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NEW DELHI/METRO
Thursday, August 24, 2023

Hindustan Times
FIRST VOICE. LAST WORD.

CHANDRAYAAN-3, 2, 1... CONTACT

Vikram lands at 6.03pm, making India the 4th country to successfully park on the Moon, and the 1st in history to reach the lunar south pole

Grand moment of success for India comes after a 20-year-long lunar programme and 4 years after Chandrayaan-2 did not succeed

'India is on the Moon,' declares Isro director S Somanath as country hails massive team of scientists that pulled off a flawless mission

Celebrations across the country and accolades from across the world, as Isro opens doorway to lunar exploration and future space missions

MOONSHOT MOMENT

Soumya Pillai
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BENGALURU: India became the first country to land near the Moon's uncharted south pole region at 6.03pm after 18 nail-biting minutes of descent ended in a perfect touchdown, offering irrefutable evidence of the astronomical abilities and galactic ambitions of a nation that on Wednesday announced itself as one of the world's foremost space powers.

Chandrayaan-3's touchdown — which completed an extraordinary arc of decades of scientific perseverance culminating in the automated choreography of 12 big and small rocket engines executed to clinical precision — also opened new vistas for the country's space programme in the lucrative market of space exploration and commerce.

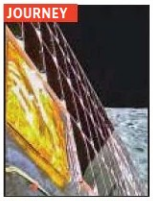
"India is on the Moon!" S Somanath, the chief of Indian Space Research Organisation (Isro) said, as the Chandrayaan-3's lander Vikram, with the Pragyan rover contained within, made a safe and soft landing on the Moon.

The watershed moment came mere days after Russia — a space veteran — crashed its mooncraft while attempting to reach the same territory. At an estimated budget of $75 million, Chandrayaan-3 was built at a fraction of the cost of not only previous American lunar missions but also this summer's cinema blockbusters *Oppenheimer* and *Barbie*.The Russian Luna-25 had cost $200 million.

"This is a victory cry of a new India," said Prime Minister Narendra Modi, waving the Indian flag as he watched the landing from South Africa. Beaming scientists and officials burst into applause and hugged each other in joy at Isro's mission operations complex at Bengaluru after the Vikram lander finally came to a rest on the rugged lunar terrain after 18 minutes that pushed millions in India on the edge of their seats.

The two robotic explorers Vikram and Pragyan will now take readings and images of Earth's satellite,

continued on →8



The Moon as captured by Chandrayaan-3's Lander Imager Camera moments after landing. ISRO/X

MADE IN INDIA
The success of Chandrayaan-3 is likely to boost the Centre's Make in India programme and spur investments in private space enterprises. Isro officials said the agency took help from several private partners to ensure that parts of the spacecraft are manufactured in India. →P10


The Rocketeers: Stars of the moon mission

THE DREAM TEAM OF ISRO
Five key figures at Isro were instrumental in the Chandrayaan-3 mission, each helming a separate arm of the project and ensuring a soft, stable landing on the Moon. →P11

A LOW-COST MIRACLE
Chandrayaan-3 was built and launched at an estimated budget of $75 million, according to the most recent information available. In comparison, Russia's Luna-25, which crashed while trying to reach the same area of the Moon last week, took roughly $200 million to build and launch. →P11

18 tense mins to a timeless milestone

Soumya Pillai and Jamie Mullick
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BENGALURU/NEW DELHI: When Russia's Luna-25 crashed during its attempt to touchdown on the lunar surface on Saturday, it brought global attention on the grave challenges that even space superpowers face in missions of such magnitude.

Indian scientists were well-versed with these challenges.

Chandrayaan-3's descent on Wednesday started, as planned, at 5.45pm IST. The entire landing process largely comprised seven steps, with one additional step at the end that marks the release of the Pragyan rover.

During this 18-minute-long landing procedure, Chandrayaan-3 would drop 30km in altitude, and it would fluctuate between speeds of 5,760km per hour, to a near-still hovering at around 150m from the surface, to finally dropping down. →P2

FULL COVERAGE ON PAGES 2, 10, 11

'Moon landing a clarion call for developed India'

BENGALURU: The Chandrayaan-3 mission successfully landing on the moon is a clarion call for developed India, a sign that the country's space mission will continue to break new ground, a success that belongs to all humanity, and an event that and will help moon missions by countries across the world, particularly the Global South, Prime Minister Narendra Modi told a roomful of cheering Isro scientists, minutes after the event.

Separately, Modi also dialled Isro chief S Somanath and congratulated him and his team for the achievement. "Somanath ji, your name has Somanath in it, which is associated with the moon... Many congratulations to you and your team from my side." →P11

CHANDRAYAAN-3
with the primary objective of uncovering hidden lunar secrets. The rover slid down a flap from the lander around 10pm, once the plumes of moondust kicked up by the landing had settled. It will conduct experiments, including an analysis of the mineral composition of the lunar surface.

The mineral composition will be key to answering whether water ice is present at the south pole. This breakthrough could be crucial for drinking, breathing and rocket fuel resources to advance human space exploration deeper into the solar system in the future.

The mission itself, Isro officials said in the past and reiterated on Wednesday, was meant to demonstrate the Indian space agency's aspirations of interplanetary travel and doing so at shoestring budgets unheard of in other countries. Till now, India had not successfully landed a craft on any celestial object.

Isro's technological prowess was evident on Wednesday evening, when the Vikram lander, with the Pragyan rover in its belly, began a delicate and treacherous descent from an altitude of 30km and a speed of 6,048 km/hr. The lander, which separated from the orbiter on August 17, had circumvented the Moon 120 times over four days.

"In this time, all systems were certified and validated," said Somanath.

It was in this complex descent phase four years ago that Chandrayaan-2 had failed to land, spinning out of control and crash landing onto the surface. That project's orbiter, however, is still active and helped Indian scientists piggyback communications to the new spacecraft.

" Chandrayaan-3's work started four years back, but our scientists have been working on Chandrayaan-2 and before that on Chandrayaan-1 for years. We failed last time, but the lessons that we learnt from our failure, helped us perfect this mission," Somanath said.

The descent itself was automated, sent as a series of computer commands 48 hours prior to the actual descent . The execution was the result of nine instruments — items that calculate altitude, sport hazards, estimate angles of incline and approach — made entirely in India.

P Veeramuthuvel, project director, Chandrayaan-3, who was also associated with Chandrayaan-2, said that landing success was a team effort at several levels.

"So many people have contributed to this mission. From the conception plan to building and improving the hardware, to rebuilding the craft, and ensuring that the mission achieves its targets in each step," he said.

The successful landing heralds a new era for India's comparatively frugal space programme that is closing on milestones set by space powers such as the US and former USSR, at a fraction of the cost — a testament to the skills of the country's engineers and scientists who have adapted indigenous technology and devised novel ways to compensate.

Mastery over the technique to land crafts on the Moon will be crucial for the country to conquer a chunk of the burgeoning space exploration market — the next frontier in international economic and military forays. It will also bolster India's position in international space collaboration made possible by the 2020 Artemis Accords anchored by the US.

As Vikram slowly descended on the Moon, millions across India crowded around televisions in offices, shops, restaurants, school classrooms, and homes, breathlessly following every update of India's third lunar mission. Many prayed for the success of the mission in temples, mosques and churches.

Bharat Selvan, a businessman who was distributing sweets at the gate of ISTRAC on Wednesday after the landing, said that it was a moment of pride for every Indian.

"I do not know the details of the mission. I will leave that for the scientists to discuss. But today every Indian is proud of what we have achieved. We have managed to do what no other country has done, even the developed nations. This will encourage the younger generations to take up science and make us a superpower," Selvan said.

The landmark moment held echoes of the iconic July 1969 Moon landing, which galvanised a generation of Americans and propelled innovation and scientific temper, sealing US's position as a leading military and industrial power for the next half-century.

After the landing, congratulations poured in.

"Today with the successful Moon landing ...our scientists have not only made history but also remade the idea of geography...the kind of event that happens once in a lifetime making India proud," President Droupadi Murmu said in a video message.

"Chandrayaan 3's soft landing on the uncharted lunar south pole is the result of decades of tremendous ingenuity and hard work," Rahul Gandhi said in a post on X, formerly called Twitter.

Praise also came in from around the world. "Your success will power the imagination and light the future of people around the world," the US State Department's Bureau of Oceans and International Environmental and Scientific Affairs posted on X.

"Incredible!" European Space Agency's director general Josef Aschbacher tweeted. "I am thoroughly impressed."

Nasa's former science mission chief, Thomas Zurbuchen, who now works at ETH Zurich, a public research university in Switzerland where he is leading its space initiative, said he felt proud of the achievement.

Russia's space agency Roscosmos congratulated India on the landing.

"Exploration of the Moon is important for all mankind. In the future it may become a platform for deep space exploration." it said in a post on its Telegram channel.

SPOTLIGHT MOONSHOT MOMENT

THE MISSION ANATOMY

Chandrayaan-3 started its journey to the Moon on July 14 from Satish Dhawan Space Centre Second Launch Pad in Sriharikota.

Lessons from 2019 play out in 18 mins

In the 4 years since Chandrayaan-2, Isro scientists learnt all they could from their failure, then executed those lessons in a tense 18-minute show of perfection

Soumya Pillai and Jamie Mullick
letters@hindustantimes.com

Isro scientists and engineers at mission operations complex in Bengaluru on Wednesday. ISRO

BENGALURU/NEW DELHI: When Russia's Luna-25 crashed during its attempt to touchdown on the lunar surface on Saturday, it brought global attention on the grave challenges that even space superpowers face in missions of such magnitude.

Indian scientists were very well-versed with these challenges.

Not one Indian Space Research Organisation (Isro) scientist working on Chandrayaan-3 needed reminding that the final moments before the craft's landing would be the most perilous. In the four years since Chandrayaan-2, they had spent sleepless nights reliving these final moments of that craft — moments that were perhaps the ones that brought them the most pain.

This time, they knew exactly what they wanted: Braking commands had to be far more precise to ensure that the autonomous landing was executed in a controlled manner and velocity, adequately dropped. And ground stations had to ensure continuous uninterrupted contact with the lander module to keep track of the progress of the descent and make any corrections, if needed.

This time, they knew how to get it done to avoid a repeat of September 2019.

This is why the landing of Chandrayaan-3 marks a pivotal milestone in India's colossal space ambitions. It redraws the global list of space superpowers – placing India among the very elite group consisting of just three other nations that have landed a spacecraft on the Moon.

Chandrayaan-2, and the lessons from it

Speaking to reporters after the landing, Isro chief S Somanath said scientists working on Chandrayaan-3 spent years analysing each contingency and rectifying the errors of Chandrayaan-2, strengthening the hardware and software of the craft, and have prepared for worst-case scenarios.

"The unsuccessful attempt to soft land with Chandrayaan-2 has really helped us to perfect the landing methodology [for Chandrayaan-3]. We were also able to have a large number of experiments that helped us perfect the process of landing. And today, it is efforts like these that have paid dividends," Somanath said.

"Most of the people who were involved in Chandrayaan-2 are working with us and helping us on Chandrayaan-3. And they have gone through such an agony of what went wrong [Chandrayaan-2]. They spent a year, thrashing through the data of Chandrayaan-2... The credit goes to those people," he added.

"Four years is not a short period [of time], and we have utilised every bit of it in bettering our mission, to map all contingencies and prepare backup plans. In fact, we have prepared backups of our backup plans as well," he told HT in an interview on Tuesday.

How the landing was executed

Chandrayaan-3's descent started, as planned, at 5.45pm IST. The entire landing process largely comprised seven steps, with one additional step at the end that marks the release of the Pragyan rover.

During this 18-minute-long landing procedure, Chandrayaan would drop 30km in altitude, and it would fluctuate between speeds of 5,760 km per hour, to a near-still hovering at around 150m from the surface, to finally dropping down.

The first phase of the Chandrayaan-3's descent was a phase called "rough braking". As it was orbiting the Moon at an altitude of 30km, and around 750km away from the landing spot, all four main engines of the craft were activated, plummeting it down towards the lunar surface. In the next 11 minutes, Chandrayaan dropped nearly 23km and reduced around 4,500 kmph of horizontal speed (at which it was headed to the landing spot).

In the second phase, where altitude dropped from 7.4km to 6.8km, eight smaller thrusters fired on the spacecraft, tilting its orientation from 90° to 59° – giving it the ability to photograph the surface and identify its final landing spot.

Still barrelling towards the landing location at over 1,300kmph, the spacecraft entered its third stage, with the main rockets firing once again to reduce horizontal speed. Meanwhile, the small thrusters worked to bring the orientation of the Vikram lander to near-straight. During this stage, altitude of the craft dropped from 6.8km to 800m.

Stage four, known as "fine braking" stage, is where Chandrayaan-3 had struggled. As altitude drops from 800m and 150m, the craft uses its cameras to scrutinise an obstruction-free path to reach the selected spot to land – in the case of Chandrayaan-3, this was a 4km by 2.5km patch of highland between the Manzinus and Boguslawsky craters. Four years ago, the engines of Chandrayaan-2 ended up providing slightly more thrust than needed due to an error, which led to the craft to spinning around this time. Another issue with Chandrayaan-2 was that its target landing zone was much smaller – just 500m by 500m, giving the spacecraft very little room for error in final manoeuvre.

The Isro chief said that additions of new world-class sensors on Chandrayaan-3 helped them overcome the obstacles they struggled with the last time.

"The technology we have deployed in Chandrayaan-3 is no less complex and advanced than any other technology that goes to the Moon [by other countries]. We have the best of the sensors in the world, and we have used them in Chandrayaan-3. One of the main differences between Chandrayaan-2 and Chandrayaan-3, is an instrument has been added that is called laser doppler velocimeter. This is a world-class instrument developed by one of the labs of Isro and it is capable of measuring minute changes in velocity," Somanath said.

Stage five was when most scientists could feel they were within seconds of history. In this stage, Chandrayaan successfully managed to drop to an altitude of 150m and then hovered for about half a minute. During this hover, it was able to make final adjustments and deviated to a slightly safer location to land.

From here, it was easy cruising.

In stages six and seven, the craft dropped to an altitude of 10m, from where thrusters powered down, dropping the lander on the lunar ground. In doing so, Somanath said, Chandrayaan-3 managed a far safer speed than they were prepared for.

"We were able to achieve most of the optimal conditions required for landing. The final landing velocity we achieved was far less than 2 metres per second (around 7km per hour), which gives us a lot of confidence that the health of the craft will be very good. This also tells us that we will be able to roll out Pragyan and conduct our experiments as planned."

Next steps

The Vikram lander is carrying the Chandra's Surface Thermophysical Experiment (ChaSTE) to measure thermal conductivity and temperature; Instrument for Lunar Seismic Activity (ILSA) for measuring the seismicity around the landing site; Langmuir Probe (LP) to estimate the plasma density and its variations. A passive Laser Retroreflector Array from the National Aeronautics and Space Administration (Nasa) is also accommodated for lunar laser ranging studies.

The Pragyan rover has the payload of the Alpha Particle X-ray Spectrometer (APXS) and Laser Induced Breakdown Spectroscope (LIBS) for deriving the elemental composition in the vicinity of landing site. It rolled out around four hours later without any problems, according to senior Isro officials.

Both modules – the lander and rover – will now activate their sensors one by one and start measurements in the hours after the landing and will continue for one full lunar day – about 14 days on Earth.

As Somanath said: "We are looking forward to very exciting 14 days for Chandrayaan-3!"

HOW WEDNESDAY'S LANDING UNFOLDED

5.45pm

STAGE 1
ALTITUDE **30.3 to 7.4 km**
HORIZONTAL SPEED **5,760 km/hr**
VERTICAL SPEED **0 km/hr**

ROUGH BRAKING
Here the craft starts its descent. During this phase, the craft drops from the 30km orbit – where it's travelling at 5760km/hr horizontally – to an altitude of 7.4km. The spacecraft drops at a peak speed of 256km/hr.

STAGE 2
ALTITUDE **7.4km to 6.8km**
HORIZONTAL SPEED **1,325 km/hr**
VERTICAL SPEED **220 km/hr**

TILT ADJUSTMENT
Here the craft starts its descent. During this phase, the craft drops from the 30km orbit – where it's travelling at 5,760km/hr horizontally – to an altitude of 7.4km. The craft drops at a peak speed of 256km/hr.

STAGE 3
ALTITUDE **6.8km to 800m**
HORIZONTAL SPEED **1,300 km/hr**
VERTICAL SPEED **215 km/hr**

ORIENTATION FIX, HORIZONTAL BRAKING
During this phase, the craft performs the critical manoeuver of straightening its orientation from 59° inclination to near-vertical. Rockets, meanwhile, fire once craft is straight to reduce the dropping speed.

STAGE 4
ALTITUDE **800 to 150m**
HORIZONTAL SPEED **15 km/hr**
VERTICAL SPEED **40 km/hr**

FINE BRAKING
Between 800m and 150m, the rapidly dropping velocity is brought under control as the spacecraft uses its cameras to scrutinise an obstruction-free path to reach the landing spot.

5.56pm

5.57pm

STAGE 5
ALTITUDE **150 to 60m**
HORIZONTAL SPEED **0-1 km/hr**
VERTICAL SPEED **0 km/hr**

HOVERING, LOCAL NAVIGATION
This is the stage Chandrayaan-2 failed to achieve. Here, the craft hovers at an altitude of 150m above the lunar surface, making small adjustments to place itself right above the precise landing spot.

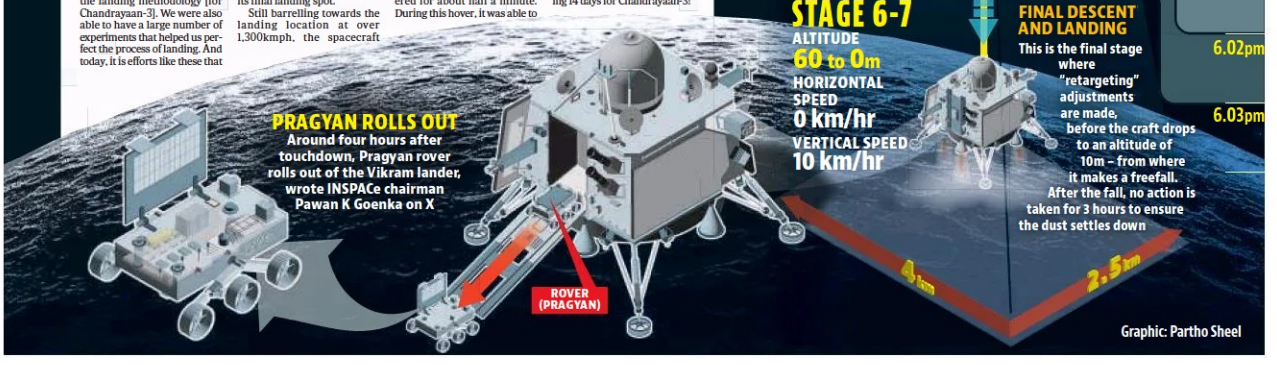
6pm

STAGE 6-7
ALTITUDE **60 to 0m**
HORIZONTAL SPEED **0 km/hr**
VERTICAL SPEED **10 km/hr**

FINAL DESCENT AND LANDING
This is the final stage where "retargeting" adjustments are made, before the craft drops to an altitude of 10m – from where it makes a freefall. After the fall, no action is taken for 3 hours to ensure the dust settles down

6.02pm

6.03pm

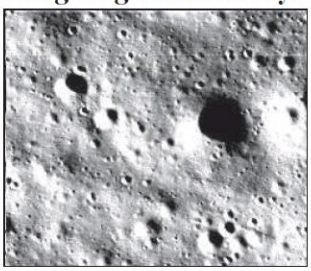
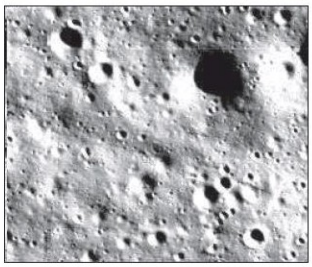


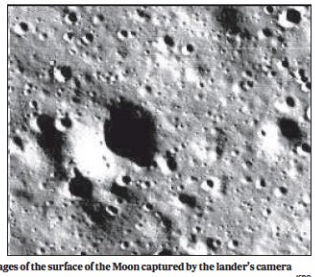
Graphic: Partho Sheel

SPOTLIGHT MOONSHOT MOMENT

Inception, propulsion... and new glimpses of the Moon: Defining images of Chandrayaan-3





(Anti-clockwise from top) The lander and propulsion modules of Chandrayaan-3 before their transportation to the launch pad; the LVM-3 rocket, carrying the spacecraft to the launchpad; the spacecraft launched from Sriharikota centre in Andhra Pradesh. ISRO

The Indian Space Research Organisation on Wednesday shared images of the surface of the Moon captured by the lander's camera during its descent. ISRO

'We dreamt on Earth, fulfilled on the Moon'

Modi says India's space mission will continue to break new ground, and help moon missions by other countries

Prime Minister Narendra Modi waves the Indian flag while watching the live telecast of the Chandrayaan-3's successful soft landing on the Moon, via video conferencing in Johannesburg. PTI

HT Correspondent
letters@hindustantimes.com

BENGALURU: The Chandrayaan-3 mission successfully landing on the Moon is a clarion call for developed India, a sign that the country's space mission will continue to break new ground, a success that belongs to all humanity, and an event that will help moon missions by countries across the world, particularly the Global South, Prime Minister Narendra Modi told a roomful of cheering scientists from the Indian Space Research Organisation (Isro) minutes after the historic event.

Modi, who is in Johannesburg for the Brics Summit, virtually joined the scientists gathered at Isro's Telemetry, Tracking and Command Network (ISTRAC) in Bengaluru to follow the final moments of the descent, and waved the Tricolour on the screen when it became clear that India had become the first country in the world to land on the lunar south pole.

In the minutes that followed, Isro chief S Somanath took to the mike, and said to the Prime Minister, "Sir, we have achieved soft landing on the Moon. India is on the Moon."

Prime Minister Modi responded: "When we see history being made in front of our eyes, life is blessed. This moment is unprecedented. This moment is unimaginable; this moment is developed India's clarion call... In the first light of 'Amrit Kaal', this is the 'Amrit Varsha' of success. *Humne dharti par sankalp liya, aur chand par usse sakaar kiya* (we dreamt of this on earth, and made the dream come true on the Moon). As our scientist colleagues said, India is now on the Moon."

Modi describes "Amrit Kaal" as the period between India's 75th and 100th years of Independence, between 2022 and 2047, and said in his Independence Day speech last week that the aim was to make India a developed country by the time this 25-year period ends.

In his brief address on Wednesday, Modi said that though he was in South Africa, like everyone else in the country, his mind was with the Chandrayaan-3 mission.

"This new history has meant every Indian is full of joy. In every home, there is a festival. I congratulate Team Chandrayaan, team Isro, and all scientists in the country, those who have worked for years for this moment," Modi said.

The Prime Minister said that landing on the Moon's south pole was an achievement no other country in the world could boast of.

"From today, the myths associated with the Moon will change... In India, we call the earth "*ma*"(mother) and the moon "*mama*" (uncle). It was once said "*chanda mama bahut door ke hai*"(the Moon is very distant). Now, one day will come when children will say *chanda mama bas ek tour ke hai* (the Moon is just a tour away)," he said.

Modi also addressed the "people of the world" and said the success of the moon mission is not India's alone. "This is a year where the world is witnessing India's G-20 presidency. Our approach of one earth, one family, one future is resonating across the globe. This human centric approach that we present and represent has been welcomed universally," he said.

The Prime Minister said that the moon mission was also based on this "human-centric" approach and was evident that countries from the Global South could match these achievements.

"This success belongs to all of humanity and it will help moon missions by other countries in the future. I am confident that all countries in the world, including those from the Global South, are capable of achieving such feats. We can all aspire for the Moon and beyond," he said.

Modi also said that India's space programme would not stop here, would test the limits of the solar system, and work to realise the infinite possibilities of the universe.

"We have set big targets for ourselves. Soon, for a deep study of the sun, Isro will launch Aditya L1. Venus is in our sight. And for Gaganyaan – India's first human space flight mission – India is preparing hard...today's success is proof that through lessons learnt, defeat can be turned into victory," Modi said.

Separately, Prime Minister Modi also dialled Isro chief S Somanath and congratulated him and his team for the historic achievement.

"Somanath ji, your name has Somanath in it, which is associated with the Moon. Your family will also be tremendously happy today. Many congratulations to you and your team from my side.," Modi said, adding that he would soon meet and felicitate the scientists in person.

The word "Somanath" means "lord of the moon".

CHRONICLING THE THREE LUNAR MISSIONS

Feb 7, 2023: Isro identifies possible landing sites for Chandrayaan-3

March 16: Space agency successfully conducts key tests for the project

May 19: Isro starts assembly process for payloads for Chandrayaan-3

July 14: The spacecraft lifts off from Sriharikota centre

July 15: Performs 1st orbit-raising maneuver successfully; health of spacecraft 'normal'

August 1: Chandrayaan-3 completes its orbits around the Earth and heads towards the Moon

$75 million
Total cost of the Moon mission

August 5: Spacecraft inserted into the lunar orbit, initiating mission's final phase to the Moon

August 6: Isro releases first images of the Moon captured by the spacecraft

Aug 23: Chandrayaan-3 successfully lands on the lunar south pole

August 17: Propulsion module successfully separated from Chandrayaan-3's lander

Chandrayaan-1

Oct 22, 2008: Five years after Vajpayee's announcement, Chandrayaan-1 takes off from Satish Dhawan Space Centre at Sriharikota

Nov 8: Spacecraft enters a lunar transfer trajectory, a maneuver to set it on a path that will cause it to arrive at the Moon

Nov 14: As planned, the Moon Impact Probe ejects and crashes near the lunar South Pole. With the mission, Isro becomes the fifth national space agency to reach the lunar surface

Chandrayaan-2

Sept 18, 2008: The then PM Manmohan Singh-led cabinet approves Chandrayaan-2

Feb 16, 2018: Minister Jitendra Singh announces Chandrayaan-2 will land on moon in April 2018

July 22, 2019: Chandrayaan-2 lifts off from Satish Dhawan Space Centre, Sriharikota

Sept 2: The lander is separated while orbiting the Moon. The orbiter continues to provide data

Sept 6: It makes a 'hard landing' on the Moon. The mission partially meets its objective

{ BILL NELSON } NASA ADMINISTRATOR

...Congratulations to India on being the 4th country to successfully soft-land a spacecraft on the Moon. We're glad to be your partner on this mission.

Make in India gets shot in arm as Isro breaks new ground

HT Correspondent
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BENGALURU: The success of the Chandrayaan-3 mission on Wednesday is likely to boost the Centre's ambitious Make in India programme by spurring investments in private space launches and related satellite-based businesses, according to experts.

The Indian Space Research Organisation (Isro)'s remarkable feat has opened new vistas for the country's space programme in the lucrative market of space exploration and commerce and is expected to assist private space companies increase their share of the global launch market.

Following the successful completion of the lunar project, shares of 13 Indian space-sector companies, including PTC Industries Ltd, Zen Technologies Ltd. and Centum Electronics Ltd., rallied and added more than $2.5 billion in market value this week, according to data compiled by Bloomberg.

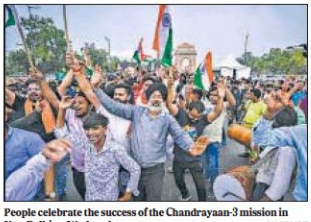
The Make in India programme dates back to 2014, the first year of the Narendra Modi government's first term in office, and is aimed at attracting investments in the manufacturing sector. Since then, the government has focussed heavily on indigenising a space programme that so far leaned heavily on foreign manufacturers.

According to officials, for the lunar mission, Isro took help from private partners to ensure that parts of the spacecraft, the hardware and other components are manufactured in India. This also ensured that the mission was cost effective in the longer run.

Tata Consulting Engineers Limited (TCE), the largest Indian private-sector engineering and project management consultancy, engineered unique and indigenously built critical systems and sub-systems for the project. These facilities played an important role in the launch of the mission. Similarly, Godrej Aerospace, a business unit of Godrej and Boyce, made significant contributions by supplying liquid propulsion engines such as Vikas Engine and satellite thrusters. "The mission's overarching goal is to advance and showcase novel technologies essential for future interplanetary endeavors. While this is Isro's mission, not many of us are aware of the hard work and contributions of many other private companies like Larsen & Toubro, Walchandnagar Industries, Centum Electronics, Godrej & Boyce, Ananth Technologies who have contributed," Lt. Gen. AK Bhatt (Retd.), director general, Indian Space Association, said.

{ ACROSS COUNTRY }

Celebrations break out as Indians revel in success of lunar mission



People celebrate the success of the Chandrayaan-3 mission in New Delhi on Wednesday. RAJ K RAJ/HT

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NEW DELHI: India erupted in rapturous celebrations on Wednesday, feting the milestone landing of Chandrayaan-3 on the Moon's lunar surface, as scores of people burst crackers, distributed sweets, and went out on the streets with the Tricolour in their hands and songs on their lips.

Special screenings of the spacecraft's landing on the Moon were organised by educational and public institutes and organisations across the country. The Indian Space Research Organisation (Isro) made the live events available on its official website, YouTube channel and Facebook account, and on public broadcaster DD National.

"When the countdown began, there was pin-drop silence in the school hall and after the Moon successfully made a soft landing, everybody was shouting with pride. We are lucky that we saw this moment live," Aditya Shrivastava, a Class 8 student of NRI Global Discovery School in Bhopal, said.

"I am so proud of India's space research and successful missions. Isro has put India in the world map of space missions and made us feel proud to become the first country to land on the south pole," Vedika Purohit, a BBA student of Vivekananda Global University in Jaipur said.

Several people danced to drum beats and chanted slogans.

"We feel so proud of our country. We saw how the Vikram lander touched the Moon. It was an emotional moment for all of us," Rahul Sarkar, a trader in Ahmedabad, said.

People in several parts of the country also held special prayers at temples, mosques and gurdwaras for the successful landing, while several schools remained open for a few extra hours to enable students to watch the historic moment. In Delhi, Union housing and urban affairs minister Hardeep Singh Puri, along with others, joined a special "*ardas*" (prayer) at Gurdwara Bangla Sahib to pray for the success of the mission. Nearly 150 girl students of Al Jamiatul Islamia Islahul Banat madrassa at Mandoli were also part of a special prayer held there, hours before the scheduled landing.

Government schools in Uttar Pradesh remained open for an extra hour, on the directions of chief minister Yogi Adityanath, to watch the live streaming of the landing. A similar order was also issued by the Assam government to its schools.

SPOTLIGHT MOONSHOT MOMENT

HISTORY, ETCHED IN SPACE

Relief, delight in the Isro command centre as a nation waiting with bated breath for 18 anxious minutes exhales and exults

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BENGALURU: At 6pm, S Somanath, the chairman of the Indian Space Research Organisation (Isro), knew that his agency had done it. He got up from his seat at Isro Telemetry Tracking and Command Network (ISTRAC) in the Peenya industrial area of Bengaluru, smiled at the anxious faces around him, and nodded his head as if to tell himself the mission was successful.

Two minutes later, the communications centre, from where he and his team were tracking Chandrayaan-3 as its lander descended onto the lunar surface, broke into loud cheers and applause. Minutes later, Somanath commandeered a microphone and said five words that only caused the applause and the cheers to grow louder.

"India is on the moon!"

Until then, the air in the large room was thick with tension. The landing process was preprogrammed but a bunch of things could go wrong, like they did four years ago when Chandrayaan-2, the predecessor of the current mission, Chandrayaan-3, saw its lander crash onto the lunar surface. The team picked itself up, dusted itself off, and got down to work. And as Somanath described it in an interview ahead of the launch, it ensured that it was ready with backup plans for backup plans.

It wasn't just them. For 18 minutes (that's how long the landing process actually lasted), a nation held its collective breath. Earlier in the day, people performed prayers in places of worship around the country; schoolchildren spoke of space and their dreams; and nothing else seemed to matter. Not since the US moon landing in 1969 has an entire country been galvanised by the possibility of a breakthrough in space explorations as India was on Wednesday.

Over 60 million people watched a simulation of the landing on the space agency's website; and many more did on TV channels and news websites airing the same feed. Prime Minister Narendra Modi joined the viewing party at Isro remotely from the Brics Summit in Johannesburg, and responded to Somanath's announcement by waving the Indian flag.

"To be witness to such a historic event is a great blessing...It is only the beginning for India, we now have to claim success with missions to the sun and Venus, among many more," he said.

Later, in a phone call with the Isro chief, Modi said, "Your name itself is associated with the moon (Somanath means the lord of the moon), and today you have helped India raise our flag on the moon. Your family will be proud of you, as is every Indian."

That they were. Outside the centre, people gathered with flowers and boxes of sweets. Some danced. Others cheered. And still others looked skyward, as if to visualise the lander (called Vikram) in their minds.

And everyone at the space agency was visibly moved. K Kalpana, the mission's associate project director said that since the last mission, the team had pretty much lived and breathed Chandrayaan-3. Not far from her, but outside the centre, waving the Indian tricolour enthusiastically, Madan Adarsh, a cleaner at ISTRAC said that Wednesday's landing felt like a personal success to him.

Other scientists flashed V and thumbs-up signs; Isro's complement of women engineers, increasingly written about in recent years after years of working in near-obscurity, milled around, hugging each other and posing for the cameras. Kalpana summed it up, her eyes tearing up.

"This is the happiest moment of my life, and I am sure it is the same for many of us today. Each failure comes as a lesson and we did not get disheartened from our last failure, instead we learnt from it and improved ourselves."

Somanath himself appeared to be happy to let his team have their moment in the sun, preferring to let them do much of the talking. When he spoke, he generously credited all those who came before at the space agency. And he pointed to how this was only the beginning.

The project's director P Veeramuthuvel said the success would mean that after four years, scientists and engineers at the agency would "sleep peacefully".

He was speaking metaphorically. While the celebrations went on till late, so did work. The rover, Pragyan, rolled out of the lander nearly four hours later. The next phase of the mission had started.

Isro employees watch the successful soft-landing of Chandrayaan-3 on the surface of the Moon, in Bengaluru. PTI

The Rocketeers: Stars of the moon mission

A look at the 5 key figures behind India's lunar mission — Chandrayaan-3 — that propelled the country to a historic success

S Somanath
(Isro chairman)

Leader of the lunar mission, Somanath took charge of Isro in 2022, two years after Chandrayaan-2 failed to land on the Moon. An aerospace engineer, the Isro chairman helped design India's most trusted launch vehicle —Launch Vehicle Mark-3 — that carried the Chandrayaan-3 spacecraft. Since July 14, he has been closely monitoring its progress, including ensuring that all tests were successfully conducted, manoeuvres were done to perfection and finally the landing was achieved successfully. He is an alumnus of Indian Institute of Science.

P Veeramuthuvel
(project director)

In charge of the overall mission of putting together Chandrayaan-3 in coordination with multiple Isro centres, Veeramuthuvel started working on India's third lunar mission in 2019 and is known to have made key contributions to the improved design of the Vikram lander. The Tamil Nadu-based scientist was also involved in the developments of the Chandrayaan-2 mission. An alumnus of the IIT-Madras, Veeramuthuvel was earlier the deputy director of Space Infrastructure Programme Office.

Kalpana K
(deputy project director)

Second-in-command, Kalpana is known as a scientist who pays extra attention to the minute details of the mission. According to her colleagues, she ensured that the mission progressed even during the pandemic. After the mission was announced a success, Kalpana said, "This is the happiest moment of not only my life but the lives of all Indians. I am unable to form words to express how stoked I am." She was previously involved in the second lunar mission and the Mangalyaan mission.

M Sankaran
(director at UR Rao Satellite Centre)

Sankaran heads the UR Rao Satellite Centre that built the Chandrayaan-3 spacecraft. He took charge of the centre in 2021. He has played a pivotal role in the development of solar arrays, power systems, and communication systems for India's two previous lunar missions — the Chandrayaan 1 and 2 and the Mars Orbiter Missions (MOM), also known as Mangalyaan. Sankaran earlier held the position of deputy director for the Communication and Power Systems Unit at URSC.

M Srikanth
(mission director)

He spearheaded the navigation aspect of the mission and was also closely involved in the development of both Chandrayaan 1 and 2. Addressing the space agency's scientists after the success of the mission, he said, "It gives me immense pleasure to address you all for the success of the Chandrayaan-3 and to be a part of this momentous mission. I would like to thank each and every scientist who was involved in the project for fulfilling your part so meticulously and ensuring the success today".

KEY MOMENTS FOR INDIA IN SPACE

1962: Indian space programme, called the Indian National Committee for Space Research (INCOSPAR), is set up

1969: The Indian Space Research Organization (Isro) supersedes INCOSPAR with an expanded role to harness space technology

1975: India's first satellite, Aryabhata, is launched. Named after the famous astronomer, the satellite was entirely designed and fabricated in India and launched by a Soviet Kosmos-3M rocket from Kapustin Yar

1980: Satellite Launch Vehicle-3 was India's first experimental satellite launch vehicle, which placed Rohini satellite (RS-1), in orbit, making India the sixth member of an exclusive club of space- faring nations

1984: Wing Commander Rakesh Sharma became the first Indian citizen to enter space when he flew aboard the Soviet rocket Soyuz T-11 launched from Baikonur Cosmodrome in the Kazakh Soviet Socialist Republic

2014: Mars Orbiter Mission (MOM), also called Mangalyaan, was India's first interplanetary mission that made Isro the fourth space agency to achieve Mars orbit

Years of hard work paid off: Isro chief credits success to his team

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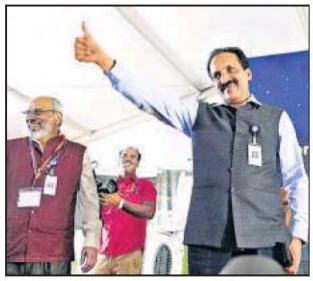
BENGALURU: The lessons that we learnt from our failure helped us perfect this mission, Indian Space Research Organisation (Isro) chief S Somanath said on Wednesday as he credited the success of Chandrayaan-3 mission to the hard work of all the scientists who worked on it for over a decade.

"Many, many years of hard work has paid off today. Chandrayaan-3's work started four years back, but our scientists have been working on Chandrayaan-2 and before that on Chandrayaan-1 for years. We failed last time, but the lessons that we learnt from our failure, helped us perfect this mission," Somanath said while addressing the media at the Isro Telemetry Tracking and Command Network (ISTRAC) in Bengaluru, after the spacecraft's successful soft-landing.

Chandrayaan-3 is a follow-up mission of Chandrayaan-2, India's second lunar mission which was launched in 2019 but failed to make a soft landing on the Moon.

Acknowledging the contribution of a generation of leadership by the scientists of the country's space agency for the mission's success, he said this is an "incremental progress" and "definitely a huge one".

"It (success of Chandrayaan-3 mission) gives confidence to configure missions to not only go to the Moon, but also to go to Mars, sometimes (perhaps) land on Mars, maybe in future go to Venus and other planets... We went through a lot of pain and agony," he said.



Isro chairman S Somanath addresses the media in Bengaluru. PTI

"Most of the people who were with Chandrayaan-2 are with us helping us to do Chandrayaan-3. They are a part of this, they have gone through such an agony...the technology that we have in Chandrayaan-3 is no less complex or inferior to any other technology that goes to the Moon. So, we have the best of the sensors of the world, best in class (equipment) in Chandrayaan-3", he said, explaining that it was a completely "Made-in-India" mission using world-class components.

Conveying the greetings of Prime Minister Narendra Modi to the Isro team, he said, "The Honourable PM called me and conveyed his greetings to each one of you and your family for the wonderful work you did in Isro."

He further halled the support from the government in pursuing the space missions, both scientific and commercial. "Thanks to him (PM) for the support he is giving to us for missions like Chandrayaan-3 and missions that are in the offing. That's the great word of comfort that we are receiving for pursuing the inspirational work that we are doing for the nation."

The Prime Minister is "very, very clear about the long-term vision, and wants to make sure that we remain very, very dominant in the area of space exploration and science", he added.

Addressing the Isro team at the Mission Operations Complex, he thanked all those who prayed for the mission's success, and in particular named Isro veterans like A S Kiran Kumar (former ISRO chief).

"Everyone was praying in their own way. Today's success is a result of all your prayers, love and blessings," he said.

In another press conference in Delhi, Union minister of science and technology and space, Jitendra Singh, said that the landing was just the first step of India's lunar mission. The next few days will ensure that the space agency mines troves of critical data and minerals from the lunar surface.

He further hailed the agency for converting that to reality which the world dreams of.

"While the world fantasises about the moon, we have actually felt the moon...the world dreams of the moon, and we have seen the dream getting converted into reality...sky is not the limit," Singh said.

"We have the ability to achieve success through cost-effective means," he added.

With PTI inputs

THEY SAY

This is a big step forward in space exploration and of course a testament to the impressive progress made by India in the field of science and technology.

VLADIMIR PUTIN, Russian President

This will herald new avenues in scientific research and discovery and it represents a milestone in the march of the nation.

JUSTICE DY CHANDRACHUD, CJI

The achievement is not only testament to the power of Indian genius but also launches India's voyage through the Amrit Kaal to emerge as a global leader in the realm of space...

AMIT SHAH, Union home minister

The success is the result of decades of tremendous ingenuity and hard work by our scientific community...

RAHUL GANDHI, Congress leader

@ISRO represents the best of India. Humble, hardworking women & men, coming together, overcoming challenges, and making our tricolour fly high.

SACHIN TENDULKAR, Cricket legend

Now, Isro sets eyes on Aditya L-1, Gaganyaan

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BENGALURU: The successful landing of India's third lunar spacecraft, Chandrayaan-3, is only the beginning of India's space missions. Repeating the words of Prime Minister Narendra Modi, Indian Space Research Organisation (Isro) head, S Somanath, said on Wednesday that the "golden era" of India's space programme has only begun.

Somanath said that while the focus of the space agency over the last few months has been to ensure the success of Chandrayaan-3, Isro is also working on some other big-ticket projects that are lined up for the coming months. He added that with this mission, India has cemented its name as a worthy player in the global space industry.

"Going to the moon and making a soft landing is a tough mission. It is very difficult for any nation, even with the most sophisticated technology, to achieve this, but we have done it in just two missions. The first mission had a narrow miss and now we have achieved it so perfectly," he said.

He said that this mission will give the space agency confidence to explore the vastness of space to a greater degree, and that for the next three months, Isro has its hands full with missions

People celebrate the success at the Nehru Science Centre in Mumbai. BHUSHAN KOYANDE/HT PHOTO

Aditya L-1

"We have some big missions that are lined up. After Chandrayaan-3, we will immediately be taking up Aditya-L1 project, which is our sun mission...It has already been integrated and has been moved to Sriharikota and maybe today or tomorrow the rocket will also be integrated," Somanath said, adding that the launch of India's first sun mission is being planned for early September.

Aditya-L1 is India's first dedicated scientific mission to study the sun. Earlier, this mission was conceived as Aditya-1 with a 400 kg class satellite carrying one payload, the Visible Emission Line Coronagraph VELC, and was planned to be launched in an 800 km low earth orbit.

However, since a satellite placed in the halo orbit around the first Lagrangian Point (L1) of the sun-earth system has the major advantage of continuously viewing the sun without any occultation/eclipses, the Aditya-1 mission was renamed as Aditya-L1 mission, which will be inserted in a halo orbit around the L1—1.5 million km from the earth towards the sun.

Isro scientists said that the instruments of Aditya-L1 are tuned to observe the solar atmosphere, mainly the chromosphere and corona. In-situ instruments will observe the local environment at L1. "The spacecraft carries seven payloads to observe the photosphere, chromosphere and the outermost layers of the sun (the corona) using electromagnetic and particle and magnetic field detectors. Using the special vantage point L1, four payloads directly view the sun, and the remaining three payloads carry out in-situ studies of particles and fields at the Lagrange point L1, thus providing important scientific studies of the propagatory effect of solar dynamics in the interplanetary medium," Isro's latest mission document said.

Gaganyaan abort mission demonstration

The space agency also announced that the next in line would be a key aspect of India's first human spaceflight mission, Gaganyaan.

The abort mission demonstration for Gaganyaan is expected around the last week of September or early October.

The project envisages demonstration of human spaceflight capability by launching a crew of three members to an orbit of 400km for a three-day mission and bringing them back safely to earth, by landing in Indian sea waters.

"The project is accomplished through an optimal strategy by considering in-house expertise, experience of Indian industry, intellectual capabilities of Indian academia and research institutions along with cutting edge technologies available with international agencies," Isro said in its mission document.

"The prerequisites for Gaganyaan mission include development of many critical technologies including human rated launch vehicle for carrying crew safely to space, life support system to provide an earth like environment to crew in space, crew emergency escape provision and evolving crew management aspects for training, recovery and rehabilitation of crew," it added.

A mission to the Moon, at a fraction of the cost

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NEW DELHI: Chandrayaan-3, which became the first spacecraft to land near the moon's uncharted south pole on Wednesday, was built and launched at an estimated budget of $75 million, according to most recent information available.

In comparison, Russia's Luna-25, which crashed while trying to reach the same area of the moon last week, took roughly $200 million to build and launch, making India's programme notable for success despite requiring much lower spending. The mission itself, Isro officials said in the past and reiterated on Wednesday, was meant to demonstrate the Indian space agency's aspirations of interplanetary travel and doing so at shoestring budgets unheard of in other countries.

Wednesday's success also bodes well for the country's attempts to open up its space sector. "The thing is that everyone wants to collaborate with agencies that can produce successful missions. But over the years we have established our place in the global space industry. We are known to successfully conduct exploratory missions at a much cheaper cost," S Somanath, Isro chief, told HT in an interview on Tuesday.

CHANDRAYAAN-3 SPACECRAFT BUILT AND LAUNCHED AT AN ESTIMATED BUDGET OF $75 MN

The difference between Luna-25 and Chandrayaan-3 illustrates how Isro saved costs. The Russian craft was strapped with a more powerful rocket at launch, and had more powerful thrusters to boost its journey from Earth to moon — features that allowed it to complete the (eventually unsuccessful) journey in 10 days.

By comparison, Chandrayaan-3 took 40 days, using less powerful rockets. The additional days it spent in space were first, in gathering momentum, using the Earth's gravity to slingshot to the moon after multiple revolutions around the planet (Luna-25 circumvented Earth just once), and then around the moon to slow down. India's approach was to make the mission more cost-effective by using the "slingshot" method, officials told HT shortly after the Luna-25 crash, stressing on the fact that comparisons may not be fair.

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{ OUR TAKE }

A moonshot for the future

Chandrayaan-3's success bodes well for lunar opportunities and India's scientific temper

Kicking up plumes of moondust, Vikram landed at 6.03pm, completing an improbable two-decade-long arc in India's lunar exploration. If Chandrayaan-1 in 2008 pushed India into the elite club of space-faring nations, its third iteration propelled the world's most-populous country into its front row. Only three countries have successfully reached the lunar surface before. And no one has done so on the south pole, where critical evaluations of the moon's surface, atmosphere, and the presence of water are possible. This traverse – the 20 years it took for a country to sharpen its indigenous science and technology capabilities, and for thousands of men and women to not be daunted by shoestring budgets to make possible the 384,000 km journey to our nearest neighbour, all to ensure that Vikram, with Pragyan rover in tow, seamlessly decelerated from 6,048 km/h to zero, in 18 heart-stopping minutes – should stand among our proudest moments as a nation.

But as glorious as the past may have been, the moon is about the future. The success heralds a new era for India's space exploration, not just for scientific pursuit but also for business opportunities. A 2021 PWC report appraised the lunar economy at a promising $170 billion with the potential of exponential growth, focussing on transportation, lunar data, and *in situ* resources utilisation. The first deals with the lucrative market of ferrying people and objects to the moon and back. The second allows scientists and agencies to collect and exploit technical data. The third includes mining and extracting resources and products for scientific and commercial purposes. A formidable hurdle was the ability to soft-land a mooncraft regularly and with accuracy – something India showed it is capable of. From the science fiction promise of building lunar colonies to the cold commerce of interplanetary flights, this moment is a watershed.

Space is the ultimate frontier for any nation because it exemplifies the zenith of human exploration. But for a country that threw off the shackles of colonialism a mere 76 years ago and is still pulling millions out of crushing poverty, conquering the moon means so much more. For a pantheon of young boys and girls who watched India step confidently into the vastness of our universe – hunched over rickety wooden benches in their cramped classrooms and village homes – Chandrayaan-3 represented the shattering of limits. Few things can galvanise a nation and imbue scientific fervour like an interplanetary mission. At 6.03pm on a Wednesday evening, a 1,752 kg craft ignited that spark for a new generation of Indians. It showed them that anything is possible.

Chandrayaan opens new vistas for India

The mission's success propels India to the threshold of multilateral joint space missions, exploration of outer space and use of celestial resources in the future

K Radhakrishnan

As Vikram touched down on the surface of the Moon smoothly and safely on Wednesday evening, India became the fourth nation to soft-land an uncrewed craft on the lunar surface, and notably, the first to soft-land on the south pole of the Moon.

Every Indian rejoiced with pride while the whole world watched with awe our rising acumen in the arena of outer space under the leadership of Prime Minister (PM) Narendra Modi, a space buff himself. The technological feats were executed brilliantly by the Indian Space Research Organisation (Isro) along with a host of partners from industry, start-ups, and academia.

Space missions are exciting, but exacting too. They are complex pieces of technology and must operate for long, in the harsh and somewhat uncharted environment of outer space. India hurtled into space in 1962 with modest efforts in space science and rapidly grew on the bedrock of the indomitable vision of Dr Vikram Sarabhai and an exemplary organisational edifice crafted by professor Satish Dhawan. Risk management and failure recovery are part of the practice in rocket science.

The hallmark of India in the global space sector is the focus on its helpfulness for humankind through a constellation of Earth-oriented satellites (for communication, navigation, remote sensing) and an effective institutional tie up with all stakeholders along with concomitant self-reliance in space technology and launch capability. Their impact on stakeholders — in the government, industry and the public at large — is quite high. By the turn of this century, scientific and space exploration missions were here to stay, inspiring young minds, and propelling national pride. India has been expanding its limits in this tough domain and exploring new possibilities, armed with space sector reforms of 2020, and the Indian Space Policy 2023 enunciated recently.

Chandrayaan-1 (2008) and the Mars Orbiter Mission (2014) underscored India's ability for precise navigation into deep space and for the tricky capture of the orbit of these celestial bodies, after a long journey (400,000 kilometres to Moon, and 660 million kilometres to Mars). The Moon Impact Probe of Chandrayaan-1 established a smooth separation from the mother craft in lunar environs, for an intended free fall to the lunar surface and crashing on it.

In contrast, a soft landing on the lunar surface is quite intricate and technologically challenging, as we saw in the last lap of the Chandrayaan-3 mission. Here, an orbiting Vikram lander, while at around 30 kilometres above the Moon and at a velocity of 1.68 km/sec (i.e., about 6,050 km per hour), slammed the brakes on itself (using a set of rockets onboard) to the touchdown velocity of about 0.6 metres per second within 20 minutes and concurrently steered itself to the designated area on the lunar surface with the help of a set of sensors, algorithms and software aboard. At the same time, the suitable site of the landing (without boulders, ridges, and craters) was also ascertained while on the descent.

The success accentuated the intrinsic resilience of the Indian space fraternity to learn and adapt from past failures (the crash landing of Chandrayaan-2), institutional synergy and team excellence. This was achieved by the selfless service of a few thousand men and women at all levels with varied specialisations, working together 24x7 with a singular focus — the success of the mission and ensuring the rise in Isro's stature and national pride.

Vikram carries a suite of scientific instruments built by Indian scientists to study lunar seismic activity, plasma environment and thermal properties (near-surface), spectral signatures of the Earth from the lunar orbit, as well as elemental composition in and around the landing site (by the Pragyan Rover) during its life within a lunar day (i.e. 14 days of Earth). Hopefully, these instruments will bring forth path-breaking scientific findings like that from Chandrayaan-1.

Significantly, Chandrayaan-1 provided the platform for international cooperation by accommodating scientific payloads developed by five other nations, particularly that from the National Aeronautics and Space Administration (Nasa) in the United States (US), which discovered the presence of water molecules in the lunar North Pole. The Vikram lander carries Nasa's Laser Retroreflector Array, a lightweight structure with eight retroreflectors that can serve as a long-term geodetic station and a location- marker on the lunar surface.

Astrosat, India's first dedicated multi-wavelength space telescope that was launched in 2015, has been a globally acclaimed mission for space astronomy. The forthcoming Aditya-L1 mission is aimed at observing and understanding the chromospheric and coronal dynamics of the Sun.

India is now on the threshold of climbing the next step of the technology ladder to embrace multilateral joint space missions (robotic and human-in-loop) for the exploration of outer space and the use of celestial resources (from the Moon, Mars, comets and asteroids) for the scientific, economic, and social growth of the world.

Thanks to the futuristic vision and diplomatic prudence of PM Modi, India became a party to the 2020 Artemis Accords led by the US. This opens new vistas for India. The joint missions undertaken within the framework of existing technological and economic prowess as well as geopolitical aspirations of the emerging new world order, will drive several technological advancements and spin-offs for the future, along with scientific revelations.

K Radhakrishnan is former chairman, Isro.
The views expressed are personal

Every Indian rejoiced with pride while the whole world watched with awe our rising acumen in the arena of outer space HT PHOTO