INDIA'S MOONSHOT

This year has been remarkable for Indian space research and exploration. ISRO was an early developer of cutting-edge technologies like sensors, inertial navigation, guidance, and control systems. The success of extremely important missions like the Mars Orbiter Mission, Aditya-L1, and Chandrayaan-3 can be attributed to its unparalleled capacity.

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In the midst of a time when space agencies around the world were vying for space race, the Indian space programme was developed for scientific research and applications in the mid-1960s. Since then, the programme has expanded, with an emphasis on societal benefits and self-sufficiency. Many important technologies, materials, and industrial processes have been developed by Indian scientists, who have made extensive use of in-house and external resources. During the last 50 years, self-reliance has been achieved in designing and manufacturing launch vehicles and satellites. The electronics for launch vehicle avionics and satellites have always been a challenge with imports and customisation. ISRO overcame these obstacles and is now well on its way to putting in place the necessary technologies and infrastructure for manufacturing, assembly, and testing of the sub-systems. With this, ISRO made its mark on the international space arena as one of the top five space agencies with full capabilities in Earth observation, communication, navigation, and planetary exploration.

ISRO has developed a one-of-a-kind space transportation system. It can now launch payloads ranging from 500 kg to 8000 kg into low, medium, or high Earth orbit using its four operational launch vehicles. PSLV, ISRO's workhorse, offers exceptionally reliable and cost-effective solutions for commercial users worldwide to launch payloads in the 2t class. The turnaround time is excellent, and it can be set up in a number of ways to meet the needs of individual clients. PSLV's growing popularity can be attributed to its versatility; the rocket can launch many satellites in a single flight, its upper-stage liquid engines can be started and stopped, it can inject orbits into a variety of different geostationary orbits, and it can host research on its PS4 orbital platform.

Incredibly complex missions, like as Chandrayaan and the OneWeb commercial launches, were successfully completed by LVM3, the most adaptable and made-in-India launch vehicle. Since its first test flight, it's been the most reliable vehicle in its class. It is another excellent choice for the worldwide commercial markets for both LEO and GEO payloads with capacities of 4t and 6t, respectively.

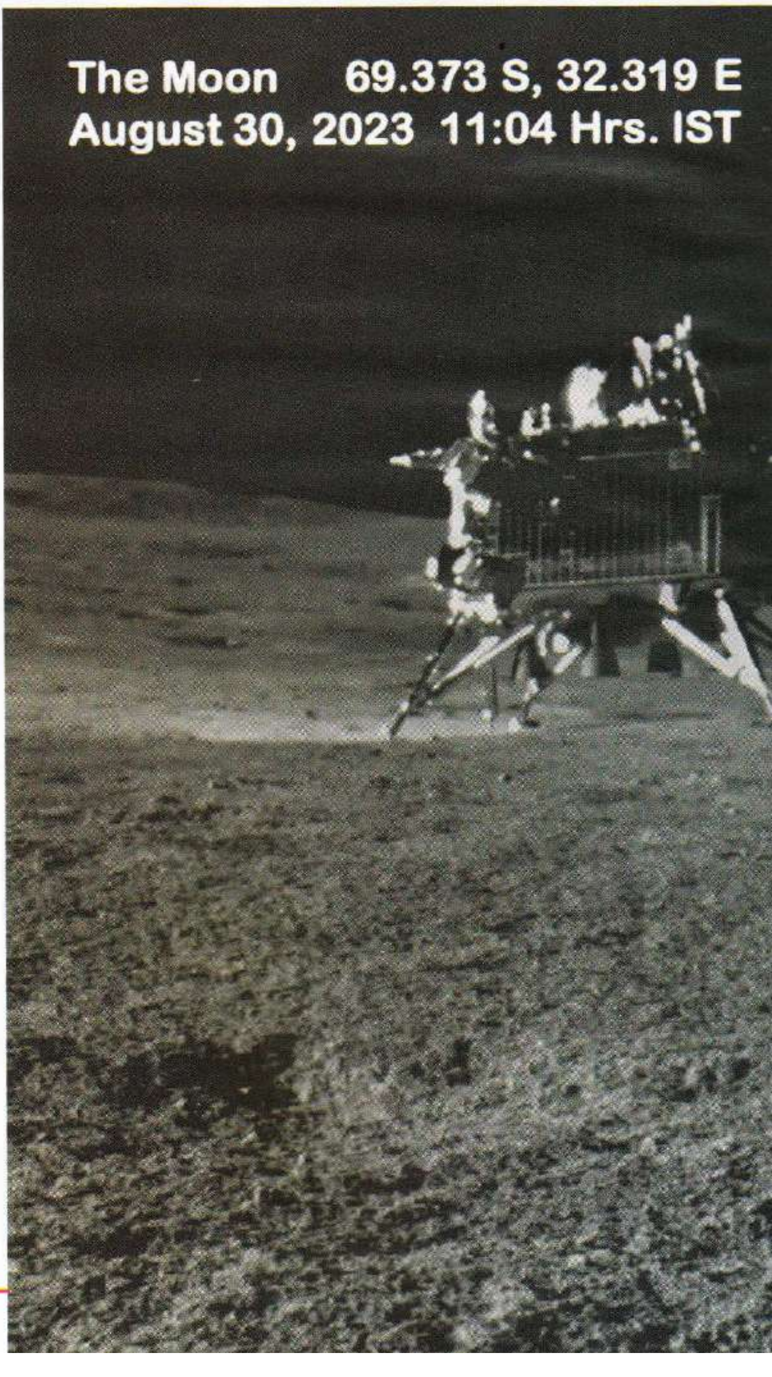
The newly inducted Small Satellite Launch Vehicle (SSLV), which was developed in record time to satisfy the requirements of the small satellite launch vehicle market, is one of the demand-driven solutions offered by ISRO to the Indian industry.

ISRO was an early developer of cutting-edge technologies like sensors, inertial navigation, guidance, and control systems. The success of extremely important missions like the Mars Orbiter Mission and Chandrayaan-3 can be attributed in part to its unparalleled capacity. Having in-house optics and opto-electronics expertise has allowed for the creation of a wide range of specialised payloads for use in earth observation and planetary exploration.

ISRO has dedicated groups to research and design satellites and their associated payloads. Satellite systems, including antennas, reflectors, and radio frequency (RF) systems, are constantly updated to meet or surpass global standards for technical progress.

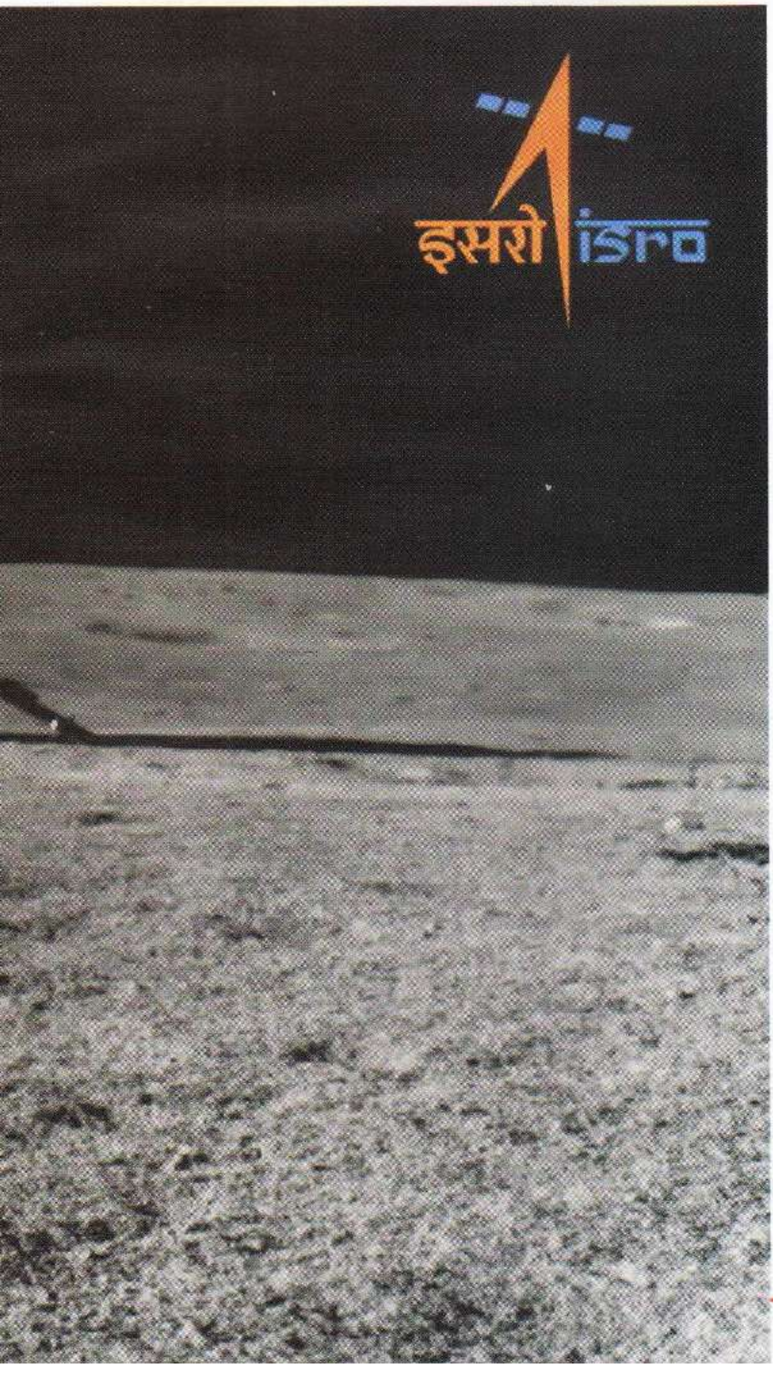
In the country and along the round paths of both eastward and southward launches, ISRO has its own ground systems. All EO, communication, navigation, and scientific satellites are monitored around-the-clock by the master control facility and the tracking and telemetry facility. ISRO is now going into the new arena of Space Situational Awareness (SSA) that involves a comprehensive understanding and knowledge of the space environment including location, and behaviour of space objects such as satellite, debris, and other celestial bodies and their future evolution. The infrastructure required to complete the operations is currently being planned by ISRO.

ISRO has significantly expanded its infrastructure in recent years in order to accommodate numerous critical space missions and technological developments. Some of the important facilities are: Trisonic wind tunnel,



high-altitude test facilities, semi-cryo testing and integration facilities, Gaganyaan facilities, and the ability to integrate and launch multiple launch vehicles simultaneously with little delay. Near India's southernmost tip, a new launch pad is being constructed to give the commercial launch industry unfettered access to launch privately developed launch vehicles into low-Earth orbits.

The foundation was laid by NNRMS in the early 1980s for the use of EO data in GIS applications at the national level, spanning all potential ministries and departments. With this objective in mind, ISRO created the IRS programme, which included first-generation satellites. Progress has been made in a wide variety of specialised areas, as evidenced by satellites like Cartosat, RISAT (Radar Imaging Satellites), ResourceSat, OceanSat, and many more. High-resolution data is provided by these satellites to a wide range of users. ISRO now maintains a significant number of EO satellites for continuous coverage. Programmes including MGNREGA, PMGSY, PMKSY, AMRUT, PMFBY, SVAMITVA, and UIDIA have benefited from and are making extensive use of EO data.



ISRO possesses a fleet of high-throughput and conventional communication satellites to fulfil the enormous demands of satellite communication.

The Indian Regional Navigation Satellite System (IRNSS), with an operational name of NavIC stands for NAVigation with Indian Constellation. It provides accurate real-time positioning and timing services over India and the region, extending approximately 1500 km around the Indian Mainland. The variety of services offered by NavIC aid in different applications like vehicle tracking and fleet management, location-based services integrated into mobile phones, terrestrial navigation aid for travellers, time dissemination, disaster management, and more, including services to our strategic users. IRNSS consists of three segments: space, ground, and user. The space segment consists of a base-layer constellation of seven satellites in the GEO and GSO planes. The constellation has been augmented recently with the NVS-01 Satellite, which is the first of the second-generation navigation satellite series. NVS-01 is based on the standard I-2K bus structure and has a mass of more than two thousand two hundred kilograms. The NVS-01 satellite has a navigation payload working in the L1, L5, and S frequency bands. As compared to the first-generation satellite series, the second-generation satellite series includes the L1 navigation band and incorporates an indigenously developed Rubidium atomic clock. The inclusion of the L1 navigation band, improves the positioning, navigation, and timing services for civilian users and also facilitates interoperability with other GNSS services. The indigenously developed space-based Rubidium atomic clock designed by the Space Applications Centre Ahmedabad is an important technology that only a handful of countries possess. The satellite is powered by two solar arrays, which generate power up to 2.4 kW. The NVS-01 satellite is designed for a mission life of about 12 years.

AstroSat, India's first space observatory, was launched on September 28, 2015, with a lift-off mass of 1515 kg, by a PSLV-C30 (XL) rocket from Satish Dhawan Space Centre Sriharikota. Almost

2,000 people from 54 different countries have signed up to use AstroSat data. In September 2022, more than 275 pieces for academic journals and about 500 pieces for the GCN circular, the Astronomer's Telegram, and conference papers were published using Astrosat data.

On 5 November 2013, the Mars Orbiter Mission was launched, and after 300 days of travelling between planets, it was placed in orbit around Mars on 24 September 2014. Over the course of its eight-year lifetime, the mission, which carried a total of five scientific payloads, made major contributions to our understanding of the Martian atmosphere, exosphere, surface features, and so on. The Mars Orbiter Mission lost touch with Earth in April 2022 because of a protracted eclipse after spending nearly eight years in Martian orbit and accomplishing a wide range of scientific goals on Mars and the Solar corona. More than 7,200 users have registered with the ISSDC portal in order to have access to the MOM data, and these users have downloaded over 27,000 pieces of science data. There are almost 400 registered users that are located in over 50 different countries.

India's first spacecraft, Chandrayaan-1, was launched on 22 July 2008, and it orbited the Moon at 100 kilometres. It was equipped with eleven high-tech instruments. It was a spectacular demonstration of our technological prowess, and it forever changed the course of Indian lunar exploration. The Chandrayaan-1 Orbiting Spacecraft launched a Moon Impact Probe (MIP) designated Chandra's Altitudinal Compositional Explorer (ChACE). ChACE has a camera, altimeter, and mass spectrometer for analysing the lunar surface. The Man in the Moon (MIP) probe was the first artificial object to reach the Moon's South Pole. With this, India's lunar programme officially got underway.

India successfully launched their follow-up mission, Chandrayaan-2 on 22 July 2019. This mission consists of an Orbiter, Lander, and a Rover. Despite the unsuccessful soft landing, the orbiter is still operational and gathering data. Multiple first-of-their-kind instruments, including an L-band SAR operating for the first time on the Moon, a large area X-ray spectrometer with the ability to create elemental maps with a resolution of 12.5 kilometres, and an instrument to study the global exospheric dynamics of noble gases, are aboard the orbiter. The ongoing observations have now lasted for five years.

The Chandrayaan-3 mission set out to prove that a soft-landing and roving capabilities could be accomplished on the Moon. The Moon mission was launched on 14 July 2023, and it made a soft landing near the Moon's South Pole on 23 August 2023. After touching down, the science payloads spent the next 14 lunar days investigating the immediate vicinity. The initial ChaSTE experiment revealed the thermal behaviour of the lunar surface to a depth of 10 cms. Sulphur was detected by LIBS on the lunar surface. Then, ILSA recorded the vibration caused by the rover's movements, while RAMBHA-LP measured the plasma near the surface. The goals of the mission have been successfully completed.

The Aditya-L1 mission is the first in India to focus solely on solar science. When the spacecraft reaches a distance of around 1.5 million kilometres from Earth, it will enter a halo orbit around Lagrange point 1 (L1) in the Sun-Earth system. The satellite will enter a halo orbit around the L1 point to ensure that its observations of the Sun are unaffected by occultation or eclipse. In addition, this will make it possible to track the effects of solar activity on space weather in real time. In order to investigate the photosphere, chromosphere, and corona of the Sun, the spacecraft is outfitted with seven instruments that measure electromagnetic fields, particles, and magnetic fields. From the privileged position afforded by the Lagrange point L1, four payloads directly observe the Sun, and the remaining three payloads conduct in-situ research on particles and fields, allowing for crucial scientific studies of the propagatory influence of solar dynamics in the interplanetary medium.

ISRO has begun its XPOSAT mission of scientific research, as well as the crucial NASA-ISRO Synthetic Apparent Temperature Radar (NISAR) initiative in which the two organisations will work together. ISRO is currently moving forth with a more comprehensive plan for a succession of lunar missions, including the man-on-the-moon and Gaganyaan missions, which will eventually result in the construction of a Bharat Space station. The requisite technologies and heavy lift launch vehicles are now in the planning stages, with a short timeline to realisation. ❑