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BALLOONSAT AS A PLATFORM FOR DEPLOYING THE NEUTRON COUNTER

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The BalloonSat program is a NASA Space Grant funded ballooning opportunity for students. The platform is adaptable to host payloads to more than 30 km and a flight time of 2 to 4 hours. The latex sounding balloon can lift approximately 5kg to altitude. At the University of Alabama in Huntsville the BalloonSat platform is used for outreach, research, demonstrations, and to test components of a CubeSat, currently under development. At UAH one BalloonSat is a thermal neutron counter scientific payload. Here, research is underway in determining the initiation and effects of lightning in the atmosphere. Students have developed the mechanical system to host the counter. Previous research suggests that neutrons may occasionally be produced in lightning storms. The student flight team has the ultimate goal of a flight profile bringing the neutron counter near active lightning storms. Initial flights are necessary to characterize the natural neutron flux profile of the target environment. The BalloonSat may have an advantage in measuring thermal neutrons considering the platform hardware has low mass. There will be less local interactions with cosmic rays and moderating material (i.e. Hydrogen) than previous carriers of neutron counters. Therefore, fewer local cosmic ray interactions would be present, and the counter will register neutrons from the environment. The measurements will be compared to those made by the Deep Space Test Bed, a 2000kg balloon flown by NASA. Previous research using BalloonSats demonstrate the effectiveness of the platform as a versatile and low cost test bed for atmospheric and high altitude research. I will present the development of the BalloonSat as a test platform and introduce the motivation of the neutron counter research. I will show development and testing of the custom BalloonSat hardware, introduce the initial flights, and present the plans for flights into the target environment.

I. THE BALLOONSAT PLATFORM

The BalloonSat system is an experiment platform to study the atmosphere from ground level to high-altitude, 30 km (100,000 ft). To accomplish a repeatable, cost effective, and timely launches, the BalloonSat program adheres to a system under the minimum requirements of regulated ballooning. By following these FAA regulations closely, the BalloonSat system is able to be launched with minimal interaction with the FAA. An excerpt of the considered regulations is in Appendix I.

System Requirements

Based on the FAA regulations, the BalloonSat Team at the University of Alabama in Huntsville maintains the following requirements for flight:

1) Maximum total payload mass of 5.44 kg (12 lbs)
2) Maximum individual payload mass of 2.72 kg (6 lbs), with maximum size to weight ratio of 131 kg/m^2 ($3 oz/in^2$)
    a) Except if less than 1.81 kg (4 lbs)
3) 22 kg-test payload line (50 lb-test)
4) Redundant Tracking Systems
    a) Closest to primary payload
5) Parachute Recovery System

COSMIC RAYS

Cosmic rays are nuclei of all the elements that originate outside our solar system. These particles are 90% Hydrogen, 9% Helium, and 1% everything else. Their mean energy is around 3 GeV, but their energy spectrum extends orders of magnitude higher. Research has been performed in understanding the effects and sources of these high-energy particles in the atmosphere. It benefits the community to understand the environment around us, and how we are affected by it.

“These cosmic rays interact with the nuclei of atmospheric constituents to produce a cascade of interactions and secondary reaction products that contribute to cosmic ray exposures. These decrease in intensity with increasing depth inside the atmosphere[1].”

The atmosphere offers protection to the surface by using both the Earth’s magnetic field and the density of air, being approximately 10,000 kg/m^3, comparable to 10 m of water[1].

Neutron Detection

Students at the University of Alabama in Huntsville are working with the NASA National Space Science and Technology Center (NSSTC) to perform neutron research in our atmosphere. To meet the scientific goals of the neutron research, the UAH/NSSTC team has developed and built a payload to host a neutron detector tube. The team is using a 5 cm by 25 cm Helium-3 proportional counter to detect the neutrons. The payload includes an electronics system, referred to as the Neutron Counter, which powers, measures, and records the detector through flight.

NEUTRON COUNTER PAYLOAD REQUIRMENTS

In order to fly the Neutron Counter the student design team developed flight requirements to accommodate the expected flights of the unit. The flight plan is initially clear weather environments, and later to fly near clouds, and ultimately near and within a thunder storm. There are procedures developed for power-up, take-off, balloon burst, landing, and shut-down. This paper will focus on the requirements, design, and testing of the mechanical hardware of the payload only.

Flight Phases and Challenges

1) Power up
    a) Rapid assembly of less than 1 hour due to power consumption
2) Launch
    a) Easy mechanical connection to payload line
3) Ascent
    a) Exposure to low temperatures, see Figure I.
4) Balloon Burst
    a) Resistance to catching balloon line when in free-fall
5) Descent
6) Landing
    a) Hard impact of up to 20 m/s
    b) Chance of water landing
7) Power down
    a) Rapid power down for safe recovery

Payload Requirements

1) Maximum mass of 2.72 kg (6 lbs), with maximum size to weight ratio of 131 kg/m^2 (3 oz/in^2) [FAA Regulations]
2) Exposed Helium-3 detector tube [scientific mission]
3) Hermetically sealed electronics housing [gas for convection]
4) Condensation prevention inside electronics housing [protection of electronics payload]
5) High-voltage isolation [safety to launch team, recovery team]
6) Data storage in non-volatile memory [recoverable data if power loss]
7) External control of electronics payload [Rapid launch operations]
8) Faraday Cage, except for electrical pass through for external sensors and controls [Lightning Protection]

MECHANICAL DESIGN

The mechanical design includes all aspects of the payload requirements, as well as availability of fabrication tools and materials. The housing is designed to be rugged, contain the electronics, and be supportive of the sensor tube. Taking these considerations the team develops the payload.

Development

The electronics housing is a rectangular box, 0.05 m x 0.05 m x 0.15 m (4 in x 4 in x 6 in), with two square lids. The detector tube is mounted in the ‘top’ lid, which is opposite the ‘bottom’ lid. The detector tube is 0.05 m diameter x 0.25 m long (2” diameter x 10” long). The two lids will be pulled together by eight all-thread bolts. Silicone gaskets are used for a sealing surface between channels in the lids and the ends of the square tube. The payload line attaches to two points on either side of the top lid. The electronics for the counter will remain at 1 atmosphere to distribute any heat generated in the electronics and to avoid high-voltage arcing. The detector tube points up as to avoid direct impact when landing. Having the frame of the electronics payload impact first, the force on the detector tube is minimized.

On some flights, the neutron detector will have a moderator installed over the detector to include epithermal neutrons in the data. On one flight, a sleeve of cadmium will be used to observe the effects of multiple charged particles in the cosmic ray air showers that masquerade as neutrons, as the cadmium blocks thermal neutrons.

Inside the housing, the counter system electronics is mounted to the top lid to permit assembly of the electronics without interference to the housing wall.

The housing is penetrated in four locations. The detector tube screws into the top lid, which permits the high-voltage line to pass through to the housing interior. The detector ground connection is the housing. The electrical feed through uses a hermetically sealed DB-15 connector penetrating the top lid. For condensation prevention the container is purged with nitrogen, which requires two sealable ports located on the bottom lid.

To insulate the payload from changes in temperature, a 2cm thick layer of polystyrene foam is installed around the entire payload. The payload lines enter the top of the foam housing and secure to the two mount holes on the top lid; this is sufficient to maintain orientation of the payload. The insulation is sufficient to keep the temperature inside the payload above 0 degrees Celsius in an environment where the atmospheric temperatures drop to -40 Celsius at around 20 km in altitude. See Figure I below.

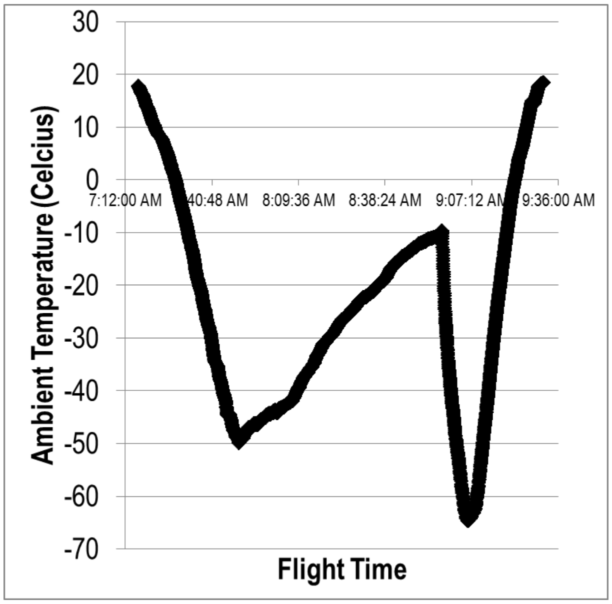

Fig. I: External Ambient Temperature Profile of Balloon Flight, University of New Orleans, LaACES 2009 (Note: The author was project leader for the UNO LaACES payload shown here.)

Mass Budget

	Mass	% Total Mass
Detector Tube	280g	15.6%
Moderator	520g	28.9%
Electronics	150g	8.3%
Frame	600g	33.3%
Foam	250g	13.9%
Total Mass	1800g	

Table I: The mass budget table offers the estimated mass of each payload at launch.

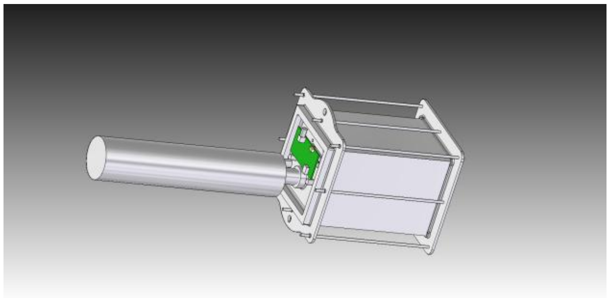

Figure II: Neutron Counter Payload

Fabrication

The electronics enclosure was milled from sheet aluminium using computer control. The internal electronics mounts were produced by rapid prototype printing. This permitted a rapid production of complex design. The ABS plastic used for printing is an electrical insulator.

Simulation and Testing

Simulation of the expansion of the housing was conducted to verify the effectiveness of the gasket. Results concluded that the stainless all-thread bolts would shrink less than the aluminium housing, but the gasket would easily make up for this difference.

Testing the mechanical housing used a soap-bubble test followed by a positive pressure test of two atmospheres, gage, for two days. No pressure loss was observed. Finally, the pressure test was repeated in a cold environment, simulating an extended duration flight. The pressure does drop due to temperature drop, however the air does return to full pressure when the housing warms.

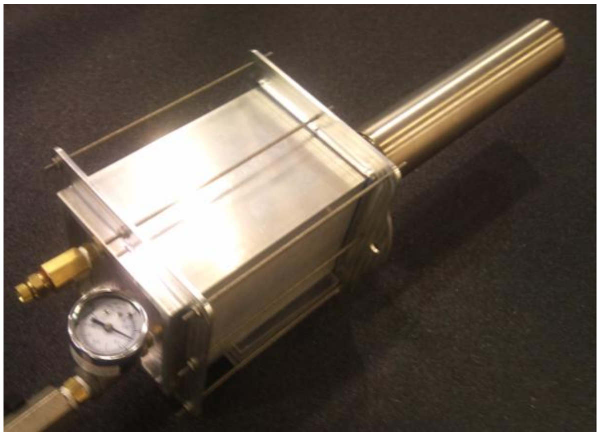

Figure III: Neutron Counter Payload during pressure test.

EXPERIMENTAL RESULTS

The initial flight of the neutron counter was designed to demonstrate the ability of the payload to measure the thermal neutron flux in the atmosphere. To compare, the team uses data retrieved from the NASA Deep Space Test Bed (DSTB), a 1.8 metric tons (4018 lbs) payload launched 6/18/2005 at the Scientific Balloon Flight Facility, New Mexico. The neutron detector tube used here is identical to the ones used on-board the DSTB.

The UAH/NSSTC team launched the neutron detector on 8/26/2011 from the NSSTC facility, Alabama. The payload reached 29,680 m (97,400 ft), and data demonstrates effective operation of the neutron detector and neutron counter. The maximum count rate is significantly different compared to the DSTB, as is the altitude of maximum count rate. This may be attributed to the differences in Earth's magnetic field at the launch locations. Also, the DSTB results were filtered in data analysis to exclude the lower pulse height regions which is most affected by multiple-particle cosmic ray showers in the atmosphere. Data analysis will continue. See Figure IV.

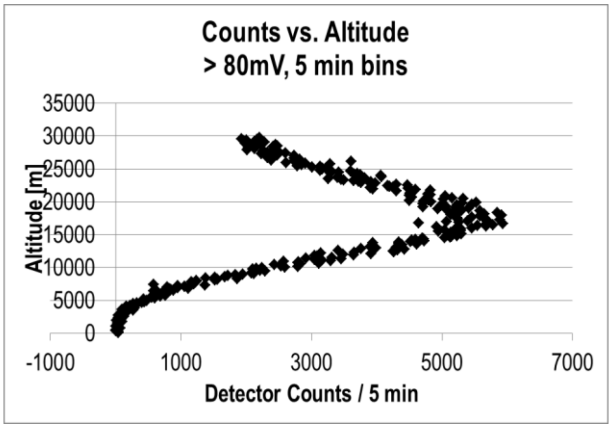

Fig. IV: Results from Space Hardware Club BalloonSat 15, where the line represents an un-moderated detector. The peak is approximately 5400 neutron counts per 5 minute period. This is around 16,800 m (55,000ft). The height of the maximum count rate is called the Pfotzer Maximum, around 17,000 m (55,700 ft) for this flight.

FUTURE FLIGHTS

Future flights will be performed to better understand how the detector is interacting with particles other than thermal neutrons. Once the team is confident in the measure of neutrons, the balloon will be targeted to measure a cloud environment, as there is more H_2 in cloud droplets for neutron interactions. Finally, the balloon would be targeted to fly near an active thunderstorm.

BENEFITS OF THE BALLOONSAT PLATFORM

The BalloonSat platform is a popular launch platform due to low cost, low risk flight operations. Because the total mass of the payload allotment is low (compared to DSTB), the team expects to find less local neutrons due to cosmic ray interactions with the instrument and carrier.

APPENDIX I

This is the excerpt from the FAA regulations that defines the requirements of unregulated unmanned ballooning.

FAA Regulations for Ballooning (FAA, 2009)

§ 101.1 Applicability.

(a) This part prescribes rules governing the operation in the United States, of the following:

(4) Except as provided for in §101.7, any unmanned free balloon that—

(i) Carries a payload package that weighs more than four pounds and has a weight/size ratio of more than three ounces per square inch on any surface of the package, determined by dividing the total weight in ounces of the payload package by the area in square inches of its smallest surface;

(ii) Carries a payload package that weighs more than six pounds;

(iii) Carries a payload, of two or more packages, that weighs more than 12 pounds; or

(iv) Uses a rope or other device for suspension of the payload that requires an impact force of more than 50 pounds to separate the suspended payload from the balloon.

§ 101.7 Hazardous operations.

(a) No person may operate any moored balloon, kite, amateur rocket, or unmanned free balloon in a manner that creates a hazard to other persons, or their property.

(b) No person operating any moored balloon, kite, amateur rocket, or unmanned free balloon may allow an object to be dropped therefrom, if such action creates a hazard to other persons or their property.

ABOUT THE AUTHOR

Mark Becnel is a graduate student at the University of Alabama in Huntsville. He is pursuing a Master's Degree in Aerospace Engineering with a focus on Electric Propulsion. Prior to UAH, he earned a Bachelor's of Science in Physics from the University of New Orleans, New Orleans, LA. His immediate goals include securing support in research of electric propulsion, especially the Inertial Electrostatic Confinement Device.

Mr. Becnel is a member of the UAH Space Hardware Club Neutron Counter team. He is working as part of the Space Hardware Club to develop the neutron counter for deployment in future BalloonSat missions.

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