FEATURE ARTICLE

Aditya-L1: First Indian Mission to Study the Sun

Anand Kumar Sharma

INDIA'S first spacecraft for exclusive studies on the Sun is scheduled for launch this year. Aditya-L1 spacecraft will orbit around the Sun–Earth Lagrangian point 1 (L1), about 1.5 million kilometres from the Earth, carrying seven payloads to observe the photosphere, chromosphere and corona of the Sun in different wavebands.

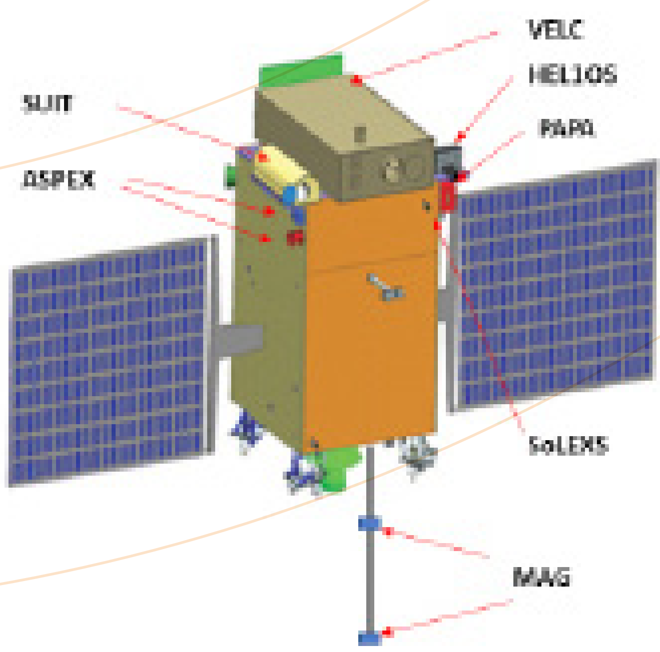
The Aditya-L1 mission was conceptualised in January 2008 as a small 400 kg, 800 km low-Earth orbit Sun synchronous satellite with a coronagraph (Visible Emission Line Coronagraph, VELC) to observe only the solar corona. The corona is the outer layer of the sun extending to thousands of kilometres above the disc (photosphere), which we see during a full solar eclipse. It has a temperature of more than a million Kelvin which is much higher than the solar disc temperature of around 6000 K. How the corona gets heated to such high temperatures is still an unanswered question in solar physics.

The scope of the mission has since been expanded. The spacecraft will be inserted in a halo orbit around the L1 point, where it will act as a comprehensive solar observatory studying coronal heating, solar wind acceleration, coronal magnetometry, origin and monitoring of near-UV solar radiation (which drives Earth's upper atmospheric dynamics and global climate), coupling of the solar photosphere to chromosphere and corona, in-situ characterisations of the space environment around Earth by measuring energetic particle fluxes and magnetic fields of the solar wind and solar magnetic storms.

The payloads used for these studies have to be placed outside the interference from the Earth's magnetic field and could not have been useful in the low earth orbit.

Exploring the Sun

The Sun has been studied in great detail, but still there are many unanswered mysteries. How is the corona heated to more than a million degrees? Where and how does the solar wind obtain its acceleration? Which processes in the lower corona lead to the gigantic mass ejections? What are the sources that heat the chromosphere, the transition region and the solar corona, above the much cooler photosphere?



Mission Objectives of Aditya-L1

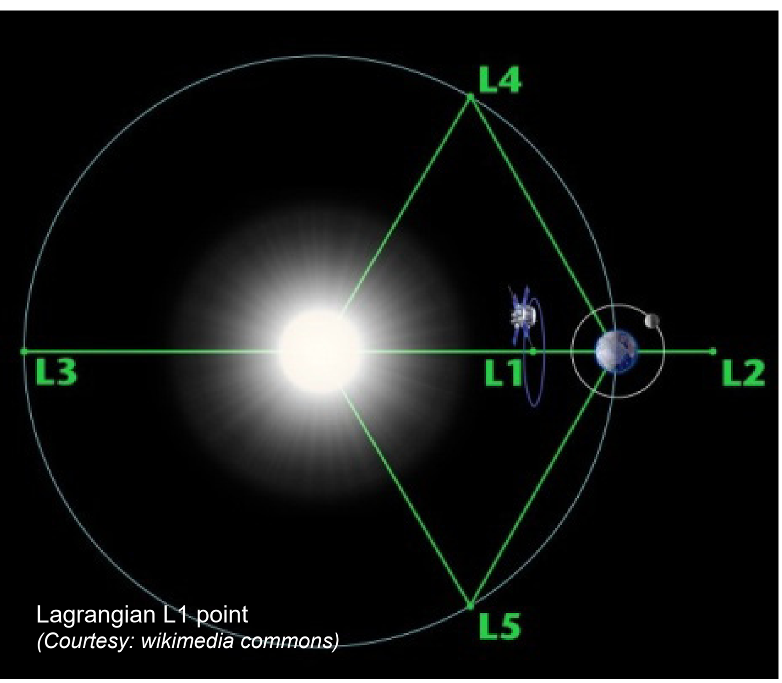
- Understanding the coronal heating and solar wind acceleration.
- Understanding initiation of coronal mass ejection, flares and near-earth space weather.
- Knowledge of coupling and dynamics of the solar atmosphere.
- Understanding solar wind distribution and temperature anisotropy.

The eruptive phenomena of flares and Coronal Mass Ejections (CMEs) which expel huge amounts of particulate matter and energy have direct consequences on space weather. How exactly the Sun's radiation affects the dynamics of the Earth's atmosphere on shorter as well as on longer time scale is yet to be comprehended.

To understand some of these mysteries, Aditya-L1 is planned with a suite of instruments to obtain a better understanding of the star. The extended scope of the mission with additional payloads demanded a larger satellite platform. The 1,500 kg Aditya-L1 now carries seven science payloads. The nominal design life of spacecraft is five years.

Lagrange Points: Parking Places in Space

A Lagrangian point is a location in space near two large bodies where a smaller object will maintain its position relative to the large orbiting bodies. It is a location in space where the combined gravitational forces of two large bodies, such as Earth and the Sun or Earth and the moon, equal the centrifugal force felt by a much smaller third body (e.g. artificial satellite). At other locations, a small object would go into its own orbit around one of the large bodies.



Lagrangian L1 point
(Courtesy: wikimedia commons)

In the Sun–Earth system, the Lagrange points are special locations where an artificial satellite will stay stationary relative to the Earth. At these locations, the pull of gravity from the Earth cancels out the pull of gravity from the Sun. Anything placed at these points will feel equally pulled toward the Earth and the Sun and will revolve with the Earth around the Sun.

Many astronomical and Earth observatories are located at the Lagrange points, providing a vantage point of our planet and space. L1 point gets an uninterrupted view of the Sun and therefore is a good position to monitor the Sun. The constant stream of particles from the Sun, the solar wind, reaches L1 point about an hour before reaching the Earth.

L1 point is currently occupied by the Solar and Heliospheric Observatory (SOHO-1995), the ESA/NASA solar watchdog and the NASA/NOAA Deep Space Climate Observatory (2015). There are many satellites carrying particle experiments at L1, like NASA's spacecraft Wind (1994) and ACE (Advanced Composition Explorer-1997), and NOAA's Deep Space Climate Observatory (DSCOVR-2015).

Payloads

Aditya-L1 has seven payloads – two imaging telescopes (VELC and SUIT), two X-ray instruments (SoLEXS and HEL1OS), two particle instruments (PAPA and ASPEX) and an advanced digital magnetometer (MAG).

i. **Visible Emission Line Coronagraph (VELC):** VELC the main payload on-board Aditya-L1 to study the solar corona in three visible and one infra-red bands. The coronagraph mimics total solar eclipse by blocking the sunlight with an occultor and enabling the observation of extended coronal atmosphere of the Sun. VELC is capable of simultaneous imaging, spectroscopy and spectro-polarimetry close to the solar limb.

ii. **Solar Ultraviolet Imaging Telescope (SUIT):** The primary goal of SUIT instrument is to understand how the solar atmosphere is energized. The instrument developed at the Inter-University Centre for Astronomy and Astrophysics (IUCAA) in collaboration with ISRO and other institutes weighs nearly 35 kg.

    This instrument will measure the solar eruptive events up to 1.1 solar radii in the near ultraviolet wavelength range (200–400 nm). The Sun has never been observed from space in this wavelength range.

    SUIT will simultaneously map the photosphere and chromosphere of the Sun providing full disk images of different layers of the solar atmosphere and also study solar irradiance variations which are closely connected with magnetic activity on the solar disc.

iii. **High Energy L1 Orbiting X-ray Spectrometer (HEL1OS):** HEL1OS will observe the dynamic events in the solar corona and provide an estimate of the energy used to accelerate the solar energetic particles during the eruptive events. This payload has been developed by U.R. Rao Satellite Centre (URSC), Udaipur Solar Observatory (USO) and Physical Research Laboratory (PRL).

iv. **Solar Low Energy X-ray Spectrometer (SoLEXS):** SoLEXS will monitor the X-ray flares for studying the enigmatic coronal heating mechanism of the solar corona. SoLEXS instrument has been developed at the U.R. Rao Satellite Centre (URSC).

v. **Plasma Analyser Package for Aditya (PAPA):** PAPA instrument is designed to understand the composition of solar wind and its energy distribution. This payload has been developed by Space Physics Laboratory (SPL), VSSC.

vi. **Aditya Solar wind Particle Experiment (ASPEX):** ASPEX will study the variation and properties of the solar wind as well as its distribution and spectral characteristics. This instrument was developed at the Physical Research Laboratory (PRL).

vii. **Advanced Triaxial High Resolution Digital Magnetometer (MAG):** This instrument will measure the magnitude and nature of the interplanetary magnetic field (IMF) and has been developed by Laboratory for Electro-optic Systems (LEOS) and U.R. Rao Satellite Centre (URSC).

Launch and Operations

Aditya-L1 is expected to be launched during the first half of 2020 by the Polar Satellite Launch Vehicle XL version (PSLV-XL) from Sriharikota. XL version has six extended length (XL) strap-on motors. The satellite will be launched into an elliptical Earth Parking Orbit of 245 km by 21,000 km. The satellite propulsion is employed to carry out orbit manoeuvres to raise the orbit, transfer around the L1 point, insertion and maintain orbit about L1. The orbit period of the spacecraft is 177.86 days.

The insertion around L1 will take place in about 100 days from the launch (coast phase). Aditya-L1 is expected to provide the very first results of the magnetic field of the Sun's corona almost two months after the launch.

The ISRO Telemetry Tracking and Command Network (ISTRAC) will track and control the spacecraft. For the initial phase operations, additional network stations from other agencies will also be utilized. The payload data will be acquired through Indian Deep Space Network (IDSN). These data will be processed and disseminated through the Indian Space Science Data Centre (ISSDC).

Aditya-L1 is the first Indian mission to study the Sun and the first venture of the country to place a spacecraft into the halo orbit at the Lagrangian point. It is expected to provide a multipronged holistic approach to the understanding of some of the outstanding problems of solar physics. The spacecraft will provide the observations of Sun's Corona (soft and hard X-ray, emission lines in the visible and NIR), chromosphere (UV) and photosphere (broadband filters).

VELC instrument will enable the study of the dynamics at the corona. The SUIT payload will study the intensity enhancement at the chromospheric layers. The SoLEXS and the HEL1OS instruments will provide observations on the initiation of the impulsive phase of the flares. This combination of measurements will help in providing a comprehensive picture of the solar eruptive events and help fine-tune models providing a physical understanding of these events, and hence the drivers affecting space weather.

In addition, particle payloads (PAPA, ASPEX) will measure the particle flux emanating from the Sun and reaching the L1 orbit, and the magnetometer payload will measure the variation in magnetic field strength at the halo orbit around L1.

The mission will be a significant milestone for the Indian space programme in that it will not only provide valuable solar science data to Indian scientists but will also benefit the global scientific community in understanding the sun.

Dr. Anand Kumar Sharma is Former Distinguished Scientist, ISRO. Address: Anukampa, No. 14-15, 1 Main, 2 Cross, Sri Veerbhadra Nagar (Basava Nagar), Marathahalli Post, Bangalore-560037, Karnataka. Email: anukampa2003@yahoo.com