Expanding High-Altitude Ballooning to Middle Schools

(A Space Grant Precollege Project)

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High-altitude ballooning activities, both extra-curricular and in the form of a freshman seminar class, have been going on at the University of Minnesota – Twin Cities for several years, funded in part by the Minnesota Space Grant Consortium. In line with recent NASA encouragement to engage more middle school teachers and students in Space Grant activities, we have expanded our ballooning activities to involve middle school teachers and provide them with flight opportunities for student-built payloads. This program offers training to middle school teachers in curriculum and techniques associated with high-altitude ballooning, plus follow-on flight opportunities over two academic years for student-built payloads. We use internet streaming to deliver video coverage of launches and in-flight data transmissions. We also provide post-flight data analysis support.

During the summer of 2010, we offered a workshop to science and technology teachers from nine Twin Cities middle schools. We subsequently, increased the number to twelve schools, several of which served under-represented student populations. Workshop attendees successfully designed, built, tested, flew, and analyzed data from balloon payloads during the four day workshop. Their payloads contained cameras (still and video) as well as sensors to measure temperature, relative humidity, pressure, radiation levels, solar panel output, and acceleration. The participants also spent time discussing standards-alignment of ballooning activities, planning ways to implement aspects of high-altitude ballooning at their schools, and generated curriculum to use with their students and to share with other participants.

This is an on-going project and results from this initiative are preliminary at this time. The first round of student-payload-building occurred in the spring of 2011, with the first set of middle school payload flights in May of 2011.

I. Introduction

HIGH-altitude ballooning activities at the University of Minnesota allow many students across the University to increase their knowledge about aerospace science and engineering techniques. During the past year we have expanded high-altitude ballooning activities to engage middle school teachers and students. This endeavor is in line with the recent NASA encouragement to engage more middle school teachers and students in Space Grant activities. The middle school program was directed by Dr. James Flaten, Associate Director of the MN Space Grant Consortium, and the members of the high-altitude ballooning team at the U of MN. This program ultimately included one or two teachers, plus a team of their students, from twelve Twin Cities area middle schools that had a variety of background experience in aerospace-related studies. This program provided training to middle school teachers in curriculum and techniques associated with high-altitude ballooning. It is also providing follow-on flight opportunities over two academic years for student-built payloads. The Minnesota Space Grant Consortium and the

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Pentair Foundation funded the program which included contributing over $500.00 worth of high-altitude ballooning sensor devices and cameras to each middle school. The type of sensor devices and cameras that were given out were first used in the teachers' workshop. The MN Space Grant funded high-altitude ballooning team provided the actual launches as well as internet streaming which delivered video coverage from the launches site and in-flight data transmissions. The team also provided post-flight data analysis support.

II. Mission Overview

During the summer of 2010, we offered a workshop that involved science and technology teachers from nine local Twin Cities area middle schools. Over the course of 4 days the workshop attendees successfully designed, built, tested, flew, and analyzed data from their payloads. These payloads contained cameras (still and video) as well as sensors that measured temperature, relative humidity, pressure, radiation levels, solar panel output, and acceleration. During the workshop teachers also discussed standards-alignment of ballooning activities as well as ideas about how to implement high-altitude ballooning at their schools.

Prior to the workshop we reviewed the Minnesota Academic Science standards and we highlighted the most relevant and important ones that would best fit this initiative. Science standards that are well-aligned with high-altitude ballooning include the basis of the engineering design cycle, atmospheric studies, and highlighting the effectiveness of data analysis in science experiments (see Appendix). The standards associated with the engineering design cycle were incorporated into assembling and integrating the sensor devices and constructing the actual flight payload box [1]. One activity that we encouraged was to have the students build 3-D model payloads with realistically-shaped devices made of Styrofoam. Some of the standards that aligned with atmospheric studies were blended into discussions of the layers of the atmosphere and what life forms could potentially survive there. The standards relating to data analysis were incorporated in the data analysis section of the program. It was helpful to give out analyzed data from past flights to show the teachers and students what to expect from their experiments. We incorporated most of these standards, additional standard-aligned activities, and additional ideas generated from the workshop participants into a set of educational teaching documents (see Appendix).

In the fall of 2010 three additional middle schools that were added to the program. These three middle school teachers had a "crash course" about high-altitude ballooning, discussed the connections of certain standards to ballooning, and gathered ideas of how to implement this project into their curriculum for the year. The difference was that these additional teachers did not get to build, design, test, or fly their own payloads prior to introducing this project to their students. All of the middle schools teams had many questions about how to arrange and use the sensor devices that were given to them.

III. Program Overview

Thus, the program grew to include a total of twelve local Twin Cities area middle schools. The middle schools that participated were Battle Creek (Saint Paul), Metcalf (Burnsville), Calvin Christian (Edina), Columbia Heights (Columbia Heights), Farnsworth Aerospace (Saint Paul), Field-GEMS[3] (Minneapolis), Field-GISE[4] (Minneapolis), Hastings (Hastings), Shakopee (Shakopee), South View (Edina), Stillwater (Stillwater), and Saint Anthony Village (Saint Anthony Village). Most of the teachers decided to divide their students into smaller teams in order for them to effectively understand unique engineering techniques associated with this project. It was easier to have smaller teams of students, especially with the design, experimental stages, and with teaching about each scientific sensor device that was involved. There were additional curricular activities provided by the high-altitude ballooning team that most teachers chose to incorporate into their curriculum. Some of the mini activities included learning to solder scientific devices (none of the schools actually choose to implement that since they also had access to pre-soldered devices), using "snap-together" heaters (to learn about basic electrical circuits), and experimenting with the HOBO[5] device. Later on most of the students worked on the final flight payload together. Each student incorporated their own ideas and experiments into the project. All of the students had many questions that they wanted to answer about what could survive and operate effectively in near-space.

As mentioned earlier we composed a set of educational documents for the teachers to refer to throughout the year. These educational documents included overviews and basic instructions for each part of the program (see Appendix). These documents were posted for the teachers. The most popular documents that were used included

[3] Girls in Engineering, Math, and Science (GEMS).
[4] Guys in Science and Engineering (GISE).
[5] HOBO Onset Data Logger with temperature probe and solar panel inputs. http://www.onsetcomp.com/products/software

Teacher Overview to High-altitude Ballooning, *Snap-together Heater Activity*, *Building a Basic Payload Box*, and *Testing Payloads*. Other documents included How-To documents about data analysis, using flight hardware, and photo documents for soldering components [2].

A. Approaches to Teaching High-Altitude Ballooning in the classroom

In preparation for this conference paper I asked the participating teachers a variety of questions relating to their experiences with the program. I received feedback from three schools prior to the inclusion of this paper, in part because they were still busy finalizing their payloads at the time. Each school provided information about how high-altitude ballooning was implemented into their classrooms, the students' benefits, and some of challenges they faced.

1) Columbia Heights Middle School

In general, most of the middle schools used the educational documents as aids to creating their own activities and exercises for their students. There were a variety of approaches in teaching high-altitude ballooning to the students. In particular, the teacher from Columbia Heights Middle School chose to create her own multi-part lesson plans for this project. She created an eighteen lesson plan that involved topics such as history behind the space program, interviewing skills, how to run a business, designing a scientific experiment, data analysis of the experiment, making presentations, and more [3]. She chose to not spend a large part of her time in building the actual flight payload, but rather to focus on other aspects of the project. Essentially her objective was to have her students realize that this was a real professional project with goals and challenges.

The students that participated in this project were 7^{th} and 8^{th} graders. This project was incorporated into her students' Engineering Science classes. Her students mainly benefited from working with a real client (Dr. Flaten) and the client needs (the supplies for the payload box, floating ability, durability, etc). Also it was beneficial for her students to review concepts of series and parallel circuits, evaluating the documents, and applying the data found when writing a "the letter to the president." Another benefit was with writing science lab reports for testing the ability of the box to float, withstand a fall, and to maintain its temperature in near-space. Students from Columbia Heights traveled to their launch and were able to participate with final preparations to their payload.

2) Stillwater Middle School

Stillwater Middle School chose to not generate new lesson plans for their students. They mainly focused on the documents that were posted by the ballooning team. The curriculum that was most helpful to them were the directions of how to build the different components. The teachers decided to divide the group into pairs to try to build the certain components. The challenges that the students found were putting the components together and asking for help from the teachers. The teachers were rather inexperienced in building the components and had to refer to the directions often.

Stillwater's approach to the program was rather different to that of Columbia Heights Middle School. The teachers at Stillwater decided to create an after-school club that met once a week to build and design their payload. To generate interest for the club, students were shown pictures, video, and analyzed data from previous balloon flights. The students' questions were the main guide for the presentation. This after-school club was created in the winter/spring of 2011. Most of the students that participated were 8^{th} graders, of which a core of six students mainly worked on the main flight payload. The students' main benefit from this project was problem solving skills. The concept of problem solving kept reappearing often during building the flight payload.

3) Farnsworth Community Middle School

The Field teachers had an interesting approach to teaching high-altitude ballooning to two groups of students--GEMS (girls) and GISE (boys) in their after-school program. The program only allowed 7^{th} and 8^{th} graders to participate in this project. The groups had about eight students each. The teachers thought that the older students would benefit more with this project. The after-school program met with both of the groups once a week for two hours during the spring of 2011. This program was especially geared to be more hands-on experimentation.

Field did not generate any defined curriculum and did not document such curriculum for this project. The teachers also chose not to use the curriculum provided by the ballooning team. The teachers instead helped the students learn about the different layers of the atmosphere, what can be found in these layers, and concentrated on understanding the sense of scale with respect to heights of these layers. The students compared ballooning to known heights of buildings and how high airplanes fly, to develop a better understanding of what could potential survive in that layer of the atmosphere.

The teachers encouraged the students to think about other practical, non-traditional experiments that could be tried in near-space. The main goal was for the students to conduct science experiments and to answer their questions. The teachers decided to not focus much time in building the actual payload boxes. Instead they bought mini coolers to use as the insulated flight payload enclosure. The students spent their time running their experiments on the ground to get a better basis for the expectations before sending their experiments into near-space. The students also spent time reviewing data from earlier flights into near-space in order to better predict and set up their own experiments.

The Field groups also decided to include additional experiments on their flight payloads. Their experiments were sterile agar plates (to use after the flight) and marshmallows (to observe with a camera during the flight). These experiments were externally connected to the payload boxes. The students had to figure out how to set up these experiments and the capabilities of the available cameras to visually record the marshmallow throughout the flight. The students decided to tie the two payloads together to in order to have the cameras see the external experiments better. The students benefited mostly with working with these additional experiments and with the variety of sensor devices that were included in their flight payload. The students learned how the sensor devices actually worked and that it was possible to get coded data from them in order to be analyzed later.

B. Flight Status

In mid-May 2011, we took delivery of all of the middle schools flight payloads (except for one school which decided not to fly this year). The ballooning team then checked out the payloads and made any necessary adjustments, including retesting all the sensor devices and replacing all the batteries. We flew three payloads on a single "stack" under each balloon. There were two launch days with two balloon stacks flown on each day. The schools involved first day of flights had stack A1: Columbia Heights, Shakopee, and Burnsville and stack A2: Farnsworth, Battle Creek, and Hastings. The second flight day had stacks B1: Stillwater, Calvin Christian, and University of Minnesota (stepping in for Saint Anthony Village) and on stack B2: South View, Field (GISE), and Field (GEMS). Data from all payloads was posted for use by all schools (see Appendix) [5]. The ballooning team provided internet streaming of video coverage of the launches and in-flight data transmissions (via Stratostar[6] and APRS[7] tracking system).

C. Data Analysis from the Middle School Stacks

1. Photos from the flights

The ballooning team had four successful launches and recoveries. The ballooning team provided post-flight data analysis of the sensor devices and the tracking systems. The raw and analyzed data files, plus photos with videos, were posted. We received many impressive in-flight still photos from the middle school payloads. Still cameras took photos in different directions looking out of the payloads (out, up, and down).

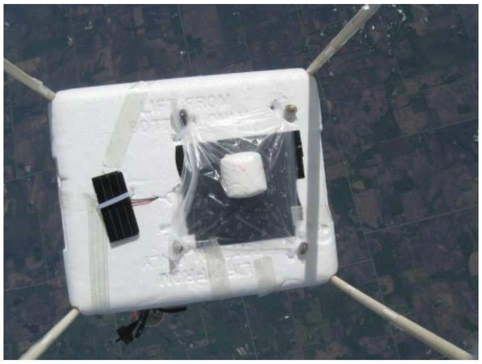

Figure 1. A photo pointing down, with the view of the ground below and to the Field (GISE) to the marshmallow experiment on the lower (connected) payload.

[6] Stratostar is a 900 Mega-hertz telemetry unit also known as StratoSat Command Pod. http://www.stratostar.net/

[7] Automatic Packet Reporting System (APRS). http://aprs.fi

Figure 2. A photo facing outward viewing the horizon at 92,000 ft.

2. Altitude

In order to understand the balloon's flight we usually graph Altitude (feet) versus Time (minutes). Figure 3 shows how the altitude increases over time of the flight. Notice that the burst of the balloon occurred approximately at t = 75 minutes with an altitude of 93,000 ft. Also notice that the graph is quite linear on the ascent and then becomes parabolic on the decent. Understanding this graph is essential in order to interpret the important features of the other data that was collected during flight.

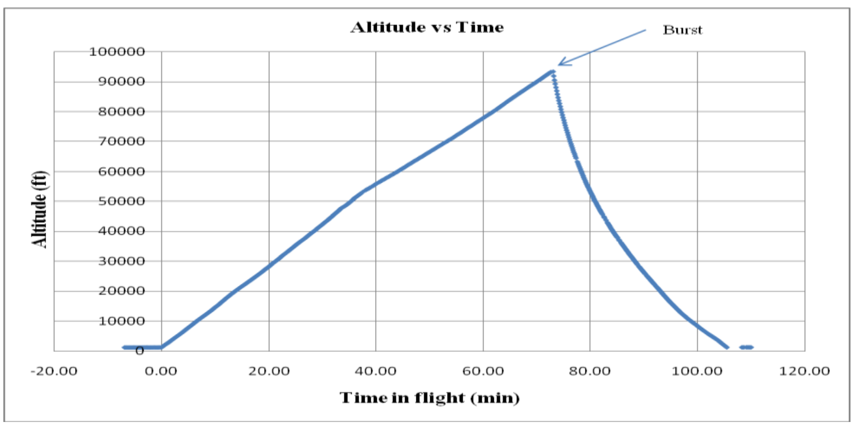

Figure 3. The Altitude (in feet) versus Time (in minutes) graph of the balloon flight for stack A2.

3. Relative Humidity

We collected basic weather data using temperature, pressure, and relative humidity sensor monitored with BalloonSat Easy[8] flight computers. Figure 4 shows the relative humidity versus time graph from the Farnsworth payload. Notice spikes in the relative humidity early in the flight and just before landing (around t = 120 min) as the payload passes through clouds on the way up and down. Also notice how very dry it is in the upper atmosphere (between t = 50 and 100 min).

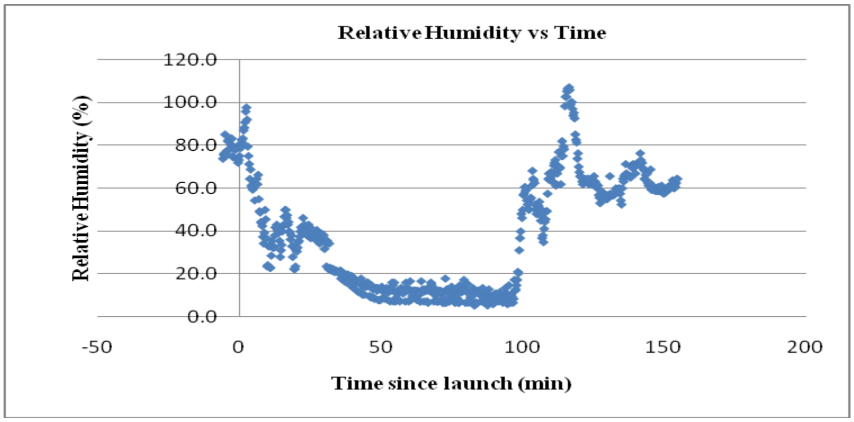

Figure 4. Relative Humidity (in percentage) versus Time (in minutes). This is data collected by a BalloonSat Easy flight computer in the Battle Creek payload.

4. Cosmic Radiation

Some of the payloads measured cosmic radiation using a Geiger counter and a BalloonSat mini flight computer. This data shows the number of counts of radiation as recorded by the Gieger counter during 5-second intervals throughout the flight (see Figure 5). This data can be aligned with altitude data from GPS tracking systems, allowing us to report radiation as a function of altitude (See Figure 6).

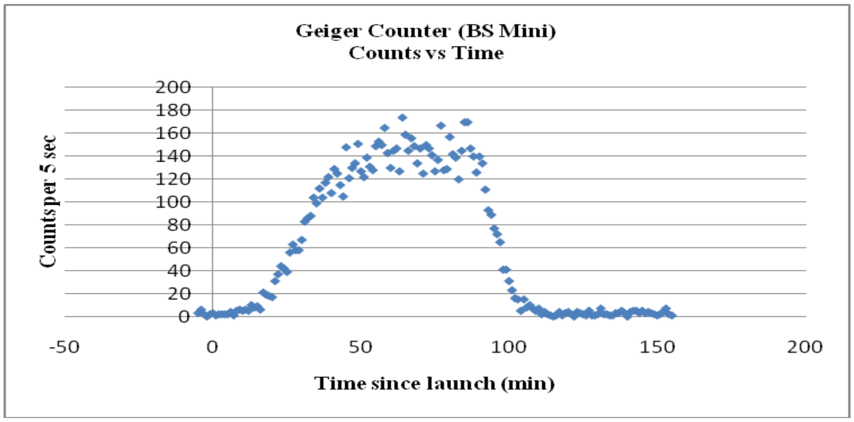

Figure 5. The number of Radiation counts (per 5 second intervals) versus Time (in minutes).

[8] BalloonSat Easy is a flight computer that can be connected to a Weather Station to collect temperature, relative humidity, and pressure data while in-flight. http://www.nearsys.com/catalog/balloonsat/easy.htm

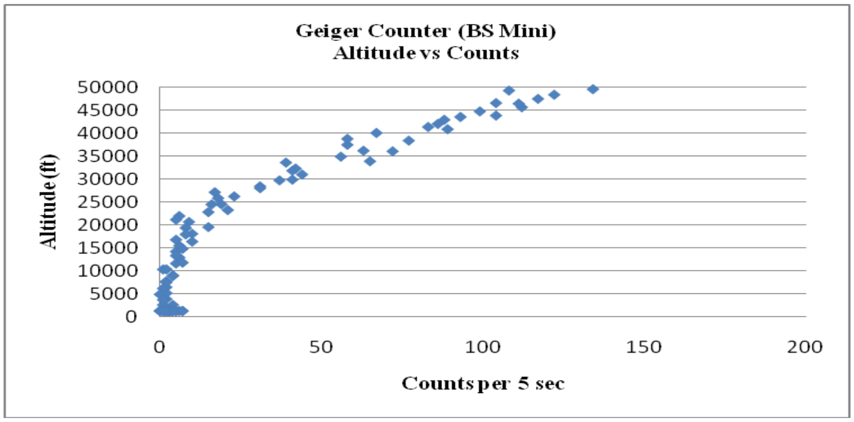

Figure 6. Radiation counts (per 5 second intervals) versus Altitude (in feet).

5. Acceleration

We also flew accelerometers to record vibration in x, y, and z directions (the x-axis pointed up). Figure 7 shows the x-axis "acceleration" value (needs to be compensated for our 1-g environment) versus time (in minutes). Vibration signatures for launching the payload, burst, and landing are clearly visible, as well as two periods of stillness after landing (one with the payload on its side).

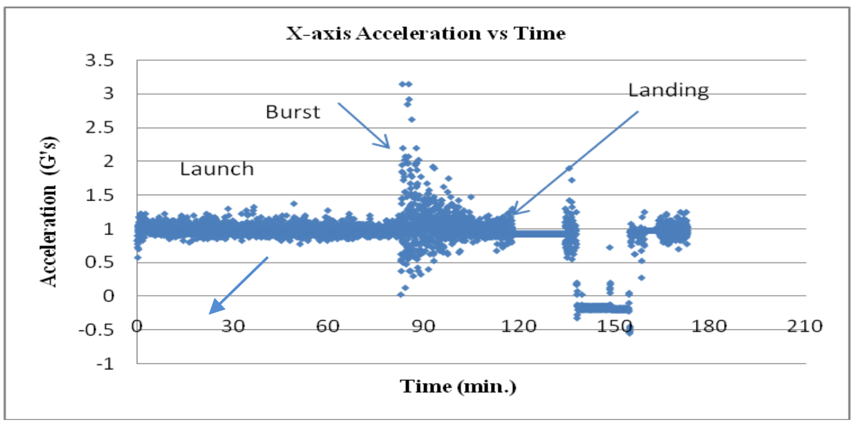

Figure 7. The x-axis acceleration (in G's) versus time (in minutes) graph during all stages of flight from the Columbia Height's payload.

D. Future Outcomes

Since this is a two year program, the same schools will get another opportunity to experiment and launch their ideas into near-space again next spring. Based on the feedback we received from the teachers, we anticipate some changes in the second year. Columbia Heights Middle School would like to have their students actually apply and interview for the jobs, as stated in their curriculum lesson plans. Their teacher would especially like to have only one engineering project going during the same class so that she can focus more of her time to that project. It would also be beneficial to change the timeline of this project so that there is more time for data analysis and letter writing. Stillwater Middle School would like to involve more students in this project. They would like branch out into different aspects of high-altitude ballooning, of whether it is with the design, tracking, or the data analysis of the payload. They would also like to have additional student-geared experiments on next year's flight. Finally, the Field Community Middle School groups would like to repeat their radiation experiment from this year and include ever more additional experiments. In general, some of the changes for each school will be to allow enough time for this project and to make a few adjustments to their curriculum. It may be easier for the middle schools teachers to teach this project next year since they now have more experience and their confidence in high-altitude ballooning techniques is higher.

The ballooning team would also like to consider some changes for next year. We could be more organized in areas such as preparation of multiple middle school payloads, doing several launches, and a lot of data analysis over the course of just a few days. The ballooning team would like to do more communicating with the middle schools during the months and weeks prior to the launch date. Both the middle schools and the ballooning team will benefit from communicating with each other more regularly. The ballooning team would also like to fix any of the sensor devices that may have given out bad data for either of the flights and tweak any streaming issues and in-flight transmission problems.

IV. Conclusion

The University of Minnesota high-altitude ballooning team has provided flight opportunities for middle school students and teachers this past year. This program was offered to 12 Twin Cities middle schools. This program engaged students to learn more about near-space and to perform unique experiments. Many of the Minnesota Academic Standards (Science K-12) were incorporated in the high-altitude ballooning curriculum generated for and by the teachers involved. Most of the standards that were used were in the middle school grade levels though some the standards may have come from a different grade levels in order to have high-altitude ballooning techniques be most efficiently taught.

Thus far this program has been successful with respect to the feedback from the teachers and the students involved. The ballooning team has gained insights as to the benefits that the students especially gained from this experience. The ballooning team has also understood many of the challenges that the teachers faced with teaching this topic to their students. The future outcomes and changes will be adjusted prior to the next academic round of student flights.

Appendix

<u>The educational documents which were written for this program and their descriptions are the following [2]:</u>

- The *Teacher Overview to High-altitude Ballooning* document included topics such as an introduction to High-altitude Ballooning, monitoring Near Space missions, and analyzing data.
- The *Main Payload Components* document described each payload component in specific detail.
- The *Photos of the Main payload components* document accompanies the above document.
- The *Building a Basic Payload Box* document shares standards to curriculum overview as well as instructions in building the basic payload box from different materials (such as Styrofoam or foam-core with inner layers of black foam).
- The *Snap-Together Heater Activity* document shares four activities that teachers can get their students involved with circuitry methods. This main activity also addresses a couple of Science standards for grade the 6th grade level. There are photos that accompany this activity that provide even better detail to these activities.
- The *Testing Payloads* document shares a variety of different methods to test the flight payload prior to the actual flight.
- The *Geo-caching Activity* document shows the importance of finding the payload after it lands.
- The *Flight Prediction Activity* document shows the flight prediction website we use to prior to launching the balloon.
- The *Setting Up a Control Center and Doing Live APRS Plotting in Flight* document displays the website to follow the balloon track live on the internet. It also includes information in how to plot the APRS data especially to get a plot for Altitude versus Time of the balloon during live feed.
- The *Interpreting Graphs from Near-Space Missions* document possibly the most important of these documents that are mentioned. This document provides an outline in how to do data analysis from near-space missions. It also provides insights to how the APRS tracking system tracked past flights and what information can be gained from these tracking maps.

<u>Minnesota Academic Standards – Science K-12 [4]:</u>

There were certain highlighted standards that could be connected to High-altitude Ballooning concepts. The following are a few examples of the codes and their benchmark explanations.

1) Code: 8.3.2.2.1 Describe how the composition and structure of the Earth's atmosphere affects energy absorption, climate, and the distribution of particulates and gases. (8th grade benchmark)
2) Code: 8.3.2.2.2 Analyze changes in wind direction, temperature, humidity and air pressure and relate them to fronts and pressure systems. (8th grade benchmark)

3) Code: 8.1.3.3.2 Understand that scientific knowledge is always changing as new technologies and information enhance observations and analysis of data. (8th grade benchmark)

4) Code: 7.1.3.4.1 Use maps, satellite images and other data sets to describe patterns and make predictions about natural systems in a life science context. (7th grade benchmark)

5) Code: 7.1.1.2.2 Plan and conduct a controlled experiment to test a hypothesis about a relationship between two variables, ensuring that one variable is systematically manipulated, the other is measured and recorded, and any other variables are kept the same (controlled). (7th grade benchmark)

For a link to Minnesota Academic Standards, refer to the References section.

For a link to the posted data from the Middle School flights, refer to the References section.

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[3]Brown, A., "Lesson Plans for Space Travel," Curriculum, Columbia Heights Middle School, Columbia Heights, MN, 2011 (unpublished).

[4]Minnesota Department of Education, "Minnesota Academic Standards- Science K-12," Minnesota Department of Education [online database], URL: http://education.state.mn.us/MDE/Academic_Excellence/Academic_Standards/index.html [cited 28 May 2011].

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ftp://yspace.augsburg.edu/Augsburg Ballooning/AHAB/MnSGC MS Ballooning 2/
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