Engagement in Practice: Final Design Projects on High-altitude Balloon Payload, Integrated with Low-cost Open Source Hardware, a Tool for STEM Education in Rural Paraguay – a Case Study

Mr. Oscar Matias Gonzalez Chamorro, Proyecto Arapy

Oscar Matías González Chamorro was born in Caaguazu city. He is a sophomore electromechanical engineering student from the School of Engineering at Universidad Nacional de Asuncion. Oscar currently works as a teaching assistant and a junior researcher. He also collaborates with the Paraguay Space Agency (AEP) and, the Aerospace Research Group (GADI) from the Polytechnic School at Universidad Nacional de Asuncion. In 2017 he has participated in the first round of Paraguay Science Clubs, a Scientific Enterprise Initiative workshop developed by the Benjamin Franklin Science Corner. Oscar mainly stands out for its leadership and talent in the development of community projects. He is the General Coordinator of a project called PROYECTO ARAPY - GLOBO SONDA PARAGUAY. He was awarded the Outstanding Young of the City of Caaguazú award in the year 2017. He was the winner of TOYP JCI CDE, Ten Outstanding Young Persons organized by the Junior International Chamber, in the category of scientific and technological development in 2018. The ARAPY Project intends to carry out aerospace explorations in different parts of the country with the use of the High Altitude Balloons (HAB). The purpose is to support the development of technology and science exploration processes, scientific research and education. Arapy project purpose is to spark awareness to young Paraguayan students in scientific research, to motivate the interest in science and technology. With these objectives, Arapy project carried out workshops, trainings and competitions, in rural community schools, to allow them experience scientific and innovative teaching methods.

Prof. Gustavo Ramón Samaniego Balbuena, Colegio Inmaculada Concepción

Gustavo Ramón Samaniego Balbuena was born in Escobar city, at the state of Paraguari, Paraguay. He has a degree in Pedagogy with an emphasis in Mathematics. He had graduated from the Catholic University of Asuncion. In addition, he is a tenured professor of Basic Sciences with emphasis in Natural Sciences by the Superior Don Bosco Salesian Institute. Prof. Gustavo Samaniego holds a Diploma in Social Communication and Art. He is also a Specialist in Methodology of Scientific Research by the Intercontinental Technological University. He has served as Physics and Chemistry Coordinator at Proyecto Arapy, a High Altitude Balloon project, intended for scientific and educational purposes. He has 19 years of experience as a teacher of basic school education, intermediate and university level. He is currently teaching Physics, Chemistry, Natural Sciences and Health at the Immaculate Conception School, as well as Coordinator of Scientific Research Projects at local community.at Proyecto Arapy, a High Altitude Balloon project, intended for scientific and educational purposes. He has 19 years of experience as a teacher of basic school education, intermediate and university level. He is currently teaching Physics, Chemistry, Natural Sciences and Health at the Immaculate Conception School, as well as Coordinator of Scientific Research Projects at local community.

Dr. Jorge H. Kurita, Universidad Nacional de Asuncion

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. For his contributions to the Paraguayan society education in the field of science and engineering, he was acknowledged as the ”Exceptional Protagonist of 2017” by the Ultimahora News, a major newspaper in Paraguay. In the same year, he was distinguished with the ”Outstanding Citizen Award,” granted by the city council of the City of Asuncion.

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Oscar Gonzalez Proyecto Arapy

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Abstract **- It is presented here, how a rural community was engaged, through its local high school, on the design of a payload to be deployed through a stratospheric platform. In this particular case, low cost open source hardware was integrated to a High Altitude Balloon (HAB) Payload. The main purpose of this activity was to support STEM education in rural communities by encouraging high school students to design, build, test, operate and data process HAB Payloads. The learning of fundamentals of this type of technology as well as, the study of the previous art, the design of experiments, the wiring of sensors to a microcontroller board and the open source program coding were all valuable learning experience to students. As a result of the success of this activity, in supporting STEM education, made the local government initiate the process to include Space Education as part of the curriculum initiatives.**

Keywords—HAB, STEM, Space Education, Open Source Hardware, Low Cost)

I. INTRODUCTION

In spite of the early creation of the Paraguayan Space Agency by congress in 2014, Law 5151/14, [1] it didn't start office up until 2017 by executive order Act 6466/17 and Act 7364/17. During this period of time, by initiative of academia, i.e. Facultad Politecnica Universidad Nacional de Asuncion (FPUNA), an attempt to conduct a near space exploration was performed. This space related activity had the purpose of expediting the establishment of an official national space agency.

Following previous successful experiences on balloon-borne platform, also known as High Altitude Balloon (HAB), by several foreign Space Agencies [2] [3] [4], the Aeronautics Department at FPUNA pioneered the near-space exploration activity in Paraguay, by launching the first HAB dedicated for this purpose [5]. As a result, a program and a mission were defined. The name of the program was EMOÑEPYRUPY (GENESIS in Guaraní), the mission was named as AEP-UNA-GS001.

The availability of low-cost hardware to integrate as payload, as well as, the open source nature of these, supported the active participation of the academia in the development of this payload. Existing publications on the application of this kind of low-cost open-source hardware are widely available [6]

As a result of this, many other student-faculty groups from different academic institutions from all around Paraguay, high schools and universities, started to carry out similar activities. One remarkable case was the ARAPY project, conducted at a rural high school in Caaguazú city. This activity was led by a science school teacher and his former student. The duration of this project was 10 months; this is, during school year 2017. In order to be able to design this payload, participants were trained by volunteers every weekend including Sundays. The use of open source hardware and the software programming was never experienced before on these students. Support from senior undergrads from engineering schools, as well as the newly stablished local Space Agency was provided.

II. MISSION DESCRIPTION

A. *Hardware Setup*

The payload architecture was based on Arduino environment. One of the goals was to capture images at high altitudes using a 3D camera and analyze the influence of ultra violet rays on native tree seeds provided by the national forestry agency.

In order to guarantee the accomplishment of the mission, the recovery of this flight data was critical. For tracking this flight computer and data logging device, two Global Positioning System (GPS) devices were utilized. An Arduino based GPS shield and a commercial on-the-shelve satellite messenger SPOT. The Arduino based GPS data was continuously sent to a cellphone by text message using a mobile phone carrier network. The SPOT device GPS data instead, was obtained directly from the SPOT satellite constellation through the cloud. (See Fig. 1)

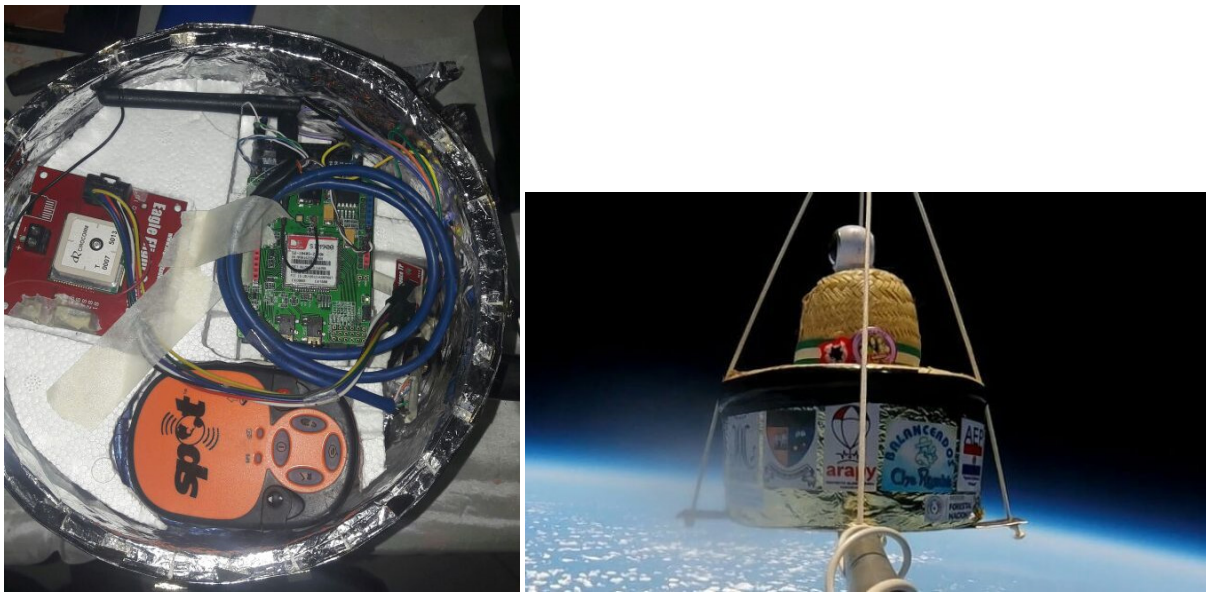

Fig. 1. Payload hardware configuration.

The balloon utilized for this mission was a 1200 grams latex balloon. The gas used to fill this balloon was helium, flyby type. It was needed about 3 m^3.

In addition, a radar deflector as well as a parachute was integrated to this HAB. It totally weighted about 2000 grams. (See Fig. 2)

Fig. 2. HAB team before launching.

B. *The Launch and Landing*

The scheduled launch day was January 4th, 2018. The planned launch time was 7am however, the actual flight started at 10:43am. The precise launch location was Latitude/Longitude -25.4639/-56.0113 (Caaguazú city), Paraguay.

At the moment of launching, the lift force was measured, by using a dynamometer; it showed a total force of 22 Newton.

The landing site was located at Latitude/Longitude -25.55045/-55.99332, Paraguay. After 3 hours of flight, it landed on a plain land at 13:51 pm. No visible structural damage was observed.

A free simulation tool from Cambridge University Spaceflight was utilized to predict this landing location. The prediction proven to be reliable, since actual landing occurred at a very close distance from simulation.

III. TEACHING METHOD

Initial 3 months were dedicated to literature review. Even though this step is obvious in any research process, in Paraguay is not the case. Special lectures on how to browse for reliable information as well as how to cite publications were conducted. This was a very difficult task since; reading papers in English is especially hard for students having Guarani and Spanish as native language. A very interesting outcome from this activity was the student awareness of the state of the art in this type of space activity. As a result, they implemented an investigation on UV effect on tree seeds, similar to other experiments conducted at different countries.

In the following 3 months, special topics in physics and chemistry were lectured. These were focused on the employment as a tool to design their payload as well as calculate propulsion. Calculations on buoyancy force from balloon filled with helium, as well as, net lift force were conducted. As part of this process, a dummy payload was launched for validation at the end of these lectures. Historical wind data from local meteorology agency was obtained to predict flight trajectory. They learned from earth science perspective, the existence of different wind profile as a function of altitude. Later, as part of their calculation verification, a free flight simulation from the University of Cambridge was utilized. Chemistry was focused on reaction to obtain hydrogen gas. This was just for enhancing some understanding on chemical reactions. The actual gas utilized to lift payload was helium, mainly for safety reasons.

The remained 4 months, were dedicated to train on microprocessor programming and payload integration. This last part of the project was the most hands-on activity students experienced. Here, external lecturers were participating on training in Arduino programming. Local community government, Caaguazú governor, purchased open source hardware, e.g. Arduino and its shields,

for payload development. Current curricula did not include electronics fundamentals. Therefore, project success was heavily depended on the accomplishment of capacity building in this area. A key factor for achieving this objective was the low cost of these open source hardware, in this case, Arduino style microprocessors. Rural schools are very limited in funding for lab equipment purchasing.

As we could observe, this multidisciplinary nature of this project allowed a very comprehensive support in STEAM education. Teachers from different subjects were involved such as mathematics, physics, chemistry, geology, computer science and arts. This space related "Project-Based-Learning" was first time implemented in Paraguay as an extracurricular activity.

IV. CONCLUSSIONS AND DISCUSSIONS

The deployment of this type of stratospheric platforms for near-space exploration in Paraguay was a successful experience. Massive press media covered this event [7]. A month after this activity, the local government issued an executive order to appoint the Paraguayan Space Agency's president and the twelve members of the board of directors. Two months later, agency started to function.

This motivated students and faculties of Caaguazú city. They initiated an extracurricular activity to be able to launch their own HAB. Figure 3 and Figure 4 are showing one of those classes during Sunday's training.

Fig. 3. Arduino programming class.

Fig. 4. Physics and math class.

Having a space related topic as their science project was very attractive subject for students. This motivated them to deepen their understanding in STEAM related subjects. Applying what they learned from theory to solve and/or achieve their goal was essential. No longer was the idea of uselessness present.

A significant improvement in student performance was observed. A 15% reduction in fail was seen. A survey among peers showed a 99% approval to continue this teaching fashion. For the first time in 12 years, 4 science projects using Arduino processors were presented at the 2018 science fair. Inspired from their HAB experience, student projects like Acoustic Levitation, Heart Beat Counter, Domotics and Motorcycle Automatic Start System were presented at the fair.

This engagement in practice, the case of Arapy project, was the baseline to draft a Space Education program, to be implemented in high school and colleges nationwide. The Space topic was included for the first time by the Ministry of Education and Science as part of the government curricula.

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