How Japan's moon-landing attempt in January will affect Chandrayaan 4 | Explained

PREMIUM

After successfully entering lunar orbit on Christmas Day, SLIM will attempt to soft-land on the moon on January 19.

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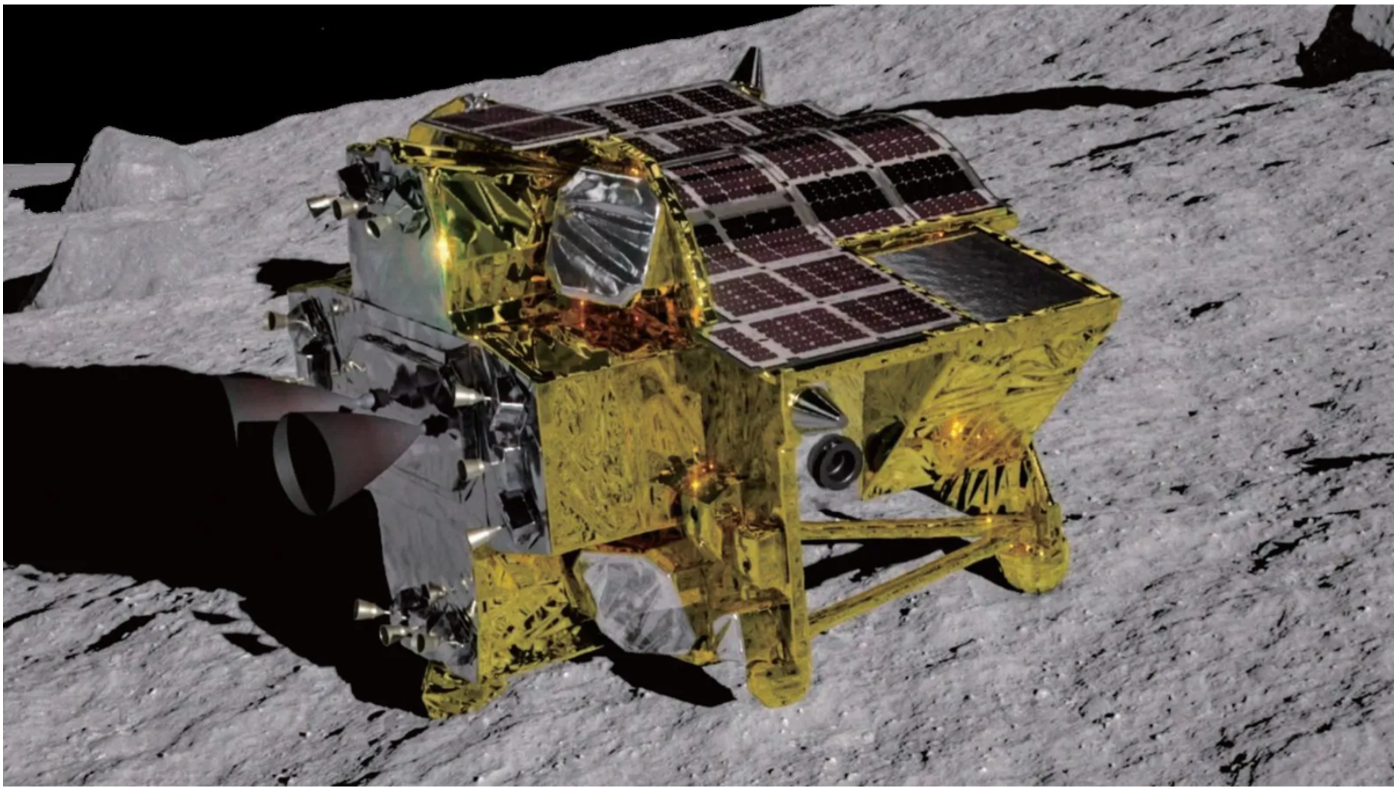

An artist's impression of SLIM on the lunar surface. | Photo Credit: JAXA

At 1.21 pm IST on December 25, Japan's Smart Lander for Investigating Moon (SLIM) spacecraft entered into orbit around the moon after a months-long journey, and ahead of its planned moon-landing attempt on January 19. If the attempt succeeds, Japan will become only the fifth country to soft-land a robotic craft on the natural satellite, months after India succeeded with its Chandrayaan 3 mission in August. Perhaps more importantly, SLIM's success or failure will also affect the upcoming Chandrayaan 4 mission.

What is SLIM?

SLIM is a spacecraft built and launched by the Japan Aerospace Exploration Agency (JAXA) on September 7, 2023, from the Tanegashima spaceport. It weighed only 590 kg at launch, which is almost one-seventh of Chandrayaan 3, which weighed 3,900 kg at launch. Of course, the latter mission also carried a larger suite of instruments.

SLIM was launched together with XRISM, a next-generation X-ray space telescope, onboard an H-2A rocket. JAXA had planned to launch SLIM and XRISM together, so delays in readying XRISM pushed SLIM's launch date from 2021 to 2023.

On December 25, SLIM entered into an elliptical orbit around the moon over three minutes or so. Its apogee (farthest point) in this orbit is 4,000 km and perigee (closest point) is 600 km above the lunar surface.

Notably, JAXA launched SLIM only two weeks after the surface component of India's Chandrayaan 3 mission succeeded and Russia's Luna 25 spacecraft failed. SLIM will also mark the second Japanese attempt this year to soft-land on the moon: the HAKUTO-R M1 lander, built by Japanese company ispace, crashed in late April after its engines shut down too soon during the landing.

How did SLIM get to the moon?

SLIM is lighter because it carried much less fuel. Of Chandrayaan 3's 3.9 tonnes, the propulsion module alone weighed 2.1 tonnes. This is why the mission was launched on July 14 and could reach the moon less than a month later, by following a route called the Hohmann transfer orbit.

On the other hand, SLIM took four months because it followed a longer but more fuel-thrifty route based on weak-stability boundary theory.

Once it was launched into an orbit around the earth, SLIM swung around the planet multiple times, building up its kinetic energy with each swing. Once it was travelling fast enough, it shot up towards the moon's orbit. Chandrayaan 3 followed a qualitatively similar path until this point. Once it got close to the moon, Chandrayaan 3 applied its brakes – which consumes fuel in space – so that it could slow down enough to be captured by the moon's weaker gravity.

But once SLIM got near the moon, instead of slowing down and being captured by the moon's gravity, it allowed itself to be deflected in the moon's direction even as it shot past lunar orbit, deeper into space (see image below). This deflection is the result of the combined forces exerted by the earth and the moon. Physicists worked it out in the late 1980s for another JAXA mission, called 'Hiten'.

A diagram illustrating SLIM's path from the earth to the moon, spanning four months. | Photo Credit: JAXA

SLIM was subsequently on a larger, more loopy path that was designed to bring it back near the moon in December, after it had slowed down further. This event happened on Christmas Day, followed by orbital capture the next day.

By sacrificing some time, SLIM could be more fuel-efficient.

What will SLIM do on the moon?

All this said, SLIM's standout feature is its reputation as the "moon sniper" – a title derived from what it will do on the moon on January 19: it will try to land within 100 metres of its chosen landing site. This is an unusually tight limit given the history of moon-landing missions. For example, the 'Vikram' lander of Chandrayaan 3 was designed to descend in an elliptical area that was 4 km long downrange and 2.5 km wide cross-range, and it eventually landed at a spot 350 metres away from a predetermined one.

(Downrange means in the direction of the craft's motion and cross-range means to either side. In effect, these distances specify how much the craft's path can deviate in these two directions.)

NASA's hulking 'Curiosity' rover was tasked with landing at the centre of a 20 km x 7 km ellipse in Gale Crater on Mars on August 6, 2012, and it landed 2.4 km away. The most precise moon-landing in history was China's Chang'e 3 spacecraft: it landed 89 metres away from its chosen spot in the Mare Imbrium plain on the moon on December 14, 2013. However, it was still allowed to land anywhere inside an ellipse of 6 km x 6 km.

SLIM, in effect, will set the record on January 19 for attempting to soft-land with the smallest ever area tolerance on the moon. The chosen site is near the Shioli Crater, at 13.3° S and 25.2° E. Just as the 'Vikram' lander of the Chandrayaan 3 mission used data from the Chandrayaan 2 orbiter to help guide its descent, SLIM will use data from JAXA's SELENE orbiter, which ended in 2009.

Its lower mass – only 120 kg excluding fuel – will help in this endeavour by rendering it more manoeuvrable while its small size will be a test of its economical design.

Just before it lands, SLIM will deploy two small rovers called Lunar Excursion Vehicle (LEV) 1 and 2. LEV-1, LEV-2, and SLIM will together study the lunar surface near the landing point, collect temperature and radiation readings, and attempt to study the moon's mantle.

How will SLIM affect Chandrayaan 4?

Scientists are interested in the moon's south pole region at large because parts of some of the craters here are always in shadow, allowing the temperature there to drop very low as well as sparing them the effects of sunlight and diurnal temperature variations. We already know these parts contain water-ice, and a lunar surface mission could potentially explore these sites and attempt to extract water.

When the Indian Space Research Organisation successfully executed its Chandrayaan 3 mission by soft-landing a robotic craft on the moon's surface, on August 23, it also concluded the second phase of its lunar exploration programme. The first mission of its third phase is the Lunar Polar Exploration (LUPEX) mission, a.k.a. Chandrayaan 4.

LUPEX will be an Indian-Japan joint enterprise (however, while JAXA has approved LUPEX, India is yet to) with an earliest launch date in 2026. It will explore an area closer to the moon's south pole than Chandrayaan 3 did – and this makes all the difference.

The terrain near either of the moon's poles is rocky, pocked with several craters, and full of steep slopes. Axiomatically, if there is a suitable landing spot for a (relatively) large landing module or rover, its downrange and cross-range limits will be lower than they were for Chandrayaan 3. The craft will have to land as close to the site as possible, if not at the site itself.

The technologies JAXA will test with SLIM, but especially a feature-matching algorithm and navigation systems, will be crucial for this aspect of LUPEX. For now, JAXA is expected to provide the launch vehicle and the lunar rover while India will provide the lander module. The landing site is yet to be fixed; to compare, the 'Vikram' lander landed 600 km from the south pole.

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