Building 1U CubeSat as a Tool to Promote Project-Based Learning in Paraguay, a Case Study

Mr. Cristhian David Coronel, Nihon Gakko University

I am a Electromechanical Engineering student, currently developing my final project in order to graduate. I find space development and technologies very fascinating, as well as innovative solutions to any engineering problems. I am looking forward to extend my knowledge and experience about new technologies and the development for a better and processing future.

Miss Mayra Luján Mosqueda, Nihon Gakko University

I am a student at Nihon Gakko University, I am currently finalizing the final degree project for the Electromechanical Engineering program. I am interested in technologies and I believe that dedicating to the technologies that relates to aerospace science can maximize capacity building.

Mr. Blas Fernando Vega BV, Agencia Espacial del Paraguay

Mr. Blas Vega was born in Asunción-Paraguay. He had graduated from the Faculty of Polytechnics at the Asuncion Nacional University. His major was in Electronics Engineering, with an emphasis on Industrial Control Systems. After graduation, he worked for ABInBev Company and CocaCola Company as an instrumentalist. In 2018, Mr. Vega was admitted to a graduate school at the Gulich Institute, in the Argentinean Space Agency (CONAE). Currently, he is enrolled in a Master of Science program in Satellite Instruments, expecting graduation in 2021. Now working in research projects at the Paraguay Space Agency.

Dr. Diego Herbin Stalder, Universidad Nacional de Asunción

I'm currently working as a full-time researcher at Asuncion National University, Engineering School (FIUNA). I'm teaching also C/C++ programming and physics at the engineering school FIUNA. We have several research projects on Space Engineering and Deep Learning Applications.

I obtained my Ph.D. at the National Institute for Space Research (INPE), where my research was focused in two main projects: (i) Bayesian Surface Photometry Analysis and (ii) the study of the Environmental effects on galaxies probed with MAGGIE.

I started my Ph.D. in 2013 under the supervision of Reinaldo R. Rosa and Reinaldo R.Carvalho. Thanks to the Brazilian Science Without Borders Scholarship and Gary Mamon (my advisor at the IAP) I was working at the IAP as a visitor.

Before, I obtained my BA in Electronic Engineering from the National University of Asunción (UNA). My final year project: Optimal boundary control parareal algorithm for cooling electronics circuits, developed under the advice of Christian E Schaerer. In 2013, I obtained my MSc degree in Applied Computing and Mathematics at INPE with the project: A new gravitational N-body GPU simulator for Computational Cosmology

Dr. Jorge H. Kurita, Universidad Nacional de Asunción

Dr. Jorge Kurita attended Universidad Nacional de Asuncion in Paraguay, where he got his BS in Electromechanical Engineering. After graduation, he spent some time in academia working as faculty. During this tenure he taught courses on heat transfer, fluid mechanics and physics. In 2004 Dr. Kurita was granted the Fulbright scholarship to attend a graduate program on Mechanical Engineering at Michigan Technological University. He has finished his MS and then continued with a doctorate program. His doctorate research was funded by NASA and the NSF. Dr. Kurita's contribution to his field was well published in several papers from high impact journals. From 2011 Dr. Kurita worked as a development engineer II, in the competitive automotive industry, Filtran LLC, located in Des Plaines Illinois. His experience as an experimental researcher helped Filtran to develop special testing techniques never implemented before on

filtration systems. In addition, Dr. Kurita worked in the CAE group, contributing to develop simulation techniques to help develop state of the art filtration systems. From 2016 Dr. Kurita is back to his alma mater as an assistant professor in Universidad Nacional de Asuncion. Later the same year, he is appointed to lead the research department of the School of Engineering. From 2017 he is appointed to be the head of the Mechanical Engineering Department at Universidad Nacional de Asuncion. He is currently working as the director of the Planning Directorate of the Paraguayan Space Agency.

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Introduction

In Paraguay, various higher education institutions such as universities do not have properly equipped engineering laboratories because it requires a significant investment [1]. Also, these laboratories may require extensive infrastructure and a variety of types of equipment. The common types of equipment are the Didactic Modules, which are essentially hardware that simulate a typical industrial machine or system situation. It has a design that allows the student or apprentice to learn, through practice, how to operate the system. Some laboratories do not require much spacing nor very complex equipment. This is the case of laboratories dedicated to electronics, mechatronics, and their equivalents, especially in data acquisition and data processing. Disciplines such as control systems, electronics, physics, and mathematics require data acquisition and data processing concepts. These disciplines are widely applied in space science [2], especially in the development of nanosatellites such as CubeSats.

A proposal arose to design and build a prototype of a didactic module for nanosatellite development whose main objective is to apply space science in Paraguay's educational sector through project-based learning methodology. To achieve this objective, we proposed the following specific objectives:

- Know the requirements and standards for the design of a 1U CubeSat,
- Develop a simple structure that meets CubeSat manufacturing requirements,
- Replicate three functions of a commercial Programmable Logic Controller (PLC) in the 1U CubeSat concept, such as temperature reading, electrical current measurement and switch control,
- Design a graphical user interface (GUI) to monitor the data acquired by the module.

Applying this prototype in higher education institutes will allow the gradual and controlled incorporation of space technology, providing new lines of research for different university careers and improving teaching as well as providing Paraguay an initial basis on the current trend in the world.

Design and construction

To obtain concrete and defined results, we based the development of this prototype on a mission to be carried out by a satellite with similar characteristics. The mission of this prototype is subdivided into two parts, Telemetry and Telecommand. The first involves transmitting through Wi-Fi the data acquired by an inertial measurement unit (IMU), current, and voltage sensors. Regarding the remote-control functions, the CubeSat must receive signals that allow it to turn on or off a LED and play a melody employing a piezoelectric Buzzer. The commands will be sent from a computer that will serve as an earth station.

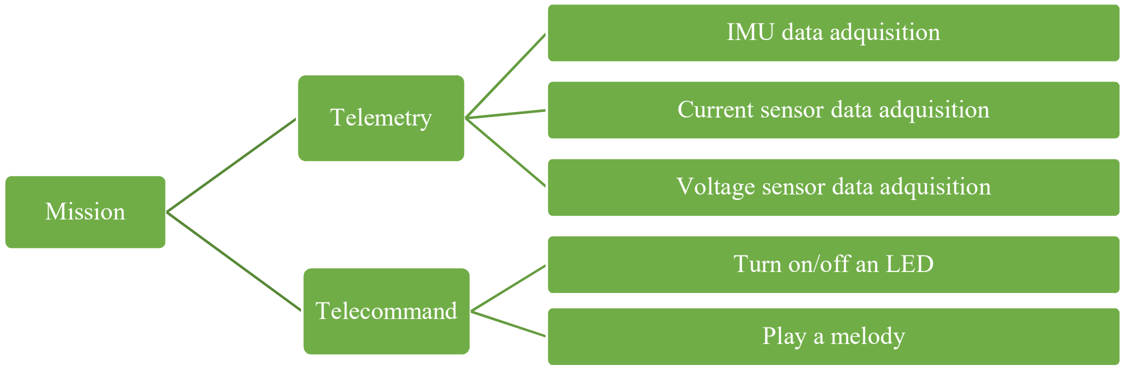

Figure 1 Mission description for the prototype

To apply systems engineering concepts, some requirements were defined, seeking in this way to prepare a guide that serves to control the success of this prototype's functionalities.

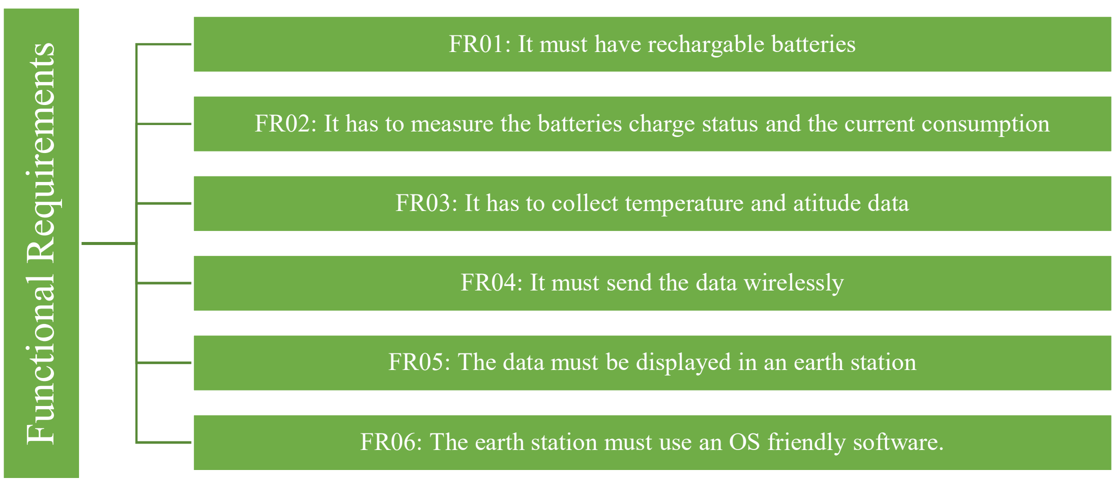

Figure 2 Functional Requirements

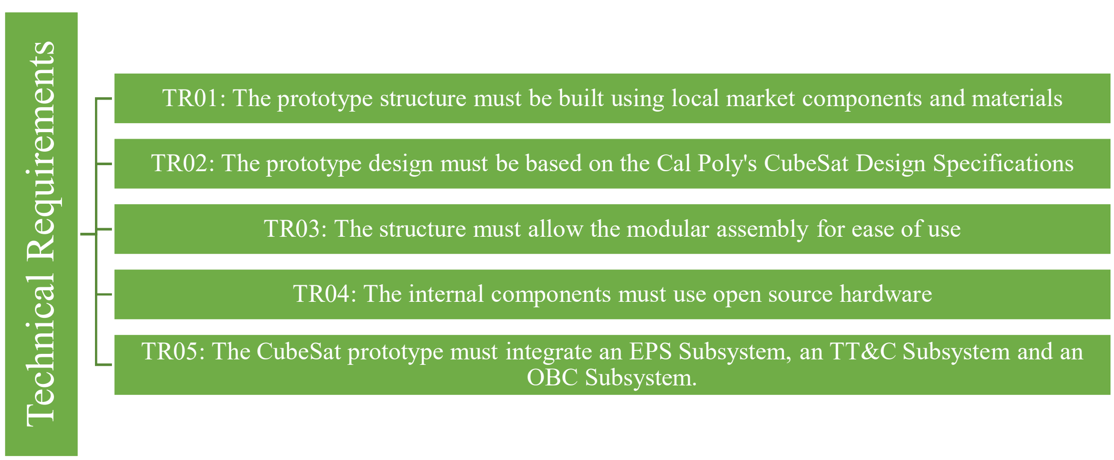

Figure 3 Technical Requirements

Functional requirements refer to the construction characteristics of the prototype and the functions it must perform and technical requirements refer to the way the prototype will be built.

External structure

For the construction of a CubeSat type nanosatellite, it is suggested to follow the requirements offered by CalPoly through the CubeSat Design Specifications (CDS) [3]. To comply with TR02 and TR03, two model ideas were obtained for a structure with new manufacturing methodologies.

Model idea 1

This model is based on the application of aluminum plates cut in such a way to cover the subsystems. For this, we proposed to use 1mm thick aluminum sheets. The cuts will be arranged in 4 lateral faces and 2 faces to cover the upper and lower parts as shown in the figure below.

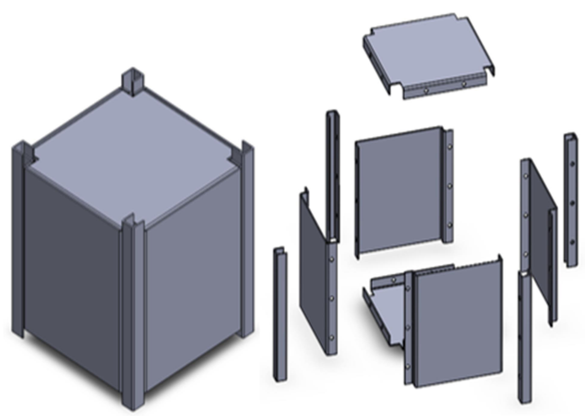

Figure 4 Model idea 1

Analyzing this idea's structure, we observed that it would be necessary to have an element that allows mounting the electronic boards inside. This led us to design and propose the use of thermoplastic materials through the 3D printing manufacturing methodology. Assembly tests were carried out and a large number of failures were also noted due to problems in measuring the cuts, perforations, and even the folds.

Model idea 2

On the other hand, when analyzing the design of the first model, tests with 3D printing were carried out, and the high precision and speed offered by this manufacturing method was noted. With this model, the structure is completely ready to assemble directly at the end of printing. Therefore, this model was the one chosen to be applied in the prototype final design.

The preliminary design is a cube with open spaces in such a way as to allow the insertion of the set of internal components of the CubeSat, the plastic used for the manufacture is a polymer known as PETG (Polyethylene terephthalate Glycol) [4].

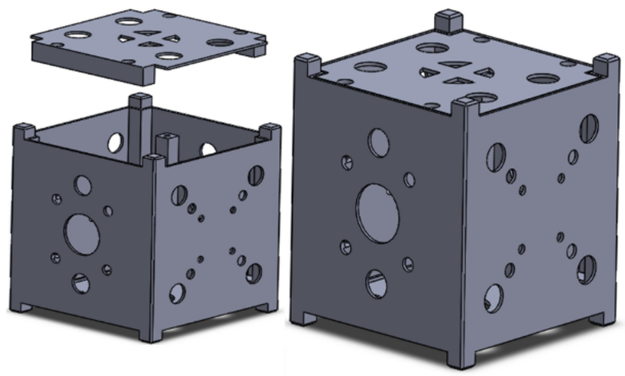

Figure 5 Model idea 2

Internal structure

The structure assembly of this prototype is based on the following model.

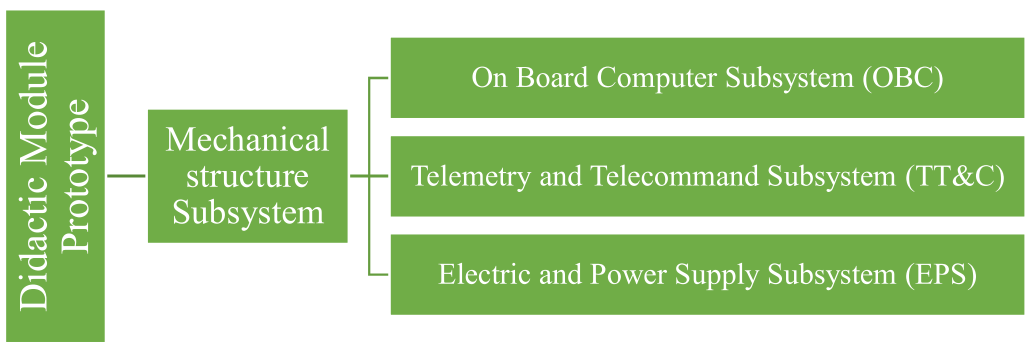

Figure 6 Didactic Module Prototype structure assembly

The OBC subsystem will be represented by a Raspberry Pi Zero W development board, with a built-in wifi antenna which makes it ideal for this prototype. This is interfaced with an Arduino NANO microcontroller, which will be in charge of carrying out the data acquisition processes with the sensors, thus forming the Data Acquisition System. In this system are the IMU, the voltage, and the current sensors. The IMU also has a temperature sensor that makes it an essential element to meet all the objectives of the CubeSat.

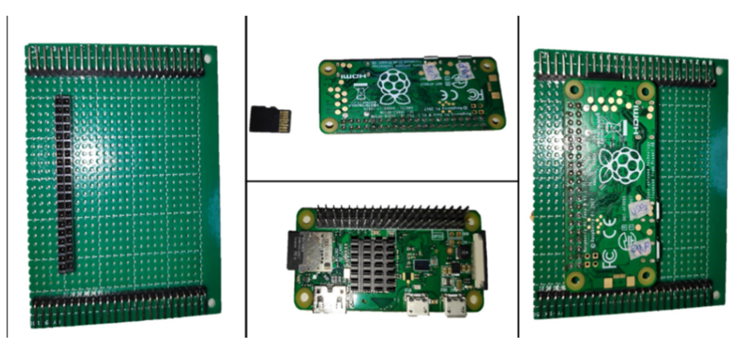

Figure 7 OBC Assembly

As for the Telecommand subsystem, an LED and a piezoelectric buzzer were used to simulate the sending of signals to the CubeSat, process them, and execute them through the Arduino.

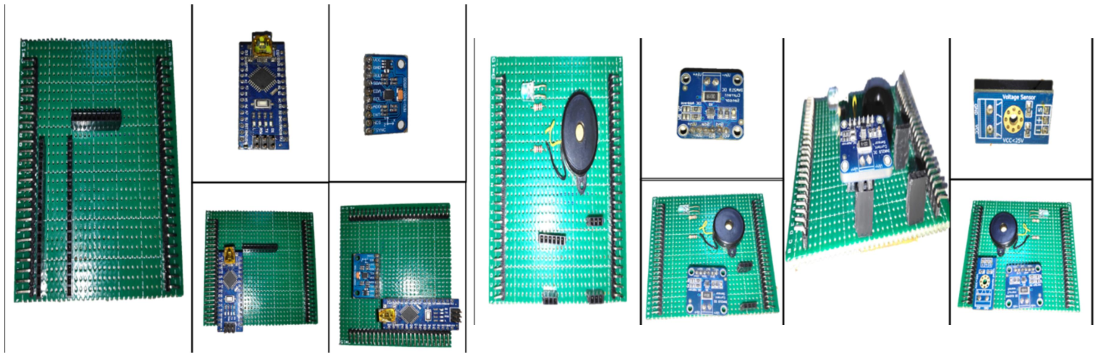

Figure 8 Telemetry and Telecommand subsystems

The EPS Subsystem contains rechargeable nickel-metal hydride (NiMH) batteries in conjunction with the Arduino and sensors for measuring the battery charge status and the current consumption.

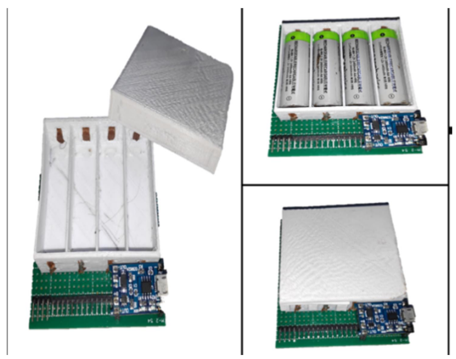

Figure 9 Electric Power Supply Subsystem

For the Mechanical Structure subsystem, based on the TR03, a system of plates with header pin-type connectors was designed to allow the connection of the components that make up the subsystems.

Likewise, each board is interconnected with the others by this same method, this arrangement resembles the connection buses seen in complex logic boards such as those used in computers and biomedical equipment.

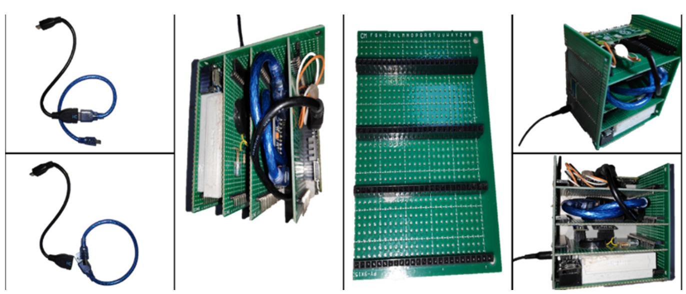

Figure 10 Mechanical Structure Subsystem

The final model was printed using a standard 3D printer with default settings for the use of PETG filaments. The structure along with all the internal components assembly can be seen in the picture below.

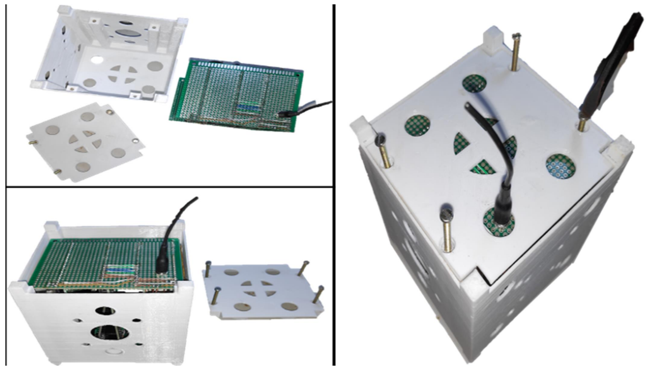

Figure 11 Finished assembly of the prototype

Earth station

The earth station for this prototype will be emulated by a laptop, it must be connected to the same local area network via Wi-Fi to the CubeSat.

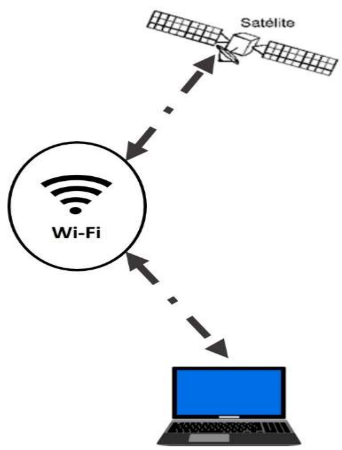

Figure 12 Earth Station suggested for this prototype

The GUI for the earth station interface was created using MyOpenLab [4], a Java-based graphical programming software, which in addition to allowing the design of intuitive interfaces efficiently, allows the use of communication protocols between different devices, such as Android, Arduino, Raspberry Pi or even web interfaces.

The interface, which was named as DidactiCube ®, is based on the exchange of data through Wi-Fi, the CubeSat collects data through sensors. This data is previously processed by the Arduino, which is responsible for encrypting and transforming them into binary values to be sent through a Serial port on the Raspberry Pi board, from there the already encrypted data is transmitted over the wifi network to the ground station computer that runs the same GUI to perform the reverse operation to display the data.

Figure 13 DidactiCube (R) GUI window view

As can be seen, using MyOpenLab gave great results for a visually friendly GUI.

Conclusions

Regarding the external structure, the 3D printing manufacturing method allowed to obtain very precise results and in a short amount of time.

All the electronic components were used as they were acquired in the local market for the development of the subsystems, this means that they have not been modified in terms of their manufacture. This could, indirectly, promote the growth of commercial establishments that include electronics components.

As of the proposed specific objectives:

- It was possible to know the requirements and standards for the design of the 1U CubeSat, which allowed the development of a simple structure that conforms to these standards.
- It was possible to replicate three functions of a commercial PLC, this was based on obtaining the reading and processing of temperature data, the current measurement of the batteries, and the control of switches with the on and off of LEDs and the Buzzer.
- While designing and developing this prototype we were able to appreciate the benefits of the application of project-based learning methodology, as well as the systems engineering concepts. Therefore, the application of the project-based learning methodology has been demonstrated when preparing the engineering project, defining a mission for the CubeSat with technical and functional requirements.

The main objective of this prototype is to apply space science in the educational sector of Paraguay through a project-based learning methodology. Though classroom tests have not yet been carried out, it has been noticed a high increased interest from students and teachers in the technical area who are waiting for the prompt implementation of this relatively new concept in Paraguay as seen in the university website news [6] [7]. For this, we believe that the best approach will be a workshop session like the ones already applied and validated by J. Moreira and L. Moreira [8]. The results should be very similar to theirs with the application of this prototype but on a higher education learning group of students.

In addition, for future applications in classroom environments we propose the use of this prototype as a baseline, this means that the class could start by forming groups of students who will then set their objectives and missions for their CubeSats and improve the development by applying this prototype as an example alongside with the GUI to add new innovative features.

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