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ADITYA-L1: Illuminating the Solar Frontier- Charting Hopes and Scopes'

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Abstract:

The article delves into the aspirations and prospects of solar missions, with a focal point on the Aditya-L1. It explores the mission's potential for advancing our understanding of the Sun and its impact on Earth, encompassing solar phenomena, space weather, and cosmic relations. It delves into the potential and prospects of the Aditya-L1 solar mission, exploring its critical role in advancing our understanding of the Sun. It examines the intricate details of the mission, from its scientific objectives to its technical intricacies, highlighting the expectations and opportunities it presents for solar research. The paper underscores the invaluable data and insights Aditya-L1 is poised to deliver, shedding light on solar phenomena and their impacts on Earth. Through a blend of meticulous observation, analysis, and thoughtful suggestions, this work propels Aditya-L1 into a transformative agent in our quest to decode the secrets of our nearest star.

Keywords: *corona, coronal mass ejections and flares, Lagrange point 1, Trans-Lagrangian Point 1 Insertion, Orbit determination, payloads*

1. Introduction:

The Sun, Aditya, a cosmic enigma, teems with boundless energy, primarily hydrogen and helium, eluding full comprehension. Its dynamic nature, marked by eruptions and energy release, necessitates scrutiny for potential disruptions to Earth's space environment. Historically dependent on other nations' solar missions, India now launches Aditya L1, a dedicated solar observatory. This article explores India's motivations, challenges, and advancements in understanding the Sun's impact on Earth's climate, emphasizing the urgency of space exploration.

The article starts with global missions carried out in the past and then focuses on ventures closer home- in INDIA. It details the structure of ADITYA L1 and finally specifies the outputs and results that can be expected in the near future. That is followed by future planning for the Space Mission of India and other Countries and ultimately the conclusion.

2. Global Missions and Scientific Expeditions:

There have been many expeditions and missions in the past. They have all been on a global basis. Some of them are-

(i) SOHO (Solar and Heliospheric Observatory), a collaboration between the European Space Agency (ESA)[1] and NASA[2], launched in December 1995 and remains operational. NASA provided three instruments and launch services.

(ii) STEREO[3] (Solar Terrestrial Relations Observatory), launched in October 2006, comprises two spacecraft—STEREO-A and STEREO-B—orbiting the Sun.

(iii) Hinode (Solar-B), a Japanese mission launched in September 2006, follows Japan's YOHKOH[4] mission.

Table-1: A list of Solar Missions Launched by Other Countries Since 2000 is as follows[5]:

Mission Name	Lunch Year
SOHO	1995
STEREO	2006
Hinode (Solar-B)	2006
SDO	2010
IRIS	2013
Solar Orbiter	2020
Parker Solar Probe	2018

China will also be sending its mission satellite to study the sun in the near future[6]. It had already taken a step forward back in 2022 to explore solar dynamics by launching the Kuafu-1 satellite[7]. India has not launched any satellite in the past and therefore its first solar satellite is ADITYA L1.

3. Indian Missions and Scientific Expeditions from Ancient to Present[8]:

The Indian Space Program, led by the Indian Space Research Organization (ISRO)[9], has undergone a transformative journey since its inception in the 1960s. Emerging as a developing nation, India aspired to join the exclusive league of countries capable of launching satellites into Earth's orbit.

[1] https://www.esa.int/Science_Exploration/Space_Science/SOHO_ https://www.esa.int/
[2] https://soho.nascom.nasa.gov/ , https://www.nasa.gov/
[3] https://stereo.gsfc.nasa.gov/
[4] https://r.search.yahoo.com/_ylt=AwrKF1GxGt5lMEwTF2i7HAx.;_ylu=Y29sbwNzZzMEcG9zAzEEdnRpZAMEc2VjA3Ny/RV=2/RE=1709083442/RO=10/RU=https%3a%2f%2fen.wikipedia.org%2fwiki%2fYohkoh/RK=2/RS=diOUeTaqWRftZMMeFVff_xp_s94-
[5] Solar missions and expeditions https://www.jagranjosh.com/general-knowledge/how-many-solar-missions-have-been-launched-since-2000-1693569595-1
[6] China's next solar mission in 2026: https://in.mashable.com/science/60740/china-is-planning-to-send-mission-to-study-the-sun-see-how-its-different-from-indias-aditya-l-1-miss
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[9] https://r.search.yahoo.com/_ylt=Awr1QPVTG95lj6AR4de7HAx.;_ylu=Y29sbwNzZzMEcG9zAzEEdnRpZAMEc2VjA3Ny/RV=2/RE=1709083604/RO=10/RU=https%3a%2f%2fwww.isro.gov.in%2f/RK=2/RS=YAcE0Tqo3CDXFBGNeWoCaUrxLeE-

In 1962, the Indian National Committee for Space Research (INCOSPAR)[10] was formed, marking the inception of the Indian space program. Dr. Vikram Sarabhai, regarded as its visionary founder, laid the groundwork for what later evolved into ISRO. The primary objective of INCOSPAR was to develop indigenous capabilities in space technology and research, a significant endeavor for a nation emerging from colonial rule. India's inaugural step into space occurred on November 21, 1963, with the launch of a Nike-Apache sounding rocket carrying a sodium vapor payload from the Thumba Equatorial Rocket Launching Station (TERLS)[11] in Kerala. This event marked India's formal entry into space research. Despite setbacks, notably the 1980 failure of the SLV-3 rocket carrying the Rohini Satellite RS-1, ISRO remained undeterred. In 1983, the organization successfully launched the Satellite Launch Vehicle – III (SLV-3)[12], making India the seventh nation globally capable of designing and launching its own satellites.

The 1980s witnessed ISRO's emphasis on remote sensing, culminating in the launch of India's first remote sensing satellite, IRS-1A[13], in 1988. These satellites played a pivotal role in providing invaluable data on natural resources, land use patterns, and disaster management, establishing India as a global leader in remote sensing technology. The 1990s marked a rapid expansion of the Indian space program with increased funding, technology transfers, and successful satellite launches. The INSAT[14] series satellites and the Polar Satellite Launch Vehicle (PSLV) became integral components, enhancing telecommunications, broadcasting, and meteorological services. India's lunar exploration commenced with Chandrayaan-1 in 2008, achieving historic milestones such as placing a Moon Impact Probe (MIP)[15] containing the Indian tricolor flag on the lunar surface. Chandrayaan-1's discoveries of water molecules on the Moon reshaped global understanding. In 2013, India set its sights on Mars with the Mars Orbiter Mission, Mangalyaan, achieving the remarkable feat of entering Martian orbit on its first attempt. This mission, costing only $74 million USD, set a Guinness World Record as the least expensive Mars mission to date.

[10] https://r.search.yahoo.com/_ylt=Awr1QPV7G95l0sMT8Rq7HAx.;_ylu=Y29sbwNzZzMEcG9zAzEEdnRpZAMEc2VjA3Ny/RV=2/RE=1709083643/RO=10/RU=https%3a%2f%2fen.wikipedia.org%2fwiki%2fIndian_National_Committee_for_Space_Research/RK=2/RS=j36U7pgCyEkDzTvRk5np0I4aaDc-

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[12] https://www.isro.gov.in/SLV.html

[13] https://r.search.yahoo.com/_ylt=AwrKF1FEHN5l99IT9g67HAx.;_ylu=Y29sbwNzZzMEcG9zAzIEdnRpZAMEc2VjA3Ny/RV=2/RE=1709083845/RO=10/RU=https%3a%2f%2fen.wikipedia.org%2fwiki%2fIRS-1A/RK=2/RS=i86.p1D2UE7.oa565FVFeC4C_B4-

[14] https://geographicbook.com/insat-series-indian-satellites/

[15] https://r.search.yahoo.com/_ylt=Awrx.OqrHN5l7XQSA7e7HAx.;_ylu=Y29sbwNzZzMEcG9zAzEEdnRpZAMEc2VjA3Ny/RV=2/RE=1709083948/RO=10/RU=https%3a%2f%2fen.wikipedia.org%2fwiki%2fMoon_Impact_Probe/RK=2/RS=02ue_ORmInvsGZiOeFJ0Yyi0Z_w-

ISRO's ambitious Gaganyaan project, slated for mid-2024, aims to send three astronauts into low Earth orbit, showcasing India's technological prowess and inspiring future generations. Aditya-L1, focused on studying solar flares, and Chandrayaan-3, aimed at exploring the lunar south pole region, illustrate ISRO's commitment to advancing scientific knowledge. The Indian Space Program's future includes innovations such as the Small Satellite Launch Vehicle (SSLV) and plans for a space station by 2030, signaling India's intent to redefine space exploration capabilities. From its humble beginnings in the 1960s, the Indian Space Program has evolved into a global player, contributing significantly to humanity's understanding of the cosmos. With each mission, India solidifies its position as a key participant in the ever-expanding realm of space exploration.

4. Aditya L1 - A Feat of Engineering and Scientific Ingenuity - Aims and Objectives:

To answer the innumerable questions about Aditya, the Sun, the scientists of ISRO designed a groundbreaking wonder, a satellite, with the aim of exploring the beyond. It stands as a remarkable machine, a technological marvel poised to unravel the profound mysteries concealed within the solar realm which will orbit the Sun at a proximate distance and capture a vivid tapestry of invaluable data. This machine, primarily equipped with sophisticated instruments, promises to scrutinize the solar dynamo, seeking answers to the persistent riddles surrounding the star that sustains life on our planet.

The objectives of the Aditya L1 mission are many; they include, but are not limited to, the study of Solar upper atmospheric dynamics, physics of the partially ionized plasma, initiation of the coronal mass ejections, and flares, study of chromospheric and coronal heating, observation of the in-situ particle and plasma environment providing data for the study of particle dynamics from the Sun, identification of the sequence of processes that occur at multiple layers of the sun and more. Nigar Shaji[16] is leading India's first solar mission as project director for Aditya L1. Shaji's leadership in the Aditya-L1 project is a testament to her exceptional career and her pioneering role in a traditionally male-dominated field. Her success in steering this ambitious mission marks a crowning achievement in her illustrious journey. The satellite is intended to gather data about the sun's outermost layer, the solar corona. The mission, expected to operate for at least five years, will be placed in a halo orbit around the Lagrange point 1 (L1) of the Sun-Earth system (approximately 1.5 million km from the Earth). Following the successful Chandrayaan-3 mission on August 23, 2023, the Indian Space Research Organization (ISRO) achieved another milestone by launching its inaugural solar mission, 'Aditya-L1,' on September 2, 2023, using a PSLV-C57 rocket from the Sathish Dhawan Space Centre SHAR (SDSC SHAR), Sriharikota. Aditya-L1's ultimate destination is

[16] https://www.newindianexpress.com/states/tamil-nadu/2023/sep/02/meet-nigar-shaji-from-tns-tenkasi-aditya-l1-mission-project-director-2610872.html

the Halo orbit of the Lagrangian Point 1 (L1) within the Sun-Earth system. L1 is a point in space where gravitational forces between two larger orbiting bodies, in this case, the Sun and Earth, balance, providing a stable equilibrium for a small object. This unique position allows continuous observation of the Sun, making it an ideal resting point for Aditya-L1. However, before reaching L1, Aditya-L1 underwent a crucial Trans-Lagrangian Point 1 Insertion (TL1I) on September 19, 2023, initiating its 110-day journey to the destination. This maneuver was akin to the one performed by ESA for its Euclid telescope to reach L2. Several spacecraft have ventured to the Sun-Earth L1 point, including the International Sun-Earth Explorer (ISEE-3), the Genesis mission, ESA's LISA Pathfinder, China's Chang'e 5 lunar orbiter, and NASA's GRAIL mission. Notable missions like NASA's Wind mission and the Solar and Heliospheric Observatory also observe solar wind and monitor space weather from L1.

Despite the expected arrival at L1 approximately four months post-launch, ISRO faces challenges due to the instability of L1 as an equilibrium point. Orbiting L1 involves regular 'station-keeping' maneuvers to correct trajectory errors, requiring precise orbit determination. To address this, ISRO developed new orbit determination software for Aditya-L1. Given the critical nature of operations at L1, the space agency sought validation from the European Space Agency (ESA)[17]. The orbit determination process involves applying mathematical formulas to tracking data, ensuring accurate calculations of the spacecraft's past, present, and future locations. While ISRO's software plays a crucial role, the ESA's support enhances the validation process, mitigating potential errors associated with operating a spacecraft at the challenging L1 point. ISRO has set a target date of January 6, 2024, for Aditya-L1 to enter orbit around Earth at Lagrange Point 1, marking a significant achievement in India's solar exploration endeavors.

4.1 Team works of ISRO and ESA:

From April to December 2022, ESA and ISRO teams worked together intensively to evaluate ISRO's strategy for operating Aditya-L1 and challenge their new orbit determination software. "With its experience flying and even rescuing missions at the Lagrange points, ESA was in the perfect position to help ISRO improve their new orbit determination software and demonstrate that it has the fidelity and accuracy that the organization needs in order to operate a spacecraft at a Lagrange point for the first time," said ESA Flight Dynamics expert Frank Budnik. The collaboration between the European Space Agency (ESA) and the Indian Space Research Organization (ISRO) for the Aditya-L1 mission demonstrates the immense value of international cooperation in space exploration. This partnership involved a multifaceted approach, with both teams actively engaged in sharing knowledge and expertise.

[17] https://www.esa.int/Enabling_Support/Operations/How_is_ESA_supporting_ISRO_s_Aditya-L1_solar_mission

ESA initiated the collaboration by envisioning various scenarios that ISRO might encounter while operating Aditya-L1. Both agencies then employed their respective orbit determination software to predict the mission's orbit evolution and compared their results. ESA further enriched the collaboration by providing ISRO with simulated tracking data, mirroring real-life mission challenges.

4.2 Parts of the Satellite:

India's Aditya-L1 solar mission deploys seven payloads for sun study. Apart from the primary payload by the Indian Institute of Astrophysics, smaller institutes contribute six unique payloads. The Visible Emission Line Cornographs (VELC)[18], the primary payload, captures solar images.

Ultraviolet and Visible Imaging Equipment provides high-res images, revealing magnetic fields and sunspots. The satellite's bus supports essential components, including power supply and communication systems. Solar panels convert sunlight for power, while communication systems transmit data to Earth. Advanced thermal protection shields the satellite from extreme solar conditions. The Propulsion System maintains orbit, and an onboard computer manages data processing and transmission. Prof. Dipankar Banerjee emphasizes the importance of combining data from various instruments for comprehensive solar understanding.

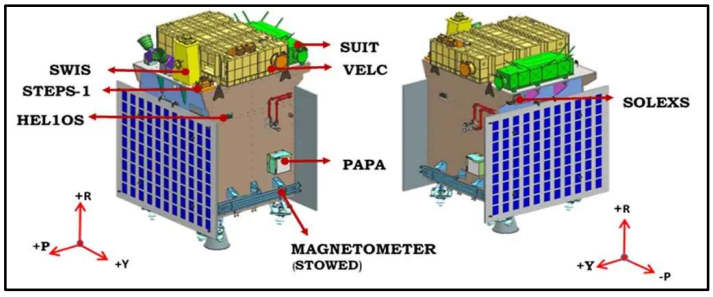

Fig-1: Diagrammatic representation of the PAYLOADS of the ADITYA L1 Satellite *[Google]*[19]

Fig-2: The functioning satellite captures images of Earth, Moon *[Google]*[20]

[18] https://r.search.yahoo.com/_ylt=AwrKAgNmHd5lF8sSia67HAx.;_ylu=Y29sbwNzZzMEcG9zAzIEdnRpZAMEc2VjA3Ny/RV=2/RE=1709084135/RO=10/RU=https%3a%2f%2fwww.hindustantimes.com%2findia-news%2fadityal1-launch-live-updates-isro-what-is-the-purpose-of-velc-primary-payload-corona-101693640652330.html/RK=2/RS=hDTg4e6SBTBHW3ctZKTyTiqETnw-

[19] https://in.images.search.yahoo.com/search/images;_ylt=Awrx.vpkakJlmHgXoDi7HAx.;_ylu=Y29sbwNzZzMEcG9zAzEEdnRpZAMEc2VjA3BpdnM-?p=adtya+l1+payloads+diagrmatic+representation&fr2=piv-web&type=E210IN826G0&fr=mcafee#id=22&iurl=https%3A%2F%2Fwww.isro.gov.in%2Fmedia_isro%2Fimage%2FADITYAL1_large.png.webp&action=click

[20] https://in.images.search.yahoo.com/search/images;_ylt=Awrx.9FJG0Nltu4GAha9HAx.;_ylu=c2VjA3NlYXJjaARzbGsDYXNzaXN0;_ylc=X1MDMjExNDcyMzAwNQRfcgMyBGZyA21jYWZlZQRmcjIDc2EtZ3Atc2VhcmNoBGdwcmlkA0pWT21KWlBsUURTUndsSW5mSUhyZUEEbl9yc2x0AzAEbl9zdWdnAzEEb3JpZ2luA2luLmltYWdlcy5zZWFyY2gueWFob28uY29tBHBvcwMxBHBxc3RyA3BheWxvYWRzIG9mIGFkdGl5YSAEcHFzdHJsAzE5BHFzdHJsAzIxBHF1ZXJ5A3BheWxvYWRzJTIwb2

4.3 Budget Plan:

According to official disclosures, a substantial sum of approximately Rs 378.53 crore has been allocated for this solar mission, excluding the costs associated with the launch. For Aditya-L1, the allocation is reportedly even leaner than the Rs 600 crore earmarked for the country's Chandrayaan mission. Evidently, this staggering financial commitment underlines the monumental scale and ambition of the undertaking. Nonetheless, the overall budget for this cosmic crusade has been estimated to orbit around the astronomical figure of Rs 400 crore. Such a sum represents a colossal investment in scientific exploration, indicative of India's unwavering commitment to advancing its prowess in space research.

4.4 Outputs Revealed:

The Indian space agency ISRO has shared the first images sent by the country's solar observation mission as it makes its way towards the Sun.[21] ISRO shared two photographs taken on 4 September, 2023 by a camera mounted on Aditya-L1.
One of the images shows the Earth and the Moon in one frame - while the Earth looms large, the Moon is a tiny speck in the distance. The second photograph is a "selfie" that shows two of the seven scientific instruments the solar mission is carrying.

5. Paving the Way for Future Developments- Hopes and Scopes:

The Aditya-L1 mission, with its four remote sensing instruments, is poised to revolutionize our understanding of the Sun and its impact on space weather. What sets Aditya-L1 apart from its predecessors is its enhanced focus on identifying source regions of solar activity, offering a unique edge in studying the origins of solar eruptions and flares. This heightened focus is expected to provide invaluable insights into the Sun's behavior, shedding light on the mechanisms driving these explosive phenomena. Dr. Dibyendu Nandi, Chair of the Space Weather and Monitoring Committee of Aditya-L1, emphasized the mission's potential to issue space weather alerts. This novel approach involves utilizing data from the satellite to predict space weather events, thus allowing timely measures to mitigate potential disruptions. Furthermore, Dr. A N Ramaprakash, one of the principal investigators responsible for the Solar Ultraviolet Imaging Telescope (SUIT), highlighted the significance of gathering information about the space environment around the L1

YlMjBhZGl0eWElMjBsMQR0X3N0bXADMTY5ODg5Njg4OAR1c2VfY2FzZQM-?p=payloads+of+aditya+l1&fr=mcafee&fr2=sa-gp-search&ei=UTF-8&x=wrt&type=E210IN826G0#id=6&iurl=https%3A%2F%2Fwww.isro.gov.in%2Fmedia_isro%2Fimage%2FADITYAL1_large.png.webp&action=click

[21] https://www.bbc.com/news/world-asia-india-66738230

point. This information is pivotal for comprehending space weather, as it enables a deeper understanding of the conditions that affect satellites and other technological infrastructure.

6. Solar Missions Made Easier:

Being optimistic, Aditya-L1's success will pave the way for future solar missions by providing crucial data and experience in operating spacecraft near the Sun. Its findings and operational insights will make upcoming solar exploration endeavors more achievable, offering a springboard for enhanced understanding of our nearest star.

7. Suggestions:

Optimization of power management and spacecraft resilience can be done in the future to prolong the mission's operational lifespan, allowing for more long-term data collection. Incorporating autonomous systems for spacecraft operations may reduce the need for continuous human intervention and ensure mission continuity.

8. Conclusion:

As the narrative arc of Aditya-L1's journey unfolds, its reverberations traverse the scientific echelons, echoing the resounding promise of revolutionized solar research and more profound insights into our dynamic solar system. With hearts aglow and minds alight, we stand at the threshold of enlightenment, ever eager to embrace the vibrant future foreseen through the eyes of Aditya-L1. The scopes and hopes enshrined within this discourse are but a prelude to the epic unfolding of the solar symphony, where Aditya-L1 assumes its rightful place as an immortal and luminous note in the annals of cosmic exploration.

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