A COMPREHENSIVE REPORT ON ADITYA-L1

~By Trishit Malik

1) Introduction: "Aditya" in Sanskrit means the Sun. L1 here refers to Lagrange Point 1 of the Sun-Earth system. For common understanding, L1 is a location in space where the gravitational forces of two celestial bodies, such as the Sun and Earth, are in equilibrium. This allows an object placed there to remain relatively stable with respect to both celestial bodies.

Aditya-L1 is a satellite dedicated to the comprehensive study of the Sun. It has 7 distinct payloads developed, all developed indigenously, five by ISRO and two by Indian academic institutes in collaboration with ISRO.

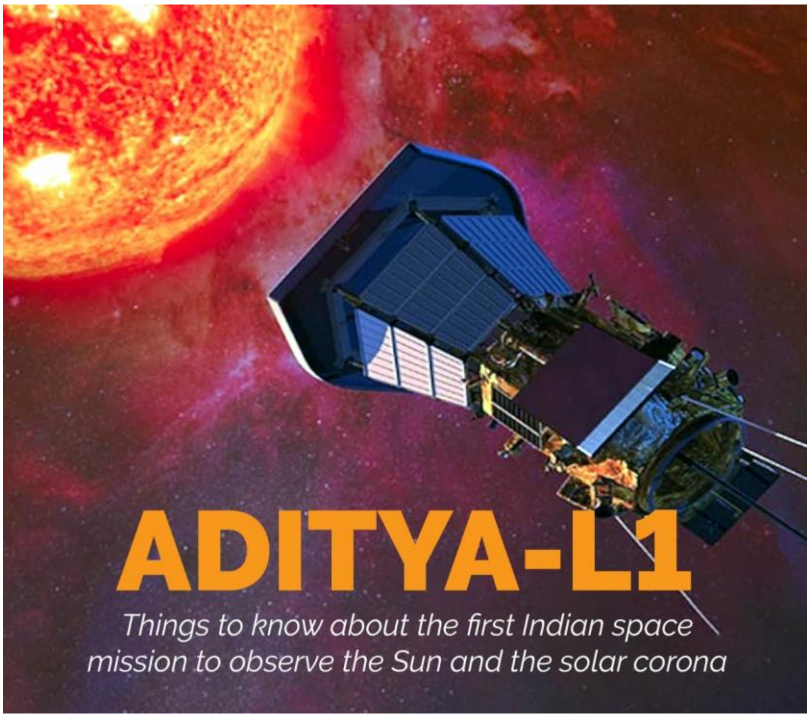

Fig-1: Aditya-L1, a milestone in India's space mission history

2) Discussion on Lagrange points: If we want to know about the working process of Aditya-L1, then we should have a basic knowledge of Lagrange points.

Lagrange points, also known as **liberation points**, are unique locations in space where the gravitational force of two massive bodies (like Sun and Earth) precisely equals the centripetal force required for a small object (like spacecraft) to move with them. This makes Lagrange points an excellent location for space crafts as orbit corrections and hence fuel requirements, needed to maintain the desired orbit, are kept at a minimum.

For any combination of two orbital bodies (like Sun-Earth and Earth-Moon systems), there are **five Lagrange points (L1 to L5**), all in the orbital plane of the two large bodies (figure-1). The three points - **L1, L2, and L3 are dynamically unstable** and **lie on the line through the centres of the two large bodies**, while the remaining two points - **L4 and L5 are stable points** and each acts as the third vertex of an equilateral triangle formed with the centres of the two large bodies.

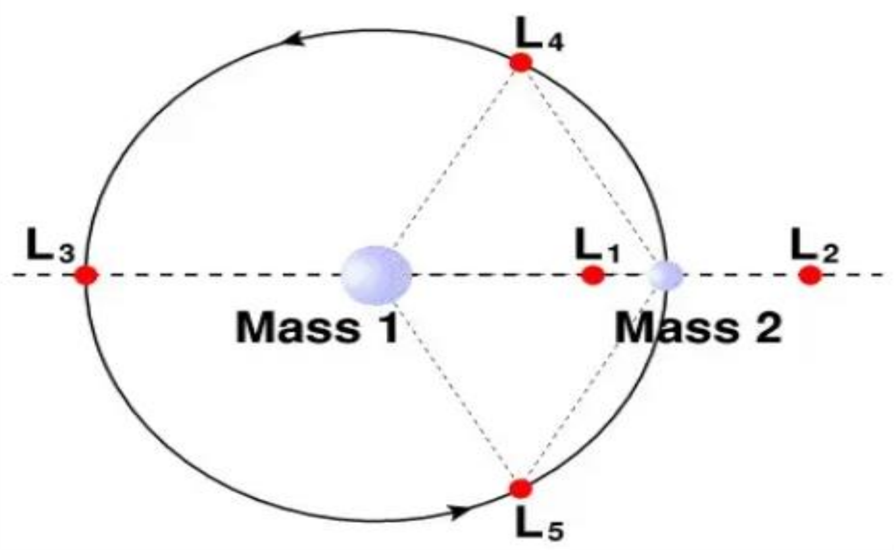

Fig-2: Lagrange points in Sun-Earth system

L1 is particularly significant because it is situated between the two primaries (the Sun and Earth), making it an ideal location for spacecrafts because they allow continuous observation of primary bodies, continuous communication with earth and an unobstructed view of celestial bodies. These orbits are well-suited for scientific missions like Aditya which will act like a solar observatory around L1 and communication to Earth.

3) Instruments: The instruments of Aditya-L1 are tuned to observe the solar atmosphere mainly the chromosphere and corona. In-situ instruments will observe the local environment at L1. There are total seven payloads on-board with four of them carrying out remote sensing of the Sun and three of them carrying in-situ observation.

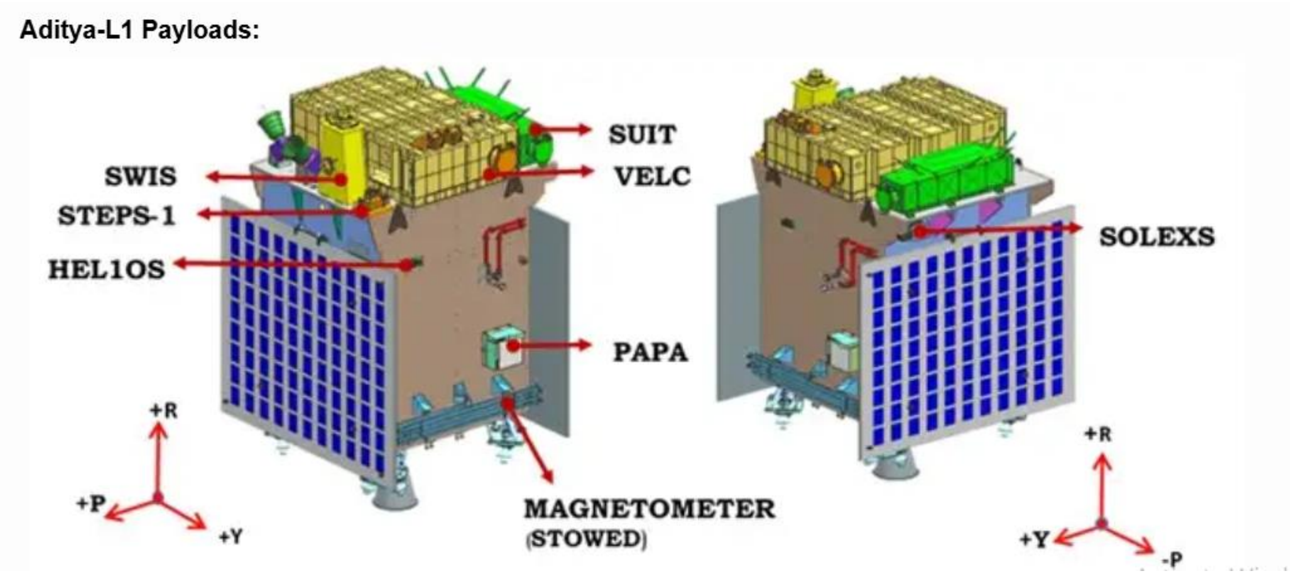

Fig-3: Detailed structure of Aditya-L1

Here is an informative summary of the instruments:

A) Remote Sensing Payloads (observe the Sun from L1)

a) VELC (Visible Emission Line Coronagraph):

- Studies **solar corona**
- High-resolution **coronal imaging & spectroscopy**
- Key for understanding **coronal heating & CMEs**

b) SUIT (Solar Ultraviolet Imaging Telescope)

- Images **photosphere & chromosphere**
- Narrowband + broadband UV imaging
- Helps link **lower solar atmosphere → corona**

c) SoLEXS (Solar Low Energy X-ray Spectrometer)

- Measures **soft X-rays**
- Sun-as-a-star observation
- Studies **solar flares & coronal plasma temperature**

d) HEL1OS (High Energy L1 Orbiting X-ray Spectrometer)

- Measures **hard X-rays**
- Sun-as-a-star observation
- Probes **energetic flare processes**

B) In-situ Payloads (measure space environment at L1)

a) ASPEX (Aditya Solar wind Particle Experiment)

- Detects **solar wind protons & heavy ions**
- Measures **energy, flux, and direction**

b) PAPA (Plasma Analyser Package for Aditya)

- Measures **electrons & heavier ions**
- Provides **velocity distribution and direction**

c) Magnetometers (Tri-axial, High Resolution)

- Measures **interplanetary magnetic field**
- Components: B_x, B_y, B_z
- Crucial for **space weather studies**

4) Scientific objective: The major science objectives of Aditya-L1 mission are:

- Study of **Solar upper atmospheric** (chromosphere and corona) dynamics.
- Study of **chromospheric and coronal heating**, physics of the partially ionized plasma, initiation of the coronal mass ejections, and flares
- Physics of solar corona and its heating mechanism..
- **Development, dynamics and origin** of CMEs.
- Identify the sequence of processes that occur at multiple layers (chromosphere, base and extended corona) which eventually leads to solar eruptive events.
- **Magnetic field topology** and **magnetic field measurements** in the solar corona .
- Drivers for space weather (origin, composition and dynamics of solar wind .

5) Detailed summary and analysis of both earlier and recent published data:

Aditya-L1 has now moved beyond "mission description" into **real science output**, so it's useful to separate **earlier (initial/expected + early calibration phase)** results from **recent peer-reviewed findings (2024–2025)**.

Below is a **physics-focused, detailed but readable summary.**

A) Measurement of supra-thermal and energetic ions: The Supra Thermal & Energetic Particle Spectrometer (STEPS) instrument, a part of the **Aditya Solar Wind Particle Experiment (ASPEX)** payload, bwgan the collection of scientific data on **Sept 18, 2023**.

STEPS comprises **six sensors**, each observing in different directions and measuring **supra-thermal and energetic ions** ranging from 20 keV/nucleon to 5 MeV/nucleon, in addition to electrons exceeding 1 MeV. These measurements are conducted using low and high-energy particle spectrometers.

- **Importance:** The data collected during Earth's orbits helps scientists to analyse the **behaviour of particles surrounding the Earth, especially in the presence of the magnetic field of Earth.**

Here a figure displays measurements depicting variations in the energetic particle environment within Earth's magnetosphere, collected by one of the units.

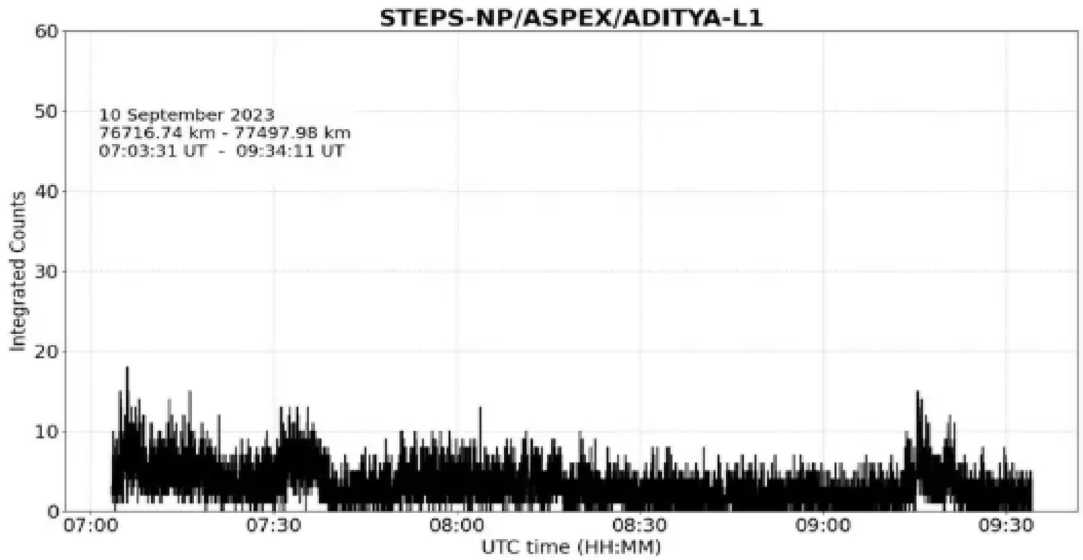

Fig-4: Variation in integrated counts over time recorded by the STEPS Sensors on September 10, 2023

B) First High-Energy X-ray glimpse of Solar Flares:

During its first observation period from approximately on October 29, 2023, the High Energy L1 Orbiting X-ray Spectrometer (HEL1OS) on board Aditya-L1 has recorded the impulsive phase of solar flares. The recorded data is consistent with the X-ray light curves provided by NOAA's GOES.

Commissioned on October 27, 2023, HEL1OS is currently undergoing fine-tuning of thresholds and calibration operations. The instrument is set to monitor the Sun’s high-energy X-ray activity with fast timing and high-resolution spectra.

- **Importance:** HEL1OS data enables researchers to study explosive energy release and electron acceleration during impulsive phases of solar flares.

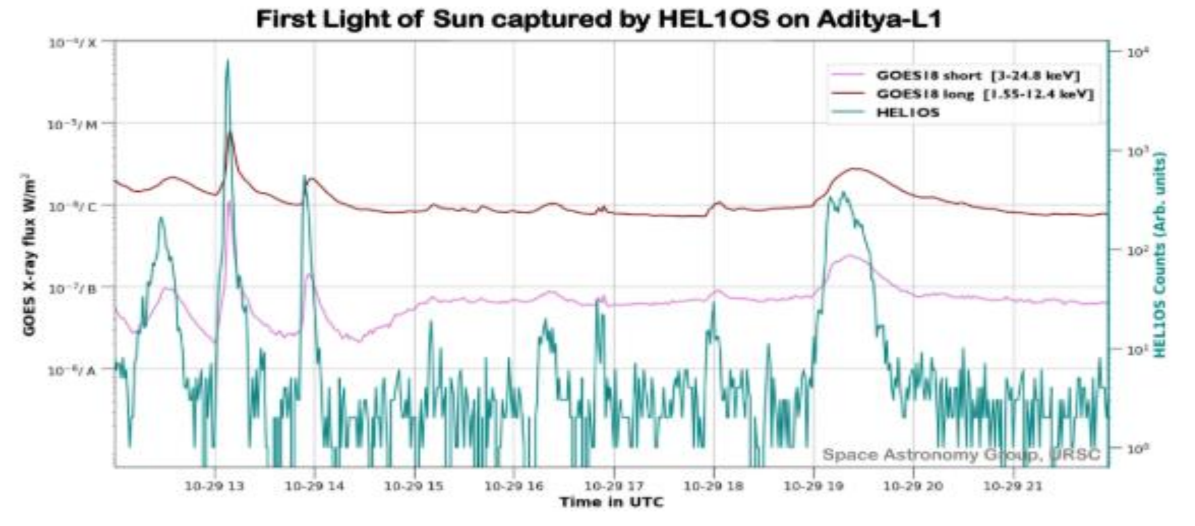

Fig-5: X-ray flux (detected by HEL1OS) vs. time graph

C) Full-disk images of the Sun in near ultraviolet wavelengths:

On November 20, 2023 the **SUIT (Solar Ultraviolet Imaging Telescope**) payload was powered ON. Following a successful pre-commissioning phase, the telescope captured its first light science images on December 6, 2023. These unprecedented images, taken using eleven different filters, include the first-ever **full-disk representations of the Sun** in wavelengths ranging from **200 to 400 nm.**

- **Importance:** Among the notable features revealed are **sunspots, plage, and quiet Sun regions**, providing scientists with pioneering insights into the intricate details of the Sun's **photosphere and chromosphere**. SUIT observations will help scientists study the dynamic coupling of the magnetized solar atmosphere and assist them in placing tight constraints on the effects of solar radiation on Earth's climate.

D) Halo-Orbit Insertion of Aditya-L1 Successfully Accomplished:

The orbit of Aditya-L1 spacecraft is a periodic Halo orbit which is located roughly 1.5 million km from earth on the continuously moving Sun – Earth line with an orbital period of about 177.86 earth days. This Halo orbit is a periodic, three-dimensional orbit at L1 involving Sun, Earth and a spacecraft. This specific halo orbit is selected to ensure a mission lifetime of 5 years, minimising station-keeping manoeuvres and thus fuel consumption and ensuring a continuous, unobstructed view of sun.

- **Advantages:** Placing the Aditya-L1 in a halo orbit around L1 point has advantages as compared to placing in a Low Earth Orbit (LEO):

  i) It provides a smooth Sun-spacecraft velocity change throughout the orbit, appropriate for helioseismology.

  ii) It is outside of the magnetosphere of Earth, thus suitable for the "in situ" sampling of the solar wind and particles.

  ii) It allows unobstructed, continuous observation of the Sun, and view of earth for enabling continuous communication to ground stations.

E) Decoding the Impact of a Powerful Solar Storm on Earth's Invisible Magnetic Shield:

Space weather refers to conditions in space caused by transient activity on the Sun, such as solar plasma eruptions, which can affect satellites, communication and navigation services, and power grid infrastructure on Earth. During such strong space weather events, Earth's magnetic shield can be significantly disturbed.

During October 2024, a powerful solar storm affected the Earth which was detected by none other than Aditya-L1. The storm was caused by a massive eruption of solar plasma material from the Sun. The study revealed that the most severe effects occurred during the impact of the turbulent region of the solar storm, which was identified with the help of **Aditya-L1** observations.

This turbulent region strongly compressed Earth's magnetic field, pushing it unusually close to the Earth and briefly exposing some satellites in geostationary orbit to harsh space conditions. During the turbulent phase of the storm, currents in the auroral region (high latitudes) super intensified, potentially heating the Earth's upper atmosphere and causing enhanced atmospheric escape.

- **<u>Advantages:</u>** The finding of this study shows further importance of understanding of space weather phenomena and their real time assessments to safeguard the critical space assets.

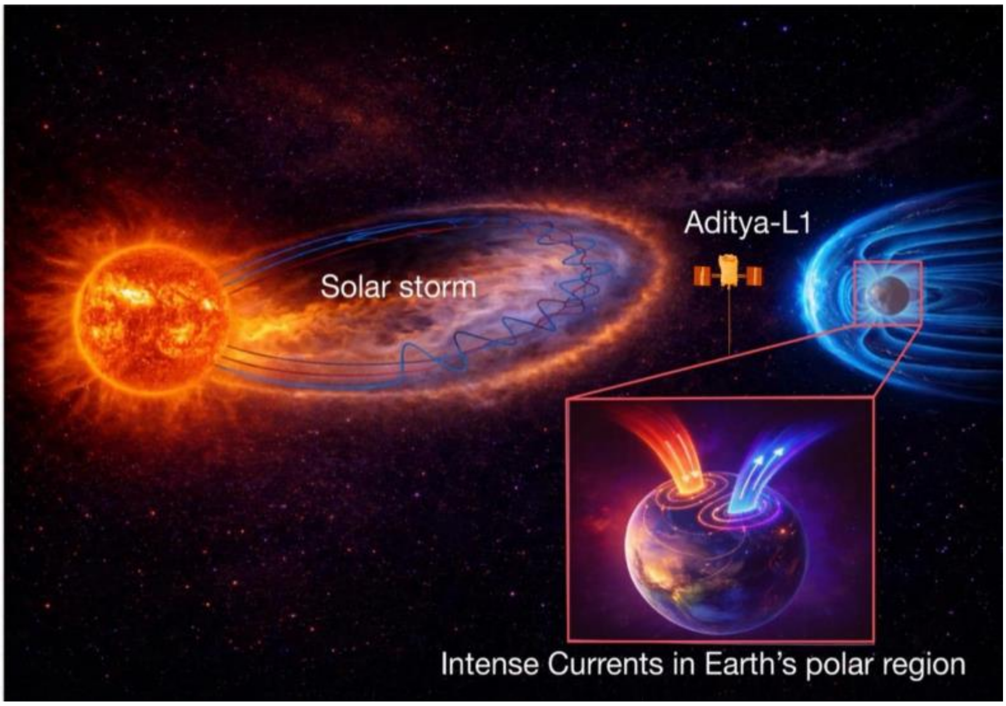

Fig-6: Solar storm and its interaction with Earth's magnetosphere

6) Future of Aditya-L1:

A) Mature Science Phase: Aditya-L1 will move from "case studies" to statistical solar-cycle science. It will be able to have a **long-term tracking of:**

- **Coronal dynamics**
- **Solar wind variability**
- **Magnetic field turbulence**

B) Space Weather Forecasting: It will do **better** lead-time predictions for:

- Geomagnetic storms
- CME impacts

Thus it will be integrated with **Indian space weather services.**

C) Mission Extension: Although the designed mission life of Aditya-L1 is of **5 years**, but it may be **extended** if:

- Fuel margin remains
- Payloads stay healthy (very likely)

7) Conclusion:

Aditya-L1 is undoubtedly a major milestone in India's space science program by enabling continuous, simultaneous observations of the Sun and the near-Earth space environment from the L1 point. Its comprehensive set of remote-sensing and in-situ instruments have already provided valuable insights into the solar atmosphere, solar wind, and space-weather drivers. As the mission continues, Aditya-L1 is expected to play a crucial role in advancing our understanding of Sun–Earth interactions, improving space-weather prediction capabilities, and contributing lasting scientific data to the global heliophysics community.

- *References:*
  i) www.isro.gov.in
  ii) Wikipedia