India’s Chandrayaan-3 mission:

The spacecraft launched to the moon on July 14, 2023, at 5:05 a.m. EDT (0905 GMT or 2:35 p.m. local time July 14) from the Satish Dhawan Space Center in Sriharikota, India atop the medium-lift Launch Vehicle Mark-III (LVM3) rocket.

Chandrayaan-3 successfully landed near the moon's south pole on Aug. 23, 2023, at 8:33 a.m. ET (1233 GMT or 6:03 p.m. India Standard Time).

The mission is managed by the Indian Space Research Organisation (ISRO). ISRO's roots go back to the beginning of space exploration, as a predecessor agency was set up in 1962 and its first rocket launch was in 1963. ISRO itself was established in 1969.

In June 2023, shortly before the scheduled Chandrayaan-3 launch, India also signed on to the NASA-led Artemis Accords aiming for peaceful human and robotic exploration of the moon. While the immediate benefits of the accords accrue to human spaceflight, according to the White House, the data from Chandrayaan-3 may be useful for future Artemis human landings too.

CHANDRAYAAN-3 MISSION GOALS

Chandrayaan-3 costs roughly $77 million USD, according to the Times of India.

The three main objectives of Chandrayaan-3 are to land safely on the surface, to demonstrate rover operations and to perform scientific experiments on site, according to the official website.

The mission called for a propulsion module to ferry the Chandrayaan-3' Vikram ("valor") lander and the solar-powered rover named Pragyan (Sanskrit for "wisdom") rover together to the south pole of the moon, according to NASA.

The module then entered lunar orbit and maneuvered into a roughly circular path about 60 miles (100 km) above the surface. Then the lander separated from the module and aimed for a soft landing on the surface, achieving this on Aug. 23, 2023.

The lander and rover will collect science on the surface for 14 Earth days (a single day on the moon), while the propulsion module will gaze at our planet for its own science experiment.

The spacecraft package (rover, lander and propulsion module) includes "advanced technologies" to meet the mission objectives, ISRO says. Examples include hazard detection and avoidance on the rover, a landing leg mechanism to aim for a soft touchdown, and altimeters and velocity instruments to estimate altitude and speed above the moon.

ISRO has performed several technology tests to simulate lunar conditions, the agency emphasized, focusing on matters such as soaking instruments in cold temperatures similar to the moon or doing a lander leg test on a simulated surface under different landing conditions.

CHANDRAYAAN-3 SCIENCE PAYLOADS

Science on the Chandrayaan-3 mission is split between the lander, the rover and the propulsion module payload.

"The lander is ... generally box-shaped, with four landing legs and four landing thrusters," NASA writes of the design. Its approximate 3,900-pound (1,752-kilogram) mass will include 57 pounds (26 kgs) for the rover.

The lander includes:

- Chandra's Surface Thermophysical Experiment (ChaSTE) to measure thermal conductivity and temperature on the surface;
- Instrument for Lunar Seismic Activity (ILSA) to detect moonquakes;
- Langmuir Probe to estimate the density and variation of plasma, or superheated gas, in the moon's environment;
- A Laser Retroreflector Array (from NASA) to measure distances using laser ranging..

The rover "is a rectangular chassis mounted on a six-wheel rocker-bogie wheel drive assembly," NASA added. The rover sends its communications to Earth through the lander. Rover instruments include:

- Alpha Particle X-ray Spectrometer (APXS) to look for elements in the lunar soil and rocks;
- Laser Induced Breakdown Spectroscope (LIBS) to examine the chemical and elemental composition of the lunar surface.

The propulsion module "is a box-like structure with one large solar panel mounted on one side and a large cylinder on top ... that acts as a mounting structure for the lander," NASA says. The propulsion module is more than 2.2 tons (2 tonnes in mass.)

The module's single experiment is the Spectro-polarimetry of Habitable Planet Earth (SHAPE) investigation that will assist with exoplanet searches. The experiment will "gather data on the polarization of light reflected by Earth so that researchers can look for other planets with similar signatures," according to Nature.

PAST CHANDRAYAAN MISSIONS

Chandrayaan-1 was India's first mission to the moon. It launched Oct. 22, 2008 from the Satish Dhawan Space Center in Sriharikota, India, aboard a Polar Satellite Launch Vehicle rocket. It achieved lunar orbit on Nov. 8. It released a Moon Impact Probe on Nov. 14 that deliberately crashed into the moon later that day.

Chandrayaan-1 is best known for finding evidence of water ice on the moon. NASA made the announcement on September 2009, based on data collected by the agency's Moon Mineralogy Mapper. The instrument found evidence of hydroxyl (a form of water, hydrogen and oxygen) in the moon's regolith or dust.

The Moon Impact Probe also found water's signature before impacting the surface, providing a separate set of data. More confirmations came from the Cassini spacecraft and the Deep Impact spacecraft's extended EPOXI mission.

Chandrayaan-2 was India's second mission to the moon. It launched from the Satish Dhawan Space Center in Sriharikota, India, aboard a Geosynchronous Satellite Launch Vehicle (GSLV) rocket on July 22, 2019. It made it to lunar orbit on Aug. 19, 2019.

On Sept. 6, Chandrayaan-2 released the Vikram moon lander, but mission officials lost contact with it as it was just 1.3 miles (2.1 km) above the surface. Although the lander was lost, the orbiter continues to work well. It carries eight different instruments and continues to send back high-definition imagery of the lunar surface.

LESSONS LEARNED FROM FAILED CHANDRAYAAN-2

Chandrayaan-3 will build upon the "lessons learned" from the unsuccessful landing that took place during Chandrayaan-2, ISRO told the Business Standard.

"With optimized payload configurations, improved lander capabilities, and utilizing existing (spacecraft) resources, the mission is expected to address past challenges," the Business Standard wrote of ISRO's approach to Chandrayaan-3.

For example, Chandrayaan-3 will simplify its mission design to not include an orbiter. The predecessor mission, Chandrayaan-2, will therefore handle all communications to Earth from the propulsion module, the rover and the lander.

The propulsion module ferrying Chandraayan-3 to the moon will also only include a single science instrument, as opposed to Chandrayaan-2's orbiter which carried nine. This will simplify the amount of work the propulsion module performs, allowing engineers to focus on its crucial role in bringing the rover and lander to the moon.

The lander of Chandraayan-3 also includes key upgrades. ISRO stated it will have two "lander hazard detection and avoidance cameras" meant to help the lander avoid obstacles on the surface during the descent. Chandrayaan-2 only carried one such camera, and Chandrayaan-3's cameras aim to be more robust than the predecessor mission.

India’s ADITYA-L1 mission:

Aditya-L1 is a solar observatory operated by the Indian Space Research Organisation (ISRO).

The solar observatory will monitor the sun with seven specially designed distinct scientific payloads, five of which have been developed by the ISRO. It will do so from its position at a gravitationally stable point in the Earth-sun system called Lagrange point 1 — around 1 million miles (1.5 million kilometers) from Earth — where a spacecraft can remain stable in relation to both bodies. ISRO describes the mission as a "satellite dedicated to the comprehensive study of the sun." The L1 suffix in the mission's name refers to this location, while "Aditya" means "the sun" in Sanskrit.

The Aditya-L1 spacecraft will not come any closer to the sun than this, studying our star from this distance, around 1% of the total space between the Earth and the sun, for the duration of its mission, which is estimated to be around 5.2 years. Placement at L1 will allow the spacecraft a view of the sun that is uninterrupted by eclipses or occultations, according to ISRO.

Aditya-L1 will investigate the sun's atmosphere, the corona, and its surface, the photosphere. The data it collects could help solve lingering solar mysteries, such as how the corona is considerably hotter than the photosphere despite being around 1,000 miles (1,609 km) further away from the sun's main source of heat, the nuclear fusion that takes place at its core.

The proximity to Earth will also allow the mission to study Earth's magnetic field, the magnetosphere, and how it reacts to charged particles that stream towards Earth from the sun in solar winds and in coronal mass ejections (CMEs). The Indian mission will also study the space environment around L1.

WHEN DID ADITYA-L1 LAUNCH?

The Aditya-L1 spacecraft blasted off from Satish Dhawan Space Centre in Sriharikota, an island off the coast of the Bay of Bengal, at 2:20 a.m. EDT (0620 GMT, 11:50 local India time) on Sept. 2, 2023, atop a Polar Satellite Launch Vehicle (PSLV).

Aditya-L1 was deployed into low-Earth orbit by the PSLV around 63 minutes after launch, as planned. After this, it underwent a Trans-Lagrangian1 insertion maneuver. The journey to L1 after launch is estimated to take around 110 days, over which time five further maneuvers will be performed to give the spacecraft the velocity needed to reach this gravitationally stable point.

When arriving at L1, Aditya-L1 will execute a further maneuver to "bind" itself to an orbit around the location. The orbit established around 127 days after launch will be irregularly shaped and will be in a plane approximately perpendicular to a line joining the sun and Earth, according to the ISRO.

The successful launch of Aditya-L1 marks the culmination of over 15 years of planning. The mission began life in January 2008 as a concept from the Advisory Committee for Space Sciences (ADCOS), as a small 400 kg (880 lb) satellite that would remain in a low-Earth orbit. The scale of the mission grew significantly over a decade and a half of strategizing, and it was given a new name — "Aditya-L1" — in July 2019 to reflect this growth.

WHAT WILL ADITYA-L1 DO?

The Aditya-L1 spacecraft had a launch mass of 3,252 pounds (1,475 kilograms). It is a cube-shaped satellite with a honeycomb sandwich structure. Its main body has dimensions of 2.9 feet x 2.9 feet x 2 feet (89 centimeters x 89 cm x 61.5 cm), according to the European Space Agency.

The Aditya-L1 starts its journey in a folded configuration. When unfolded, the spacecraft will have two wings with two solar panels, each of which is 3.9 feet x 2.7 feet (120 cm x 81 cm). These will assist the spacecraft's lithium-ion battery to provide Aditya-L1 with power. The craft will monitor its position with a miniaturized GPS receiver, which provides the position, velocity and time data in real time.

The Aditya-L1 craft has a payload of 7 scientific instruments, each with distinct functions, which weigh around 538 pounds (244 kg) and will be carried on the spacecraft's top deck. The instruments of Aditya-L1 and their functions are:

Magnetometer (MAG)

Located on a boom on the sun-facing side of Aditya-L1, the magnetic sensor MAG developed by the Laboratory for Electro Optics Systems (LEOS) will measure the magnitude and direction of the interplanetary magnetic field around Earth. MAG will also examine events like CMEs, measuring their impact on the space environment immediately around Earth. It will also detect waves in solar plasma at L1.

Visible Emission Line Coronagraph (VELC)

VELC will make observations of the solar corona close to the limb of the sun. This will include measuring coronal magnetic fields and detecting CMEs and so-called "coronal loops" outflows of plasma emerging from the sun's upper atmosphere. The aim of this will be to uncover the mechanism that causes the corona to be heated to many times the temperature of the underlying photosphere.

High Energy L1 Orbiting X-ray Spectrometer (HEL1OS)

HEL1OS will concentrate on solar flares, outbursts of electromagnetic radiation from the sun, examining both thermal and non-thermal emissions that occur as flares evolve. It will also study pulsations of X-rays during solar flares to understand how these high-energy emissions are linked to mechanisms accelerating particles like electrons around the sun.

Solar Ultraviolet Imaging Telescope (SUIT)

Developed by the Inter University for Astronomy and Astrophysics, SUIT is an ultraviolet telescope that will image the solar disk. The aim of this will be to understand how energy is channeled from the photosphere to the corona. It will also examine the wavelengths at which solar flares radiate the most energy and how different phases of flares appear at different layers of the sun's atmosphere.

Solar Low Energy X-ray Spectrometer (SoLEXS)

SoLEXS will measure the flux of X-rays from the sun at L1 to investigate properties of the corona. Again, the aim of this will be to search for the mechanism that is driving the heating of the solar corona. SoLEXS will also look at the dynamics of solar flares from their most powerful variety, X-class flares, to lower power sub-A class flares.

Aditya Solar wind Particle EXperiment (ASPEX)

ASPEX will make measurements of the solar wind, a constant stream of charged particles from the sun, at L1. This will help investigate where particles in the solar wind originate from and characterize events that accelerate these particles.

Plasma Analyser Package for Aditya (PAPA)

The two sensors of PAPA will also study the solar wind, investigating its composition and the distribution of energy within it. It will examine the speed of electrons in the solar wind and the differences in temperature of these particles and protons at different points in that stream of solar plasma. **WHAT WILL ADITYA-L1 DO?**

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