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As dust settles, Pragyan preps to explore Moon

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BENGALURU: India took a walk on the moon, the Indian Space Research Organisation (ISRO) announced on Thursday, as the Pragyan rover, which emerged from the belly of the Vikram lander on Wednesday night, was set to roll across the lunar surface hours after the latter created history by becoming the first craft to land on the Moon's south pole, propelling India into the top echelons of space powers.

ISRO chief Somanath said scientists were about to start the next phase of the Moon mission, which, over the course of the next fortnight, could revolutionise global understanding of the seismology, soil profile, mineral composition and atmosphere of the uncharted southern pole of the moon, and even lay the foundation of future lunar missions.

"Made in India, made for the Moon! The Chandrayaan-3 rover ramped down from the lander and India took a walk on the moon!" India's space agency posted on X.

Even as they pored over computers to calibrate experiments, scientists at the ISRO control room revelled in the adulation that poured in from around the globe over Chandrayaan-3's perfect touchdown at 6.03pm on Wednesday.

The soft landing completed an extraordinary arc of scientific perseverance made possible by the automated choreog-



A still from a video ISRO released on Thursday of the Chandrayaan-3's landing approach. ISRO

raphy of 12 big and small rocket engines executed to clinical precision. It also mended the nation's heartbreak at the crash of the mooncraft's previous iteration in 2019.

The tests are expected to open new vistas for the country's frugal space programme in the lucrative market of space exploration and commerce because they will confirm the presence of water at the lunar south pole. If proven, this breakthrough can be crucial for

drinking, breathing and rocket fuel resources to advance human space exploration deeper into the solar system.

"The south polar region has the advantage of being less illuminated by the sun, and as a result of that there is a potential of having better scientific content, including retention of water below the sub-surface," Somanath said.

"We have chosen the best location that can give us an advantage. The next 14 days will

set the stage for all future lunar space missions. Ultimately, we might even send a man on the Moon and establish colonies there," he added.

Somanath explained that several factors were studied before the rover could roll down. Accordingly, the flaps of the lander opened at 10pm but the roll-out of the rover commenced around 1.30am on Thursday. For most of the day, Pragyan recharged its batteries

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Chandrayaan will help us profit from the heavens

After Chandrayaan-3's success, India's goal is to not only build on ISRO's extraordinary achievement but also to harness popular enthusiasm for space exploration towards concrete outcomes for the country's high-technology economy. Unlike the IT and biotech sectors, space remains a State-led industry. Governments such as those of the United States have deep pockets and can act as anchor customers until segments of the space sector stabilise and become self-sustaining. Most government and private funding is directed towards practical space applications such as satellites that provide immediate returns on investment. Military requirements are a primary driver of satellite infrastructure as are other State-led requirements such as monitoring weather patterns and ecological degradation. All this needs cutting-edge innovation that only space exploration can drive.

Beyond space applications, there are ambitious plans to sustain human presence beyond Earth. The International Space Station (ISS) has sustained continuous human presence in low earth orbit for more than two decades. This presence has been made possible partly by private companies whose spacecraft ferry cargo and crew between the ISS and Earth. Since the ISS is due to be decommissioned by 2031, NASA plans to replace it with at least three smaller commercial space stations. Its most audacious project is the Artemis programme, which seeks to return humans to the Moon permanently. Artemis is a multinational programme involving several space agencies and private companies. NASA alone expects to spend \$41.5 billion on Artemis between 2023 and 2028. Assuming this budgetary support continues and expands, the total budget for lunar exploration across global space agencies and companies over the next 20 years could run into hundreds of billions. Indeed, a key goal of long-term programmes such as Artemis is to provide some sense of certainty to private space companies involved in lunar projects. As a signatory of the associated Artemis Accords, India can choose to participate in this gigantic enterprise and exploit its commercial potential.

The tasks of building a sustained human presence on the Moon and developing a lunar economy will require a mind-boggling range of innovations. Engineers will have to work continuously on making heavy launch vehicles less expensive, support human spaceflight, come up with radical new spacecraft designs, and develop reliable communications and navigation infrastructure. Then there are less-glamorous but equally tasks: Designing habitats, learning how to grow food in lunar green-

houses, designing solar panels suited for the Moon's dusty and atmosphere-free environment, developing new forms of power storage, extracting lunar water ice and purifying it. All of these technologies will have important spinoffs for applications on Earth.

Spacefaring nations including India hope to eventually use the Moon as a launch pad for getting to Mars and the asteroid belt. India's Chandrayaan-1 in 2009 helped confirm the presence of water ice in the Moon's polar craters, thus spurring the ongoing international race to get to the lunar south pole. Water is necessary to sustain humans on the Moon, but also provides the hydrogen and oxygen needed to fuel rockets headed into deep space.

With its success, Chandrayaan-3 has now given India a solid footing in this race. The scientific and commercial possibilities are immense. The Moon may also generate an economy of its own someday. Exaggerated claims notwithstanding, lunar mining for gold or platinum is unlikely to be financially viable because of the costs involved. However, there may be some specific elements or minerals for which a business case can be made. For example, if nuclear fusion power generation becomes feasible, the Moon's reserves of Helium-3 could become invaluable.

The potential of the space economy hasn't escaped India's attention. In April, the government announced a landmark Space Policy, which allows the private sector access to a range of space activities, including rocket launches, satellite operations and even asteroid mining. The policy makes the Indian National Space Promotion and Authorisation Centre (IN-SPACe) the sole agency for authorising space activities and seeks to create a level playing field between the private sector and ISRO. A separate policy on foreign direct investment is also expected shortly.

While these are welcome developments, some foundational problems remain. One, IN-SPACe is saddled with the dual role of both authorising private space activity and promoting it. Two, India badly needs a space law. Without one, IN-SPACe has no legal basis to act and there is no mechanism to resolve disputes, either between companies or between companies and IN-SPACe. And finally, India will need active diplomacy to ensure its private companies get to participate in multinational projects, whether in low Earth orbit, the Moon or beyond. Chandrayaan-3 must only whet India's appetite to profit from the heavens.

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CHANDRAYAAN-3

via the solar panels in preparation for its moonwalk.

"There are several factors that have to be considered before the rover can be released. The first factor is to study the temperature levels, the incline and the dust. It took us some time to sort out the initial hiccups before we could roll out the rover," Somanath said.

A senior ISRO scientist, who did not wish to be identified because of the sensitivity of the mission, said that the lack of an atmosphere and limited gravity made it take longer for lunar dust to settle. "The health of the equipment could have been damaged if we immediately rolled out the rover while the craft was still surrounded by a cloud of dust," the scientist added.

Hours after the lander touched down on the Moon, two sets of ramps were deployed — first the external ramp opened and then another ramp to support the rover was extended. A wire connection with the lander to ensure its stability before landing was also snapped once it achieved stable ground. It will now progress to complete its mission objectives in the coming days, scientists said. ISRO announced on Thursday evening that three payloads — Instrument for Lunar Seismic Activity (ILSA), Radio Amenity of Moon Bound Hypersensitive Ionosphere and Atmosphere (RAMBHA) and Chandra's Surface Thermophysical Experiment (ChASTE) on the Vikram lander module — were turned on, and the mobility operations of the Pragyan rover commenced.

ChASTE will measure the thermal conductivity and temperature. ILSA will probe the seismic activity around the landing site and RAMBHA will collate a plasma profile of the Moon. "All activities are on schedule, all systems are normal," the agency posted.

Somanath said that the experiments will give the Indian space community the advantage of culling out data that could shape humankind's understanding of the lunar surface and its composition. "The landing site was chosen because the area had the potential to establish colonies which would eventually help travel beyond the Moon," he said.

Pragyan has on board devices two spectrometers, devices that

can analyse the composition of samples on the lunar surface.

The textbook touchdown on Wednesday evening 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.

"Congratulations India," X owner Elon Musk posted. Israeli prime minister Benjamin Netanyahu called PM Narendra Modi to congratulate him. "It's an incredible feat for all the scientists and engineers involved," US vice-president Kamala Harris posted on X. "It is a matter of pride and a pat on the back for Indian scientists," Modi said at the Brics summit in Johannesburg on Thursday.

The mission 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.

Misery 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.