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FIRST VOICE. LAST WORD.

{ LUNAR ASPIRATIONS } LAUNCH AT 2.35PM TODAY

## *Destination Moon: Chandrayaan-3 mission launch countdown begins*

**NEW DELHI:** After "partial success" in 2019 with Chandrayaan-2, the Indian Space Research Organisation (Isro) is set to make another attempt at soft landing on the moon's surface on Friday, this time with an improved version — Chandrayaan-3.

The launch will take place from the Satish Dhawan Space Centre, Sriharikota, at 2.35pm.

With the success of its third lunar mission, India hopes to become the fourth country in the world to land on the moon's surface and the first to land near the lunar south pole. HTC

**Indian space odyssey scripts a new chapter**

**Ahead of the launch of Chandrayaan-3, a look at why the third lunar mission is significant for furthering India's space ambitions.**

FULL COVERAGE→P2


# Chandrayaan 3 is an invaluable milestone

**The Moon mission will show the world India can undertake complex projects. And, it will create a new pantheon of heroes for the country**

Somak Raychaudhury

In July 1969, I was in primary school. My heroes were cricketers — Farokh Engineer, BS Chandrasekhar and MAK Pataudi. For some of my friends, the idols were film stars. That changed overnight with the American moon landing. I put up large pictures of Neil Armstrong, Buzz Aldrin and Michael Collins, cut out from newspapers, on the walls. My father bought me a large towel with pictures of astronauts and the Moon. Half a century later, the new Indian descendants of the rocket boys — many of them women — are our new stars.

In September 2019, as the launch of Chandrayaan-2 approached, a hundred of us huddled in the cavernous lecture hall of the Inter-University Centre for Astronomy and Astrophysics (IUCAA) in Pune, watching the descent of the *Vikram* lander – the *Pragyan* rover in tow — on the lunar surface, its thrusters in full force, slowing down the free fall of the delicate component of the Chandrayaan-2 spacecraft, all 1,498 kg of it hurtling down, pulled in by the gravity of the Moon.

It had detached from the rest of the spacecraft four days ago, leaving the orbiter in its path about 100 km above the lunar surface, where it was going to spend at least seven more years, its instruments sending back crucial scientific information about the Moon, its environment and even the Sun.

We were applauding the green dot on the plot of the landing trajectory — showing the altitude and the range of the lander — till it reached about 2 km above the surface. Our spirits fell as it deviated from the expected course, and got stuck, indicating that we had lost communication. This is the phase that then Indian Space Research Organisation (ISRO) chief K Sivan described as "15 minutes of terror". The country was crestfallen.

However, the orbiter on Chandrayaan-2 continued to operate, and after the landing dust settled, we told ourselves that the failure of the lander did not mean that the mission was unsuccessful.

We were right. The rest of the mission went on to yield unambiguous evidence of water on the Moon, with the 3-micron absorption feature in the infrared spectrum, and made important breakthroughs in surface mineralogy, composition of the ionosphere and measuring the seismic disturbances on the lunar surface. Chandrayaan-3, its successor, concentrates almost exclusively on the lander and rover. The orbiter will be mostly a propulsion module, and there will be only one experiment on the orbiter.

What went wrong in the landing last time has been analysed in great detail by several teams, based on ISRO's own information, and images and research shared by space agencies across the world. Almost everything that can go wrong has a backup plan, and many more sensors have now been added to raise relevant alarms.

The lander will have a number of changes, including two TTC (tracking, telemetry and command) antennas, two hazard avoidance cameras, a larger fuel tank, and a single engine. There is a laser doppler velocimeter that will be used to measure the velocity of the lander during descent. The landing site has been changed to be about 100 km away, and software vastly improved to prevent the glitch that occurred during the Chandrayaan-2 heartbreak.

The Moon and Earth are supposed to be sisters — formed from the same nebula as the Sun and the rest of the inner solar system. Some models say that the composition of the Moon and the Earth should be similar, though the distribution of the components may be different. Therefore, minerals found deep in the Earth's surface could be found near or on the surface of the Moon. Understanding the formation of the Moon can go a long way in understanding how our own planet was birthed.

Also, our knowledge of the nature of the Moon's thin atmospheric layer, the abundance of charged particles near the surface, and the availability of water will all be very pivotal if we hope to make the Moon a base for future space exploration.

**Chandrayaan-3 is a major undertaking, and has the potential to make significant scientific discoveries** ANI

Chandrayaan-3 is a major undertaking, and has the potential to make significant scientific discoveries. The mission will provide us with new insights into the Moon's history, composition, and potential resources. The lander and rover will conduct detailed studies of the lunar surface, including its composition, mineralogy, and geology.

The mission will also search for water ice, which could be a valuable resource for future lunar missions, as it could be used for drinking water, fuel, and other purposes. Characterising the lunar atmosphere will help us understand how the Moon's atmosphere interacts with the solar wind and other factors. Studying the lunar seismic activity will help us grasp the Moon's internal structure and evolution. And all of this knowledge will come together to paint a better picture of the Moon's formation and evolution.

As for the impact on the general public, and indeed on Indian science, the mission that flies off today is an invaluable milestone.

It further demonstrates India's technological prowess. The successful launch and landing of Chandrayaan-3 will show the world that India has the ability to undertake increasingly complex space missions. This will boost investor confidence and attract more private investment in the space sector., making way for close interaction with the industry for the long-term goal of becoming a major player in the international space industry.

Chandrayaan-3 spurred the development of new technologies, such as the indigenous propulsion module, lander module, and rover. These technologies will have applications in other areas, such as defence, transportation, and health care.

And crucially, it will inspire the next generation of scientists and engineers. The success of Chandrayaan-3 will hopefully motivate young people to pursue careers in science and engineering. This will help to ensure that India continues to be a leader in the global space race. The new heroes of the country need to be the new rocket boys and girls. And for the dreamers, it will bring the Moon much, much closer to us.

*Somak Raychaudhury is vice-chancellor, Ashoka University and former director, IUCAA, Pune.*
*The views expressed are personal*

# MOONSHOT MOMENT

Launching today, Chandrayaan-3 hopes to make India the 4th country to land on the moon's surface. A look at how the mission forms the backbone of the country's aspiration of being at the forefront of global space and scientific developments in the near future.

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Chandrayaan-3, the successor to India's ongoing series of lunar missions, Chandrayaan-1 and 2, is set to launch on July 14, with the target of making India only the fourth nation in the world to successfully land its spacecraft on the surface of the moon.

Isro chairman S Somanath, in an interview with HT earlier this week, said that his organisation is fully prepared for the launch and has taken its lessons from the short-comings of Chandrayaan-2 – it launched on July 22, 2019, and made what Isro described as a "hard landing" on September 6 – to go forward with a so-called "failure-based" design for Chandrayaan-3.

"We are prepared for the launch. Since Chandrayaan-2, we have rectified the errors, and have improved the spacecraft to be more flexible to possible problems," Somanath said.

The success of Chandrayaan-3 is critical not just from the scientific perspective but also because it forms the backbone of the country's aspiration of being at the forefront of global space and scientific developments in the near future.

Leading up to the launch, HT takes a look at why the third lunar mission is significant for furthering India's space ambitions, and how this will pave way for future international collaborations.

### What the mission entails

Chandrayaan-3 aims to pick up from where Chandrayaan-2 left off. With the mission, Isro aims to demonstrate its end-to-end capability in safe landing and roving on the surface of the moon.

It has three objectives — to demonstrate safe and soft landing on the moon surface (which could not be achieved with Chandrayaan-2), to demonstrate rover abilities on the moon surface, and to conduct in-situ scientific experiments.

Chandrayaan-3 will launch on-board the Launch Vehicle Mark-3 (LVM-3) rocket – a 640-tonne behemoth that has now achieved back-to-back success in six mission launches. The launch will take place from the Satish Dhawan Space Centre, Sriharikota, at 2.35pm on July 14.

The 43.5m-tall rocket will carry on it and deploy into space the two modules that form Chandrayaan-3 – a propulsion module, and a lander module.

The propulsion module is designed to ferry the lander module, which will also contain the lunar rover within it, to a 100km lunar orbit. The propulsion module contains a single experimental payload that will study the spectro-polarimetric signatures (the polarisation of light emitted by celestial objects) of Earth in the near-infrared wavelength for 3-6 months as it orbits the moon, according to Isro.

The 1,724-kg lander, which is equipped to "soft land" at a specified lunar site, contains three payloads that will have a mission life of a lunar day (or 14 Earth days) – one each to measure surface plasma density, thermal levels, and seismic activity.

A 26-kg rover will roll out of the lander on the lunar surface and will drive around and carry out in-situ chemical analysis of the lunar surface during the single lunar day it will be active.

Isro chief, Somanath said that Chandrayaan-3 is expected to start lunar orbit nearly a month after its launch, and its lander and rover are expected to land on the moon on August 23.

The landing site is near the south pole (300km from the lunar south pole) at 70° latitude. If all goes to plan, India will become the first country in the world to soft-land near the lunar south pole. Before this, all other lunar missions have only managed to make a landing in the equatorial region of the moon — a few degrees north or south of the equator. Nasa's Surveyor-7, which landed near 40°S in 1968, is the furthest that any craft has landed from the equator.

### So, what lessons were learnt from Chandrayaan-2?

A senior Isro scientist involved in the Chandrayaan-3 mission explained that Chandrayaan-2 went well till the final phase of its intended mission plan, but it could not make a soft landing. Soft landings, when a craft touches down at a safe, slow and controlled speed, are particularly critical on crewed missions or missions in which the spacecraft is expected perform scientific experiments and tests after landing.

The Chandrayaan-2 orbiter, however, is currently functional and continues to provide critical data to Isro.

"We landed with a higher velocity – we call this a crash landing. But if you analyse the mission in its entirety, we have perfected the part of reaching up to the moon. We did it during Chandrayaan-1, Chandrayaan-2 and also during the Mars orbiter mission," the official explained.

The analysis report prepared by Isro after Chandrayaan-2 highlighted that the five engines that were used for the reduction of velocity, developed a higher entry thrust than was intended. The intention was for the lander to lose most of its velocity by the time it was around 400m from the lunar surface and start the process of hovering above the intended landing site to ensure a soft vertical descent. The extra speed, however, caused it to crash on the moon's surface, Somanath explained in the interview.

Another roadblock that Chandrayaan-2 came across was that the landing spot was limited to 500m by 500m, which did not provide enough flexibility for the craft to overcome possible errors and still ensure safe landing. This time the marked landing area has been increased to 4km by 2.5km.

A major change from Chandrayaan-2, is that Chandrayaan-3 will focus on a major orbiter this time, since the scientific objective for the orbiter was already achieved in the second mission. Isro has also increased the fuel capacity so that it can move to an alternative landing site, in case of an unforeseen problem during landing.

Ajey Lele, consultant at Manohar Parrikar Institute for defence studies and analyses, said that learnings from Chandrayaan-2 have led to many improvements, which appears to go in Isro's favour this time.

"During Chandrayaan-2, we could not manage a soft landing as intended. But the learnings from this mission have helped improve the science and technology aspects of Chandrayaan-3, which is extremely important," Lele said.

### Competing missions

While India is racing to become the fourth country to land on the moon – the United States, the former Soviet Union and China have already achieved it – there are other countries also in the fray with ambitious lunar missions lined up in the weeks following Chandrayaan-3.

After much delay, Russia's space agency Roscosmos announced earlier this year that it will be launching its robotic Luna 25 lander on July 13. However, the mission is still coping with delays, and is now scheduled to launch in August. Luna 25 will be Russia's first lunar expedition since the fall of the Soviet Union, the last mission being the Luna 24 lunar sample return in 1976. The mission was earlier scheduled for 2021, but has missed deadlines repeatedly. The spacecraft, which is due to fly on-board a Soyuz-2.1b, will also target the lunar south polar region, where it will operate for at least a year.

Meanwhile, Japan's space agency — the Japan Aerospace Exploration Agency (JAXA) — earlier this week announced the launch date for its X-Ray Imaging and Spectroscopy Mission (XRISM) and the Smart Lander for Investigating Moon (SLIM) mission, for August 26. XRISM mission, in association with Nasa and the European Space Agency, is a replacement for Japan's Hitomi X-ray astronomy satellite, which failed a month after its launch in February 2016. SLIM hopes to make Japan join the elite club of lunar landing nations, and will perform a precision landing on the lunar surface.

## 384,400km

THE AVERAGE DISTANCE BETWEEN THE EARTH AND THE MOON

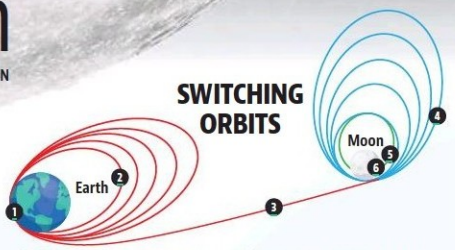
## A 48-DAY-LONG LUNAR MISSION

**Landing date**
**August 23**

**The payload**
The payload of Chandrayaan-3 consists of an indigenously made propulsion module, lander module, which will also have the rover within it

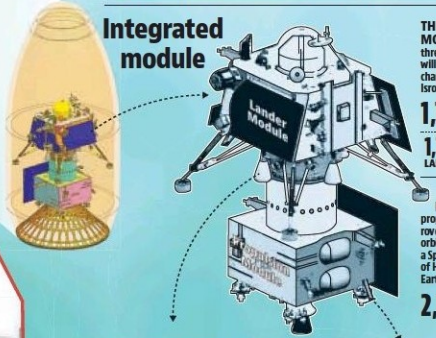
**Launch vehicle**
Launch Vehicle Mark-3 (LVM-3). It was previously known as GSLV Mk-III


### SWITCHING ORBITS




1. Chandrayaan-3 is scheduled to be launched from the Satish Dhawan Space Centre at Sriharikota on-board the LVM3 on July 14, 2023
2. After launch, it will be injected into an Earth parking orbit during the "Earth-bound Manoeuvre Phase".
3. A series of manoeuvres during this phase will raise the orbit of Chandrayaan-3 and put it on lunar transfer trajectory.
4. On entering the Moon's sphere of influence, thrusters will slow it down for lunar capture
5. The orbit of Chandrayaan-3 around the moon will be circularised to 100km by 100km through a series of complex orbital manoeuvres with the help of thrusters on the propulsion module
6. On the day of landing, the lander will separate from the orbiter and perform a series of maneuvers.

### Integrated module

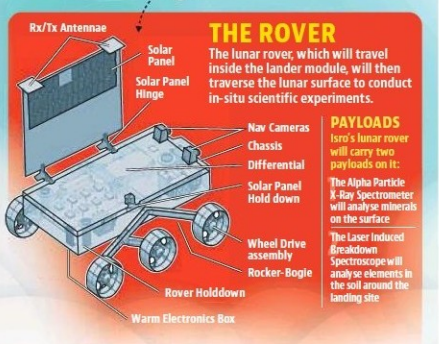



**THE LANDING MODULE** contains three payloads, and will also have a chamber to house Isro's lunar rover.

1,750kg TOTAL MASS
1,724kg LANDER | 26kg ROVER

**PROPULSION MODULE** will propel the lander and rover till 100km lunar orbit. In it there is also a Spectro-polarimetry of Habitable Planetary Earth (SHAPE) payload

2,145kg TOTAL MASS

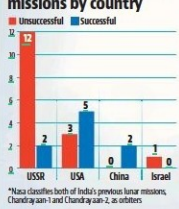




**THE ROVER**
The lunar rover, which will travel inside the lander module, will then traverse the lunar surface to conduct in-situ scientific experiments.

**PAYLOADS**
Isro's lunar rover will carry two payloads on it:
The Alpha Particle X-Ray Spectrometer will analyse minerals on the surface
The Laser Induced Breakdown Spectroscope will analyse elements in the soil around the landing site

# Where Chandrayaan-3 lies in the historical context of lunar exploration

**CHART 1 All previous lander missions by country**

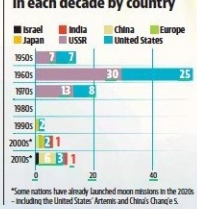



*Nasa classifies both of India's previous lunar missions, Chandrayaan-1 and Chandrayaan-2, as orbiters

**CHART 2 Total moon missions in each decade by outcome**


Source: Nasa

**CHART 3 Total moon missions in each decade by country**




*Some nations have already launched moon missions in the 2020s – including the United States' Artemis and China's Chang'e 5.

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**NEW DELHI:** When the 640-tonne Launch Vehicle Mark-3 (LVM-3) rocket takes off on Friday, it carries not only the Chandrayaan-3, but also the weight of history as it seeks to place India in an elite club of nations that have successfully landed on the moon. Here are some charts that explain how this mission is placed in historical context.

### India aims to be the 4th nation to ever achieve a soft landing on moon

A soft landing takes place when a spacecraft lands intact on the lunar surface and does not, intentionally or unintentionally, crash. Till date, four countries – the former Soviet Union, the United States, China and Israel – have previously attempted such landings on the moon. All but Israel have succeeded.

This means that if Chandrayaan-3 is a success, India will be the fourth nation to ever accomplish this feat. The Chandrayaan-2 mission, which ended in a "hard landing" on the lunar surface on September 6, 2019, was also an orbiter mission (which succeeded). Thus, it is not included in Nasa's aggregation of past lander attempts. (See Chart 1)

### Interest – and success – in lunar missions is rising

The Space Race between the United States and the Soviet Union during the Cold War inspired intense investment in space exploration from the late 1950s to the mid-1970s. After a lengthy hiatus – no country executed a single lunar mission in the 1980s – exploration of the Moon resumed in the 1990s. In the time since the Space Race, the portion of successful missions has only generally increased, data shows. (See Chart 2)

### A growing list of nations are starting to join in

With the conclusion of the Space Race, more countries jumped in to join the United States and Russia beginning in the 1990s. Japan executed the first successful lunar mission by a country other than the US or Russia in 1990. Europe, China also accomplished trips to the moon, with the first successful European lunar mission launching in 2003 and the first successful Chinese one launching in 2007. India was not far behind, as the first Indian mission – Chandrayaan-1 – was executed in 2008.

Israel has also since tried, with Beresheet in 2019 becoming the first privately funded mission sent into outer space. It did not, however, land successfully on the lunar surface. (See Chart 3)