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LOW COST PICO SATELLITE BUS FOR EDUCATIONAL AND PERSONAL SCIENTIFIC SPACE MISSION

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Abstract

Humanity's passion for new discoveries and understanding the world where we live drove us to develop extraordinary inventions and technologies. After centuries, humanity changed the way education was done many times, trying to fit different cultures and countries into a certain type of teaching. In Brazil, education has been out of date for a long time, since it hasn't changed enough according to technological and social changes. So to face this problem, the mission GalaxySat-1 is the first step to bring new forms of educational ideas with a low budget space mission. The GalaxySat-1 is a Pocketqube standard satellite with 5x5x5cm, 250g of mass and is defined as 1P. The first mission with the satellite will study the possibility of predicting the formation of lightnings. These natural events in several places can cause electrical and structural damages, fires, power outages, and disruptions in communication and data systems. One important data needed for this mission is the satellite position combined with payload data and put in the map to produce visual graphics in order to cause the least possible damage. All data will be available and anyone can make individual studies and compare with other satellites data. This is another way to encourage students to learn new content outside of the classroom. His work with the mission, from launching their own nanosatellite will approach and open doors for other high school students with interest in space exploration to develop their own missions and engage kids and teenagers to become STEAM scientists.

Keywords: Pocketqube, GalaxySat-1, Satellite, lightning

Acronyms/Abbreviations

AITV - Assembly Integration & Verification
COTS - Commercial Off-The-Shelf
EPS - Electric Power System
GPS - Global Positioning System
INPE - National Institute for Space Research
LEO - Low Earth Orbit
LISE - Integrated Laboratory for Space Systems
OBDAH - On Board Data Handling
PCB - Printed Circuit Board
RBF - Remove Before Flight
TT&C - Telemetry, Tracking and Command
UHF - Ultra High Frequency

1. Introduction

GalaxySat-1 is the first individual person satellite mission by a high school student. It is a 1P Pocketqube, with two principal objectives, which are to test homemade subsystems that are made with COTS components and collect data with lighting detector payload. All final verification tests and flight-model satellite needs to be assembled at the end of Q3 of 2024

to make an integration with the deployer in Brasilia, Brazil and send to be launched between Q4 2024 and Q1 2025.

The payload has only one experiment to study and collect data to predict lightning formation. That prototype has already been tested with a lightning formation machine made only for this purpose. The payload was created with COTS components to decrease his complexity and costs, because space is a hard environment to test low budget missions with out of the box ideas.

Beyond this scientific mission, GalaxySat-1 will be an open hardware nanosatellite with 1P Pocketqube standard [1] for anyone in the future with the idea to make and launch his own real low cost space mission, principally for educational purposes. This commercial standard is lighter, smaller, and cheaper in comparison with Cubesat (as shown in Table 1), so it opens new possibilities for students like Kevin Xilai Tang around the world.

The idea to develop a space mission arouse at the middle of the pandemic of COVID-19, more precisely in the end of first semester of 2020. Due to the high cost

and difficulty of the project, the starting of the project was in 2022 and the predicted launch was between 2023 and 2024. This paper describes the GalaxySat-1 Pocketcube (section 2) featuring its payload and bus subsystems (2.1 and 2.2 respectively), describing technical aspects of the project. In the (2.3) subsection it will be describing the steps of the project and difficulties faced.

Table 1. Major comparison between Cubesat and Pocketcube

Standard	Volume	Size	Launch Cost*
Cubesat	1000cm ²	10x10x10cm	50K USD
Pocketcube	125cm ²	5x5x5cm	20K USD

* Lowest price

2. The GalaxySat-1 Pocketcube

GalaxySat-1 is a 1P Pocketcube developed with COTS components, without any subsystem bought from other suppliers. Several design features were inspired on Fossa Systems and Libre Space open source Pocketcube missions, because they have flight heritage of previous successful missions which can decrease the possibility of failures. Examples of this include the microprocessor, tape-measure antenna, and the battery.

The nanosatellite has been made with many types of manufacturing processes in different pieces of the GalaxySat-1. The principals are CNC machining of 7075 and 6061 aluminium alloy to produce the structures (see fig. 1) and SLS (Selective Laser Sintering) for small components.



Fig. 1. GalaxySat-1 structure

The GalaxySat-1 was designed so that the main subsystems are placed in a stack (see fig. 2) and the side, top and bottom panels are connected by picoblade model cables. This solution already has a long history of flight heritage, being a way of occupying the maximum possible space, especially in nanosatellites such as Pocketcube and CubeSat.

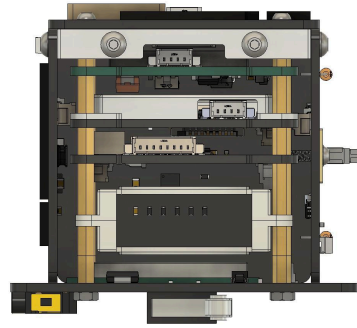


Fig. 2. GalaxySat-1 stacked 3D CAD

2.1 Payload

In this section a deeper look at the lighting payload (see fig. 3), describes the development and validation of a data collection system for atmospheric discharges [2], specifically adapted for a Pocketcube standard. The payload was conceived together with the National Institute for Space Research (INPE), that led the research and the Integrated Laboratory for Space Systems (LISE), subsequently adapted for Pocketcube size.

The primary objective was to detect and count lightning strikes from LEO. Functioning as a radio signal receiver, the system captures the electromagnetic pulses generated by lightnings, enabling precise quantification of these events. This device offers a compact, cost-effective solution for monitoring electrical activity during storms, thereby contributing to advances in meteorology and the understanding of Earth atmospheric phenomena.



Fig. 3. Engineering model of payload

To validate the payload on the ground, a high-voltage generator module, an Arduino Uno microcontroller connected to a computer, and a spark gap formed by the high-voltage module's wires were

employed. The tests involved connecting the payload board to the Arduino Uno and positioning the high-voltage generator at a certain distance from the board, powered by a battery. During the experiment, the electrical discharges generated in the spark gap were detected by the payload (see fig. 4), confirming the correct operation of the system.



Fig. 4. Electrical discharges detection test graphic

A clear correlation was observed between the number of electrical discharges occurring in the spark gap and the number of events detected by the payload. The results demonstrated that activating the high-voltage generator led to a linear increase in the number of detections, as expected. Conversely, when the generator was turned off or no discharges occurred, the number of detections dropped to zero, confirming the system's sensitivity and accuracy in detecting electromagnetic events.

2.2 Bus Subsystems

2.2.1 OBDH

The standard of electrical communication between the PCBs have inspiration from PQ60 [3]. However, GalaxySat-1 has its own particularities to match with this and possible future missions requirements. Therefore, the software is made in house to support the hardware to do as efficiently as possible.

The OBDH (see fig. 5) has some sensors to work together with payload. Include a 9 axis gyroscope, temperature and humidity sensor, and the GPS module. The GPS and payload can get simultaneously the position and data in this order, to produce a map with latitude and longitude where each detection happened. In order to save all data before passing over to the ground station, a micro SD card slot with a maximum of 32GB was implemented.

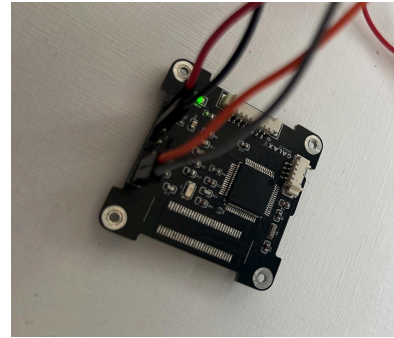


Fig. 5. OBDH subsystem PCB

2.2.2 EPS

The Electric Power System (EPS) is projected to attend the energetic necessity with the most efficient and low failure design. In this way, it only implemented a system for regulating voltage, voltage sensor, maximum power point tracker (MPPT) for charging the battery with energy provided by solar panels, and safety circuit with RBF and kill switches.

The satellite works in most parts with 3.3 Volts, so in the EPS there is one 3.3V regulator circuit but the transmission and reception module needs 5 Volts. To fix this, the TT&C subsystem has a pull up circuit only for it. In addition, to design EPS with capacity for supplying all electronic components and the path where electricity flows, it is important to draw a schematic for such visualisation (see fig. 6).

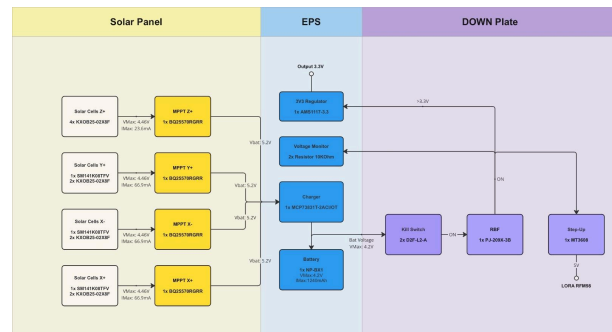


Fig. 6. Electric schematic of GalaxySat-1

2.2.3 TT&C

The Telemetry, Tracking and Command (TT&C) system is one of the most critical elements on the success of any satellite mission, since it is responsible for sending data to the ground station and receiving commands for controlling what should be done in each phase of its estimated lifetime. It consists of a RFM98W UHF Radio module mounted on the side with a 5V pull up. In another PCB is mounted a dipole antenna with 33cm total length made with COTS metallic tape measure, as well as antenna deployer: it consists of two circuits with one resistor and one MOSFET each. The

nylon thread, which holds the antenna for the launch, later will be cut by heat (see fig. 7).

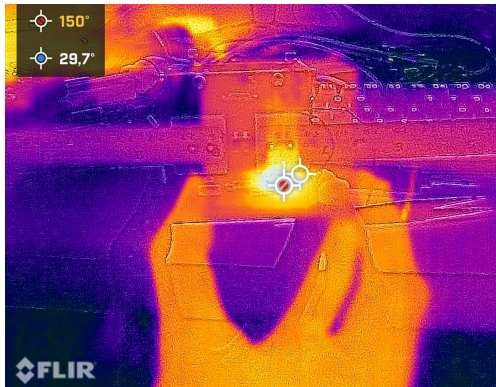


Fig. 7. Thermal imaging of the antenna opening

Besides the space segment, the construction of ground segments is a fundamental importance for the success of the mission, without it the communication with the satellite would be impossible. For this mission, will be used one ground station located in Sao Paulo, one in the Northeast region of Brazil and possibly one in Europe to have the greatest possible coverage of the GalaxySat-1 passes.

2.3 Developing Steps and Issues

Developing an aerospace mission like GalaxySat-1 is challenging and finding mistakes during the process is normal for a high school student. One of the main difficulties arises from the limited time students can dedicate to personal hobbies and projects. School schedules are typically designed for the average student and not for those involved in complex projects like designing and building their own space mission.

Given this significant challenge, a custom and flexible deadline is necessary to ensure that all critical steps are completed carefully. For GalaxySat-1, the project was structured with a long-term deadline, with the key constraint being that the satellite needed to be completed before university application deadlines and launched before receiving acceptance letters.

To further manage the development process, the schedule was divided into checkpoints to mitigate risks. The order and expected time to complete each phase were as follows: MDR – 3 months, PDR – 7 months, CDR – 4 months, Integration and Tests – 2 weeks, and Launch – dependent on the launch provider. The minimum project duration was one year and three months, but this timeline could be extended for various reasons, such as launcher delivery requirements or

potential delays due to legal documentation and tests [4] needed for satellite launch approval.

3. Discussion

3.1 Space Project Opportunities for Education

The opportunity for students to engage in hands-on space projects has historically been limited due to the high costs associated with aerospace missions. Although costs have decreased, financial aid remains a significant challenge. However, hands-on experience is one of the most effective ways to develop essential "soft skills," such as problem-solving, teamwork, and adaptability.

Developing an aerospace mission like GalaxySat-1 is complex, and mistakes are expected during the early stages of the project. One notable error in the first GalaxySat-1 model was the incorrect optimization of screw lengths, particularly due to the placement of solar panel screw holes at the extreme points of the PCB (see fig. 8). This mistake, while seemingly minor, provided a valuable learning opportunity.

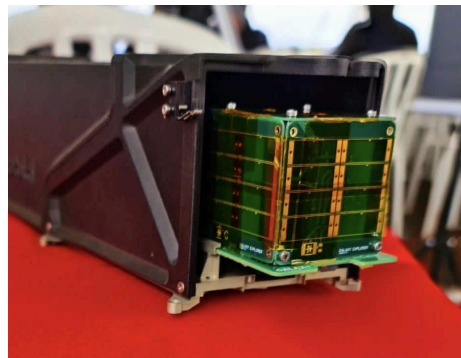


Fig. 8. GalaxySat-1 first engineering model

The lessons learned from the GalaxySat-1 mission are numerous. Perhaps the most significant takeaway for the student involved, Kevin X. Tang, was the importance of seeking help from experts when faced with challenges. Collaboration with experienced individuals not only helps solve technical problems but also accelerates learning and improves outcomes.

3.2 Student Perspective

“Developing the GalaxySat-1 mission has been the realization of a dream for me, especially because I am doing it while still in high school. I learned a lot from the challenges I faced during the process, which will be essential for my future, particularly in university.”

“The fast-paced and practical nature of this space project has provided me with new skills and knowledge that are usually only taught to college students. In addition to this, I’ve had opportunities to meet people at events that would never have happened if I hadn’t decided to make the GalaxySat-1 mission a reality.”

Kevin's feedback reflects his positive outlook on how this project has shaped his skills and knowledge, as well as its applicability to future student-led projects. In the near future, the success of this years-long effort will be seen as the mission is fully realized.

4. Conclusions

The GalaxySat-1 mission represents a groundbreaking achievement in the realm of student-led space exploration, particularly as it was developed by a high school student using accessible technologies and a low-cost approach. This mission not only demonstrates the viability of utilizing COTS components for space missions but also highlights the hands-on experience value for education.

Through the development and testing of the satellite, the project has demonstrated that it is possible for students to engage in aerospace engineering at a young age, acquiring both technical and soft skills that will be essential for their future academic and professional career. The interactive "learn through failure" approach, combined with a flexible project deadline, teaches resilience and adaptability, indispensable skills for success in the quickly evolving areas like space exploration and STEM.

Additionally, the mission's open hardware initiative creates a new precedent for educational space projects, making satellite design and development more accessible to students around the world. This approach not only reduces barriers to start but also encourages innovation within the global educational community, inspiring future generations to pursue their own scientific missions.

As the GalaxySat-1 mission moves forward, its success will be measured not only by the scientific data it collects but also by the lasting impact it has on educational practices, inspiring young minds to explore the possibilities of space science. By proving that space exploration is within reach for anyone with passion and dedication, this mission paves the way for more student start projects, developing a curiosity, creativity, and scientific discovery.

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