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DivyaSat: Green Horizon Explorer

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Abstract: The "DivyaSat" project aims to tackle climate change and global warming by employing miniature, cost-effective instruments on a CubeSat platform. Inspired by the success of MeznSat, DivyaSat plans to utilize a shortwave infrared (SWIR) micro-spectrometer, called Argus 2000, to measure greenhouse gas concentrations in the atmosphere. Alongside the SWIR spectrometer, DivyaSat will incorporate a high-definition camera for accurate geolocation. This combination of instruments positions DivyaSat as a unique CubeSat mission capable of generating valuable data for atmospheric correction algorithms. This abstract provides an overview of DivyaSat's mission objectives, design, and potential contributions to understanding greenhouse gas concentrations in the atmosphere.

Table of Contents

1. Introduction

As India continues to make significant strides in space exploration and technological innovation, the proposed "DivyaSat" mission emerges as a beacon of environmental stewardship and scientific advancement, aligning with India's commitment to addressing critical global issues. The mission is particularly relevant as it tackles escalating concentrations of greenhouse gases, primarily driven by human activities, serving as the foremost catalysts for climate change. With a specific emphasis on the unique challenges faced by arid and semi-arid regions, including potential negative impacts on water quantity and quality, the "DivyaSat" mission positions itself as a response to India's dedication to proactive environmental management. The urgency of addressing issues highlighted in the Abu Dhabi State of Environment Report 2017, such as sea-level rise, coastal flooding, increased salinity of coastal aquifers, impacts on the marine environment, heat stress, extreme weather events, dust storms, and the risk from airborne contaminants, underscores the need for effective monitoring and mitigation strategies, aligning with the broader goals of sustainable development.

The mission takes a holistic approach by targeting two prevalent greenhouse gases—carbon dioxide and methane. Recognizing the disproportionate heat-absorptive properties of methane, the mission emphasizes comprehensive monitoring of both emissions to effectively mitigate the impact of climate change. Moreover, the mission extends its scope to address the pressing issue of algal blooms in the Arabian Gulf, a phenomenon

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threatening the UAE's economy, water availability, and environmental health. In addition to monitoring greenhouse gases, the "DivyaSat" mission aims to comprehensively study chemical reactions occurring in the atmosphere and monitor other climatic issues. This multifaceted approach positions the mission as an all-encompassing tool for understanding and addressing various environmental challenges faced not only by India but globally. The research component of the "DivyaSat" mission introduces an innovative approach to sensing in the shortwave infrared (SWIR) region (1000–1650 nm). By combining SWIR sensing with an RGB camera, the mission aims to predict and monitor algal bloom occurrences through estimating nutrient concentrations in coastal waters. This proactive strategy is crucial for managing the optimal operation of desalination plants, preserving water quality, and safeguarding marine ecosystems.

2. Mission Concept

This section provides a comprehensive overview of the DivyaSat mission, detailing its overarching goals, the scientific instruments utilized, the selected satellite platform, orbital considerations, and the detailed Concept of Operations (ConOps).

3. Mission Objectives

DivyaSat's mission objectives encompass a multifaceted approach:

- ***Primary Science: Monitoring Greenhouse Gases (GHGs) in the Atmosphere:*** DivyaSat prioritizes the use of a cutting-edge SWIR spectrometer to meticulously analyze methane and carbon dioxide levels within the Earth's atmosphere. This objective is pivotal for advancing our understanding of climate dynamics and contributing to global environmental monitoring efforts.
- ***Tentative Science: Integrating SWIR Sensing with RGB Imaging for Coastal Studies:*** In a pioneering move, DivyaSat explores the synergy between SWIR sensing and RGB imaging. The mission aims to assess the feasibility of using this combination to estimate nutrient concentrations in coastal waters, with the overarching goal of predicting and understanding the dynamics of algal blooms, thus providing valuable insights into marine ecosystem health.
- ***Educational Outreach: Fostering Space Mission Design Skills:*** Beyond its scientific endeavors, DivyaSat is committed to nurturing the next generation of space scientists and engineers. The mission actively engages university students in the UAE, offering them a unique opportunity to participate in the practical aspects of building and designing space missions. This educational facet aligns with DivyaSat's broader mission to inspire and empower emerging talent in space exploration.

The integration of these diverse objectives underscores DivyaSat's holistic approach, combining scientific innovation with educational outreach for a more profound impact.

4. Scientific Payloads

The cornerstone of DivyaSat's scientific mission lies in the exploration of the shortwave infrared (SWIR) region, specifically targeting wavelengths ranging from 1000 to 1650 nm. The primary scientific objective is to discern and monitor levels of methane and carbon dioxide in the Earth's atmosphere **[1]**. DivyaSat employs a dual-payload strategy to achieve this objective, with a primary focus on the SWIR spectrometer and a complementary secondary payload, the RGB camera. This synergistic pairing endows DivyaSat with a distinctive capability, facilitating the concurrent monitoring of greenhouse gases (GHGs) and offering geolocation functionality through the RGB camera.

The primary payload chosen for this critical mission role is the Argus 2000 SWIR spectrometer, illustrated in Figure 1. This space-proven, miniature spectrometer operates with remarkable efficiency, measuring a mere 4.5 × 8 × 8 cm in size. The instrument's operational mechanism involves dispersing incident light through a 300 groove/mm grating, directing it onto a 256-element Indium-Gallium-Arsenide detector array. A Peltier cooler minimizes dark currents, ensuring optimal performance. The Argus 2000's spectral range spans from 1.0 to 1.65 micrometers, featuring a spectral resolution of 6 nanometers across 100 spectral channels. Noteworthy gases within this range include oxygen (1.25 µm), carbon dioxide (1.57 µm, 1.61 µm, and 2.05 µm), water (900 µm, 1.2 µm, and 1.4 µm), carbon monoxide (1.63 µm), methane (1.67 µm and 2.25 µm), and hydrogen fluoride (1.265 µm). The Argus 2000 supports integration times ranging from 0.5 to 4.096 s **[1-13]**.

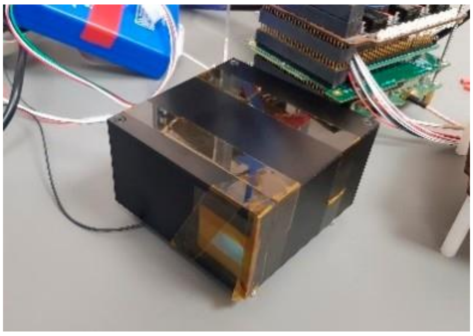

Figure-1 The Argus 2000 Spectrometer [Image Courtesy: Abdul-Halim.et.al.2019]

The optical design of the Argus 2000 features a sophisticated configuration, including a telescope lens system, field stop, and a primary parabolic mirror with a focal length and diameter of 35 mm. This design enables the generation of a collimated image of the surface tile onto a surface grating with 300 grooves per mm. The spectrally divided image is then reflected by a reflective grating onto another mirror, focusing the first spectral order of the surface tile onto the InGaAs detector.

The secondary payload, a low-voltage CMOS RGB camera (Figure 2), developed by Tokyo University of Science (TUS), enhances DivyaSat's observational capabilities. The camera incorporates the OV-9630 Image Sensor from Omnivision and interfaces with the on-board computer (OBC) through a Microchip PIC microcontroller. Communication with the OBC is facilitated by a Universal-Asynchronous-Receiver-Transmitter. With the ability to capture SXGA (1280 × 1024) and VGA (640 × 480) images, this compact and lightweight camera (45 mm × 46 mm × 15 mm, weighing 39 g) has a total power consumption of 0.11 Watts.

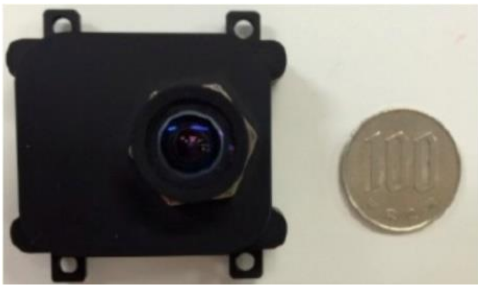

Figure-2 The RGB Camera Proposed for DivyaSat [Image Courtesy: Abdul-Halim.et.al.2019]

In essence, the integration of these payloads forms the technological backbone of DivyaSat, enabling it to delve into the intricacies of atmospheric composition and coastal phenomena with unprecedented precision and versatility.

5. Platform Selection

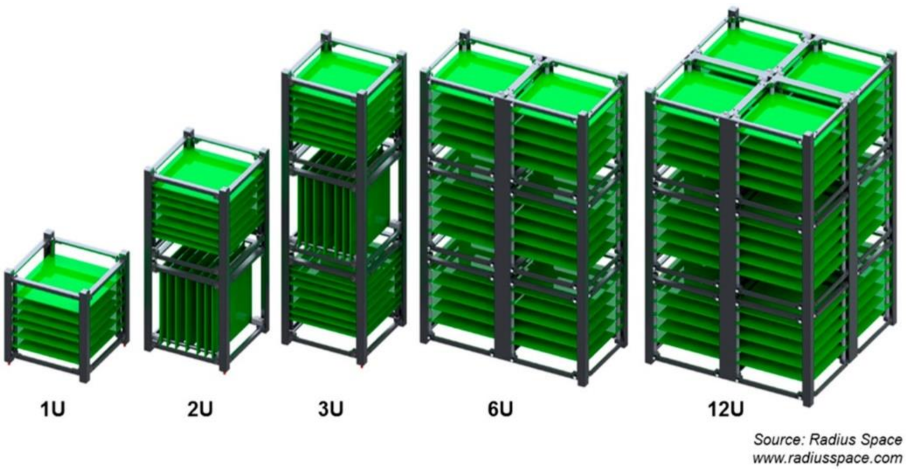

Figure-3 Comparison of various form of satellites [Image Courtesy: Radius Space]

Upon extensive examination of available satellite platforms, it was determined that the optimal choice to fulfill the mission requirements is the 3U CubeSat configuration. This configuration, depicted in Figure 3, offers the equivalent space of three 1U CubeSats, with standard dimensions of 34 cm × 10 cm × 10 cm. The primary rationale driving this selection is the ample volume provided by each platform to accommodate all necessary subsystems. Specifically, the narrow Field of View (FoV) of the Argus 2000 spectrometer necessitates precise pointing, thus requiring a sophisticated Attitude Determination and Control System (ADCS) occupying at least 0.8 U. Additionally, the payloads themselves necessitate approximately 1U of space. Consequently, the decision was made to employ a 3U platform for DivyaSat **[1-18]**.

6. System Design and Platform Subsystems

This section outlines the system-level design of DivyaSat, drawing inspiration from MeznSat while enhancing and adapting key subsystems for the mission's unique requirements. The spacecraft bus design incorporates five main subsystems crucial for supporting the operation of the mission payloads. These encompass the Electrical Power Subsystem (EPS), the Attitude Determination and Control Subsystem (ADCS), the Command and Data Handling Subsystem (CDHS), the Telecommunications Subsystem (TS), and the mechanical subsystem. Figure 5 illustrates the comprehensive system-level block diagram of MeznSat, serving as a foundational reference for the development and optimization of DivyaSat's design **[1-18]**.

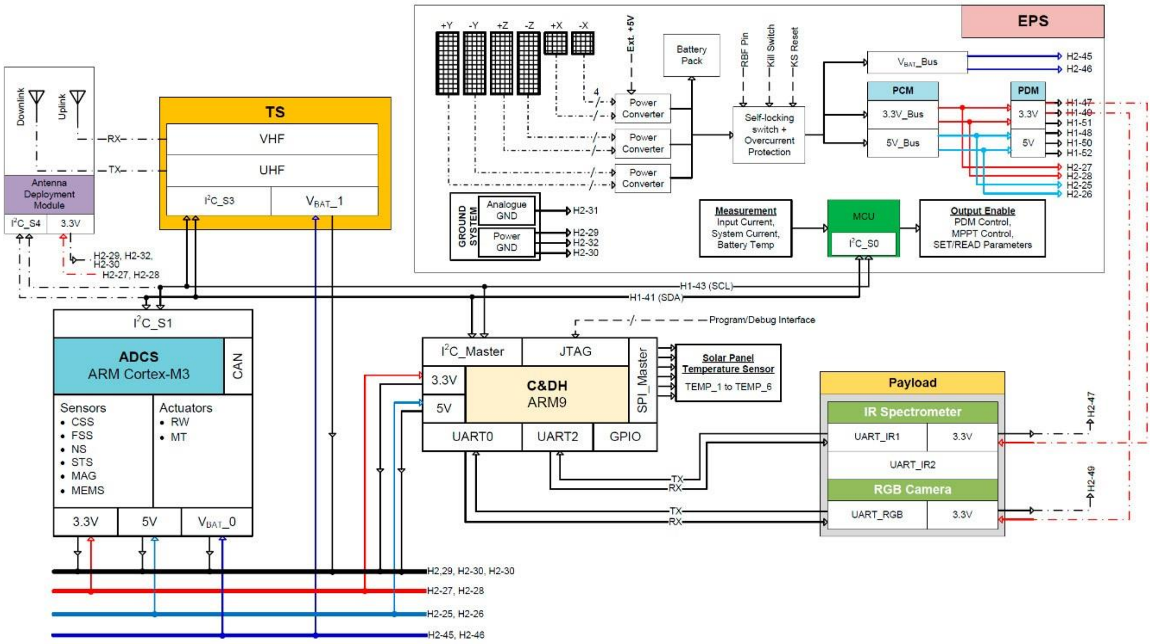

Figure-4 MeznSat system architecture (Planed to use this for DivyaSat) [Courtesy: Abdul-Halim.et.al.2019]

The mechanical structure of DivyaSat follows a 3U modular design based on the CubeSat standard developed by Innovative Solutions In Space (ISIS). It comprises three 1U PCB stacks enclosed within a secondary structure, which serves as the chassis and holds the PCBs in the stack. You can refer to Figure 6 for a visual representation of the structure.

7. Telecommunication Subsystems (TS)

The Telecommunications Subsystem of DivyaSat comprises a UHF transmitter and VHF receiver, supported by four deployable dipole antennas for both UHF and VHF frequencies. These antennas facilitate the uplink and downlink communications between the satellite and ground stations. For transmitting telemetry, scientific, and image data from the satellite to the ground station, a UHF transmitter is employed. It operates at a data rate of 9.6-9.8 kbps using BFSK modulation technique, with a transmission carrier frequency ranging from 430-450 MHz. The majority of the payload data volume originates from the RGB camera, producing 1,643,530-1,643,600 Bytes and 389,130-389,200 Bytes for SXGA and VGA format images respectively. For downloading SXGA format images, a total of ~22-24 minutes is required using the 9600-9900 bps UHF transmitter. STK simulations confirm a daily ground station access time of 28 minutes available for data download. It's important to note that these calculations do not incorporate any on-board image compression techniques. Additionally, a VHF receiver is utilized for receiving telecommands from the ground station to the satellite. The receiver employs a baseband modulator with a data rate of 1.2 kbps and AFSK modulation, operating within a frequency range from 130-160 MHz **[1-18].**

8. Attitude Determination and Control Subsystem (ADCS)

The Attitude Determination and Control Subsystem (ADCS) of DivyaSat assumes a critical role in orchestrating the precise orientation of the satellite throughout its mission lifespan. Its duties encompass detumbling the satellite post-deployment, aligning it as per mission specifications, and rectifying any spin-ups that may occur. Ensuring meticulous Field of View (FOV) is imperative, particularly for the spectrometer, the primary payload dedicated to accurate detection of greenhouse gas (GHG) sources, demanding a pointing accuracy of less than 1 degree. This requirement surpasses the capabilities of passive attitude control mechanisms like magnetorquers commonly employed in CubeSats. DivyaSat relies on advanced technologies such as reaction wheels and precise attitude determination sensing, notably star sensors. For the DivyaSat mission, the selected ADCS is the CubeADCS 3-Axis integrated bundle from CubeSpace, boasting a flight heritage exceeding ten years (excluding the star tracker). An overview of the ADCS architecture is provided in Figure 7, while Figure 8 showcases images of the ADCS hardware. This system ensures three-axis control using three Reaction Wheels, each with a maximum momentum of 1.77 mNms and a maximum torque of 0.23 mNm. Additionally, three magnetorquers are incorporated, primarily used for desaturation purposes. The sensor suite comprises a deployable magnetometer, two CMOS cameras (one for fine sun sensing and the other for horizon detection), ten coarse sun sensors, and a star tracker based on ARM Cortex-M3 architecture **[1-18]**.

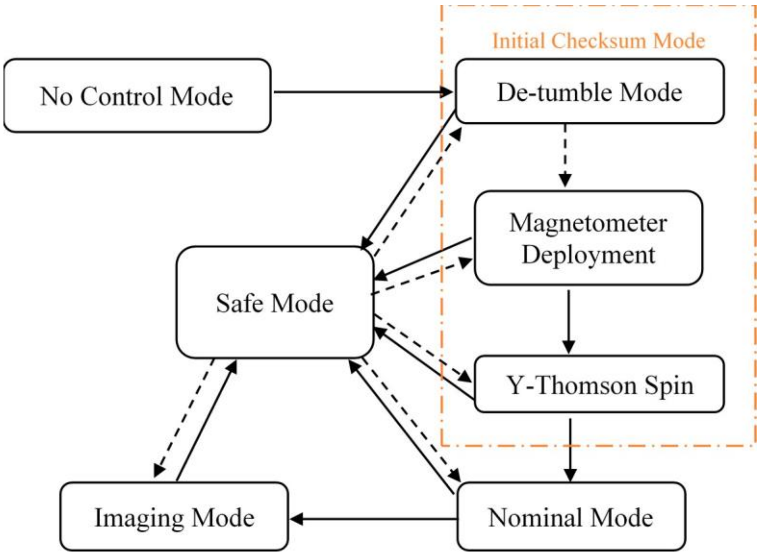

Figure-5 DivyaSat ADCS modes of operation [Courtesy: Abdul-Halim.et.al.2019]

The operational modes of DivyaSat's ADCS are outlined in Figure 5. Upon deployment, the satellite enters the "No Control Mode," adhering to CubeSat specifications that mandate no active operations for the initial 30 minutes post-deployment. Subsequently, DivyaSat transitions into the "De-tumble/Attitude Acquisition Mode," strategically reducing the rotation rate from a worst-case scenario of 10 deg/s to a slower angular rate of less than 3 deg/s. Following this, magnetometer deployment occurs upon establishing ground contact, resulting in an increase in the Y-axis angular rate. The Y-Thomson Controller intervenes, stabilizing X-axis and Z-axis angular rates while ensuring the Y-axis angular rate remains below 1 deg/s. During payload operation, the XYZ-reaction wheel mode is engaged, gradually reducing the angular rate to less than 0.03 deg/s **[1-18]**.

9. Electrical Power Subsystem (EPS)

The Electrical Power Subsystem (EPS) ensures the continuous operation of DivyaSat's various subsystems throughout the mission duration by providing electrical power. This system comprises three primary components: solar panels, a battery, and a power distribution system. Various configurations for the solar panels were evaluated, with the fixed solar panel configuration and the side deployable solar panel configuration emerging as the two most significant options. While the side deployable configuration promises higher power generation, typical power budget estimates (6.24 Whr) and maximum capacity (7.33 Whr) indicate that the fixed solar panel configuration suffices for meeting power requirements. A total of 22 solar cells are strategically distributed around the satellite's structure to generate power, as illustrated in Figure 10. Additionally, the power system is equipped with a Li-Ion battery pack boasting a density of 38.4 Whr, ensuring uninterrupted payload operation through the EPS's capability to charge the battery without disruption.

10. Command and Data Handling System (CDHS)

The Command and Data Handling Subsystem (CDHS) manages the execution of flight software and the handling of all onboard data within the satellite. At the core of the CDHS lies the on-board computer (OBC), featuring a 400 MHz ARM9 processor, accompanied by 64 MB RAM, 1 MB NOR flash for code storage, and 256 KB FRAM for critical storage. Additionally, the OBC integrates two 2 GB microSD cards to facilitate data storage. The primary bus for spacecraft communication is I2C, while UART is employed for data interchange between the OBC and the payloads **[1-18]**.

11. Flight Software

The satellite flight operating software comprises several layers. At the apex of the hierarchy sits the Mission Software, responsible for executing DivyaSat's mission-specific tasks, drawing inspiration from the MenzSat mission. FreeRTOS **[19]** has been designated as the primary operating system for the mission owing to its lightweight nature, real-time performance, and user-friendly interface. The Hardware Abstraction Layer (HAL) encompasses all hardware-specific drivers and incorporates a fail-safe FAT32 file system to ensure robust operation.

The software tasks in DivyaSat are classified into four distinct categories:

(1) Periodic Tasks: These tasks operate on a recurring basis, collecting data from subsystems at specific intervals. Examples include the Housekeeping collection task and the beacon transmission task.

(2) Temporal Tasks: This category encompasses tasks scheduled to run at predefined times. Tasks such as the ground contact task and the payload operation task fall into this category.

(3) Indefinite Tasks: Tasks in this class enter the running state once their delay period elapses, prioritizing them within the ready pool of tasks. Notable examples include the ADCS task and the normal mode task.

(4) Event-Based Tasks: These tasks await specific events to occur, such as waiting for a semaphore signal or data availability in a queue. Examples include the file management task, the command execution task, the safe mode task, and the initial checksum task.

12. Atmospheric/Surface State Retrieval Algorithm

Observations from the Argus 2000 spectrometer yield a single sounding covering a ground sampling distance of approximately 1.5 × 1.5 km from a 550 km altitude. Each sounding undergoes analysis using a retrieval algorithm, which adjusts unknown atmospheric, surface, and instrumental parameters to fit the measured spectra. This retrieval process comprises two components: a forward model and a statistical comparison method. The forward model serves as an approximate scheme to describe radiative transfer in the atmosphere, surface reflection, and instrument effects on incident radiation, generating detailed lookup tables **[20]**. Forward modeling is conducted using the GENSPECT **[21]** software, a radiative transfer modeling tool initially developed for the CANX-2 mission.

The initial step involves inputting an assumed environmental state defined by surface pressure, surface reflectance, vertical temperature profile, mixing ratios of primary gases, water vapor, other trace gases, and distributions of cloud and aerosol optical depth. These parameters can be initialized from known climatology and additional satellite data products such as MODIS for surface reflectance, cloud, and aerosol optical distribution. This information is combined with pre-tabulated, wavelength-dependent gas, aerosol, and cloud optical properties. Gas absorption cross-sections for the spectral range are derived and tabulated using GENSPECT and spectral line databases like HITRAN **[22]**. The synthetic spectra are then processed with a solar model and a model simulating the instrument's spectral response to incident radiation, producing results directly comparable to calibrated spectra **[20]**.

The comparison model assesses the synthetic radiance spectra against observations, employing an optimal estimation technique to achieve a match within the spectral range **[20]**. Subsequently, the atmospheric composition is deduced from the statistically validated best-match atmospheric state.

To validate the results, data from the Total Carbon Column Observing Network (TCCON) [23] will be utilized. The satellite will collect data over TCCON stations, and corresponding ground data acquired within ±30 minutes of satellite overpass time will be considered for comparison, as outlined in **[24]**. Additionally, a portable SWIR spectrometer will accurately measure spectral characteristics of surface and downwelling radiation at a spectrally homogenous desert site in the UAE using systematic sampling to match the ground sampling distance (GSD). This data will serve to validate instrument performance and facilitate recalibration if necessary.

13. Conclusion

DivyaSat marks a significant advancement in space exploration, particularly in understanding Earth's atmosphere and surface conditions. Its multifaceted objectives, spanning from methane and carbon dioxide monitoring to exploring the fusion of SWIR sensing with RGB imaging for coastal water analysis, highlight its versatility and potential impact. Furthermore, the mission's emphasis on providing educational opportunities for university students in the UAE demonstrates a commitment to nurturing the next generation of space scientists and engineers. The incorporation of state-of-the-art technologies, such as the Argus 2000 SWIR spectrometer and the RGB camera developed by Tokyo University of Science, underscores DivyaSat's pursuit of scientific excellence. Thoughtful selection of payloads and subsystems, including the Electrical Power Subsystem (EPS), Command and Data Handling System (CDHS), and robust Flight Software architecture, ensures the satellite's reliability and efficiency throughout its mission.

14. Expected Results and Future Outcomes

- ***Atmospheric and Surface Monitoring:*** DivyaSat's primary objective involves monitoring methane and carbon dioxide levels in the atmosphere using a SWIR spectrometer. Expected outcomes include high-resolution data on greenhouse gas concentrations, enhancing our understanding of climate change and atmospheric dynamics.
- ***Coastal Water Analysis:*** The secondary objective focuses on combining SWIR sensing with RGB images to estimate nutrient concentrations in coastal waters and predict algal blooms. Research anticipates revealing the correlation between spectral signatures and water quality, offering insights for coastal ecosystem management.
- ***Educational Impact:*** DivyaSat aims to provide hands-on experience to university students in building and designing space missions. Research outcomes extend beyond scientific data, influencing the development of future space professionals and fostering innovation in space technology.
- ***Technological Validation:*** The mission's utilization of advanced technologies, such as the Argus 2000 SWIR spectrometer and RGB camera, offers an opportunity for technological validation in a space environment. Successful operation and data collection from these payloads will contribute to validating and improving similar instruments for future space missions.

15. Future of India’s Space Exploration

DivyaSat stands as a testament to India's dedication to advancing its prowess in space exploration. With significant strides in satellite technology, Earth observation, and interplanetary missions, India solidifies its position as a pivotal player in the global space arena. The success of missions like DivyaSat not only furnishes invaluable data for scientific inquiry but also elevates India's standing as a dependable and inventive spacefaring nation. The future of India's space exploration holds promising horizons. The Indian Space Research Organisation (ISRO) has consistently demonstrated success in launching satellites for communication, navigation, and Earth observation. Planned lunar and interplanetary missions, coupled with advancements in satellite technology and space infrastructure, underscore India's aspirations for a more comprehensive and enduring presence in space. Furthermore, collaborative ventures with international partners, as exemplified by DivyaSat's educational objective involving UAE students, showcase India's readiness to partake in global space endeavors. As India continues to invest in research, development, and international cooperation, the nation stands poised for a leading role in shaping the future of space exploration, contributing both to scientific understanding and technological innovation on a global scale.

16. References

[1] Abu Dhabi State of Environment Report 2017. 2017. Abu Dhabi State of Environment. Available online: https://www.soe.ae/wp-content/uploads/2017/11/Climate_Change_English.pdf (accessed on 30 April 2024).

[2] Al Rais, A.; Al Suwaidi, A.; Ghedira, H. DubaiSat-1: Mission overview, development status and future applications. In Proceedings of the 2009 IEEE International Conference: Geoscience and Remote Sensing Symposium (IGARSS 2009), Cape Town, South Africa, 12–17 July 2009.

[3] Al Suwaidi, A. DubaiSat-2 Mission Overview. In Proceedings of the SPIE Remote Sensing, Edinburgh, UK, 24–27 September 2012.

[4] Analytical Graphics Inc. Home Page. 2019. Available online: https://agi.com/home (accessed on 30 April 2024).

[5] Argus 2000 IR Spectrometer Owner's Manual. 2018. Available online: http://thothx.com/getmedia/4c0d3242-b4fb-4e9d-abf7-85dbb5c6653f/20180815-Argus-2K-Owner-s-Manual,-Thoth-Technology,-rel-1-03.aspx (accessed on 30 April 2024).

[6] FreeRTOS, Quality RTOS & Embedded Software. 2019. Available online: http://www.freertos.org/ (accessed on 30 April 2024).

[7] Greenhouse Gas Emissions. United States Environmental Protection Agency. Available online: https://www.epa.gov/ghgemissions/overview-greenhouse-gases (accessed on 30 April 2024).

[8] Herrmann, I.; Karnieli, A.; Bonfil, D.J.; Cohen, Y.; Alchanatis, V. SWIR-based spectral indices for assessing nitrogen content in potato fields. Int. J. Remote Sens. 2010, 19, 5127–5143.

[9] Japan Launches UAE's KhalifaSat and Climate-Monitoring Satellite into Orbit (20178 Space.com). Available online: https://www.space.com/42280-japan-khalifasat-gosat-2-satellite-launch-success.html (accessed on 30 April 2024).

[10] Jallad, A.; Abdulaziz, Z.; Allam, A.; Marpu, P.; Tsoupos, A.; al Marar, A. MeznSat: A CubeSat for Greenhouse Gases Monitoring and Algal Blooms prediction. In Proceedings of the 32nd AIAA/USU Conference on Small Satellites, Logan, UT, USA, 4–9 August 2018. SSC18-WKIX-03.

[11] Natraj, V. Radiative Transfer Modeling for the Retrieval of CO2 from Space. Ph.D. Thesis, California Institute of Technology, Pasadena, CA, USA, 2008.

[12] Quine, B.M.; Drummond, J.R. GENSPECT: A line-by-line code with selectable interpolation error tolerance. J. Quant. Spectrosc. Radiat. Transf. 2002, 74, 147–165.

[13] Quine, B.M.; Jagpal, R.; Ho, A. Argus—A Canadian Pollution Monitor: Instrument Overview. In Proceedings of the 13th Canadian Astronautics Conference (ASTRO 2006), Montreal, QC, Canada, 25–27 April 2006.

[14] Rani, S.; Krishnamoorthy, N.; Harini, S.; Padmanabhan, K.; Singh, K. Sathyabama nanosatellite—Payload subsystem. In Proceedings of the Recent Advances in Space Technology Services and Climate Change 2010 Conference, Chennai, India, 13–15 November 2010.

[15] Rothman, L.S.; Gordon, I.E.; Babikov, Y.; Barbe, A.; Benner, D.C.; Bernath, P.; Birk, M.; Bizzocchi, L.; Boudon, V.; Brown, L.; et al. The HITRAN 2012 Molecular Spectroscopic Database. J. Quant. Spectrosc. Radiat. Transf. 2013, 130, 4–50.

[16] Sarda, K.; Eagleson, S.; Caillibot, E.; Grant, C.; Kekez, D.; Pranajaya, F.; Zee, R.E. Canadian Advanced Nanospace eXperiment 2: Scientific and Technological Innovation on a Three-kilogram Satellite. Acta Astronaut. 2006, 59, 236–245.

[17] St. Johns River Water Management District. 2019. Available online: https://www.sjrwmd.com (accessed on 30 April 2024).

[18] Sugano, R.; Naohiro, U.; Shinichi, K.; Koji, W.; Kenji, N.; Kazuya, Y.; Tomohiro, N. Development of a Very Small High-Performance Image Acquisition System for Asteroid Exploration Rover MINERVA-II2. In Proceedings of the 65th International Astronautical Congress, Toronto, ON, Canada, 29 September–3 October 2014.

[19] The CubeSat Program. 2014. CubeSat Design Specification Rev. 13. California Polytechnic State University. Available online: http://www.cubesat.org/s/cds_rev13_final2.pdf (accessed on 30 April 2024).

[20] TTCON. Home Page. 2019. Available online: https://tccon-wiki.caltech.edu/ (accessed on 30 April 2024).

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18. Conflict of Interest

The author declare no competing conflict of interest.

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