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A Short Review on India's Interplanetary Missions

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Abstract: India's space program has witnessed transformative achievements in interplanetary exploration, propelling the nation into the forefront of space science and technology. This comprehensive overview delves into key milestones, objectives, and outcomes of India's interplanetary missions, beginning with the trailblazing Chandrayaan-1 that altered lunar studies by detecting water traces. Mangalyaan-1's success in orbiting Mars on its maiden attempt underscored India's prowess in Martian exploration. Despite a setback in the Chandrayaan-2 lunar landing, it provided ground-breaking lunar data. The recently launched Aditya-L1 focuses on solar observation, capturing high-energy X-rays and solar disc images. Future missions, including Chandrayaan-3, Mangalyaan-2, and the Venus Orbiter Mission (Shukrayaan), exemplify India's commitment to advancing planetary exploration. These endeavours, marked by cutting-edge technology and diverse scientific objectives, highlight India's growing prominence in global space exploration and contribute significantly to humanity's understanding of the cosmos.

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1. Introduction

India's space program has made significant contribution in recent decades, with interplanetary missions playing a vital role in its success. The first interplanetary mission, Chandrayaan-1, was launched in 2008 and successfully orbited the Moon for over 300 days. This was followed by Chandrayaan-2 in 2018, which aimed to land a lunar rover on the Moon's surface. Although the landing was unsuccessful, Chandrayaan-2 achieved several milestones, including being the first spacecraft to orbit the Moon in a lunar polar orbit. India's subsequent interplanetary mission, Mangalyaan-1, was launched in 2013 and successfully entered Martian orbit in 2014. This accomplishment made India the fourth space agency to reach the orbit of Mars and the first to do so on its initial attempt. Mangalyaan-1 has been orbiting Mars since then, contributing significantly to the understanding of the Red Planet. India is currently planning several future interplanetary missions, including Chandrayaan-3, Mangalyaan-2, Aditya-L1, and Shukrayaan-1. Chandrayaan-3 is a re-attempt of Chandrayaan-2's landing mission, while Mangalyaan-2 is a follow-up to Mangalyaan-1. Aditya-L1 is a solar mission that will study the Sun from a unique vantage point, and Shukrayaan-1 is a Venus orbiter mission. India's interplanetary missions have made significant contributions to space science and exploration, enhancing our understanding of the Moon, Mars, and other celestial bodies, and paving the way for future missions to even more distant destinations. This paper aims to provide a comprehensive overview of India's interplanetary missions, discussing the objectives, payloads, and results of each mission. Additionally, it will compare and contrast the different spacecraft used and delve into India's future interplanetary mission plans. [1-4].

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2. Chandrayaan-1

Chandrayaan-1 marked India's first ever and pioneering interplanetary exploration mission, representing a significant leap for ISRO's space program. Over decades, Indian scientists meticulously honed spacecraft technologies through earth observation satellites, culminating in the successful launch and deployment of Chandrayaan-1 into lunar orbit. This breakthrough not only revolutionized India's space endeavors but also showcased scientific excellence by detecting traces of water on the lunar surface. The mission went beyond the confines of earlier Lunar Missions, like Apollo and Luna, which focused on the Moon's equator. Chandrayaan-1, however, played a crucial role in mineralogical studies, chemical mapping, altimetry, and the analysis of Lunar Poles. It contributed valuable insights into volatile transfer mechanisms to the Poles and observed localized magnetic fields using radioactive radon. Launched on October 22, 2008, from Satish Dhawan Space Center, Sreeharikota, aboard PSLV-XL, Chandrayaan-1 carried 11 scientific instruments, including five from India, two from NASA, three from ESA, and one from Bulgaria. With a dry mass of 560 kgs and 1380 kgs when wet, the spacecraft paved the way for a new era in India's space exploration capabilities. **[1-2]**.

Figure-1 CAD Model of Chandrayaan 1 [Image Courtesy: ISRO]

2.1. Mission Phases

The spacecraft took off on October 22, 2008, from Satish Dhawan Space Center, Sreeharikota (00:52 UT, 6:22 am local time). The spacecraft was launched into a 255 x 22,860 km transfer orbit with an inclination of 17.9 degrees. Reaching the Lunar transfer trajectory involved five firings of the LAM, increasing the eccentricity of the orbit around the Earth to a final apogee of 380,000 km on November 4th. On November 8, Chandrayaan was put into a 7,502 x 504 km lunar orbit, and then lowered into a 100 km circular orbit. On November 14, the Moon Impact Probe was released (14:36:54 UT) and hit the lunar surface near the Moon’s South Pole (15:01 UT) at 89S, 30W.

The spacecraft remained in the 100 km lunar orbit from November 12, 2008, till May 19, 2009, and was then raised to the 200 km orbit to regulate the orbiter's temperature. This adjustment enabled further studies of orbital perturbations, gravitational field variations, and imaging of the lunar surface. The mission concluded on August 29, 2009, when ISRO lost communications with the satellite. The scientific payload data were stored in two solid-state recorders. **Figure-2 (right) CAD Model of Chandrayaan 2 [Image Courtesy: The Planetary Society]**

The five payloads onboard Chandrayaan-1 were the Terrain Mapping Stereo Camera and Lunar Laser Ranging Instrument (LLRI) for topography mapping; Hyperspectral Imager (HySI) for mineralogical mapping; Low Energy x-ray Spectrometer; High Energy Spectrometer for Chemical Mapping. The two payloads from NASA were Mini-SAR, the miniature Synthetic Aperture Radar, to map and characterize the nature of the Moon’s Polar region; M3 - Moon Mineralogy Mapper for high-resolution chemical mapping. ESA had three payloads: Chandrayaan-1 X-Ray Spectrometer (C1XS) for chemical mapping; Near-Infrared Spectrometer (SIR 2) for mineralogical mapping; Sub keV Atom Reflecting Analyzer (SARA) to find out the lunar surface interactions along with the lunar surface magnetic anomalies. Bulgaria had its Radiation Dose Monitor RADOM to monitor cosmic energetic particle flux and the lunar environment **[1-2]**.

2.2. Mission Outcomes

The mission achieved significant milestones with an expanded lunar coverage, leading to groundbreaking discoveries. The detection of H2O and OH on the lunar surface, along with their heightened abundance toward the polar region, marked a momentous revelation. The Radiation Dose Monitor (RADOM) analyzed energetic proton and electron fluxes throughout the mission duration. The Hyper-Spectral Imager (HySI) and Terrain Mapping Camera (TMC) provided comprehensive details of lunar topography, particularly focusing on the Polar region. The Infrared Spectrometer (SIR-2) collected high-spectral-resolution data. The integration of TMC data with HySI, M3, and SIR-2 unveiled new insights into lunar surface composition, leading to the identification of a novel spinel rock type on the lunar far side.

The Moon Mineralogy Mapper (M3) covered 90% of the lunar surface, whereas the Lunar Laser Ranging Instrument (LLRI) and Miniaturized Synthetic Aperture Radar (Mini-SAR) extensively surveyed polar areas. The Sub-keV Atom Reflecting Analyzer (SARA), with its broad field view, comprehensively covered the entire lunar surface. The Chandrayaan-1 X-ray Spectrometer (C1XS) provided high-quality data, detecting characteristic X-ray signals from the lunar surface even during weak solar flares. This data aids in inferring the abundances of Mg, Al, Si, Ca at various lunar surface locations. The High-Energy X-ray Spectrometer (HEX) faced operational constraints during the noon-midnight orbit due to inadequate detector cooling, limiting its dataset but providing insights into the rate of volatile transport on the moon surface **[4-5]**.

3. Chandrayaan-2

Chandrayaan-2 embarked on its mission, launching on July 22, 2019, at 9:13 UT from Satish Dhawan Space Center, Sreeharikota. It was positioned in a 170x45, 438 km elliptic parking orbit by GSLV Mark III. The mission comprised an Orbiter and a Lander named Vikram, housing the Rover Pragyaan. Chandrayaan-2 aimed to execute a soft landing of the Lunar Lander Module on a predetermined lunar site, conducting in situ analysis and remote sensing activities on the lunar surface. The Orbiter, weighing 2369 kg, and Vikram, weighing 1477 kg, inclusive of the Pragyaan Rover weighing 25 kg, were integral components of the mission **[3]**.

3.1. Chandrayaan-2 Instruments and Payloads

Orbiter: The Chandrayaan-2 mission integrates a diverse array of instruments across its Orbiter, Vikram Lander, and Pragyaan Rover, each meticulously designed with specific objectives and crafted by esteemed institutions. The Orbiter hosts instruments such as the Chandrayaan 2 Large Area Soft X Ray Spectrometer (CLASS), aiming to determine the elemental composition of the lunar surface, and the Solar X Ray Monitor (XSM), which assists CLASS by providing X-ray Solar Spectra and intensity measurements while studying high-energy processes in the Solar Corona. Additionally, the Orbiter incorporates instruments like the Dual Frequency L Band and S Band Synthetic Aperture Radar (DFSAR), Imaging IR Spectrometer (IIRS), and Terrain Mapping Camera 2 (TMC-2), each contributing to lunar surface analysis and mapping **[6-9]**.

Figure-3 Vikram Lander and Pragyaan Rover [Image Courtesy: ISRO]

Lander: The Vikram Lander carries instruments such as the Instrument for Lunar Seismic Activity (ILSA) to study moonquakes, Chandra's Surface Thermo-physical Experiment (ChaSTE) for estimating lunar surface thermal properties, RAMBHA-LP: Langmuir Probe to measure lunar surface plasma density, and Laser Retroreflector Array (LRA) for precise distance measurement between the lunar surface reflector and satellites in lunar orbit.

Rover: The Pragyaan Rover, positioned aboard Vikram, houses instruments like Laser-Induced Breakdown Spectroscope (LIBS) and Alpha Particle Induced X-ray Spectrometer (APXS) developed by Laboratory for Electro Optic Systems (LEOS) and Physical Research Laboratory (PRL), respectively. Each instrument contributes a crucial piece to the comprehensive scientific exploration carried out by the Chandrayaan-2 mission on the lunar surface.

Table-1 Chandrayaan-2: Scientific Payloads and their Developed Nations

Module	Name	Objective	Developed by
Orbiter	1.CLASS - Chandrayaan 2 Large Area Soft X Ray Spectrometer	To determine elemental composition of Lunar Surface	ISRO Satellite Centre (ISAC)
	2. XSM - Solar X Ray Monitor	To assist CLASS instrument by providing X-ray Solar Spectra and intensity measurements as input to it. Furthermore, to study about various high energy processes in the Solar Corona	Physical Research Laboratory, Ahmedabad
	3. DFSAR - Dual Frequency L Band and S Band Synthetic Aperture Radar	To find presence of different constituents in the lunar surface. It can probe into the first few metres of the surface.	Space Application Centre (SAC)
	4. IIRS - Imaging IR Spectrometer	For Mapping Lunar Surface over a wide wavelength for study of minerals, water and hydroxyl present	Space Application Centre (SAC)
	5. ChACE 2 - Chandrayaan Atmospheric Compositional Explorer (Quadrupole Mass Analyzer)	To study Lunar Exosphere	Space Physics Laboratory (SPL)
	6. TMC - 2 : Terrain Mapping Camera 2	For preparing 3 Dimensional Map to study lunar mineralogy and geology	Space Application Centre (SAC)
	7. RAMBHA - DFRS : Radio Anatomy of Moon Bound Hypersensitive Ionosphere and Atmosphere - Dual Frequency Radio Science Experiment	To study electron density in lunar ionosphere	Space Physics Laboratory (SPL)
	8. OHRC - Orbiter High Resolution Camera	To prepare high resolution topographic maps and digital elevation models of lunar map	
VIKRAM Lander	1. ILSA - Instrument for Lunar Seismic Activity	To study about the moon quakes near the landing site	Laboratory for Electro Optic Systems (LEOS)
	2. ChaSTE -Chandra's Surface Thermo-physical Experiment	For estimating the thermal properties of Lunar surface	Vikram Sarabhai Space Centre (VSSC), Space Physics Laboratory(SPL), Physical Research Lab (PRL)
	3. RAMBHA-LP: Langmuir Probe	To measure the density and variation of lunar surface plasma	Space Physics Laboratory (SPL), Vikram Sarabhai Space Centre (VSSC)
	4. LRA - Laser Retroreflector Array	To measure the precise distance between reflector on lunar surface and satellites in lunar orbit	Goddard Space Flight Centre
PRAGYAAN Rover	1. LIBS - Laser Induced Breakdown Spectroscope		Laboratory for Electro Optic Systems (LEOS)
	2. APXS - Alpha Particle Induced X-ray Spectrometer		Physical Research Laboratory (PRL)

3.2. Mission Outcomes

The Chandrayaan missions (both 1 & 2) have yielded ground-breaking outcomes, detecting an abundance of sodium on the Moon's surface, forming a tail thousands of kilometres long due to various phenomena like photon-stimulated desorption and solar wind sputtering. Chandrayaan-2 identified water and hydroxyl ions on the Moon's sunlit regions, distinguishing between the two with the Imaging Infrared Spectrometer (IIRS).

The Chandra Atmospheric Composition Explorer-2 unveiled the spatial heterogeneity of Argon-40 in the lunar exosphere, discovering localized enhancements, termed Argon bulge, over regions like KREEP and the South Pole Aitken terrain. CLASS detected a range of elements, including magnesium, aluminium, silicon, calcium, titanium, iron, chromium, and manganese, enhancing our understanding of the Moon's magmatic evolution.

The Solar X-ray Monitor (XSM) observed micro flares outside the Sun's active regions for the first time. Instruments like DFSAR studied lunar subsurface features, detecting signatures of sub-surface water-ice, while TMC-2 provided global-scale imaging, revealing geologic signatures of lunar crustal short and volcanic domes. The OHRC mapped the Moon with a resolution of 25 cm at 100 km altitude, and the DFRS experiment shed light on the Moon's ionosphere, revealing a plasma density in the wake region one order of magnitude higher than that on the day side. These findings contribute significantly to our knowledge of lunar conditions and evolution [6-9].

3.3. Lunar Landing Sites for Chandrayaan Expeditions

Landmarks on the lunar South Pole include the landing sites of Chandrayaan-1's Mission Probe, Chandrayaan-2's Vikram Lander, and Chandrayaan-3, each contributing to our understanding of the Moon's southernmost region. The Mission Probe of Chandrayaan-1, deployed upon reaching a 100x100 km Lunar Orbit, made a historic landing near the South Pole on November 14, 2008, precisely at 70.90267°S, 22.78110°E. This location, referred to as Jawahar Point, signifies a key exploration point, as noted by Goswami and Annadurai (2009) [6] (ref.figure-4).

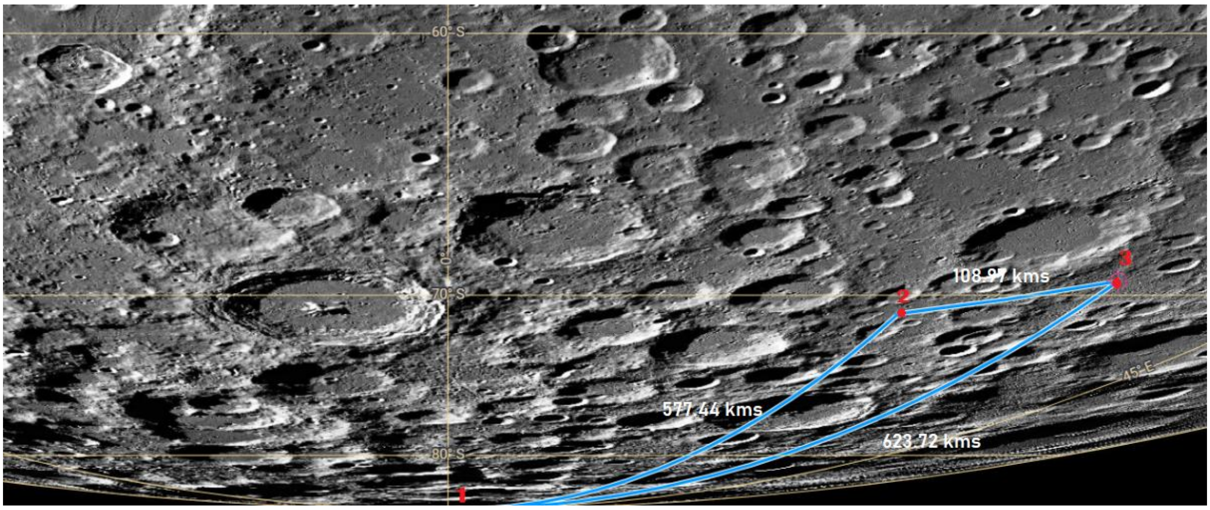

Figure-4 Landing Site of Vikram Lander [Image Courtesy: ISRO]

In the case of Chandrayaan-2, the Vikram Lander encountered a communication malfunction, leading to a crash landing at the Tiranga Point, positioned at 70.8810°S, 22.7840°E, marked as '2' on the diagram. Chandrayaan-3 achieved a successful lunar landing on August 23, 2023, at the Shiv Shakthi Point, situated at 69.367621°S, 32.348126°E, denoted as '3' on the diagram. These precise coordinates represent significant touchpoints in India's lunar exploration history.

4. Chandrayaan 3

Chandrayaan-3, launched on July 14, 2023, from Satish Dhawan Space Centre, adopts a two-module configuration, advancing India's lunar exploration initiatives. The mission unfolded through several phases, commencing with five Earth-bound maneuvers before transitioning to lunar orbit insertion following the translunar orbit. Subsequently, the spacecraft achieved a specific orbit where the lander module was detached. The mission objectives encompass demonstrating safe and soft lunar surface landing, showcasing rover mobility, and conducting in situ scientific experiments.

The propulsion module, Spectro-Polarimetry of Habitable Planet Earth (SHAPE), plays a pivotal role in propulsion and maneuvering. The lander incorporates Chandra's Surface Thermophysical Experiment (ChaSTE), Instrument for Lunar Seismic Activity (ILSA) for measuring ground vibrations, Langmuir Probe (LP), and a passive laser retroflector array from NASA. The rover module is equipped with the Alpha Particle X-Ray Spectrometer (APXS) and Laser-Induced Breakdown Spectroscope (LIBS) **[9-10]**.

The mission employs cutting-edge technologies, including lasers and RF-based altimeters, Laser Doppler Velocimeter, Lander Horizontal Velocity Camera, Laser Gyro-based Inertial referencing and Accelerometer package, hazard detection, and avoidance mechanisms, as well as a sophisticated landing leg mechanism. Chandrayaan-3 represents a significant leap in lunar exploration capabilities with its innovative technology and diverse scientific objectives.

5. Mangalyaan-1

Mangalyaan 1 stands as a monumental achievement for ISRO, successfully placing an indigenous spacecraft into Martian orbit on its inaugural attempt. Launched on November 5, 2013, via PSLV XL C-25, the spacecraft carried five scientific payloads designed to investigate Martian surface features, morphology, mineralogy, and the Martian atmosphere. Impressively, Mangalyaan 1 achieved Martian orbit entry on September 24, 2014, marking India's significant entry into Martian exploration.

The MOM (Mars Orbiter Mission) concept drew on the experience gained from Chandrayaan-I, with the feasibility report finalized in 2010. The comprehensive study report, guided by V Adimurthy, Senior Adviser at ISRO and Dean at the Indian Institute of Space Science and Technology, was prepared within three months. The project received sanction on August 3, 2012, with a total budget of approximately Rs 454 crore. Of this, Rs 153 crore was allocated to satellite costs, with the remaining budget allocated to ground station and other facilities. Mangalyaan 1 stands as a testament to India's prowess in space exploration, showcasing its capabilities on an international scale.

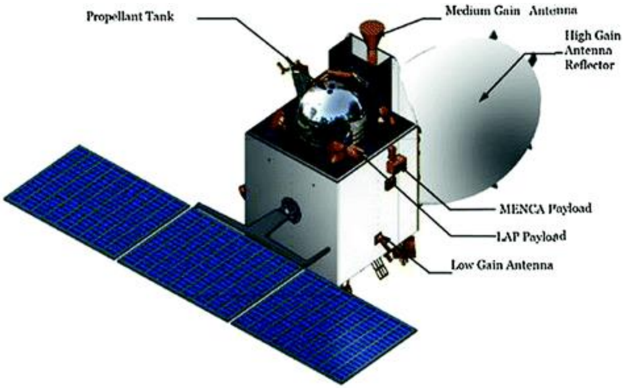

Figure-5 Mangalyaan-1 Spacecraft [Image Courtesy: Ajay.et.al.2013]

The Mars Orbiter, powered by a single solar array featuring three solar panels deployed post-launch, relies on this as its primary power source. Additionally, it utilizes a single Lithium-Ion battery as a secondary power source during eclipses encountered during Earth and Mars Orbit operations. Monitoring is conducted from the Spacecraft Control Centre at ISRO Tracking, Telemetry, and Command Network (ISTRAC) in Bangalore, with support from the Indian Deep Space Network (IDSN) antenna at Byalalu. A 2.2 m diameter high-gain antenna (HGA) facilitates the reception and transmission of radio signals, with S-band employed for Telemetry, Tracking, and Command (TTC) communication, while X-Band facilitates high-rate data downlink and uplink during Mars orbit **[10-12]**.

5.1. Mission Operations entail three key phases:

Geocentric Phase: The Mars Orbiter initially occupies a parking orbit of 250km x 23,000km, with a series of Earth Orbiting Maneuvers adjusting the orbit to 600km x 215,000 km.

Heliocentric Phase: Departing Earth's Sphere of Influence (SOI) at an altitude of 9, 18,317 kms, and the spacecraft undergoes mid-course correction maneuvers over 300 days to enter Mars' orbit.

Martian Phase: Approaching the elliptical Martian Orbit of 372 x 80,000 km, the spacecraft successfully inserts into Mars' orbit.

The mission involves meticulous analysis of perturbations, including Earth's oblateness effects, periodic variations due to solar and lunar gravitational pull, solar radiation pressure impact, and atmospheric drag from the Martian atmosphere. These considerations are crucial for the spacecraft's trajectory and long-term orbital stability, addressing potential challenges like re-entry and surface crashes. Mangalyaan's successful navigation through these dynamics underscores its robust design and operational efficiency.

5.2. MOM Payloads

Mangalyaan, equipped with five sophisticated payloads, embarked on its mission to comprehensively study the Martian environment. Developed with the objective of scrutinizing Martian surface features, morphology, mineralogy, and atmosphere, these payloads are strategically embedded in the spacecraft. The Lyman Alpha Photometer (LAP), crafted by the Space Application Centre (ISRO), serves to estimate the D/H ratio, assess the escape flux of H2 corona, and generate profiles of Hydrogen and Deuterium coronas. The Mars Exospheric Neutral Composition Analyzer (MENCA), also from the Space Application Centre, explores the Martian exosphere, analyzing neutral density and composition at altitudes above ~500 km. MENCA observes radial, diurnal, and seasonal variations and studies Phobos and the upper limits of the neutral density distribution around it. The Methane Sensor for Mars (MSM) measures CH4 at the ppb level, mapping its sources during each orbit. The Mars Color Camera (MCC), designed for optical imaging of Mars and its natural satellites, provides contextual information for other science payloads. Finally, the Thermal Infrared Imaging Spectrometer (TIS), developed by the Vikram Sarabhai Space Center (ISRO), creates a map of the Martian surface's composition and mineralogy while monitoring atmospheric CO2 and turbidity. Mangalyaan's payloads collectively contribute to a holistic understanding of Mars and its intricate characteristics **[10-12]**.

5.3. Mission Outcomes

The Methane Sensor for Mars (MSM) played a crucial role in confirming the presence of dust particles on Mars, leveraging apparent reflectance values characteristic of these particles. Utilizing five months of MSM radiance data from October 2014 to February 2015, a Global Short Wave Infra-Red (SWIR) albedo map in the wavelength band of 1.64-1.66 µm was derived, offering insights into the Martian surface. The Martian neutral exosphere's low-latitude evening conditions were explored using MENCA in-situ observations, enabling the derivation of the Martian exosphere's temperature (approximately 270±5 K) through the analysis of gas abundances at different altitudes (Fig. 3). Additionally, the imaging of the two Martian moons, Phobos and Deimos, provided valuable data for studies focusing on high-resolution images of various regions. These studies aimed to uncover morphological evidence supporting the historical presence of water on Mars, contributing to a deeper understanding of the planet's geomorphology **[10-12]**.

6. Mangalyaan-2

ISRO plans for a second mission to the Red Planet are underway, reflecting India's commitment to pushing the boundaries of space exploration. There is speculation about the inclusion of a rover in this upcoming mission, showcasing India's ambition to achieve new milestones and navigate greater challenges. Proposed payloads for Mangalyaan 2 include the Mars Orbit Dust Experiment (MODEX), aiming to study the Martian dust environment, the Radio Occultation Experiment (RO) for atmospheric analysis, the Energetic Ion Spectrometer (EIS) to investigate energetic particles, and the Langmuir Probe and Electric Experiment (LPEX) for studying electric fields. As India continues to carve its path in space exploration, Mangalyaan 2 promises to contribute valuable insights into the mysteries of Mars with an array of advanced scientific instruments **[12]**.

7. Aditya-L1

Aditya L1, India's inaugural space telescope dedicated to solar observation, embarked on its mission to capture solar activities from the Halo orbit Lagrangian 1 (L1). Launched on September 2nd, 2023, by PSLV-C57, Aditya L1 carries seven payloads designed to observe Coronal Mass Ejections (CMEs). Functionality was initiated during the spacecraft's journey, with the HEL1OS capturing the first High Energy X-Ray glimpse of solar flares and SUIT providing images of the full solar disc in near-ultraviolet wavelengths. Reaching the L1 orbit on January 6th, 2023, Aditya L1 aims to enhance our understanding of the Sun's dynamics and phenomena **[13]**.

Table-2 Scientific Payloads of Aditya-L1 Spacecraft

NO.	Payload Name	Description	Objective
1.	The Solar Ultraviolet Imaging Telescope (SUIT)	• It is a combination of medium and narrow band filter imager. • A Ritchey-Chr´etien telescope. It is a set of 11 different science filters centered around different wavelengths between 200–400 nm . • The images are recorded on a CCD that is kept at the focus. • Automatic CME detection by onboard algorithm	• To observe Sun in near Ultra Violet wavelength band (200 - 400nm) to cover the chromosphere and photosphere.
2.	Visible Emission Line Coronagraph (VELC)	• Imaging and spectroscopy done using eCMOS detectors. • Spectro-polarimetry is done using InGaAs detector system. • Automatic CME detection by onboard algorithm	• Imaging, spectroscopy and spectro-polarimetric observations in lower corona of the sun
3.	SoLEXS	• Sun integrated X-Ray spectrometer. • Has two detectors with different apperture size	• covers the energy band from 1 to 30 keV with a spectral resolution of less than 250 eV at 6keV. • The detector with smaller aperture focuses on larger flares and the detector with larger aperture focuses on the smaller flares • It has onboard intelligence to detect start of flares which will also alert the SUIT to start flare mode operation
4.	High Energy L1 Orbiting X-ray Spectrometer - HEL1OS	Consists of two detectors • CZT • CdTe	• To study impulsive phase of flared which are non- thermal. • Covers energy band from 10keV to 150 keV • There are two CZT detectors covering energy range from 20 to 150 keV. • CdTe covering energy range from 10 to 40 keV for detailed spectroscopic study
5.	Aditya Solar Wind Particle Experiment - ASPEX	Contains two ion spectrometers : • SWIS - Solar Wind Ion Spectrometer • STEPS : Supra Thermal and Energetic Particle Spectrometer	• to investigate the characteristics of CMEs and SIRs. • SWIS covers the low energy particles in the range 0.1–20 keV • STEPS detect high energy particles in the energy range 20 keV/nucleon–5 MeV/nucleon.
6.	Plasma Analyzer Package for Aditya - PAPA	There are two sensors : • Solar Wind Ion Composition Analyzer - SWICAR • Solar Wind Energy Electron Probe - SWEEP	• To study the solar wind composition and its energy distribution • SWEEP conducts study on electron flux using only electron parameters • SWICAR collects data in two modes : a. Ion operation mode - Ion parameters are measured b. Electron operation mode - Electron parameters are measured.
7.	Magnetometer - MAG	• Consists of two tri-axial flux gate magnetometers (FGMs). • Two identical FGMs is used to obtain the differential interplanetary magnetic field (IMF) by nullifying the effect of the magnetic field from the spacecraft	• to measure and monitor the magnitude and direction of the IMF locally at the L1 point. • to observe the CMEs from the Sun coming towards the Earth at the L1 point • To combine insitu magnetic measurements taken onboard with ground based measurements of geomagnetic field.

Aditya L1, India's pioneering solar observation space telescope, carries an array of sophisticated payloads designed to unravel the mysteries of the Sun. The Solar Ultraviolet Imaging Telescope (SUIT), featuring a Ritchey-Chrétien telescope with 11 science filters, focuses on near Ultraviolet wavelengths (200-400nm) to observe the chromosphere and photosphere, aided by an onboard algorithm for automatic Coronal Mass Ejection (CME) detection. The Visible Emission Line Coronagraph (VELC) employs eCMOS detectors for imaging and spectroscopy in the lower solar corona, integrating automatic CME detection. SoLEXS, a Sun integrated X-Ray spectrometer, covers an energy band from 1 to 30 keV, utilizing two detectors of varying apertures to study solar flares intelligently [14].

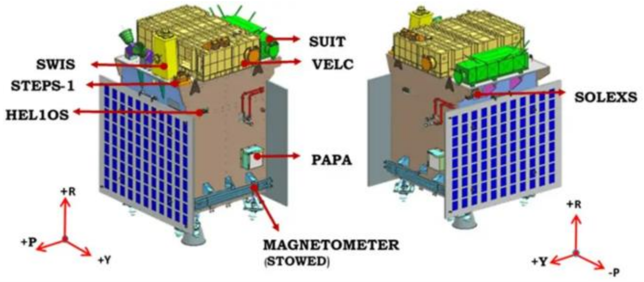

Figure-6 Technical Overview of Aditya L1 Spacecraft [Image Courtesy: ISRO]

The High Energy L1 Orbiting X-ray Spectrometer (HEL1OS) with CZT and CdTe detectors targets the impulsive phase of non-thermal solar flares, spanning an energy range from 10 to 150 keV. The Aditya Solar Wind Particle Experiment (ASPEX) hosts SWIS and STEPS ion spectrometers, probing the characteristics of CMEs and SIRs across different energy ranges. The Plasma Analyzer Package for Aditya (PAPA) incorporates SWICAR and SWEEP sensors to study solar wind composition and electron flux, measuring parameters in ion and electron operation modes. The Magnetometer (MAG), equipped with two tri-axial flux gate magnetometers, observes CMEs from the Sun approaching Earth at the L1 point, combining in-situ magnetic measurements with ground-based geomagnetic field observations for a comprehensive understanding of solar activities [13-15].

8. Venus Orbiter Mission (Shukrayaan)

The Venus Orbiter Mission, a forthcoming ambitious venture by ISRO, is set to explore the mysteries of Venus. The mission holds the key to unraveling the surface topography, composition, and the evolutionary dynamics of Venus's atmosphere. The primary objective is to gain profound insights into the intricate interplay between Venus's atmosphere and the solar wind. This ambitious project aligns with ISRO's commitment to advancing planetary exploration and promises to enhance our understanding of Venus, contributing valuable data to planetary science [16].

9. Conclusion

In conclusion, India's space program has made remarkable strides in interplanetary exploration, beginning with the pioneering Chandrayaan-1 mission, which revolutionized lunar studies and detected water traces on the Moon's surface. Subsequent missions, including the groundbreaking Mangalyaan-1, marked India's entry into Martian exploration and contributed significant insights into Mars' surface and atmosphere. Chandrayaan-2, despite a landing setback, provided groundbreaking lunar data, and the recently launched Aditya-L1 is dedicated to solar observation, capturing high-energy X-rays and images of the Sun's disc. With future missions like Chandrayaan-3, Mangalyaan-2, and the Venus Orbiter Mission (Shukrayaan) in the pipeline, India continues to push the boundaries of space exploration, aiming to unravel the mysteries of celestial bodies and contribute to global scientific knowledge. The success of these endeavors underscores India's growing capabilities in space science and exploration, positioning it as a key player in the international space community

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11. Biography

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13. Conflict of Interest

The author have no conflict of interest to report.

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