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Aditya-L1: Exploring the Sun's Mysteries from the Equilibrium Point

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Abstract:

Aditya-L1 is a satellite having 7 payloads developed indigenously will study the Sun in depth. Five by ISRO and two in collaboration with Indian academic institutes such as The Inter-University Centre for Astronomy and Astrophysics, Indian Institute of Astrophysics (IIA). Aditya-L1 is equipped with four remote sensing instruments;[1] a coronagraph for visible and infrared observations, a disc imager for Near Ultra-Violet (NUV)[2], and two full-sun integrated spectrometers[3] for soft and hard X-ray. Three devices for in-situ measurements, including a magnetometer, investigate magnetic field fluctuations during energetic events. The Sun and celestial bodies, like Earth and the Sun, maintain a stable relationship at Lagrange Point 1, where the gravitational forces are in equilibrium.

Keywords: *Sun; Satellite; Lagrange Point 1; Payloads; ISRO; Coronograph; Visible and Infrared Observations; Whole Disc Imager; Near Ultra-Violent (NUV); Spectrometers; X-ray; In-situ Measurements; Magnetometer; Lagrange Point 1; Gravitational forces; Solar Research*

1. Introduction:

Aditya-L1, India's first dedicated space-based solar observatory, launched on September 2, 2023, embarks on a mission to scrutinize the Sun's various layers and phenomena. This article aims to elucidate the mission's scientific objectives, the spacecraft's orbital dynamics, its importance globally and for India, and the unique attributes of its payloads designed for solar exploration.

2. Global Mission about Solar Mission:

Support by European Space Agency (ESA)[4] - ESA is supporting Aditya-L1 in two ways:

[1] Remote sensing instruments measure the intensity of electromagnetic radiation emitted, reflected, or transmitted by the target of interest. Instruments that receive natural emitted, transmitted, or reflected radiation from the target are passive; most instruments fall in this category.

[2] Near Ultraviolet refers to any ultraviolet (UV) light in the 180 to 400 nanometer wavelength regions of the electromagnetic spectrum

[3] A spectrometer is any instrument that's used to measure the variation of a physical characteristic over a given range, i.e. a spectrum.

[4] European Space Agency (ESA)- https://www.esa.int/Enabling_Support/Operations/How_is_ESA_supporting_ISRO_s_Aditya-L1_solar_mission

1) The Agency is providing deep space communication services to the mission, and,
2) In 2022, ESA assisted ISRO with the validation of important new flight dynamics software.

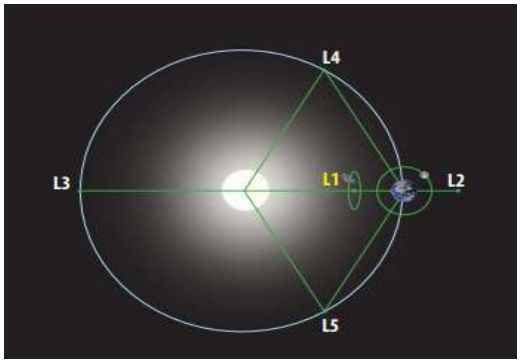

Fig-1: -Illustration of Lagrange points of the Sun-Earth system

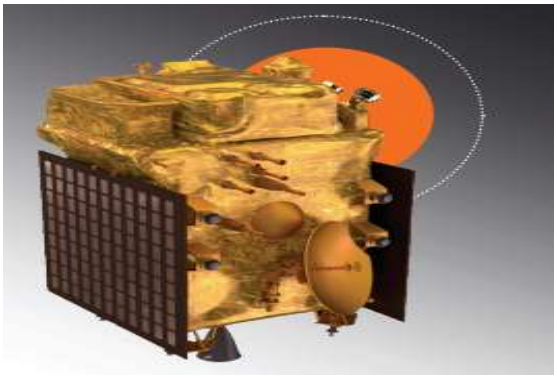

Fig-2: Aditya L1

For the Aditya-L1 mission, they provide support from all three of their 35-metre-deep space antennas in Australia, Spain and Argentina, and support from Kourou station in French Guiana with coordinated support from Goonhilly Earth Station[5] in the UK. From April to December 2022, ESA and ISRO teams worked together to evaluate ISRO's strategy for operating Aditya-L1 and their new orbit determination software. Aditya L1 will generate large quantities of scientific data as it balances in an unstable orbit. With its global network of deep space ground stations[6] and experience flying similar missions, ESA has just the right infrastructure and expertise to provide support.

3. Indian Mission about Solar Mission:

The Indian Space Research Organization (ISRO)[7] was launched in 1969 with 124 spacecraft missions, 18 satellite- missions and 94 launches, it is one of the elite space organizations in the world. Aditya-L1 will be the newest member of the solar explorers, including ESA's Solar Orbiter[8], SOHO[9], NASA's Parker Solar Probe[10] and others. The primary scientific objectives of the Aditya-L1 mission are to understand the processes governing coronal heating, solar wind acceleration, and the initiation of Coronal Mass Ejections (CMEs).

[5] https://www.goonhilly.org/
[6] https://www.esa.int/Enabling_Support/Operations/ESA_Ground_Stations
[7] ISRO. (2023, September 2). *Aditya L-1 Mission Booklet*. www.isro.gov.in. Retrieved October 29, 2023, from https://www.isro.gov.in/media_isro/pdf/Aditya_L1_Booklet.pdf
[8] ESA's Solar Orbit. https://www.esa.int/Science_Exploration/Space_Science/Solar_Orbiter
[9] SOHO; https://www.esa.int/Science_Exploration/Space_Science/SOHO
[10] NASA's Parker Solar Probe. https://science.nasa.gov/mission/parker-solar-probe/

Additionally, the mission seeks to predict solar storms, providing information for space weather forecasting. It concentrates on the photosphere, chromosphere, and corona. The Solar mission also helps India in advancing its scientific knowledge by contributing to space weather science, strengthening its technological capabilities by developing indigenous payloads and international collaboration (such as with ESA- mentioned in global mission about solar mission).

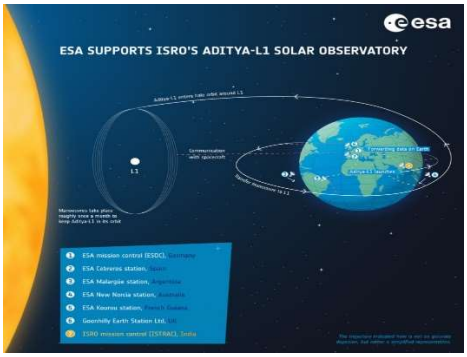

Fig-3: -ESA ground stations support ISRO's Aditya L

The primary scientific objectives of the Aditya-L1 mission are to understand the processes governing coronal heating, solar wind acceleration, and the initiation of Coronal Mass Ejections (CMEs). Additionally, the mission seeks to predict solar storms, providing information for space weather forecasting. It concentrates on the photosphere, chromosphere, and corona. The Solar mission also helps India in advancing its scientific knowledge by contributing to space weather science, strengthening its technological capabilities by developing indigenous payloads and international collaboration (such as with ESA- mentioned in global mission about solar mission). Aditya-L1 represents India's commitment to developing its space capabilities and contributing to world scientific knowledge.

Aditya-L1's achievement not only demonstrates India's space capability, but it also opens the door to deeper solar research, promoting a greater grasp of the Sun's role in our cosmic neighborhood.

4. Description of Aditya L1:

4.1 Lagrangian L-1 Point: Aditya-L1 is India's first space-based observatory-class solar mission. The spacecraft will be positioned around the Sun-Earth system's Lagrangian point1 (L1), approximately 1.5 million kilometers away from Earth. Observing the Sun without eclipse, helping observe solar activity enabling it to detect solar energy and magnetic storms before affected by the Earth's magnetic field and atmosphere.

The payloads use electromagnetic and particle detectors to study the Photosphere[11], Chromosphere[12], and the Corona[13]. The spacecraft is equipped with protective layers and special

[11] The glowing ball of light that is seen in the sky is the photosphere. The surface of the Sun is the only part that we can see from Earth.
[12] Chromosphere is a reddish and glowing layer of gas above a star's (or Sun's) photosphere. It is actually the transition between corona and the photosphere

materials designed to shield it from space-based dangers, including radiation and CME clouds. Using the special vantage point of L1, four payloads will directly view the Sun and the remaining three payloads will carry out in-situ studies of particles and fields at L1.

4.2 Function of Payload:

Payload performs the following 7 functions-

i) VELC (*Visible Emission Line Coronagraph*) - studies the solar corona and the dynamics of coronal mass ejections. There will be simultaneous observations of corona in 3 modes- *Imaging,* [14] *Spectroscopy and*[15] *Spectropolarimetry*.

ii) SoLEXS (*Solar Low Energy X-ray Spectrometer*) - Soft X-ray[16] spectrometer which measures solar soft X-ray flux to investigate the properties of the solar corona.

iii) PAPA (*Plasma Analyzer Package for Aditya*) -It studies the composition of solar wind and energy distributions and measures solar wind.

iv) HEL1OS (pronounced as *Helios- High Energy L1 Orbiting X-ray Spectrometer*) -observes solar flares using a [17]hard X-ray spectrometer.

v) SUIT (Solar Ultra-violent Imaging Telescope) - provides near-simultaneous coverage of the solar atmosphere from lower photosphere to the upper chromosphere which helps understand the dynamics of the solar atmosphere.

vi) ASPEX (*Aditya Solar wind Particle Experiment*) - it comprises of low and high energy particle spectrometers to carry out in-situ measurements of solar wind particles at L1.

vii) MAG (*Magnetometer*) -dual tri-axial magnetic sensor installed on the Sun facing deck of Aditya-L1. It measures the magnitude and direction of the Interplanetary Magnetic Field (IMF) locally, and to study solar events such as the Coronal Mass Ejections (CMEs), the impact of these events on near Earth space environment.

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[13] The Sun's corona is the outermost part of the Sun's atmosphere. The corona is usually hidden by the bright light of the Sun's surface. That makes it difficult to see without using special instruments. However, the corona can be viewed during a total solar **eclipse.**

[14] Spectroscopy is the study of the absorption and emission of light and other radiation by matter. It involves the splitting of light (or more precisely electromagnetic radiation) into its constituent wavelengths (a spectrum), which is done in much the same way as a prism splits light into a rainbow of colors.

[15] The measurement of the polarization of light at different wavelengths

[16] A type of x-ray that has its wavelength between 20 and 200 angstroms

[17] *Hard* x-rays are the highest energy x-rays.

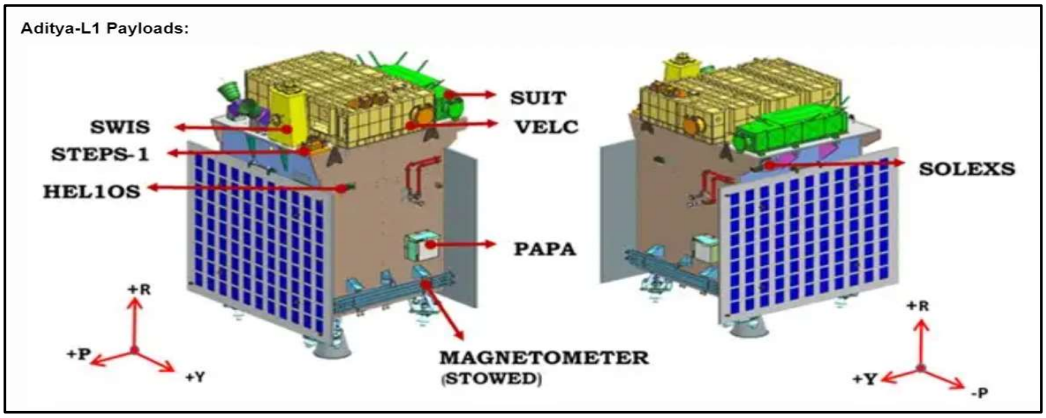

Fig-5: **Aditya L-1**[18]

-Locations of Aditya-L1 payloads on the spacecraft - R, P and Y indicate the Raw, Pitch and Roll axis of the spacecraft. ASPEX Payload Consists of SWIS & STEPS.

5. Output Revealed by Solar Mission:

In a post on X (on September 18, 2023), the Indian Space Research Organization (ISRO) said that the sensors on board Aditya L1[19] have begun measuring ions and electrons at distances greater than 50,000 km from Earth by using STEPS (an instrument in ASPEX). This data helps scientists analyze the behavior of particles surrounding Earth.

On December 5, ISRO has released visuals showcasing the shutter operation of the SUIT instrument aboard Aditya L1. This instrument has recently achieved success in capturing the first full-disk images of the Sun in the 200-400 nm wavelength range. (The Hindustan Times)[20]

6. Future Planning:

Scientists analyze data from India's Aditya-L1 solar mission, set to launch on September 2, to understand the Sun's past, present, and future. This information is used for understanding climate changes on Earth in the coming millennia. If the Sun can be monitored over a long period, it is expected to model the history of the Sun that is unknown to mankind, said the scientist who is the Director of Aryabhata Research Institute of Observational Sciences (ARIES) in Nainital.

[18] https://www.google.com/imgres?imgurl=https%3A%2F%2Fakm-img-a-in.tosshub.com%2Fsites%2Fvisualstory%2Fstories%2F2023_08%2Fstory_59078%2Fassets%2F8.jpeg%3Ftime%3D1693289741%26size%3D*%3A900&tbnid=e8PNkZavXlB-rM&vet=1&imgrefurl=https%3A%2F%2Fwww.businesstoday.in%2Fvisualstories%2Ftrending%2Fmeet-isros-aditya-l1-after-moon-its-time-for-sun-59078-29-08-2023&docid=sJWLjbMFm2YTeM&w=540&h=900&source=sh%2Fx%2Fim%2Fm1%2F0

[19] https://www.livemint.com/science/news/adityal1-starts-collecting-data-says-isro-11695037861222.html

[20] https://www.hindustantimes.com/technology/how-aditya-l1-s-suit-pictured-sun-new-isro-video-reveals-operation-101702300930490.html

7. Conclusion:

In conclusion, Aditya-L1 is an important milestone in Indian space exploration. This solar mission allows for a comprehensive study of the Sun. The mission's seven indigenous payloads use a multidisciplinary approach to comprehend the Sun's characteristics, from the photosphere to the corona, and their impact on space weather.

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