

Aditya-L1: India's First Dedicated Solar Mission

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Aditya-L1 is India's first space-based solar mission to study the Sun. It was launched on September 2, 2023, by the Indian Space Research Organisation (ISRO) into a **halo orbit** around the **Sun-Earth Lagrange point 1 (L1)**.

Aditya-L1 would provide an uninterrupted view of the Sun for prolonged periods, overcoming the limitations of Low Earth Orbits where the view is frequently blocked by the Earth itself.

Aditya-L1 will facilitate India to establish its own solar observatory in space, which would have numerous applications in day-to-day life. Further, its success would place ISRO into an elite space club along with NASA and ESA.

Why is there a Need for Solar Mission?

Our Sun is the nearest star, distancing about **150 million kilometres** and the largest object, which is the **source of energy** for our solar system.

- It is a hot glowing ball of **hydrogen and helium gases**.
- At the central region of the sun, known as the '**core**', the temperature can reach as high as 15 million degrees Celsius. At this temperature, a process called nuclear fusion takes place in the core, which powers

the sun.

- The visible surface of the sun, known as **the photosphere**, is relatively cool and has a temperature of about 5,500°C.
- The Sun is the powerhouse energising Earth's systems, but solar storms can disrupt infrastructure. Mysteries like the corona's extreme heat, the solar cycle's drivers, the origins of solar wind and eruptions like flares and **Coronal Mass Ejection (CME)** remain unresolved.
- Understanding the Sun's complex magnetic behaviour is thus crucial to **advancing space weather prediction, securing technological assets and unravelling stellar evolution**. The Aditya-L1 mission signifies India's quest to shed light on these solar uncertainties.

Aditya-L1 Mission: Capabilities and Goals

Aditya-L1 launched using a **PSLV XL** launch vehicle from the Satish Dhawan Space Centre in Sriharikota to establish a solar observatory at a halo orbit around the **L1 lagrangian point** of the Sun-Earth system. It carries **seven payloads** to examine the Sun's properties using visible and X-ray spectrometers, a coronagraph, analysers for solar winds and energetic particles, and magnetometers. This **multi-wavelength observation capacity** will probe the Sun's corona, the chromosphere, the photosphere, flares and coronal mass ejections.

Major Science Objectives of Aditya L1 Mission

- Understanding Coronal Heating and Solar Wind Acceleration.
- Understanding **initiation of Coronal Mass Ejection (CME), solar flares and near-earth space weather**.
- Understanding coupling and dynamics of the solar atmosphere.
- Understanding solar wind distribution and temperature anisotropy.

Payloads and its Objectives

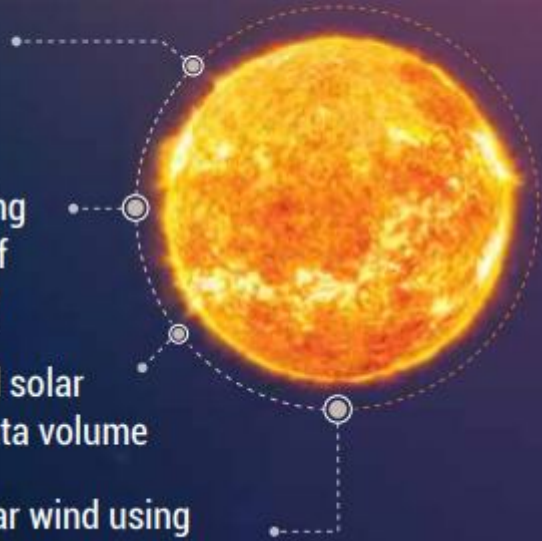
Payload	Objectives
Remote Sensing Payloads	
Visible Emission Line Coronagraph (VELC)	- Studies the solar corona. - Observe dynamics of Coronal Mass Ejections.
Solar Ultra-violet Imaging Telescope (SUIT)	- Captures images of the Solar Photosphere and Chromosphere in near Ultraviolet (UV). - Measures solar irradiance variations in near UV.

Solar Low Energy X-ray Spectrometer (SoLEXS)	- Functions as a Soft X-ray spectrometer. -Studies X-ray flares from the Sun across a wide X-ray energy range.
High Energy L1 Orbiting X-ray Spectrometer (HEL1OS)	- Acts as a Hard X-ray spectrometer. - Investigates X-ray flares from the Sun across a wide X-ray energy range.
In-situ Payloads	
Aditya Solar Wind Particle Experiment (ASPEX)	- Studies solar wind and energetic ions. - Analyze their energy distribution.
Plasma Analyser Package for Aditya (PAPA)	- Gather data on plasma characteristics and composition in the interplanetary space. - Provides insights into solar wind interactions with the environment.
Advanced Tri-axial High-Resolution Digital Magnetometers (MAG)	- To measure the low-intensity interplanetary magnetic field in space. - It has two sets of Magnetic Sensors: • One at the tip of a 6-meter deployable boom and • the other in the middle of the boom, 3 meters away from the spacecraft.

Uniqueness of the Aditya L1 Mission

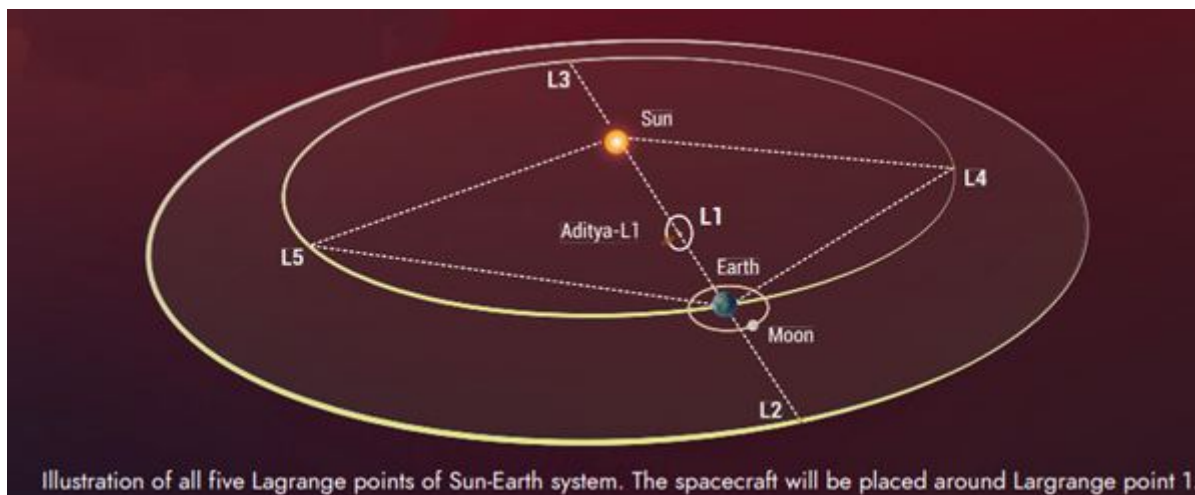
Uniqueness of Aditya-L1

- First-time spatially resolved solar disk in the near UV band
- CME dynamics close to the solar disk (~from 1.05 solar radius) thereby providing information in the acceleration regime of CME, which is not observed consistently
- Onboard intelligence to detect CMEs and solar flares for optimised observations and data volume
- Directional and energy anisotropy of solar wind using multi-direction observations



- The anisotropy of the solar wind and interplanetary magnetic field fluctuations contain important information about the solar wind origin and the evolution of the turbulent cascade during the solar wind expansion.
- The mission will significantly advance space weather prediction capabilities and improve forecasts of geomagnetic storms. By unravelling the corona's mysteries, it will boost understanding of the Sun's influence on the solar system, planets and beyond.

Lagrangian Points



Lagrange points are positions in space where the gravitational forces of two large orbiting bodies, like the Earth and Sun, produce regions of equilibrium where a smaller object can orbit while using minimal fuel.

- There are 5 Lagrange points, labelled L1 to L5. L1, L2, and L3 lie along the line connecting the two large masses.
- The L1 point of the Earth-Sun system provides an uninterrupted view of the Sun and is home to the **SOHO space telescope**.

- L2 is ideal for astronomy as spacecraft can communicate with Earth, harness solar power, and have a clear view of deep space
 - The **James Webb Space Telescope** resides at the L2 point, using little fuel as the Earth and Sun's gravity balance out.
- L1, L2 and L3 points are unstable, with L3 being less useful due to its position behind the sun.
- L4 and L5 form the corners of equilateral triangles with the large masses at the other two corners. The L4 and L5 points are stable. Objects orbiting these two points are called Trojans, named after the three large asteroids (Agamemnon, Achilles and Hector) that are found here.
- The stability and unique gravitational forces make Lagrange points valuable positions for astronomy telescopes to get a clear view of space without being blocked by large bodies.

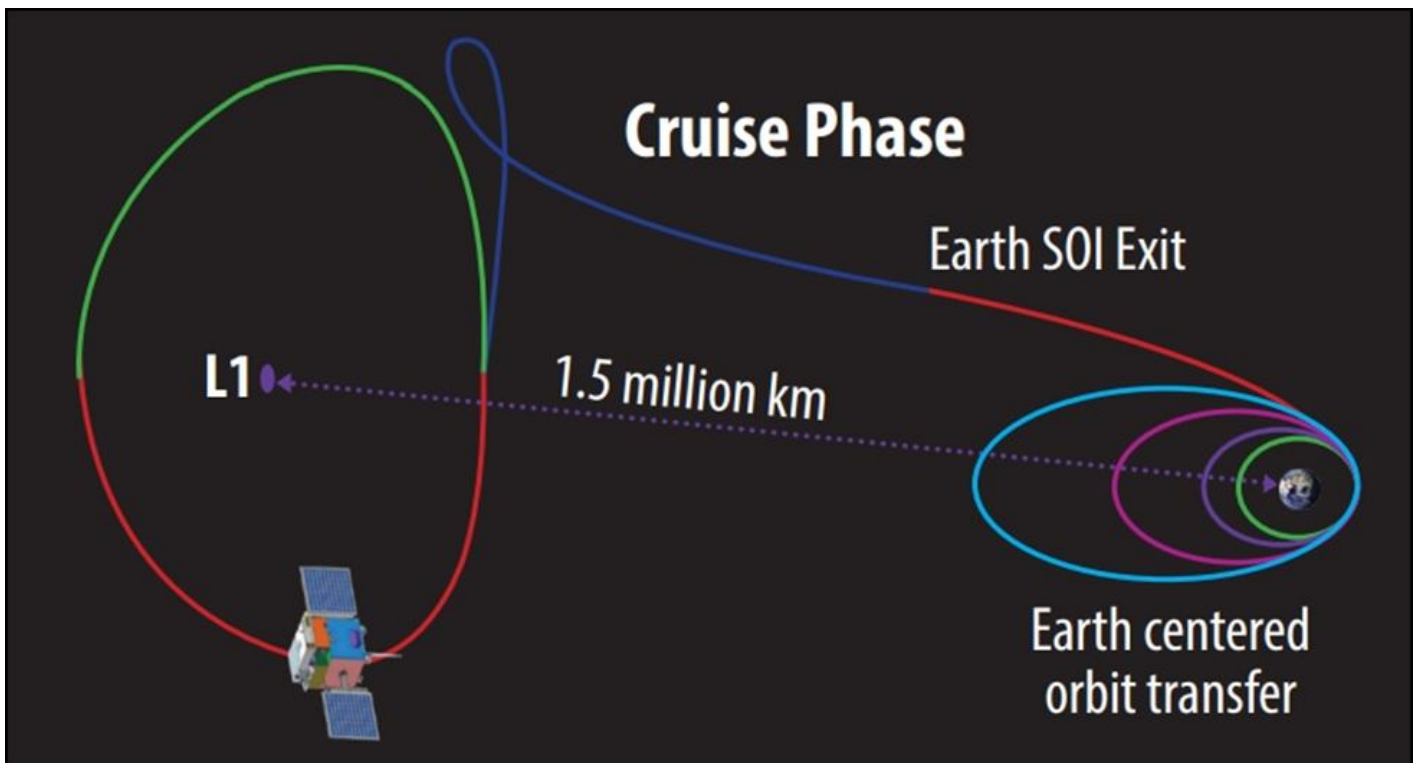
Lagrangian Point 1 and its Importance

Lagrangian Point 1 or L1 is one of the gravitationally stable points in space where the gravitational forces of two large bodies, like the Sun and Earth, balance out. Located about 1.5 million km from Earth towards the Sun, L1 provides an uninterrupted view of the Sun without any **eclipses** or occultations. Placing a solar observatory at L1 has major advantages:

- It can **continuously monitor** the Sun without any blocking of view. This allows tracking solar storms heading towards Earth from their origin on the Sun's surface.
- The satellite can be positioned to always look directly at the Sun, unlike probes in **elliptical heliocentric orbits like Parker Solar Probe**.
- Maintaining position at L1 requires relatively **little fuel** since the gravitational forces are balanced.
- L1 provides an early vantage point to **observe coronal mass ejections and solar flares** before they affect Earth. This increases lead time for space weather predictions.
- **The Solar and Heliospheric Observatory (SOHO)**, an international solar observatory, is already located at L1, demonstrating its utility.

Aditya L1's Journey from Earth to the L1 Lagrange Point

The journey of Aditya-L1 from Earth to the L1 Lagrange point involves several crucial phases and manoeuvres. The journey can be divided into three phases:



- **Phase 1: Earth-Bound Orbits and Manoeuvres**

- Aditya-L1 is launched and enters Earth-bound orbits for **16 days**.
- During this phase, the spacecraft undergoes **5 manoeuvres** to gain the necessary velocity for its journey.
- These manoeuvres are crucial for preparing Aditya-L1 for its trajectory towards the L1 Lagrange point.

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Earth-bound Maneuvers



- **Phase 2: Trans-Lagrangian Insertion and Trajectory (Cruise phase)**

- After the Earth-bound orbits, Aditya-L1 undergoes a **Trans-Lagrangian insertion** manoeuvre.
- This marks the beginning of its **110-day trajectory** towards the L1 Lagrange point.
- The spacecraft travels through space, following a trajectory that leads it to the L1 point.
- This phase involves continuous adjustments to ensure Aditya-L1 stays on the intended path.

- **Phase 3: L1 Orbit and Mission Operations**

- Upon arrival at the L1 Lagrange point, Aditya-L1 performs a manoeuvre to bind itself to an orbit around L1 (halo orbit).
- L1 is a balanced gravitational location between the Earth and the Sun.
- The satellite spends its entire mission orbiting around L1 in an **irregularly shaped orbit**. The orbit is roughly **perpendicular** to the line joining the Earth and the Sun.

- During this phase, Aditya-L1 conducts its comprehensive study of the Sun, utilising its seven distinct payloads developed by ISRO and Indian academic institutes.

Significance of Aditya-L1 mission

The Aditya-L1 mission holds immense significance in the field of space science and technology for several reasons:

- **India's own space-based solar observatory:**
 - The Aditya-L1 mission builds on ISRO's prior expertise in space astronomy missions like **Chandrayaan-1, Astrosat and UVIT**. It expands ISRO's scientific capabilities beyond Earth's orbit.
 - It highlights India's advancing space technologies, positioning ISRO as a leading space agency globally alongside **NASA, ESA and China's CNSA**.
 - Aditya-L1 signifies India's first-ever solar mission and entry into the domain of solar physics, similar to **NASA's Parker Solar Probe**.
- **Expanding India's expertise in space technology:**
 - Real-time monitoring of the Sun and observations of the corona and solar storms will boost space weather prediction capabilities. This has major applications for securing satellite systems and power grids on Earth.
 - The mission affirms India's proficiency in undertaking complex **deep space travel** and **building specialised spacecraft** and instrumentation for cutting-edge space science.
 - The mission diversifies and advances ISRO's space technology expertise beyond traditional areas like **remote sensing and communication**.
- **Future Solar Exploration:**
 - Aditya-L1 cements India's position as a major spacefaring nation with advanced capabilities spanning satellite applications as well as interplanetary science missions.
 - By cementing India's position as a leading space-faring nation adept across satellite applications to interplanetary missions, Aditya-L1 lays the foundation for the country to become a **global hub for solar system science**.
 - It also opens doors for studying the intriguing **solar poles**, unravelling mysteries of our closest star and enhancing our understanding of the cosmos.
 - ISRO aims to launch **Aditya-L2 and Aditya-L3** missions in highly elliptical orbits to further study the Sun. **Aditya-L2** satellite, placed at the L2 point, can provide the first-ever direct imaging of the Sun's far side.

Way Forward

Aditya-L1 is a breakthrough for India's foray into **solar studies and space-based astronomy**. It would mark just the start of a long journey of scientific discovery essential to unravel the mysteries of our life-giving star.

- Despite being historic, Aditya-L1 has its own limitations - regarding its resources as well as capacity and the L1 point itself. Various solar phenomena are multi-directional, and hence, it is necessary to go beyond the L1 point to study the multi-directional distribution of energy erupting out of the sun.
- Future Missions should be directed towards the L5 for studying the Earth-directed CME events and assessing the space weather more accurately.

- As the study of the sun's magnetic fields and polar dynamics is very important to know more about the various solar processes, there should be missions to study the sun's polar regions also, despite the technological challenges of the spacecraft.
- Further, Missions that would study the polarisation of solar radiations at various wavelengths would be beneficial to understand the various solar processes.

Solar Space Program of Other Countries

Several countries have initiated solar space programs to study the Sun and its various aspects. Here are some of the programs from around the world:

- **Helios 2 Solar Probe:** In 1976, the earlier Helios 2 solar probe was a collaborative project between NASA and the space agency of former West Germany. It approached within 43 million km of the Sun's surface.
- **Advanced Composition Explorer (ACE)(NASA-1997):** ACE is designed to analyze solar wind and cosmic rays, offering insights into the Sun's behaviour and its impact on the interplanetary environment.
- **NASA's Parker Solar Probe(2018):** Its key objective is to track the movement of energy and heat through the Sun's corona and also to investigate the source of acceleration of the solar winds.
 - It is a component of NASA's '**Living with a Star**' initiative, which explores various aspects of the Sun-Earth system.
- **Solar Orbiter (2020):** A Joint project between ESA and NASA, Solar Orbiter gathers data to address key questions in heliophysics.
 - These questions include understanding how the Sun generates and manages the ever-changing space environment throughout the solar system.
 - Along with **The Solar Dynamics Observatory and Parker Solar Probe**, it is a part of the international '**Living with a Star**' initiative of NASA.
- **Other Active Sun-Monitoring Spacecraft:**
 - Interface Region Imaging Spectrograph (IRIS) (NASA-2013),
 - WIND (NASA-1994),
 - Hinode (JAEA-2006),
 - Solar Terrestrial Relations Observatory (STEREO) (NASA-2006)

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