ENHANCING STEAM EDUCATION THROUGH MULTIMISSION PLATFORM DEVELOPMENT USING STRATOSPHERIC BALLOON

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Abstract

The small satellite programs have been successfully used as a platform for learning STEAM (Science, Technology, Engineering, Arts and Mathematics) disciplines, bringing benefits to education and research institutions. Technical schools have been considered expected candidates for hosting such programs due to their course components and infrastructure. More recently, with the dissemination of small satellite initiatives, non-technical institutions have been presented the opportunity of developing satellite design and implementation programs. In this context, the BalloonSat Stratos Senac I project, or simply BalloonSat, from SENAC, National Service for Commercial Education, aims to inspire young students to pursue knowledge in the STEAM areas stimulating technology-based entrepreneurship and improving science education in Brazil. The project, in partnership with INPE, National Institute for Space Research, consists of advising and supporting SENAC, in the development and manufacture of a platform transporting educational and scientific payloads to be launched into the stratosphere by a small meteorological balloon. The georeferenced data until the stratosphere, obtained by the platform and instruments, will be used in investigations and atmospheric phenomena studies. The development and space system prototype testing can be performed alternatively at a low cost using the stratosphere due to factors present such as low atmospheric pressure, radiation, and temperature extremes. This paper will discuss BalloonSat with some safety requirements, the helium stratospheric balloon remote station based on Arduino processor, CAM-M8 GPS module, and RFM69 transceiver. It will also discuss the ground station segment with a balloon trajectory prediction simulation map showing the launch, balloon burst, and payload impact sites. The ground station will be performing tracking, command, and data reception from the remote platform and instruments during the balloon flight to the stratosphere from the launch site till payload rescue. Preliminary functional test results without balloon launch will be presented. The BalloonSat is according to INPE´s mission of disseminating knowledge and technology to society and also aims to induce and train human resources.

***Keywords**: BalloonSat, STEAM, Stratospheric Balloon, Small Satellite, Platform.*

1. Introduction

The promotion of STEAM (Science, Technology, Engineering, Arts, and Mathematics) disciplines to foster youngsters' interest in careers in the techno-scientific fields has been a concern in our society. Recently with increasing small satellite initiative dissemination, non-technical institutions in the space segment area, such as SENAC (National Service for Commercial Education) has gotten a cooperation agreement with INPE (National Institute for Space Research to inspire young students to pursue knowledge in STEAM initiatives.

The development of space platforms like CubeSat [1] has made space science a little more accessible to educational and research institutions. To make it more accessible for everyone at a low cost, stakeholder teams working on these space platforms can conduct stratospheric balloon experiments to test their instruments in the stratosphere in a harsh environment. The extreme condition in the stratosphere can dive to as low as −56.5 °C in temperature and 2 kPa in pressure [2]. These kinds of balloons are useful platforms for various research and technology needs. In particular, they can be used for concept-proof demonstrations in preparation for new space missions.

A typical stratospheric balloon flight duration varies depending on the choice of the launch site, flight trajectory and season. Payloads can be flown at altitudes around 30 km lasting approximately 2 hours. Compared to satellites, balloons can be operated at a relatively low cost and with shorter times from the experiment conception to the flight. In this context, the BalloonSat Stratos Senac I (BalloonSat) project joins a high-altitude science experiment pursuing knowledge in the STEAM areas. In Science, the platform and balloon launch will be able to be designed by teachers and students for more engaging learning in various courses. In Technology, students will familiarize themselves with the dominant technology of balloon launch and track it online. In Engineering, students will design their payload and plan its launch. In Arts, students will utilize creative skills for their experiments and launch campaigns and rescues. In Math, at the end of each release, students will have a huge amount of data for their applications.

High altitude testing using a stratospheric balloon has been considered an effective demonstration of some features of CubeSats. For example, the hardware must be prepared for harsh thermal environments with temperatures over -50°C. Balloon satellites have lower costs than CubeSats in both development and launching. Stratospheric balloons allow access to near space around 30 km and provide a complementary and less expensive means for satellites to observe the Earth or the universe from above most of the atmosphere. Balloon launches can be carried out in very short terms with low cost and using state-of-the-art technologies. Improvements and project updates can be carried out from the data acquired with balloon launches.

2. The BalloonSat Project

Most balloon systems and payloads are recoverable and can be reused. As a stratospheric balloon ascends into the stratosphere, it expands until it ruptures whereupon a parachute is deployed to descend the balloon systems and payloads to be retrieved. The balloon envelope itself is not recycled, however, the payload platform and the elements such as the parachute and radar reflector are re-used for future flights. The total mass supported by the stratospheric balloon will be less than 1200 grams. Figure 1 shows the balloon flight system with a balloon, parachute, radar reflector, and payload.

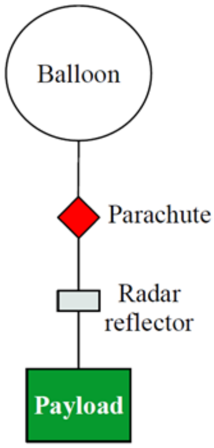

Figure 1 - Typical Balloon flight system.

The stratospheric balloon must have the following characteristics [3]:

- natural or synthetic rubber;
- homogeneous and spherical shape, uniform thickness and extensible type;
- provided with a collar of 1 to 5 cm in diameter and 10 to 20 cm in length, according to the size of the balloon;
- diameter (inflated and on the surface) of approximately 1.5 m;
- size and quality that ensure the transport of the radiosonde (from 1 to 2 kg) up to altitudes close to 30 km, with ascent rate fast enough to ensure reasonable ventilation of the measurement elements;
- it must be able to expand by at least 4 times its initial diameter and to maintain this exposure for at least one hour;
- when inflated, the balloon must have a spherical or at least circular in horizontal section.

The balloon must be inflated to perform the launch. Helium gas is considered one of the rare gases in the atmosphere and has properties such as inertness, odorless, colorless, and non-flammable. Hydrogen gas is a fuel element and the use of this gas is accompanied by a certain risk due to its highly flammable property. Factors that can cause hydrogen gas to explode, or to fire, are an unstable mixture of hydrogen and oxygen and the existence of an ignition source [3]. So the balloon launch, which involves students, helium gas must be chosen to inflate the balloon and eliminate the risk of explosion.

During the launch campaign, in order to reduce the possibility of a stratospheric balloon constituting a danger to aircraft in flight, the balloon operator must inform the local airport authority of the launch time, at least 30 minutes in advance, and other information useful for air navigation safety [3].

The BalloonSat project encompasses the balloon and ground station segments as shown in Figure 2. The balloon segment includes the balloon, inflated with Helium gas, and a radiosonde, with an Arduino processor [4], and a transmitter that sends information from the sensors and experiments to the ground station. The ground station segment receives the information sent from the balloon segment and the data processed by the Arduino are displayed on the PC. Given that Arduino processors are beginner friendly yet capable of advanced projects, Arduino is a good starting point for CubeSats built by student teams [5].

As a project development methodology, the data obtained from each launch can be used for updating and continuous improvement.

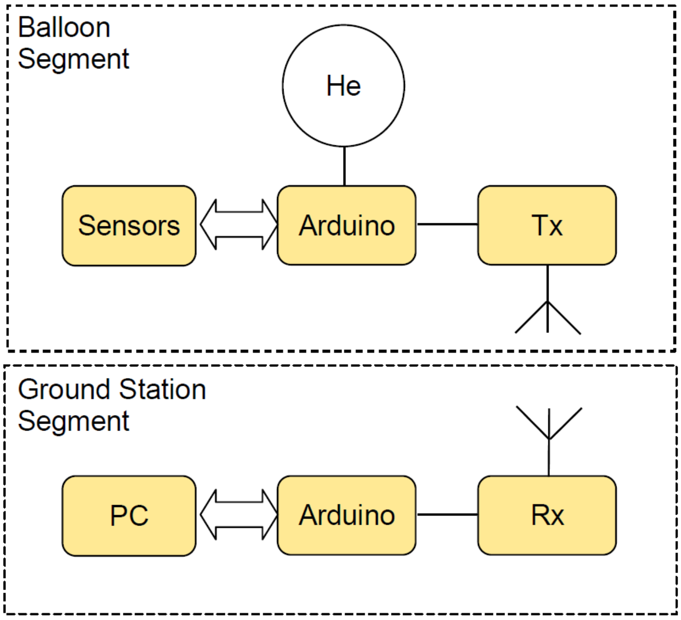

Figure 2: Balloon and Ground Station segments.

2.1. Balloon Segment

The Balloon segment block diagram is presented in Figure 3. Arduino processes time stamps, altitude, location coordinates, and altitude from the GPS CAM-M8 module [6], the sample atmospheric data, battery voltage, the internal temperature of the platform, outside temperature from the atmosphere, and payload data. The transceiver used is the RFM69HCW [7] which transmits GFSK data (4800 bps) in radio frequency (433 MHz) through an antenna to the ground station with 100 mW output power. The antenna is a monopole with an omnidirectional radiation pattern, radiating equal radio power in all directions perpendicular to the antenna's axis.

The sensors are BMP180 [8] and DS18B20 [9]. The BMP180 sensor will be used to measure atmospheric pressure, altitude, and temperature. The DS18B20 sensor is a digital thermometer with 9-bit to 12-bit Celsius temperature measurements. It communicates over a 1-wire bus. Payloads, educational and or scientific, can be embedded into the platform with data acquisition by the Arduino processor. The battery consists of a 5-volt power bank.

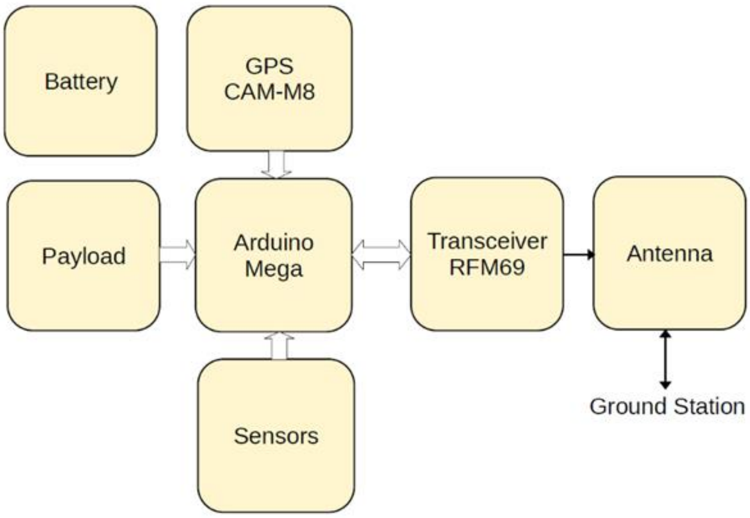

Figure 3 - The Balloon segment block diagram.

2.2. Ground Station Segment

The ground station is also based on the Arduino processor. There will be two types of the ground station, one transportable and the other mobile for the recovery of the stratospheric balloon platform. Figure 4 shows the ground station block diagram. The battery is going to use for the mobile ground station.

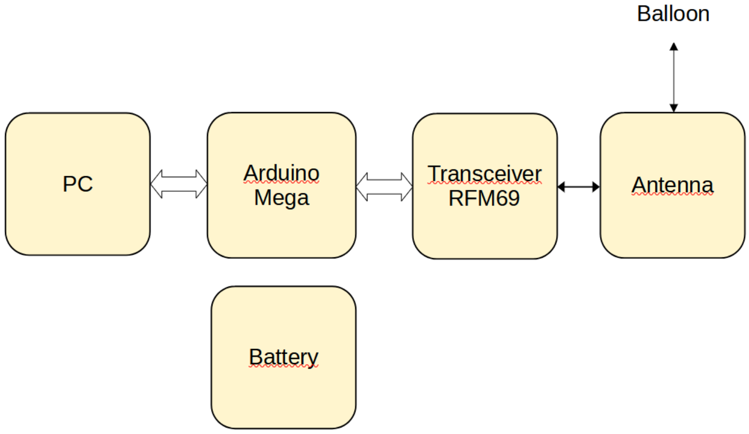

Figure 4 - Ground Station block diagram.

The visualization software was implemented using LabView [10] with Arduino processed data. Figure 5 presents the front panel view.

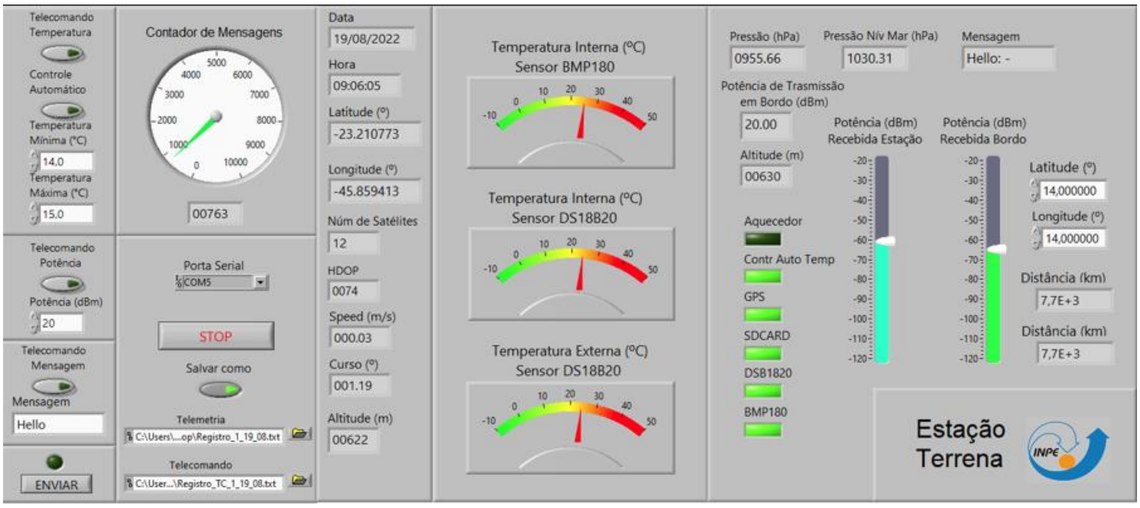

Figure 5 - Ground Station Front Panel

3. Simulation and Results

The prediction of the landing location can be enabled using a free web-based trajectory forecast tool. One of the most commonly used predictors is a CUSF [11] predictor developed by Cambridge University Spaceflight. The main advantages of this predictor are its intuitive user interface and clear trajectory maps. It also generates maps (Figure 6) and KML files directly from the predictor, allowing for easy visualization of the predicted trajectory by Google Earth (Figure 7). The simulation was performed only as an example to illustrate the predictor result. The target landing areas will preferably be open fields, away from mountains, oceans, and populated areas.

Figure 6 - Cambridge University predictor map.

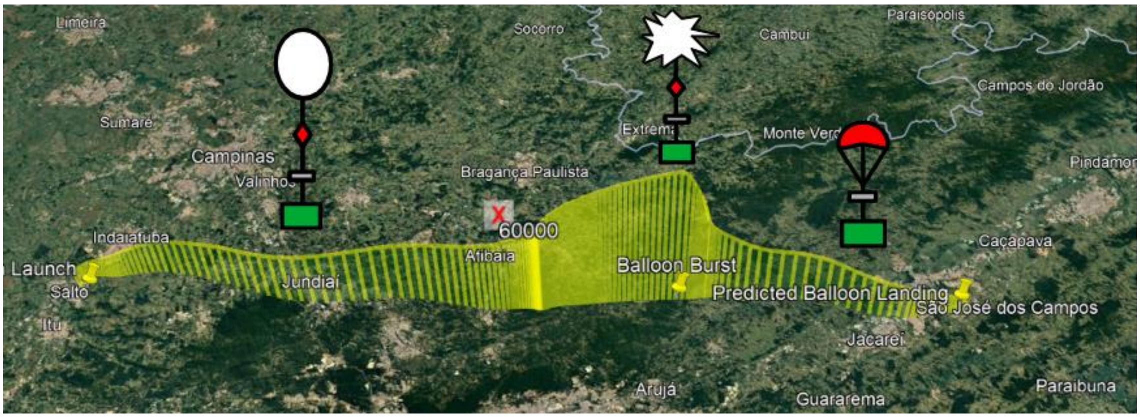

Figure.7 - Balloon trajectory forecast with Google Earth visualization.

The balloon is released and ascends to the stratosphere and during ascension, the pressure inside the balloon is bigger than the pressure of the external environment. Given the pressure difference, the balloon will start to expand up to a point at which the balloon can no longer withstand the internal pressure and will therefore burst. After bursting, the parachute will deploy and slow down the descent of the payload bus. That is significantly affected by the wind in the absence of parachute control. Finally, the search and rescue team can retrieve the payload, and the data saved onboard can be further analyzed [12].

In order to verify the general functioning of the hardware and software in development, simple tests were carried out successfully, without performing a balloon launch, between the ground station segment and the balloon transmitter located approximately 10 km away in a straight line without obstructions.

4. Conclusions

The space platform development as CubeSat has made space science accessible to educational and research institutions promoting STEAM initiatives with stratospheric balloon launches carrying satellite subsystems and experiments into the stratosphere in a harsh environment.

In this paper, we have presented the BalloonSat project with the stratospheric balloon and ground station segments based on the Arduino processor. Communication and general functioning tests between these segments were successfully carried out on the ground and the CUSF balloon trajectory prediction tool was presented with simulation.

And with the launch to be performed of the balloon into the stratosphere and their results, we can use them to improve and update the platform for future launches.

Acknowledgments

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