the localised area. While modifications were critical, more emphasis was given to testing. The spacecraft has been subjected to drop tests and rigorous tests in various flight conditions for the past two years.[7]

A successful landing on the Moon will place India in the select group of Moon-faring nations, with India being the fourth to achieve this feat. India will also be the first nation to land at the south pole of the Moon, which has immense significance for lunar exploration efforts. Having signed the Artemis Accords, India will certainly find prominence in international cooperation for future joint Lunar missions. India is already partnering with Japan in a joint Lunar exploration programme called the Lunar Polar Exploration Mission (LUPEX), which could be the next Lunar mission for India. If all goes well, a successful Chandrayaan-3 will achieve a one-way ticket to the Moon. To complete the capability cycle, a return journey also needs to be attempted. This is an even more complex process. Eventually, Moon missions need to aspire for sample returns for mineral resources and become human-rated to facilitate human presence on the Moon. This is a desirable capability for India to stay abreast of the developments in deep space exploration.

Notes:

[1] Geeta Pandey, "Chandrayaan-3: India's historic Moon mission lifts off successfully", *BBC News*, July 15, 2023, https://www.bbc.com/news/world-asia-india-66185565, accessed July 20, 2023.

[2] "Chandrayaan 2", *ISRO,* July 22, 2019, https://www.isro.gov.in/Chandrayaan_2.html, accessed July 19, 2023.

[3] "Chandrayaan 3", *ISRO,* https://www.isro.gov.in/Chandrayaan3_New.html, accessed July 20, 2023.

[4] "The Apollo Missions", *NASA*, https://www.nasa.gov/mission_pages/apollo/missions/index.html, accessed July 20, 2023.

[5] The LVM3 or Launch Vehicle Mark-3 was previously referred to as the Geosynchronous Satellite Launch Vehicle Mark III or GSLV Mk III. It is a three-stage medium-lift launch vehicle developed by the Indian Space Research Organisation (ISRO). It has a payload capacity of 4 Tons to GTO.

[6] "Why is Chandrayaan-3 taking 40 days to reach Moon? There is a Mangalyaan connect", *India Today*, July 17, 2023, https://www.indiatoday.in/science/chandrayaan-3/story/whys-chandrayaan-3-taking-48-days-to-reach-moon-there-is-a-mangalayaan-connect-2407771-2023-07-17, accessed July 20, 2023.

[7] Chetan Kumar, "How different is Vikram, the Chandrayaan-3 lander from Chandrayaan-2, and why?", *The Times of Indi*a, July 12, 2023, http://timesofindia.indiatimes.com/articleshow/101695276.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst, accessed July 20, 2023