Developing a High Altitude Balloon program at Penn State Wilkes-Barre: Lessons Learned

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Penn State Wilkes-Barre is a newcomer in the Academic High Altitude Balloon (HAB) activities with its first flight taking place in November 2010 and second flight scheduled for April 2011. Our HAB activities are focused on the Engineering and Electrical Engineering Technology programs taught at our campus. This paper is divided into four different parts. First, it describes the challenges associated with the development of the HAB. While the majority of conference attendees are very experienced in HAB, we cannot forget institutions that want to start their own HAB programs. Secondly we describe the challenges in involving our campus community beyond the faculty and students directly participating in the flight. In the third part, the paper describes the first balloon flight that took place in November 2010 making an emphasis on the problems that we encountered. Examples of these are a severely underinflated balloon with an ascent rate of 440 fpm that caused it to land far away from the predicted site, the problems we encountered due to the format of the GPS data, etc. Once again, the focus here is to share those with institutions starting their own HAB programs. The final area of this paper describes the current undergraduate research activities that take place under the HAB. We used the excitement developed by the students who participated in the first balloon flight to further their education through undergraduate research in electrical engineering technology areas.

I. Introduction

Penn State Wilkes-Barre is one of the 24 campuses that comprise The Pennsylvania State University. A student population of 766 students makes it one of the smallest campuses of the University. The campus is located in a rural setting, 13 miles west of the city of Wilkes-Barre from which it received its name. Wilkes-Barre itself is located two driving hours away from Philadelphia and two and a half from New York City.

Penn State Wilkes-Barre is focused on undergraduate education, offering 4 Associate Degrees and 7 Baccalaureate degrees. In addition, the campus offers the first two years for about 160 academic degrees that are almost all of the degrees offered by Penn State with a very few exceptions. In fact, a large percentage of students who graduate from Penn State start their education at one of the campuses. The author of this paper holds the position of Professor of Engineering, with primary teaching responsibilities in the baccalaureate degree in Electrical Engineering Technology that is one of the 4-year programs offered at the campus.

In the summer of 2009, the author was invited by the Pennsylvania Space Grant to participate in a High Altitude Balloon workshop held at Taylor University, Upland, IN. During the workshop the author was exposed to the principles of high altitude balloons, techniques for launch and recovery, hardware, communications between the balloon and ground and the other operational aspects for a launch. Deciding that it would be a good opportunity for his students, the author spent most of the academic year 2009-10 seeking funding for the project. A seed grant from the Pennsylvania Space Grant as well as several minor sources of funding from the University allowed the author to purchase all the equipment needed for high altitude balloon operations. During this time he also gave several talks at the campus in order to involve students and faculty in the project. By the time that all the equipment was set up and the preparations were finalized, the academic term was near its end. This fact, coupled with very active weather during the last week that students would be on campus made us to postpone the initial flight until Fall 2010.

II. Challenges to developing a HAB program

The development of a High Altitude Balloon program at Penn State Wilkes-Barre was not without several challenges. They were eventually overcome by the group involved in the project and were part of the learning lessons.

A. Funding

Funding is always a major obstacle to overcome at the time of initiating any new programs in an academic environment. The Pennsylvania Space Grant Consortium, one of the components of NASA's National Space Grant College and Fellowship Program provided major funding to the project through their Seed Grants. These are focused on increasing the opportunities for research activities of students in higher education. Additional funding to the project was achieved through several small grants internal to the University and the campus.

B. Campus participation

Given the nature of the project, it requires the collaboration of several faculty members and students to be successful. In addition to the author, one other faculty member, also in engineering, took an active role in engaging students and participating in the preparations for the flight, the flight itself and the recovery process. Although several other faculty members, especially in the sciences department were invited to participate in the project, they did not show an interest in participating.

The number of students who actually participated in the high altitude balloon project was also lower than desired by the author and the whole team. Although the participation was open to any student on campus, the only students taking an active role were part of the Engineering Club at the campus. Between 10 and 15 students attended our meeting in preparation to the launch and 10 students were involved in the launch. Because of the multidisciplinary aspect of this project, the author’s goal is to involve a larger number of students and particularly from disciplines other than engineering.

C. Weather

One of the tools used to predict the suitability of the weather conditions for launch was the Jet Stream Analysis from the California Regional Weather Server[1]. This site provides the prediction of the location for the 300 mb jet stream. Our mission rules that we had previously agreed indicated that for the first launch to take place, the shadowed area of the maps -that indicate the stronger winds at 300 mb- should not be located over North Eastern Pennsylvania. In addition, northwest winds could place the balloon over large populated areas such as Philadelphia or New York City, placing an additional restriction in launch ability.

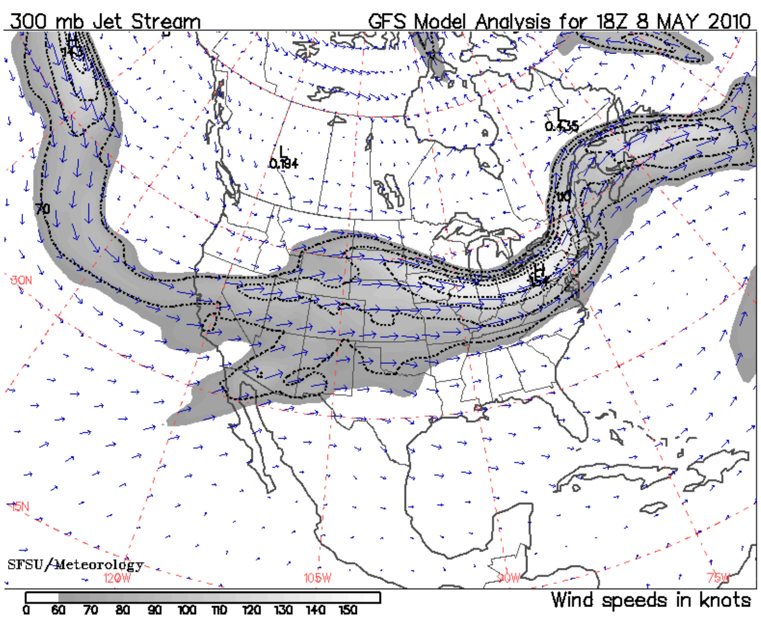


Figure 1. Jet Stream Forecast for May 8, 2010

These restrictions, tied with launching on a weekend to avoid disturbing academic activities of the students proved to be a major challenge especially when we tried to launch at the end of Spring 2010 semester. Figure 1 shows the Jet Stream Forecast for the day after final exams in Spring 2010 that was the last day students would be on campus. As shown in Figure 1, the conditions violated the mission rules previously established, forcing us the cancel the launch and reschedule it for the upcoming Fall term. Although some of these challenges could have been overcome by moving the launch site further away from campus, we wanted the initial launch to be from Penn State Wilkes-Barre campus in order to invite other members of the campus to participate in the launch process.

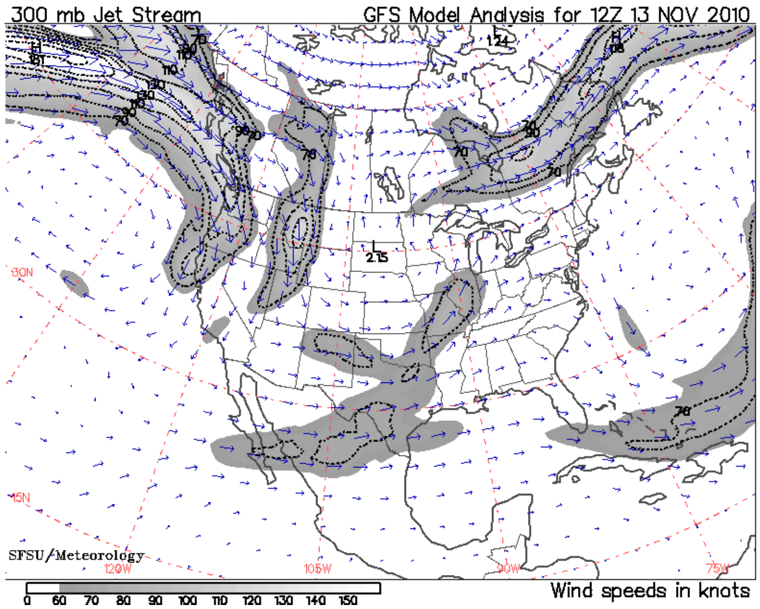


Figure 2. Jet Stream for November 13, 2010 for the first PSU-WB high altitude balloon launch.

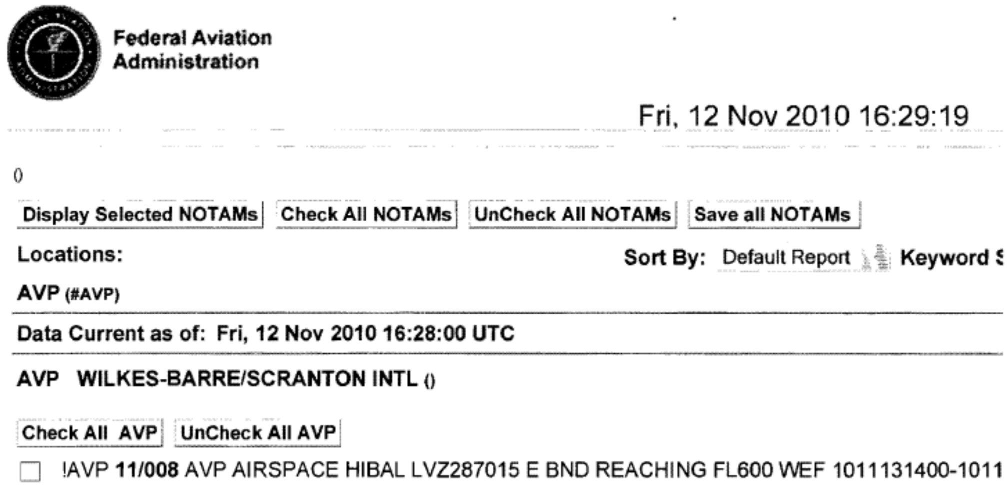
In the Fall 2010 semester we kept the same rules regarding acceptable winds prior to launch. Due to factors described later in the paper, we were unable to proceed with the launch until mid semester. By this time, the Jet Stream was already being very active over Pennsylvania. We must note that our region is affected by the Jet Stream through its westerly winds as well as the region of the Stream that bends upwards giving origin to southwesterly winds.

We were, however, able to find a Saturday with optimal weather conditions for our first high altitude balloon launch. This took place on November 13, 2010. As shown in Figure 2, the Jet Stream was minimally active that day.

We wanted to have a second launch during the Spring 2011 semester, especially as several students were working on their senior capstone design project on hardware related to the high altitude balloon. However, from April to the end of the semester we encountered the same active weather as had experienced the previous Spring forcing us to cancel a launch during that semester. One week after exams had ended and students had left the campus, the Jet Stream over our region had extremely diminished its activity as entering into a summer mode.

D. Risk Management at Penn State

Once the Office of Risk Management at the University learned about the high altitude balloon project at our campus, they asked us to refrain from launching until they could evaluate the University's liability on a potential incident. The author worked directly with the Risk Management office citing FAR 101 as well as developing a Safety Plan that described the rules for which the faculty in the project would abide. The rules agreed between Risk Management and the high altitude balloon team were mostly focused on ensuring the safety of the students participating in the project as well as not launching if the forecasted trajectory would have the balloon landing over populated areas or close to major highways. The tool used to forecast the trajectory of the balloon is the Online Flight Prediction path hosted by the NearSpace Ventures site[2]. In addition, we agreed in issuing a Notice to Airmen (NOTAM) to the appropriate FAA office prior to launching the balloon.


Federal Aviation Administration

Fri, 12 Nov 2010 16:29:19

()

Display Selected NOTAMs | Check All NOTAMs | UnCheck All NOTAMs | Save all NOTAMs

Locations: Sort By: Default Report Keyword S

AVP (#AVP)

Data Current as of: Fri, 12 Nov 2010 16:28:00 UTC

AVP WILKES-BARRE/SCRANTON INTL ()

Check All AVP | UnCheck All AVP

!AVP **11/008** AVP AIRSPACE HIBAL LVZ287015 E BND REACHING FL600 WEF 1011131400-1011

Figure 3. NOTAM filed prior to launching high altitude balloon

III. The first High Altitude Balloon Flight

The first high altitude balloon flight by Penn State Wilkes-Barre took place on November 13, 2010. The flight consisted of the balloon, a command module from StratoStar[3] and three payload boxes containing each one a video camera pointing in three different directions. The goal for the first flight was to develop the procedures for a launching, tracking and recovering successfully, so the payloads did not contain any additional sensors or electronics systems. The only environmental sensors (temperature, pressure, humidity) were those available in the command module. As described earlier, the group had to overcome several obstacles prior to reaching the launch date. However, other obstacles and challenges arose during the launch and recovery period.

A. Challenges

Although the author had secured a digital fish scale to measure the free lift of the balloon, the scale malfunctioned when we tried to use it to measure the balloon lift. We had not predicted this possibility and did not have a backup method to assess free lift of the balloon. Even worse, although we have been recommended to use a full tank of Helium to fill up the balloon as an alternative for a first flight, halfway during the filling up process the balloon looked very full. At that point, afraid that the balloon may burst, the group decided to that it was inflated enough and proceeded with the rest of the launch preparations.

Right after releasing the balloon, it was obvious to the author that the rate of ascent was somewhat lower than those he had experienced in the launches conducted at workshops. The data that arrived from the balloon confirmed this suspicion as it was possible to estimate an ascent rate much lower than the number used for predicting the trajectory of the balloon[2]. Discussing this fact with the chasing team we determined that the landing site would be downrange from the one initially predicted. We faced the additional problem that the Nearspace Ventures site was not available the morning of the launch, and therefore we were not able to predict the balloon trajectory using the rate of ascent from the received data.

Later on, once the payloads were recovered and the data was analyzed off line, we determined an ascent rate of 440 feet per minute, almost three times lower than the number used for the prediction of the flight path. This resulted in doubling the distance between the launch and landing site compared to the predictions. As it can be expected, future launches will have backup methods to measure the balloon lift.

As it was expected, in the final moments of the descent, we stopped receiving the signal from the command module after it was not in direct view of the antennas in the chase vehicles. Using the last known position and altitude we tried to estimate the flight path. At this point, we were faced with not understanding the decimal degrees format used by the GPS system for displaying coordinates and translate it into the degrees, minutes, seconds used by the maps we had. Several attempts to match both systems resulted in driving the chase vehicles to locations we erroneously thought were close to the actual landing site. Finally, and initiated by the students, by comparing the trajectory of the balloon displayed on the computer map with significant terrain features, we were able to correct our initial landing estimates to the area where the balloon should have landed. Once on the ground, close to the newly predicted landing area and away from the road we walked in the woods using a portable power supply to power the receiver and antenna connected to a laptop computer trying to detect a signal from the command module with the actual landing coordinates.

B. The high altitude balloon flight

Figure 4. Balloon flight path

Figure 4 shows the flight path for the high altitude balloon flight. Burst occurred at 84,793 feet as reported by the onboard GPS. Average rate of ascent was 440 feet per minute while the average rate of descent was 1,500 feet per minute. However, during the initial descent, the rate of descent was much higher at 4,400 feet per minute.

Once the recovery team was on the ground and received the landing coordinates from the command module, we just had to walk towards its location. Although it was in a dense forest area, it had landed on a small clearing on the ground, making the recovery much easier.

IV. Undergraduate research activities related to High Altitude Balloons

Even before the first flight, a group of students had started to do undergraduate research activities on the high altitude balloon project framed within their senior design project. The senior design project for the BS degree in Electrical Engineering Technology (EET) spans two semesters. These two courses are typically taught by this author. During the Fall semester, students develop a proposal for the project that will be built and tested during the Spring semester. One of the student groups in this course had mentioned to the author their interest in working around the high altitude balloon project. After discussing several options during the process of defining their proposal, they decided to develop two electronic modules. The first electronics module would activate the cameras in the payloads once the balloon was off the ground. The student focus on this project was to avoid the waste of battery and especially memory that results from having to turn the video cameras on before taping the payload. The second module was the transmission of an analog video signal from one of the payloads to a ground station with the ground station being able to control the rotation of the airborne camera. Their main goal was to first have an accurate measure of the range at which the ground station would still be able to receive the analog signal from the balloon before designing additional parts. Because we were not able to have a high altitude balloon flight during the Spring semester, these systems will be first tested in our next flight in Fall 2011. The goal of the author is to use the senior capstone project in EET to continuously involve his students in undergraduate research activities. In addition, he plans to continue the discussion with faculty members in other areas to try to use the high altitude balloon flights as an undergraduate research platform.

V. Conclusion

This paper has described the challenges faced by the author and other faculty members involved in developing a high altitude balloon platform at Penn State Wilkes-Barre. The lessons learned through the planning process as well as the mistakes made during the first flight can hopefully prevent newcomers to make similar mistakes. In any case, the author feels that his group is ready for subsequent flights.

One of the goals of the author is to involve other students and faculty at the campus in order to develop a set of experiences that are used to enhance student learning and retention in sciences, technology and engineering. While the main goal of the first flight was to get students interested in high altitude balloons, future flights need to be more structured and follow predetermined learning objectives.

Acknowledgements

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[1] Jet Stream Analysis – California Regional Weather Server. http://squall.sfsu.edu/crws/jetstream.html
[2] Near Space Ventures - Online Flight Prediction Tool. http://nearspaceventures.com/w3Baltrak/readyget.pl
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