UbatubaSat – A Roadmap from Public Brazilian Schools Towards Knowledge

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The teaching of science in Brazil has been achieving moderate results as well as the youngsters' interest for careers in the techno-scientific field is still low. This paper describes how the UbatubaSat project of a picosatellite might be a roadmap for public Brazilian schools to change this reality. This initiative is being developed since 2010 by the Tancredo de Almeida Neves School in Ubatuba, São Paulo, Brazil, with technological support from INPE, the National Space Research Institute. The project has seen encouraging results towards promoting students´ interest in engineering, science and technology, especially in Aerospace Engineering, by the assembly, integration, testing, coding and launch of a picosatellite. This also promotes teamwork among different levels of education because some activities are being developed by basic level, others are planned for secondary technical students and some are even within the scope of INPE's graduate courses. The project has received recognition from the national and international scientific community and received support for its activities from organizations such as UNESCO, AEB-Brazilian Space Agency, amongst others. Briefly, Tancredo1 is the first picosatellite of the UbatubaSat project and it is a compact tube-shaped pico-satellite with a mass of less than 0.75 kg based on TubeSat kit from Interorbital Systems (IOS) [1]. It will be launched in early 2015 to the Kibo (きぼう, Hope) module of ISS - International Space Station [2] having two payloads: (1) an educational voice recorder and (2) an experimental Langmuir probe. This paper completely summarizes the current project status, developments, adaptations methodologies, results and its perspectives to a broader impact in the Brazilian educational arena.

Key Words: Picosatellite, STEM education, Space Outreach, TubeSat, Langmuir Probe**.**

1. Introduction

The PISA (Program for International Student Assessment) , aims at testing, every three years, the skills and knowledge of 15-year-old students and is an international survey, developed and coordinated by the Organization for Economic Cooperation and Development (OECD), which evaluates education systems worldwide. Brazil has achieved results below the expectations of its educational systems and the country unfortunately has ranked the last positions in the PISA. The test itself is applied to students at a stage which presumably is the end of the compulsory education in most countries. Table 1 shows the results obtained by Brazil and the number of countries which took the test in all editions of PISA.

Table 1. PISA Test Results achieved by Brazil (2000-2012)

PISA Test Statistics	2000	2003	2006	2009	2012
Participating Countries	32	41	57	61	65
Brazilian Ranking	32nd	40th	52nd	50th	57th

Complementarily, Table 2 presents the statistics in the number of Brazilian attendees to the PISA test and final attendees of specific tests like Reading, Mathematics and Science.

The quality of the Brazilian educational system in the areas of science, technology and innovation is another problem identified which has received the attention of Brazilian society and the authorities. This specific problem is present in the other end of the Brazilian educational system which covers students in universities and research institutes.

Table 2. Statistics of Brazilian PISA attendees (2000-2012)

PISA Edition	2000	2003	2006	2009	2012
Students	4,893	4,452	9,295	20,127	18,589
Reading	396	403	393	412	410
Mathematics	334	356	370	386	391
Science	375	390	390	405	405

The Brazilian Ministry of Science, Technology and Innovation (MCTI) keeps track in the number of articles published in scientific journals indexed by Scopus from 2000 to 2012 1). In its statistics we found that Brazil had a large increase in the number of published articles, from a total of 13,022 in 2000 to 53,083 in 2012. Comparatively, in 2000, Australia had 23,904, almost the double the Brazilian production and has increased to 62,200 which is a difference less than 18% of the Brazilian production. Similarly, another MCTI publication2). shows the number of citations to articles published in scientific journals indexed by Scopus, 2000 to 2012. This number measures the impact of the scientific production of a country; we find that this great quantitative increase is not reflected in the relevance of the published papers. Compared to Australia which had 43,082 citations to its articles, Brazil had only 17,580 citations, both in 2012.

Another indicator that has attracted the attention of society and the authorities is the low conversion of scientific research into real innovation. This indicator can be found in another publication of MCTI[3]. which shows the total of patent applications under the Patent Cooperation Treaty of Patent (PCT) providing statistics from 1999-2013 by country of residence of the inventor and date of priority, selected countries. If we look back to Australia as a comparison, we see that the country has a number of patent applications more than 168% higher than the Brazil.

This fact is a major concern to the Brazilian society at the moment and has been the subject of intense debates and a great number of initiatives. Finding solutions to it are being identified as this constitutes a major limitation for economic and social development especially in the "knowledge age" in which we live. This might be the main motivations behind the UbatubaSat project.

2. The Ubatubasat Project.

The Ubatubasat Project began in 2010 at a municipal primary and high school named Pres. Tancredo de Almeida Neves in the city of Ubatuba in the north coast of the state of São Paulo, Brazil.

A group of teachers learned through a scientific magazine that an American company, Interorbital System, was developing a low-cost launch vehicle and commercializing a TubeSat picosatellite kits with the launch of service. They then decided to start a scientific inception project having students from the 5th grade of their elementary school.

Initially, pico and nanosatellites were developed in 1999 as cubesats by Bob Twiggs and Jordi Puig-Suari then at Stanford University and California Polytechnic State University - CalPoly respectively. These small satellites worked as educational tools aimed to undergraduates and graduate in the area of space engineering.

Since then several universities around the world have developed and launched them for exclusively educational purpose. With the advance of microelectronics, this has allowed the shipment of an increasing range of scientific payloads and even operational models motivating their proliferation.

The Interorbital tubesat kit consists of a descriptive manual, Gerber files for the manufacturing of printed circuit boards, a microcontroller, a transceiver, solar cells, battery separators connectors for PCI screws. All other components necessary for the assembling should be purchased in the market.

CubeSats are shaped like a cube with a 10cm edge which has become a standard for complying with the PPOD, deployer developed by Jordi Suari and have already been approved by most launch providers. Unlike popular cubesats, the Interorbital satellite is shaped like a hexadecagonal cylinder prism, which would only adapt to its original vehicle launcher, named Neptune that is still under development.

From the initial contact with Interorbital, Tancredo school quoted prices, a draft contract and the advise information that it would need technical support for the complete assembling of the satellite. The INPE has been contacted and it was willing to give technological support to the Tancredo School for developing the project. An agreement was formally signed in early 2011, but before, the school and INPE had met closely to discuss the project.

The resources required for the purchase of the satellite kit, contracting the launch service and all material for training the students were funded by a local businessman as a project sponsorship. The city of Ubatuba, sponsored the Tancredo Neves School and has also supported the project in various way including financial resources.

In September, 2010, the project was officially introduced to the students in their first class in a group made up of three 5th-graders in a meeting at the school´s auditorium. This event has been attended by INPE technologists and culminated in a live videoconference with Interorbital Systems´personnel.

This followed an introductory course of Electronics and Welding Techniques in which students built a low-cost version of an Arduino board. The Arduino kit processor is a physical platform for open source computing based on a simple microcontroller board and a developing environment for writing the code.

The Arduino can be used to develop interactive objects, accepting inputs from a number of sensors or switches, and a variety of controlling lights, motors or other physical outputs. By 2011, some students had already acquired sufficient experience in building hardware to work in the terrestrial environment and a first group of students made a welding course with special qualification at INPE´s Integration and Testing Laboratory (LIT). Later on in 2014, the school has set up a laboratory for hardware manufacturing based in LIT specifications and even had built a small clean room. Today, this training is conducted at the school for new students of the project.

After a few months of training, students started building some tubesats subsystems for the Tancredo 1 picosatellite. Its original version was basically the project provided by Interorbital having a payload of a digital recorder developed by INPE. A contest was setup to choose the recorded message among students of Tancredo School.

Due to successive delays in the development of the launch vehicle from Interorbital, the UbatubaSat coordinating team decided to look for alternative launch opportunities to place Tancredo 1 in orbit. Hopefully, in February 2014, the AEB – The Brazilian Space Agency, which came to know the project, included the Tancredo 1 in its support initiative for small university satellite program. AEB then hired the launch of the first Brazilian four pico and nanosattelites, one of them with the Russian DNEPR rocket and the three others with JAXA through JAMSS, a Japanese company which manages launches from the International Space Station (ISS) Kibo japanese module.

The Tancredo 1 launch from Kibo, led to the addition of a number of new safety requirements not present originally. By mid 2014, the school agreed with INPE´s Aeronomy Research Division (INPE/DAE) that it would accept a new payload onboard, a probe Langmuir. These facts have led to significant changes in the original project designed by Tube Sat Interorbital, creating a second version of Tancredo l designed by the engineer Auro Tikami as part of his work in the Master's course at INPE.

3. The Tubesat Original Platform

The Tancredo l first version was built following the design provided by Interorbital with a voice recorder, designed by INPE, as a payload.

The original TubeSat is a 750 grams picosatellite that will orbit the Earth at an altitude of 310 km, re-entering the atmosphere in about 90 days. The tubesat with its ejection cylinder is shown in Figure 1. The Tube Sat is provided as assembly kit of a satellite by the company Interorbital Systems located in the Mojave Desert - CA, USA.

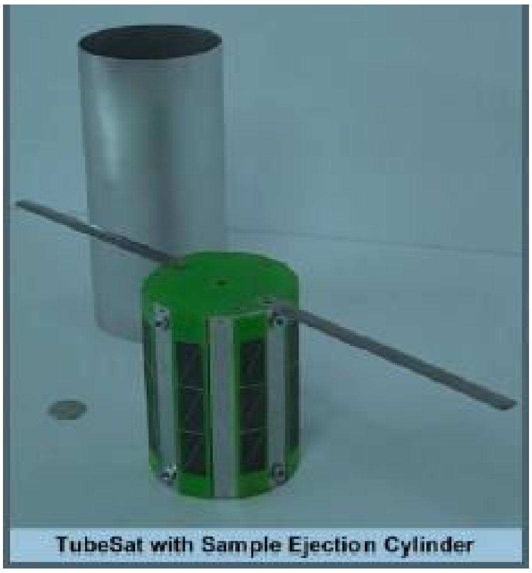

Fig. 1. Original Tubesat model with its ejection cylinder

The tubesat kit can be used as a learning tool that requires a team work as well as techniques for manufacturing printed circuit boards (PCBs). Figure 2 shows its onboard computer board where the software project runs in real time. If the tubesat is assembled correctly, it is able to support scientific experiments in orbit as well as communication functions.

As shown in Figure 3, the picosatellite consists of the following subsystems distributed into individual PCBs: (1) Antenna (2) Power Management (3) Transceiver (4) Onboard computer, (5) Payload and (6) Solar panels.

4. The Tancredo l Tubesat Systems Re-Engineering

A new redesign was needed to the original tubesat platform as a response to the change of the launch vehicle to the ISS just mentioned earlier. This led to some new requirements, especially focused in the safety of astronauts as well as those related to meeting INPE/DAE to launch a new payload in this case a small Langmuir probe in Tancredo l.

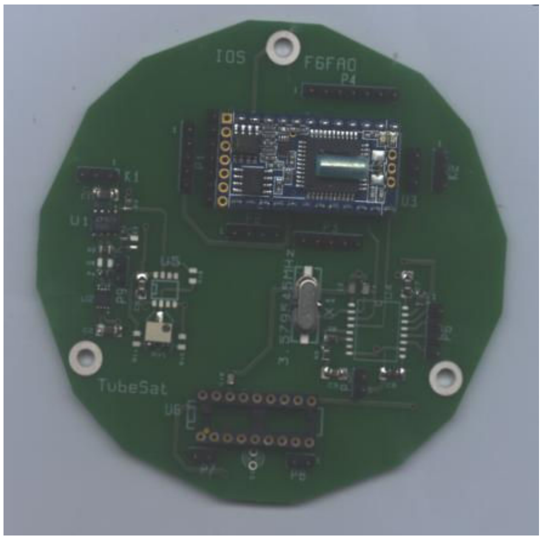

Fig. 2. The Tubesat onboard computer board

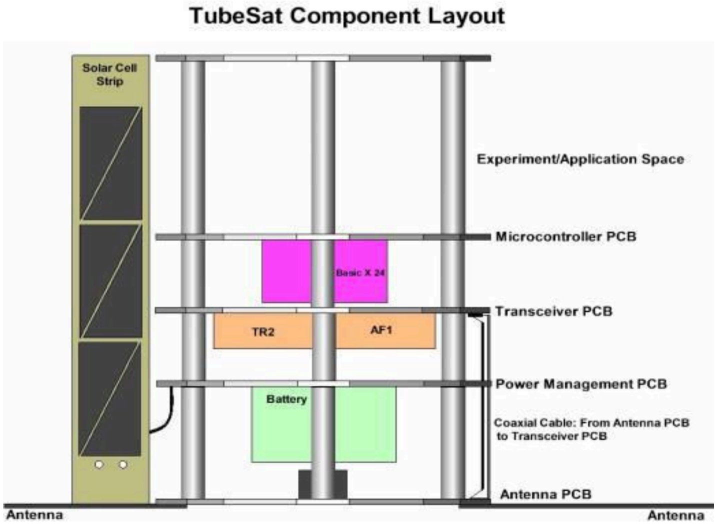

Fig. 3. Layout of all tubesat modules.

These facts have demanded a comprehensive review of the design which introduced several modifications to the original Interorbital project. The adaptation of tubesat to a new architecture was performed through a systems re-engineering indoor to meet the new requirements due to mission scope changes just mentioned.

Another key issue that appeared when assembling and testing the original tubesat design was due to the board interconnecting strategy which was done solely by wire. Even though it is a simple solution, manipulating the board with wires proved to be quite problematic since wire got twisted frequently causing circuit breaks.

The new Tancredo 1 design included basically a new PCB with the introduction of a miniaturized Langmuir probe board as shown respectively in Figures 4 and 5.

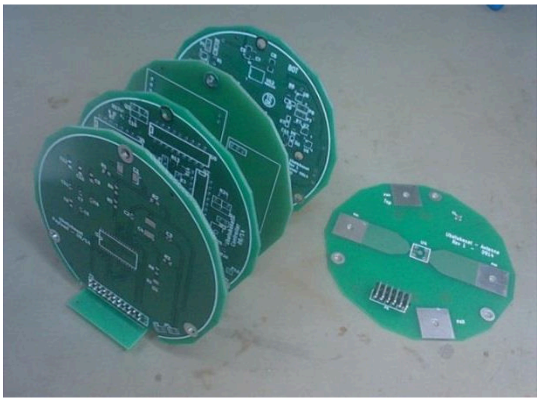

Fig. 4. New interconnecting bus concept design and PCBs

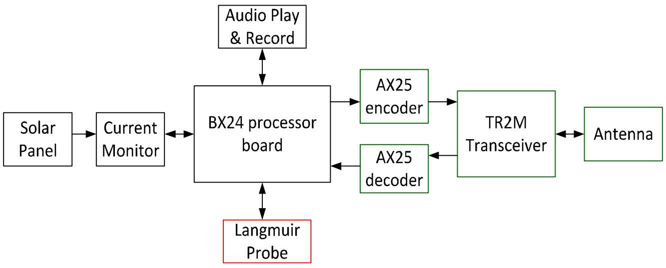

Fig.. 5. Tancredo-1Block diagram with the Langmuir Probe.

The adaptation of the Langmuir probe basically demanded the inclusion of a DC/DC converter, amplifiers and metallic sensor. Once in space, the probe is kept in a relative positive potential with respect to the picosatellite. This allows for collecting electrons which density is then measured by the current sensor exposed to the ionosphere plasma.

At the same time, a new picosatellite orbital deployer (POD) for ejection of Tancredo-1 was being developed by Bob Twiggs at Morehead State University-USA and GAUSS an Italian company, which has worked together with Ubatubasat team.

5. Some Preliminary Educational Results

The Ubatubasat Project brought some mixed educational results which changed the lives of the participating students and the school itself. In 2012, a group of twelve students from the project supervised by pedagogues[4)] conducted a survey to evaluate the impact of the project itself among the 6^{th} grade students of Ubatuba elementary school, its target audience.

In 2013, one of the students, a girl named Bruna Sakamoto and aged 14, co-author in [4)], made the presentation of the article in 29th ISTS conference. At the same time the project was being presented by the group of students in 29th ISTS Exhibition. The students` trip to Japan was funded by UNESCO.

In that student's article, we can notice that a large majority of students reckon that the participation in a project like Ubatubasat can influence their future. Some of the reasons point pointed out by the students for such influence are: (1) "*the desire to be a scientist, astronaut, engineer*"; (2) "*gaining experience, being a good professional*"; (3) "it Brings opportunities, it helps to choose a career"; and (4) "*Learning is good and important.*"

Some of the survey results are presented in Figures 6 and 7 showing that four nearby schools have been checked in the survey, and are simply indicated as "Sueli", "Esteves", "Deolindo" and "Tancredo" hereafter.

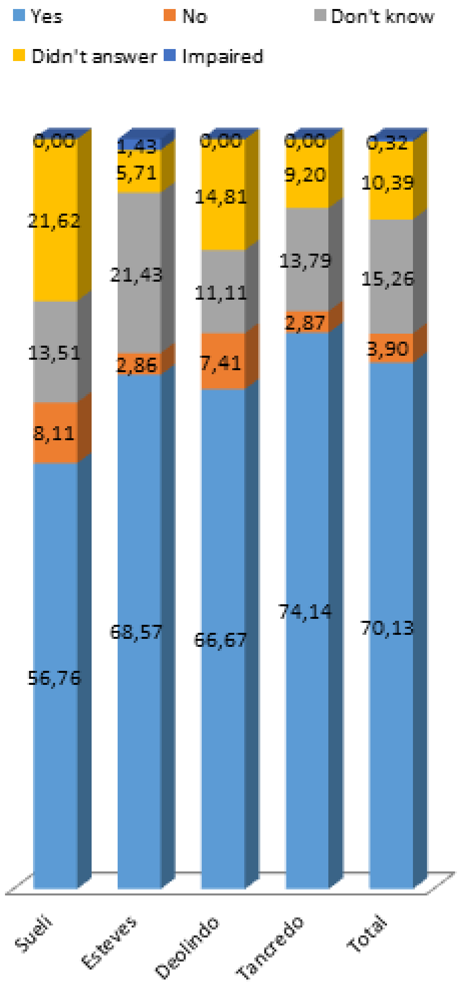

Fig. 6. Survey responses for the question of whether the project could impact students' future lives.

Another project contribution was an increase in the effective study hours of students. In Brazil, normally classes in public elementary schools and high schools take place in a single day period during of around 5 hours. One of the measures for improving schooling standards is increasing the amount of daily course study hours. The Ubatubasat Project activities were always undergone during off-class hours so that a student having morning classes could participate during the afternoons and vice-versa. This clearly contributes to the net increase of hours spent studying.

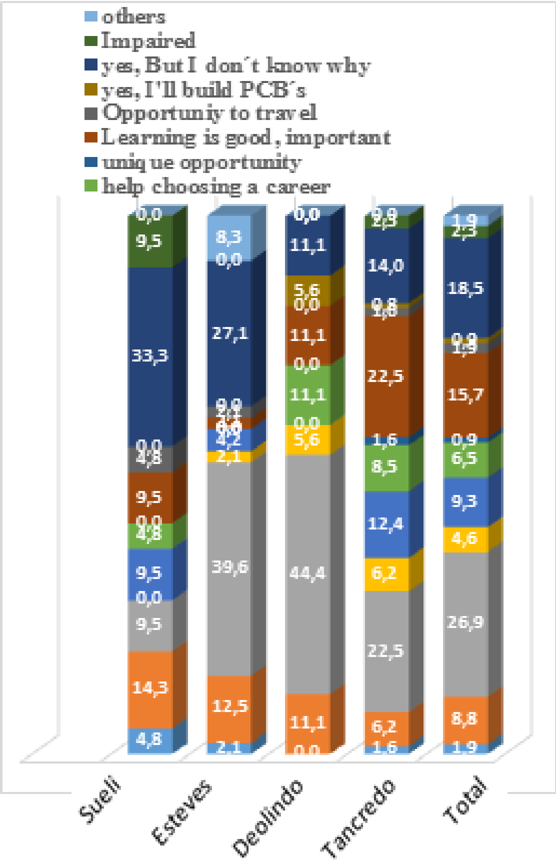

Fig.. 7. Survey responses for project motivations

Another project outcome was the inception of a technical middle school in the Tancredo school premises with differential features from the ordinary courses and other Brazilian middle schools in general. In 2012, the Ubatuba City Department of Education proposed the opening of a new high school course with innovative features. The initiative was encouraged by the results achieved by the Tancredo School.

The new proposed course is full-time and has a total hour workload which is 50% higher from the regular school courses. The science-oriented subjects like Physics, Chemistry, Biology and Mathematics have a 100% higher hourly workload and, in some cases, 200% higher workload compared to the traditional curricula adopted in Brazil. Moreover, all these disciplines have practical laboratory classes which are quite rare among Brazilian schools.

In Brazil, the subject on "Differential and Integral Calculus" is usually not taught in high school, bringing great difficulties for students in higher education was incorporated into the curriculum.

6. Conclusions

Brazil has serious deficiencies in its educational system. The proficiency rate measured by PISA of their students in reading, mathematics and sciences are one of the lowest among the participating countries. At the other end, Brazilian universities have increased significantly the formation of new researchers with master's and doctor degrees and the papers published in journals indexed by Brazilian researchers have increased by over 300% between 2000 and 2012.

However, the relevance of all this scientific production has not matched that growth which is measured by the number of citations to the published articles as well as innovation, measured by the number of new patent applications.

The Brazilian society and governmental authorities have made efforts to improve the quality of the educational and research system in the country, both at the early levels, as well as in the universities. This effort is recognized as of great importance for socio-economic development of the country.

The Ubatubasat project developed by the Tancredo de Almeida Neves School in Ubatuba, São Paulo, with close collaboration of INPE has obtained encouraging results and the recognition of organizations such as UNESCO, the Ministry of Education, the AEB and also from the national and international scientific community beyond society in general.

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