The university of Alberta High-Altitude Balloon (UA-HAB) project

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THE UNIVERSITY OF ALBERTA HIGH-ALTITUDE BALLOON (UA-HAB) PROJECT

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The University of Alberta High-Altitude Balloon (UA-HAB) project was funded by the Canadian Space Agency (CSA) Space Learning Program. The goal was to design, manufacture, test and launch a student payload on-board the NASA-funded High-Altitude Student Platform (HASP). HASP is a gondola provided by NASA to be launched using a high-altitude balloon. It's designed to carry twelve student payloads, including the UA-HAB payload. The HASP gondola was launched from Fort Sumner, New Mexico on September 8th 2011, to an altitude of about 36 kilometers with a flight duration of 20 hours using a small volume, zero pressure helium balloon. The UA-HAB payload was an experiment designed to detect the signatures of cosmic rays entering the atmosphere. Using three Geiger-Müller tubes encased in different thicknesses of steel shielding, the Maple Leaf Particle Detector was able to provide both timing and energy information of these cosmic rays. The UA-HAB program provided a unique opportunity for both undergraduate and graduate students to gain hands-on experience in all phases of a space-related mission. The primary goal of the UA-HAB project was to build knowledge and skill amongst Canadian students in experimental space science via the low cost suborbital platform of high-altitude balloons. The detailed design, manufacturing and testing of the payload provided unique insight into the processes required for a space mission. Students proceeded through the conceptual (Phase 0 and A), design (Phase B and C), manufacturing and flight (Phases D and E) phases of the Maples Leaf detector for the HASP mission. Through the NASA reporting and test requirements, students also experienced the level of professionalism associated with such a mission. Finally, the students learned scientific methods and hypothesis testing through the analysis of the flight data and submitting a final scientific report to NASA.

I. INTRODUCTION

Students are not often exposed to the full scale of a scientific sub-orbital mission in their undergraduate career, because those missions' timelines exceed the 4 years of undergraduate studies. Without knowing what these kind of missions are like or what they entail, students are less informed about what a career space science could offer them. The main goal in the University of Alberta High Altitude Balloon project was to educate students about ballooning and its capabilities as a sub-orbital platform, and to show students what a scientific mission looks like from start to finish. Other goals of the program were to provide hands-on learning opportunities on an end-to-end space mission in the span of only one year, to expose students, both undergraduate and graduate, to space-related activities at the University level, including liaison with sponsors at the Canadian Space Agency (CSA) and at the National Aeronautics and Space Administration (NASA), as well as to raise awareness of related CSA and NASA facilities. The program accomplished this through participating in the Louisiana State University's (LSU) High Altitude Student Platform (HASP).

HASP[1][2] is a NASA funded program that provides student teams the opportunity to fly an experiment on a high altitude balloon-borne mission. The team of students designed and built a payload to fly on HASP's 2011 flight. In order to be approved to fly on HASP the student teams needed to submit multiple proposals, participate in monthly teleconferences with all the other student teams and HASP organizers, meet weight, size and power requirements, and finally demonstrate through environmental and other tests that their experiment works as planned. In order to successfully participate in HASP, the team had to put in a lot of work and learn immense amounts about different subjects such as electronics, space physics, machining, and more. Students were also exposed to small scale ballooning through the weather balloon testing done on the payload, and learned first-hand the level of expertise that goes into launching a balloon experiment.

This paper explains, step by step, the various stages of the project in sections II to VI, detailing what was done at each phase and how the students proceeded. Section VII discusses what students learned during each phase of the project and how these skills will benefit them for the rest of their careers, and encourage them to pursue a career in space science.

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II. THEORY OF EXPERIMENT

The goal of the University of Alberta-High Altitude Balloon (UA-HAB) Maple Leaf Particle Detector, was to design, build, test and launch an instrument on the HASP to study the energetic radiation environment of the radiation belts. By building an instrument that is capable of determining an incoming particles energy and time of arrival, precipitation from the radiation belts can be studied over the duration of the balloon flight. The precipitation of particles from the inner radiation belt was the object of this study.

The main source of the protons in the inner radiation belt is the Cosmic Ray Albedo Neutron Decay, CRAND [3]. Cosmic rays interact with constituents of the Earth's atmosphere to produce neutrons which are emitted into the trapped region. Protons are produced by beta decay of the neutrons, which become trapped by Earth's magnetic field. The inner proton belt exhibits high fluxes during solar minimum and low fluxes during solar maximum: solar activity during solar maximum produces a shielding effect and cosmic ray flux reaching the earth is low compared to solar minimum. [4]

III. DESIGN PHASE

The Maple Leaf Particle Detector was composed of 3 LND-712 Geiger-Müller counters, encased in 1018 (low carbon) steel to provide minimum energy thresholds that particles must surpass to be detected. The steel surrounding the Geiger counters discriminated the energies of particles detected by them. For a count to be registered in one of the Geiger counters, the particle must have a minimum energy to penetrate the surrounding steel shielding. Each successive Geiger counter was encased by a thicker amount of steel (the top having the thinnest, the bottom the thickest), which leads to a higher minimum energy threshold going down the detector. The successive energy minimums of our detector were approximately 50MeV, 100MeV and 175MeV.

The thickness of the steel shielding corresponding to those energy barriers was determined by SRIM software (SRIM - The Stopping and Range of Ions in Matter), which uses probabilistic Monte Carlo methods to calculate penetration depth of ions in different materials[5] [6]. Precipitating particles detected by the Geiger tubes at the altitude of the balloon are not at their original energies in the magnetosphere, since some energy is absorbed by the upper atmosphere and the ionosphere.

The shape of the detector was a square pyramid, designed to create the different energy thresholds, as shown in figure 1. Four holes were drilled in each corner of the steel pyramid and through the HASP mounting plate, through which metal rods were used to bind the stack to itself and the mounting plate via steel nuts. Long metal bolts were used to bind a foam electronics enclosure to the HASP mounting plate via holes drilled in the mounting plate, and served to hold the motherboard to the platform through the use of more steel nuts. The entire payload was then encased in a foam board/aluminum housing which acted as a thermal and weather barrier (since steel alone rusts, and absorbs lots of heat from sunlight) and provided an extra layer of protection to the electronics board.

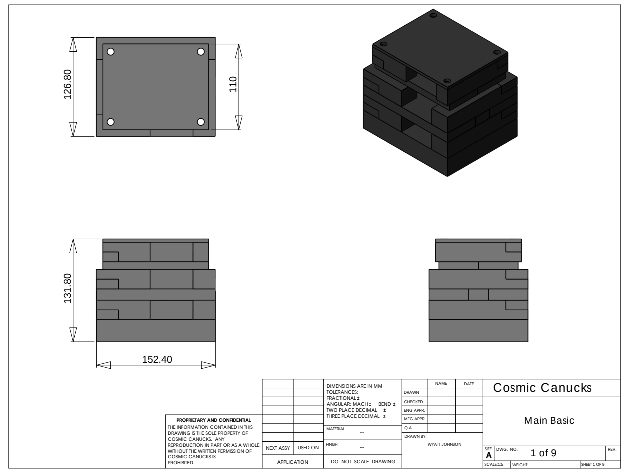

FIG. 1: Mechanical drawings of the payload shielding

The design of the electronics was outsourced to the University of Alberta Department of Physics Electronic Shop, while the undergraduates did all the populating, testing and troubleshooting of the boards. Five PCBs (Printed Circuit Boards) in total were constructed: 2 for testing, 1 prototype, 1 flight board, and 1 extra in case of damage. The basic design of the electronics board consisted of power running into a 5V regulator to establish a 5V line. To power the Geiger Muller tubes, a high voltage line of approximately 500V was needed for each channel. This was done by using a MOSFET (metaloxidesemiconductor field-effect transistor) chip and a 1:10 transformer on each channel. Communication to the PCBs was established via an RS232 serial port. The CPU of the electronics was a AVR microcontroller, which processed the counts registered by the Geiger tubes and the timing information.

An addition was later made to the PCBs specifically for weather balloon testing which is discussed further in Section V. This add-on consisted of a pressure sensor and a 1MB EEPROM (Electrically Erasable Programmable Read-Only Memory) chip to store data collected over the duration of the weather balloon flight. The additions simply plugged into the PCBs through a 6 pin header connection. This add-on was not included during the HASP flight.

IV. BUILD PHASE

Students worked on multiple parts of the detector at once in order to complete the project on schedule. Jobs were rotated occasionally in order to provide all students the chance to work on all components of the experiment.

First steel pieces had to be cut by a large hack-saw or band-saw to their approximate size. This was complicated by the machine shop moving to a new location at the University of Alberta from late April to the beginning of June. Once the initial cutting was completed, the team moved into the CPP (Center for Particle Physics) heavy lab, and the mill was used to machine all the individual pieces to the correct dimensions. The team also used the drill press to drill holes through which the connecting rods would bind the metal components. Finally, all the parts were labeled so that they could be easily assembled on the HASP mounting plate, and bound by the steel rods.

All five electronics boards were assembled as planned; the first board being constructed independently, in the old electronics shop, to be made ready for testing at the CSA's David Florida Laboratories (DFL) as described in section V. It was inspected by the electronics shop supervisor, and then given a conformal coating to be prepared for testing. The second board was manufactured immediately after the first, in two phases. First, the majority of the components were added with the pick and place machine in the old electronics shop. At this point, the University of Alberta Department of Physic Electronics Shop began to move (May-June) and further population of the PCBs was delayed. Finally, in the new electronics shop, the surface mounted components were attached and the second board was complete. Then, after a shipping delay, the parts for the final three PCB boards arrived, and they were assembled together. Soldering on the final three boards was done by hand due to an improper vent installment in the new electronics shop, which rendered the pick and place machine unsafe to use.

The firmware for the CPU was developed around the design of the PCBs. Firmware was written for each individual function of the elctronics, such as registering electrical outputs from the Geiger counters as counts and keeping timing information. All data was packaged and sent to the HASP platform through the RS232 serial port, which then transmitted the data to the ground station.

Finally, for the weather balloon flights, an EEPROM chip was soldered to a blank breadboard, with a pressure and temperature sensor. This circuit was integrated to the board's 5V line, and this allowed additional data to be stored locally on our PCB during flights, and recovered later for analysis.

V. TESTING

The team flew to Ottawa, Ontario on May 15th 2011 to conduct pressure and thermal testing at the Canadian Space Agency David Florida Laboratories (DFL). The testing followed the temperature and pressure profile specification for the flight provided by HASP.

Testing began on May 16th. The team was first given a tour of the facilities and began thermal testing at approximately 1:30pm. The purpose of the test was to evaluate the performance of the electronics and the mechanical components in a formal testing environment. Prior to the testing, a Cs 137 radioactive source was placed inside the chamber next to the detector, and another source of the same radioactive material was placed inside the case of the detector. The purpose of placing those sources outside and inside of the detector was to confirm that the detector was operational during the thermal-vacuum testing, and to confirm that the counts detected corresponded with testing performed at the university under normal conditions of temperature and pressure. The board used in the detector for this testing was the first board constructed by the team. The test lasted 4 hours, with the temperature first being dropped 3°C per minute to -50°C, and held for 2 hours. Next, the temperature was increased at the same rate to 50°C and held for 30 minutes. When the temperature reached approximately 40°C, the electronics began to exhibit an increase in count, demonstrated in figure 2.

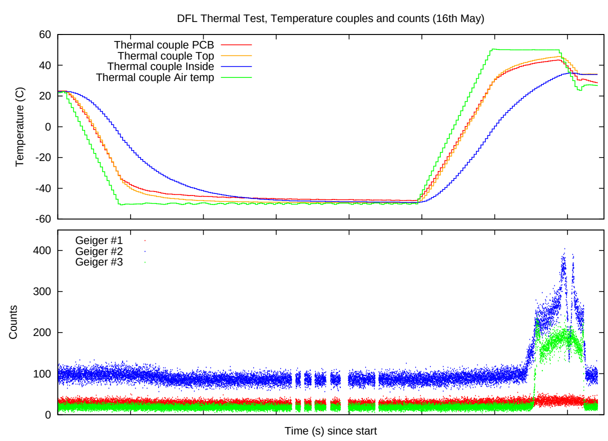

FIG. 2: DFL thermal test data. Gaps in data are due to computer outages. A large spike in counts can be seen near the end of the test.

Altitude testing of the payload was performed the following day. The procedure to ensure accurate count measurement, by placing a known radioactive source on the detector, was repeated as previously described. The payload was first cooled to -50°C, which was followed by the pressure being reduced from 760 torr down to 6.5 torr. The payload was held at this pressure for 2 hours, and then returned back to atmospheric pressure. No malfunctions were observed. Figure 3 shows the payload inside of the testing chamber.

To further investigate the anomalous counts encountered during the thermal testing, which are displayed in

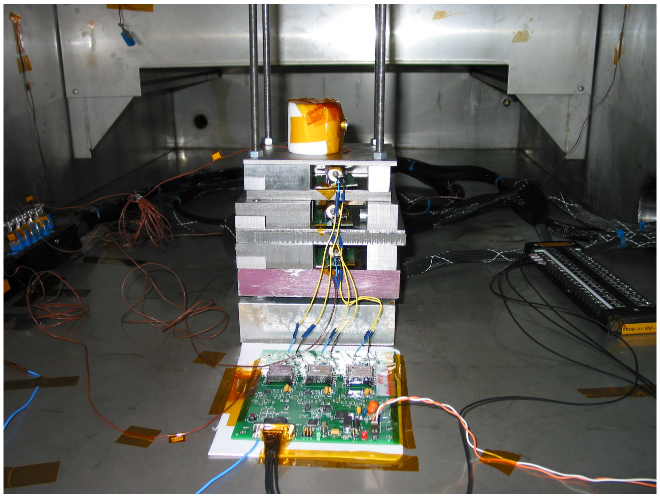

FIG. 3: Photo of payload in test chamber. Cs-137 sources can be see on top of the steel casing and in the middle chamber.

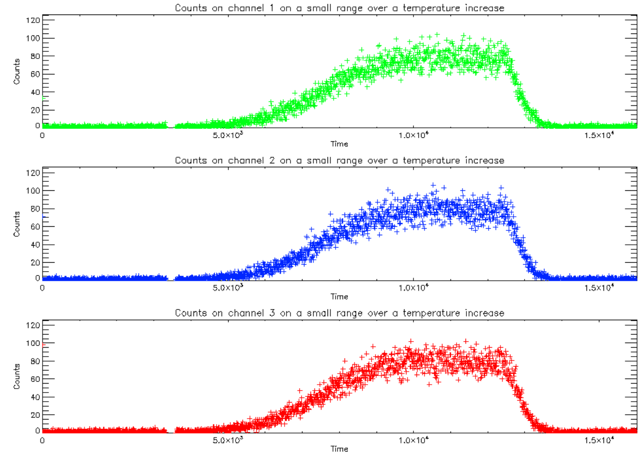

FIG. 4: Data from first weather balloon flight. Gap in data was due to a system reset.

Figure 2, the team borrowed an oven belonging to the University of Alberta Center for Particle Physics (CPP). Additional thermal testing was run on the 3 additional PCBs that had been completed at that time. While the second board constructed exhibited the same problem as the first one already tested, the third and fourth boards did not have this issue. The cause of this failure of boards 1 and 2 at high heats was thought to be caused by a heat sensitive resistor. Boards 3, 4 and 5 used parts from a different order as well as slightly different resistors.

The team also conducted weather balloon launches which provided them with the opportunity to launch and test the electronics in a near similar environment to the final HASP flight conditions. They were able to launch the payload (not including the shielding due to weight restrictions for weather balloon missions) into the atmosphere, running on a set of batteries, and collect some unshielded data from the three Geiger tubes using a helium filled bursting weather balloon. The data generated from the first weather balloon flight is shown in Figure 4. This testing was able to demonstrate the electronics' ability to function in the extreme weather conditions experienced by a weather balloon high in the atmosphere. Through all this testing it was determined that the fourth board constructed was the optimal board to choose for flight.

VI. INTEGRATION, FLIGHT AND ANALYSIS

In order for the team to fly the payload on the HASP platform, a validation test had to be passed. The team flew to Palestine, Texas for this testing, and to integrate their payload into the HASP platform. Upon arrival at NASA's Colombia Scientific Ballooning Facility (CSBF) in Texas, the team unpacked the already shipped payload, and mounted its components on the HASP mounting plate. When the payload was inspected, the team was notified of a few issues:

- The metal rods connecting the payload together extended too far below the mounting plate and prevented successful integration with the HASP platform.
- The payload lacked proper heat protection, and needed to be shielded to prevent overheating while the payload was waiting to be launched in the hot New Mexico sun.
- The data format of the payload was in binary, when it should have been formatted to output ASCII code.

The issues were resolved by: Cutting off the excess bolt, designing and building a head shield out of aluminum foil and foam board, and rewriting the data output of the firmware to output in ASCII. Figure 5 shows the final form of the payload after integration.

After integration, a large round of stress testing was conducted on one of our electronics boards with identical hardware to the one integrated into the HASP platform. These tests consisted of running the board for a long duration of time, while uploading the data to the web so the team could track whether the payload could run successfully for the entire duration of the flight and beyond.

The payload failed the first thermal vacuum integration test. It was hypothesized that the payload's electronics were discharging against the payload housing when it was below a certain pressure. This was corrected by utilizing electrical insulation tape called Multi-Layer Insulation (MLI) tape. The team additionally applied high voltage insulation on all junctions and exposed electrical components to prevent accidental discharge. That resolved the high voltage discharge issues, and allowed the board to maintain the minimum operating voltage of

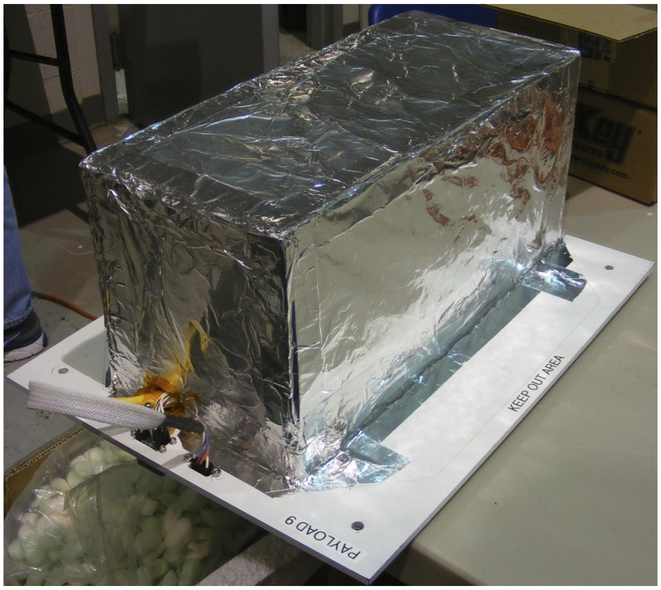

FIG. 5: Photo of completed payload at integration.

≈ 500V for the Geiger tubes to function. HASP personnel gave the team the opportunity for a second vacuum test at the end of the week (Friday), which was passed. The payload was then officially certified to fly on HASP 2011.

The team returned to the University of Alberta, while the now qualified instrument was shipped to NASA Columbia Scientific Balloon Facility at New Mexico, with the HASP platform and the rest of the payloads to be flown as part of the HASP 2011 mission. Early in September, some members of the team flew to Fort Sumner New Mexico for flight. The team members had to wait for a few days before the weather conditions permitted a safe launch. Once safe launch conditions were met, on September 8th 2011 at 4:30am local time, the team members watched the procedures carried out by the HASP personnel. The balloon carrying the HASP 2011 platform hosting the UA-HAB instrument Maple Leaf Particle Detector was launched at around 8:30am local time.

During flight, the payload reached an altitude of approximately 36 kilometers above sea level. The flight lasted approximately 20 hours. Four hours, into the flight, at 12:30pm local time, the payload's high voltage began to fluctuate wildly, and counts escalated far above normal levels. This continued for almost a half hour until a system reset was initiated, which failed to solve the problem. Therefore, only the data from before the failure was valid to be scientifically analyzed. The cause for the failure was carefully evaluated by the team and advisers after the flight, but it was never fully determined. This included the completion of a formal Non-Conformance review at the University of Alberta following the flight.

Results from the flight data can be seen in Figure 6. As one can see, the count rates increase as time elapses, because of the increased level of radiation experienced at higher altitudes, which was expected. The fact that there is no discrimination between any of the channels shows that the radiation energy level is above our maximum energy threshold. There appears to be a small spike in the count rate on channel one while the payload was rising. The team was not able to determine whether or not this was an event relative to an increased level of radiation, principally because it did not appear on the other channels and was of short duration. It is likely that the spike was a counting glitch within the electronics rather than a physical phenomenon. The rise and later decrease of the count rate seen from approximately 400s to 600s was something we did not expect to see. It seems that this occurred from approximately 40 000 feet to about 100 000 feet, with the peak being at 60 000 feet as seen in figure 7. Radiation levels are predicted to increase linearly with altitude, so a peak at 60 000 feet is not something we are currently able to explain. While this is likely a hardware malfunction, it is worth looking into to see if the results can be repeated.

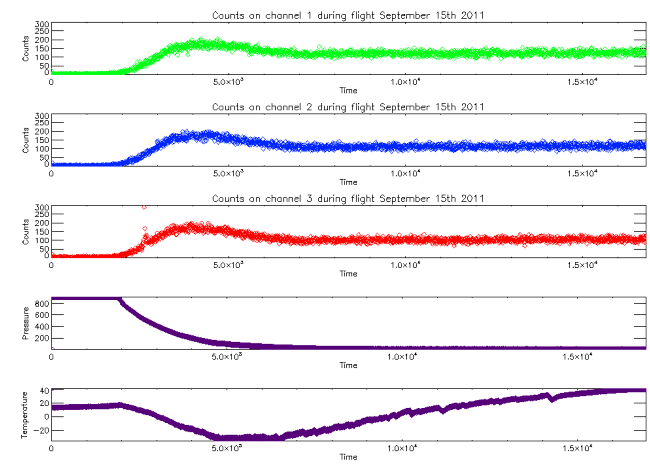

FIG. 6: Graph of counts and environmental data during flight.

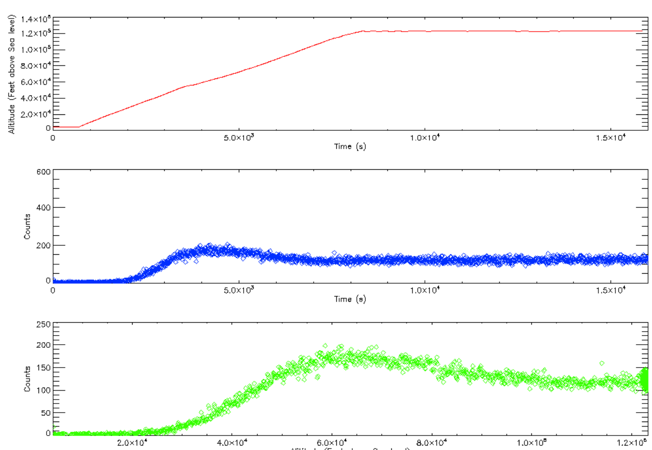

FIG. 7: Graph of altitude and counts.

VII. LEARNING OUTCOMES

A. Introduction

The learning objectives of the UAHAB program were aligned with the following CSAs objectives:

- To increase awareness. First, exposure of undergraduate and graduate students to space-related activities developed by the University of Alberta, the CSA and NASA; secondly, attract bright individuals to space careers; lastly, raise awareness of the university's facilities, the CSAs facilities and NASAs facilities.

- To provide learning opportunities. First, allow the students to highly participate in a short (one year) space mission from end to end (Grant writing, design, manufacture, testing, integration, launch, recovery of data, data analysis, publication of results, dissemination for results, final report writing). Secondly, allow students to apply the knowledge learned in their courses to a real-life, hands-on experience, following a holistic approach.

- To support the operations of organizations: Support the mandate of the university "space institute" (ISSET, Institute for Space Science, Exploration, and Technology)and the university "space club" (U of A ISSET-Students).

The graduate student coordinating the program submitted a pre-initiative assessment and post-initiative assessment to students prior and after the program, to evaluate the learning outcomes of the program, to ensure that the proposed objectives were achieved. A final report of those outcomes was submitted to the sponsor agency, CSA, which reported that all objectives were met.

In the following subsections, the project's objectives will be explored in detail, providing ample examples of outcomes and practical applications illustrating how the objectives were met. Some of the comments provided by the students will be reproduced as well.

B. Theory of Experiment

Students were introduced to the subject of space physics which none of the undergraduates had experienced before. They learned about particle precipitation, radiation belts and solar radiation. There is limited exposure to space physics in the University of Alberta's undergraduate physics program so this was a great opportunity for students to see if it was a field they were interested in pursuing further.

C. Design

The scientific goals of this project had been previously decided by the supervisor, the graduate student coordinating the project, and the advisor, in consultation with the undergraduate students participating in the project. These were documented in the grant proposal written to obtain funds for the program from the Canadian Space Agency, as well as in the final proposal submitted to the HASP program, which were reviewed and accepted by the HASP executives and the NASA officials. While trying to decide on a design for the instrument, students read papers on radiation belts, the source of protons in the inner radiation belt due to the process of CRAND, particle motion in Earths magnetosphere, particle precipitation to the upper atmosphere, on energy measurement instrumentation, and on the propagation of radiation and other topics related to the considered goals of the project and to instrument design options. This was the first time most of the undergraduate students had done this sort of research, which gave them the opportunity to learn how to consult the literature on a subject to address questions and design options, and get inspiration for ideas.

The design phase of the project, which extended for two months, gave students the opportunity to brainstorm different ideas on how to design an experiment that would fulfill the scientific goals that had been determined. Students considered many different designs before settling on the aforementioned one.

Students were also given the opportunity to learn to use the SRIM simulation software, available for free online, in order to calculate the thickness of steel needed for the desired energy absorption. This was the undergraduate students' first exposure to such simulation software, and gave them a chance to see how such a tool could be utilized to answer important questions without having to build the instrument a priori or even buy any materials.

As part of the HASP program, participating institutions are required to participate in monthly teleconferences with other student members, as well as HASP directors and NASA officers, and to present formal "monthly status reports" to HASP and NASA. Many of the students had never had the opportunity to participate in such activities prior to the program. The team learned to work collaboratively to produce good documentation to support the monthly status report, to submit them always on time, to actively participate in the monthly teleconferences, and to ask relevant questions to succeed in the program.

D. Build

During the build phase, students were exposed to the different methods and machines used to cut metal. Learning basic machining skills was not only a fun experience for students, but also gave them a better understanding of the university machine shops. It is important to know the capabilities of university machine shops, so work is not needlessly outsourced; it also gave students the opportunity to learn important skills for their future careers.

Students were also exposed to basic practical electronics, such as the population and soldering of basic components of a board, and the general use of the university's electronic shop. This was also most students' first major exposure to electronics. Students learned how different components of the payload's electronics functioned, from individual components, to subsections of the electronics such as the high voltage regulation and count registration. Since the electronics design was outsourced, learning how the different subsystems within the electronics operated was a challenging task. In order to properly troubleshoot problems, the students had to know how every subsystem operated, how it communicated with the CPU, (i.e which pin information was being transmitted to), and how the components within it functioned to produce the desired effect. Electronic knowledge is not taught in the University of Alberta's undergraduate physics program, so the skills learned during the project will be extra valuable to the students, as general electronics knowledge is useful in many fields.

The undergraduates learned about all aspects of code development for the AVR microcontroller, in order to write the firmware for the electronics. Students studied the technologies and the different subsystems, such as I2C (Inter-Integrated Circuit) and how to write software for them. In addition, students became familiar with firmware requirements in the space sector and code debugging. Embedded technology and programming is a very valuable skill to have, and therefore this will help the students tremendously in their future careers.

It is worth mentioning that the students took two project management courses given by the university during this period. These courses focused on how to successfully complete a large scale project on time and on budget. The students learned about the importance of defining the scope of a project, having a clear authority structure in the team, how to work through disagreements amongst team members and many other valuable lessons. Project management skills are generally not as part of a university degree, and the practical lessons learned were of great utility during the later stages of the program. The students will also be able to utilize these skills in virtually any career they pursue.

E. Testing

The team's trips to the David Florida Laboratories was a great experience, as it raised awareness among the students about the kinds of international scientific facilities Canada and the CSA have. Students were exposed to a professional testing environment, and got to meet the scientists who work there. This gave the students an example of the type of career they could have, within Canada, through the education they're pursuing. It also showed students the amount of considerations that are involved into this kind of facility, such as clean room precautions and security.

Launching the weather balloons was also a great experience for the team, and it gave them hands-on experience with ballooning. The team was trained by a local balloon enthusiast group called BEAR (Balloon Experiments with Amateur Radio). Each member obtained their amateur radio license and became proficient in the use of radio equipment and GPS tracking devices. By the end of the project, the team was able to successfully launch and recover a balloon mission without assistance. There are many safety considerations concern balloon missions, such as obtaining permission for the local Air Control authorities (NOTAM), running a simulation of the flight path given local weather conditions, handling pressurized tanks appropriately, and ensuring safety measures prior, during, and after weather balloon missions. The graduate student coordinating the program, with the help of the supervisor and the University's risk management office, developed the risk assessment and wrote the policy needed to ensure safe missions. The undergraduate members did a great job documenting the procedures, step by step, for a safe mission. Knowing how to conduct a small scale balloon flight is a valuable skill, as ballooning is the perfect platform for small amateur experiments in many disciplines and for running flight condition testing on hardware. The training provided to the students would allow them to conduct their own ballooning experiments in the future and teach others how to as well.

F. Integration, Flight and Analysis

In order to qualify to participate in the HASP 2011 flight, every student payload had to pass the integration and thermal-vacuum tests at the NASAs Columbia Scientific Balloon Facilities (CSBF) in Palestine Texas, US. For that, the student team as a whole traveled to CSBF for one week and participated in the integration procedures, in order to achieve a flight permit from NASA and HASP. The students became aware of the NASA facilities, as well as the practical operations on an integration test and a thermal-vacuum test. As was mentioned in section VI, the first integration test and the first thermal-vacuum test were not satisfactory, and the team learned to work together under a lot of pressure to provide fast, practical solutions to problems in order to be able to qualify for flight.

Students interacted with student teams from other universities in the US participating in HASP. Some of those teams were extremely experienced in the design and manufacture of scientific experiments because they had participated in HASP numerous times. The University of Alberta team learned valuable practical tips and knowledge to be used in their future professional careers. The students also networked with people in NASA, HASP and other institutions, opening their possibilities to pursue future careers in space science and space exploration.

During the flight operations, students participating in the launch learned of all the strict procedures related to the preparation and launch of a scientific instrument. NASA officers were there to ensure that safety and official procedures were strictly followed. Students reported that this was a great learning experience. While some members of the team participated in the launch, the rest of the members worked at the university to build a platform to display data acquisition in real time. As a result, the data collected by the detector was displayed in real time online.

After the flight concluded and the team members participating in the launch came back home, the team met with advisers to validate the data. Students learned IDL (Interactive Data Language), a scientific software, to analyze scientific data. Through the use of IDL, students were able to visualize and analyze data taken by the instrument prior to and during the flight. The team members learned important data analysis techniques, such as data reconstruction, data validation, and data comparison. The team successfully identified, using data reconstruction, that there was data missing during flight due to acquisition errors.

The team members were very proactive on the dissemination of results, by presenting the program in several local events, national meetings, and international conferences. To date, the results of the UA-HAB program have been presented at the American Geophysical Union Fall Meeting 2011 in San Francisco, USA, the International Astronautical Congress 2012 in Naples, Italy, the Canadian Undergraduate Physics Conference in Saskatoon, Canada, as well as numerous other smaller local conferences and symposiums in Alberta, Canada. For some members of the team, this was the first time presenting an oral presentation or a poster in a conference of any type. For those that did have the previous experience, the opportunity to present the program helped to refine their presentation skills.

VIII. CONCLUSIONS

The University of Alberta High Altitude program was a successful initiative that achieved all aimed objectives within deadlines and budget. For over a year, the dynamic program enriched students both in knowledge and in practical skills. The project provided the opportunity for undergraduate students to work under the close mentorship of a graduate student, a supervisor professor and a research associate advising on an end-to-end space mission, something very unusual for undergraduate students participating in a science undergraduate program. Students learned to research the scientific literature, to design and manufacture an operational scientific payload, to pass various qualification tests, launch a scientific mission, analyze the data from the detector, write publications and present the results in national and international conferences.

The program was also successful by serving as a "seed" for a permanent program in the local community such as launching weather balloons with elementary school groups, as well as instructing more university students on the balloon launch process. This ensures the continued existence of the UA-HAB program and ballooning activities at the University of Alberta. The program also helped to establish extensive framework that opens the doors to other Canadian and international institutions to participate in the HASP program and/or to develop their own balloon programs.

Overall, the project provided a unique entry to space science and space missions. The students participating in the program developed skills which would attract them and prepare them for higher studies in graduate school, in space science careers, or space engineering careers.

The full impact of this successful program will be measured in the professional careers of the participating students in the years to come.

IX. ACKNOWLEDGMENTS

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