ROCKET LAB AND BALLOONSAT: THE IMPORTANCE OF STUDENT BASED HANDS-ON EXPERIMENTS IN THE CLASSROOM

Senior Honors Thesis
Submitted in partial fulfillment
of requirements to graduate from
The Honors College

by

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Spring, 2009

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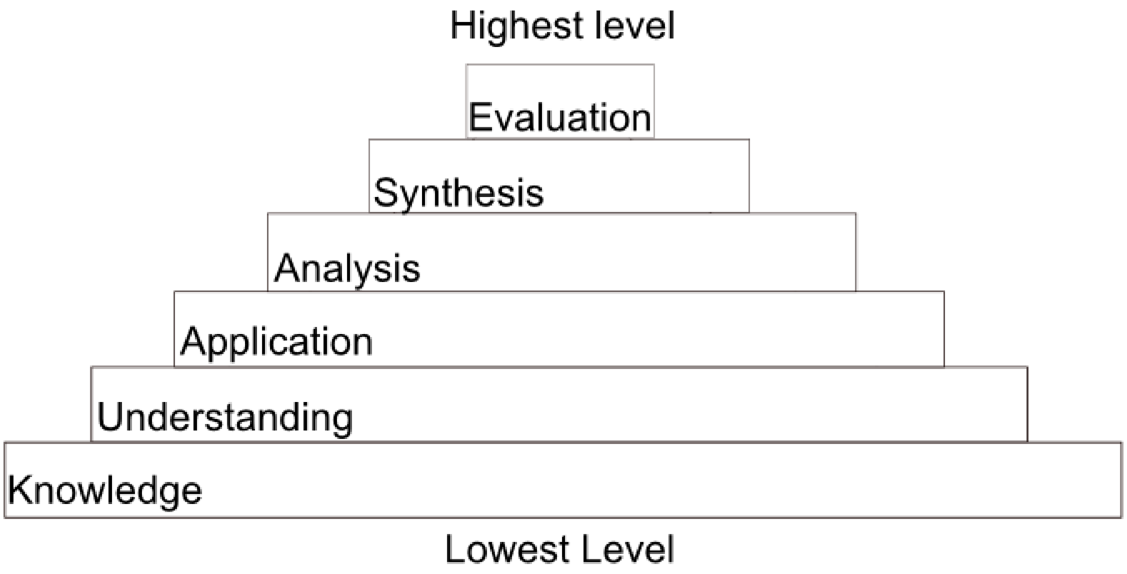
Table of Contents

Introduction

It is imperative for me, as a future science teacher, to know how students learn and understand so that I can effectively communicate the content. For students to appreciate science, they first have to understand the nature of science: how science is carried out, what scientific research is, and how science impacts our society. Students can be taught the nature of science through lecture, but through this form of teaching do students really understand or will they remember what they have been told? My job as a teacher is not just to teach students about specific topics in science, but to help them learn how to learn, which is why this interdisciplinary thesis integrates technology, educational research, and scientific research into new accessible educational materials.

Hands-on experiments are one way that students can learn about the nature of science and about a specific subject area. After students are exposed to hands-on learning, it is essential to move on to experiments in which student curiosity and thinking take the lead. Research undertaken in this area shows that as this student-controlled learning style puts the students in charge of what they learn, the information is better retained and understood (Crowther, 1999).

This learning style invokes student curiosity, puts to work what students have learned, and actively engages students in the science content at hand. In order for this teaching style to work, students must be taught according to a pyramid of learning ability such as Bloom’s Taxonomy. This pyramid involves building students up by utilizing multiple layers of teaching. This learning style starts off with the basics and encourages students to think in more complex ways. The lowest layer of Bloom’s Taxonomy is *knowledge*, which is made up mainly of memorized ideas. This is followed sequentially by *understanding*, *application*, *analysis*, *synthesis,* and finally *evaluation,* as seen in the figure below.



When using Bloom's progression of thinking it is important to start with a quality introduction to the content knowledge so that students can understand and analyze information; afterwards, students can take full advantage of hands-on opportunities that involve them in creating and evaluating new information.

The Nature of Science

The nature of science is an essential part of the education that science teachers impart to their students. Science and its practices have changed over the years and will continue to evolve. Scientific activity began with what was called "natural philosophy," which contained the study of astronomy and mathematics in order for to form a calendar for two important aspects of life: religion and agriculture. The Greeks soon followed with a philosophical science which worked to satisfy various curiosities (History of Science, 2008). During this time, Plato shaped his "ultimate reality" using big ideas and forms that spawned from thought and reason. Aristotle, his student, combined logic with reality of experience and the physical world in the studies he undertook, which included a vast study of marine animals far beyond the scope of his time (Nothiger, 2007). Around the same time Archimedes made extensive observations of the natural world. Aristotle and Archimedes were a part of the “zenith” of Greek science, utilizing close observation and thoughtful conclusions though no experimentation was done (History of Science, 2008).

Experimentation began with Copernicus in the 1500s, although his experiments were not comparable to our current standards, since this experimentation was done through observation and mental analysis. These methods made his experiments unrepeatable and unable to be tested by others (Gribbin, 2002). In the 1600s Galileo was “emphasizing the need for accurate, repeated experiments to test hypotheses, and not to rely on the old ‘philosophical’ approach of trying to understand the workings of the world by pure logic and reason” (Gribbin, 2002). Thus began a new way of viewing science.

During the 16th and 17th centuries, there was a major shift in how science was perceived. This was the birth of empirical science, defined by observation and experimentation, which was vastly different from the Greeks’ deductive methods. Previously truth was found through analyzing “big ideas” without having to verify them with observation and experimentation, and now ideas had to be upheld with physical, repeatable experimental evidence. This movement from deductive to empirical science was set into motion by Francis Bacon and Rene Descartes, who valued the reason, experimentation, and observation of the individual (Bybee, Powell, & Trowbridge, 2008).

Now science is based on what we can see, hear, and touch as a group of individuals rather than on the opinions or speculative imaginings of any one individual

(Chambers, 1999). Science is defined as both a body of knowledge and a process of inquiry about the natural world (Bybee, Powell, & Trowbridge, 2008). The National Association of Science Teachers' position statement states:

> Science is characterized by the systematic gathering of information through various forms of direct and indirect observations and the testing of this information by methods including, but not limited to, experimentation. The principal product of science is knowledge in the form of naturalistic concepts and the laws and theories related to those concepts (NSTA, 2000).

In order for science to be defined this way, we have to make a few assumptions. One is that our universe reflects patterns and abides by the same rules everywhere. This allows us to make observations concerning certain properties in our close environment and compare them to other parts of the universe. We also have to recognize that even though science as we know it is reliable, it is also tentative. It is always evolving as new discoveries are made, not making its theories less reliable but increasingly more accurate (Chambers, 1999).

If students are to more comprehensively understand the science they are doing they must understand what exactly science is. This understanding includes not only being introduced to the definition of science, but also to the rules and common misconceptions of science. The general public sees science in the many little pieces that are presented to them or that seem relevant to them. These separate pieces fit together to form our total world view of science. Understanding the nature of science, its rules, and how science daily affects us is known as scientific literacy. A more scientific world means a better educated world that is more likely to think about scientific statements rather than dismissing them without consideration or agreeing with them without thought (AAAS, 2008).

One of the first steps to scientific literacy is better understanding the scientific method. To many this term “the scientific method” has come to mean to make a hypothesis, test it, and prove or disprove that hypothesis. This is not the scientific method. In the actual scientific method there is first a question posed. This question is followed by research concerning what has already been tested and what is already known. After this research an educated statement is formed which can be tested by scientific means and be answered by a simple yes or no; this is the hypothesis. Science can only test natural phenomena. The supernatural cannot be proved or disproved by testing the concepts with scientific methods, so these endeavors cannot be considered science (NSTA, 2000). The misunderstanding of this concept has caused numerous controversies over scientific observations. Many people try to apply or claim to apply science to supernatural ideas to mislead others about scientific or supernatural findings. If more people were scientifically literate, this misuse of science would not be a problem (Rutherford & Ahlgren, 1991).

After a testable hypothesis is formed, a series of experiments are done to test the validity of the hypothesis. The scientists then form conclusions about whether the experimental data disproves or supports the hypothesis. A hypothesis can never be proven, due to the nature of science, but it can be supported by more and more evidence. After conclusions have been made, the scientist writes up his or her findings and publishes them. Published findings are read, critiqued, and retested by other scientists to improve the accuracy of the conclusions being made on the topic in question (Rutherford & Ahlgren, 1991).

Peer review is an integral part of the scientific method and a critical part of science. The knowledge that is discovered by science may be found by an individual, but the body of knowledge known as science is “a community enterprise” (Bybee, Powell, & Trowbridge, 2008). When a discovery is made by a scientist, he views the situation from a certain point of view, which depends on previous experience, knowledge and expectations. The peers of this individual review the discovery in order to make the new knowledge as unbiased as possible (Bybee, Powell, & Trowbridge, 2008). Only after an experiment has been tested and supported by the scientific community can its findings become part of the body of knowledge we know as science (NSTA, 2000).

When students can more thoroughly learn about scientific processes, they will become more scientifically literate. Better educated students mean more support for scientific knowledge and the overall advancement of science. Scientific literacy is also important to “help students realize how many different career possibilities exist in science” (AAAS, 2008). Scientific literacy is built when students are not only taught the nature of science, but when they understand science by doing it.

Education Research

In order to develop scientific literacy among students, educational research has been done with college students, high school students, and public school teachers. One of the most influential voices in education research is Lillian McDermott, the Director of the Physics Education Group at the University of Washington. This group participates in research, curriculum development, and physics education (McDermott, 2008). The research done by the Physics Education Group is undertaken in a cyclical manner: first there are investigations conducted, and the results of these investigations are then applied to programs that are in the Physics Education group. The effectiveness of these programs is assessed, and the findings are reported to their peers through lectures and articles for review. Then the process begins again, incorporating what the group learned in the previous round of research.

The research undertaken by the Physics Education Group focuses on the learning and teaching of content as well as the students' ability to undertake the reasoning necessary to understand the content. The curriculum that has come out of this research gradually gives students more and more control over the learning process. This makes the content and scientific learning more student-centered, focusing on student curiosity and questioning, rather than teacher-centered, which focuses on more structured learning. One idea that sets McDermott apart from other education researchers is that the Physics Education Group's ongoing research is evidence-based instead of hypothesis-based. Many education researchers claim that the curriculum and activities they develop are "research-based," meaning that they have used researched methods to form the curriculum. McDermott argues that this is not as useful as curriculum that is "research validated," which is what the Physics Education Group is working on. The curriculum and activities coming from the Physics Education Group's research have been tested on various groups to demonstrate its usefulness.

McDermott points out that an important part of her research is the assessment process, which is done by interview, discussion, individual demonstrations, and pre- and post-tests. The research being undertaken shows there is a large difference between what is taught and what is learned. At a recent lecture given by McDermott, she pointed out that “a coherent conceptual framework is not typically an outcome of traditional classes.” These “traditional classes” consist of a lecture portion and instructor guided experiments. Instead of the traditional method of teaching, McDermott suggests that many students need to perform ideas to understand them. Following this statement, she explains how neither demonstrations, standard labs, a good instructor, nor a favorable class size effectively change the performance of students. Students need to be “intellectually active” to better understand and remember what is being taught (McDermott, 2009).

One of the members of the Physics Education Group in Washington, Andrew Boudreaux, highlights the specific topic of control of variables in his article, “Student understanding of control of variables.” During the research presented in this article, multiple learning groups were observed: general education physics students with no science background, students in calculus-based physics, and K-8 teachers studying physics. The research showed that students of all levels had difficulty with reasoning that concerned the control of variables, even though it would be assumed that the calculus based class would be more capable in scientific reasoning. Most students do not go “through the reasoning necessary to make inferences from experimental data” which would allow them to differentiate between knowing and understanding. In order for upper level thinking to occur, students “should know how they know what they know” (Boudreaux, 2008).

An application of the research undertaken by the Physics Education Group can be seen in Pricilla Laws’ Workshop Physics. This series of workbooks is set up “to help students understand the basis of knowledge in physics as a subtle interplay between observations, experiments, definitions, mathematical description, and the construction of theories" (Laws, 1997). This workbook and Laws' teaching methods focus on students doing and understanding science instead of being taught science. Workshop Physics exemplifies McDermott's research in that it shows that student learning does not depend on the teacher, but on the students being intellectually active.

Purpose

Since research like that of the Physics Education Group has come to the attention of education departments across the nation, much more attention has been given to the nature of science and how science is being taught. The Arkansas Department of Education (ADE) has added nature of science sections to their state standards for each of the science classes offered. These Arkansas standards, or frameworks, outline what students are supposed to learn during a particular year and class in school. One Arkansas standard involves the students demonstrating the understanding of science as a method of acquiring knowledge, relating back to the nature of science. Students are also expected to be able to design and complete scientific investigations, showing the importance of inquiry in the classroom. They are also to understand the history of science; use mathematics, equipment and technology as scientific tools; understand the differences between pure and applied sciences; and be informed about possible science careers. The nature of science standards are meant to be both part of a stand alone portion of the science classes as well as being a part of the other content taught in the class (ADE, 2005).

Education research has also made an impact on the national level. The Benchmarks for Scientific Literacy from Project 2061 starts out students "actively engaged in learning” from kindergarten. Their goal, which was started in 1985, is for all “Americans [to] become literate in science, mathematics, and technology” by 2061. The benchmarks Project 2061 has written act as a guide to help make scientific literacy possible. They have been written to suggest specific content at specific ages as well as for learning about the history of science, the nature of science, and the affect of science on our world (AAAS, 1993).

These benchmarks are only a part of what is needed to help students become scientifically literate. Teachers must start out as educators and develop into coaches. My goal as a teacher is not to tell students everything I know about the content, but to encourage them to be curious and interested in science. It is important that teachers apply the research validated curriculum, which shows that students need to do science to be able to understand it.

It is important for teachers to make connections to previous knowledge in order to communicate scientific understanding to students. Students coming into any classroom have a diverse knowledge of science and its nature. Being aware of their preconceptions, and many times misconceptions, is a step toward getting students to understand science content and scientific thought. Students also need to see how science and its technology impact our society. For students to become scientifically literate, they must be exposed to actual scientific studies and participate in doing science themselves.

Application

The application of education research and education standards is a difficult process for many teachers. Between teaching around 150 students per day, doing piles of paperwork, and preparing students for standardized tests, there is little time to improve the curriculum being used in the classroom. Science curriculum must continually be evolving, since what is known in scientific fields is always changing. It is important to see the creation of new labs and the revision of old ones to keep up with the everyday world to which students are exposed. The ideal approach to accomplish the formation of appropriate, effective labs is by following the example of others who have created successful, research-validated curriculum and activities. During the last two years at UCA, I have been able to participate in the creation and revision process, exposing me to many new ideas of teaching students about science as well as allowing me to gain experience with working with new and old lab equipment. The Physics Education Group's research and Pricilla Law's Workshop Physics have been the inspiration and road map for the revision and creation of new hands-on labs.

The two labs that I have worked most extensively with are BalloonSat and a Rocket Lab. Both labs make use of equipment created by Vernier, a company that makes technology for science education (Vernier). The two labs support education at different levels in the learning process and therefore have differing amounts of student control associated with them. In order to let teachers in Arkansas know about these two labs, I have written teacher and student lab manuals. These manuals differ slightly in format due to the difficulty and amount of student control involved. The teacher manuals include information about the labs, notes on how to implement the labs, and typical experimental data, whereas the student manuals contain procedural information followed by questions needed to assess student understanding.

The first lab, the Rocket Lab, uses Estes rocket engines with Vernier's Force probe and a homemade rocket engine holder (Estes). With this setup, students can measure the force versus time that the rocket engine expels. They can compare this data to Estes data provided or even make predictions about an actual rocket flight. The initial setup is at a lower level since it will probably be taught close to the beginning of a school year since kinematics, the physics of motion, is taught early in the first semester.

The teacher's manual for the Rocket Lab gives educators the purpose, objectives, and Arkansas frameworks covered during the experiment (See Appendix A). It also contains specific lab and safety information so that the experiment can be carried out safely and efficiently to be of the best benefit to the students. The teacher's manual also contains information on how to construct the rocket engine holder and how it fits into the force probe. The student manual contains an in-depth description of the lab, including the purpose, equipment list, procedure, and safety instructions (See Appendix B). For students to think about and communicate what they have learned, I have included questions to be answered and a lab report assignment. After students have completed these assignments, the teacher will be able to assess the impact and usefulness of the lab.

The second lab, BalloonSat, is written to work with the Arkansas Space Grant Consortium funded Arkansas BalloonSat program (Roberts, 2008). This program encourages students to ask questions about the earth's atmosphere. Then it allows them to build scientific payloads to contain sensors which could potentially answer these questions. This program gets students involved from start to finish in hands-on scientific experimentation. Students ask questions, do research, form a hypothesis, build a payload to hold their sensors during a flight, participate in the launch, analyze their data, and present it to their peers. The BalloonSat lab is meant to be a higher level experiment, allowing students to be in control of the ideas behind the project while guiding them through the scientific process.

Currently in the BalloonSat program, students are putting small temperature probes, video cameras, and still cameras in their payloads (Roberts, 2008). The research that I have done with this program involves Vernier's LabPro and its sensors (Vernier). This equipment is commonly found in public school classrooms in Arkansas. During my research, I have used a variety of sensors in three launches with the BalloonSat program. Some of these sensors include a temperature probe, pressure probe, relative humidity sensor, magnetic field sensor, light sensor, UVA sensor, UVB sensor, and small Garmin GPS unit (Garmin). Since many of these sensors are owned by school districts around Arkansas and BalloonSat is a fully-funded program, it only makes sense to test how Vernier's sensors work with the BalloonSat program.

The results of the three flights in which I participated have been incorporated into the teacher's manual for BalloonSat (See Appendix C). This manual, like that for the Rocket Lab, provides a purpose, objectives, target grade levels, Arkansas Frameworks covered, an equipment list, and an outline of a possible lab format for BalloonSat. Arkansas teachers are required to give objectives and frameworks that they are covering in a lecture or lab activity, so the teacher's manual gives educators a jump start in participating in the program. Also in the teacher's manual there is information on how to get involved in the BalloonSat program as well as how to get a mini-grant from the Arkansas Space Grant Consortium (ASGC) to provide funding for travel and to help build student payloads (ASGC).

The student manual for this lab is more open-ended than that of the Rocket Lab (See Appendix D). The BalloonSat Student manual contains a possible equipment list, purpose, a general outline for participating in a BalloonSat lab, questions to think about while completing the lab, and some helpful websites. This type of outline should keep students on track during the experimentation process while allowing them to take control over the majority of the process.

Both the student manuals from these labs can be changed to cater to different age groups or intellectual levels than they were written for. They can also be changed to give the students more or less control over the experiment. The level that is appropriate for students changes throughout the school year. This level depends on how accustomed students are to the equipment and their familiarity with student-controlled labs.

The overall purpose of the four lab manuals is to communicate the possibility of these activities to teachers, while also making it easier for teachers in Arkansas to participate in more hands-on activities with their students enabling them to learn about science. Since the teacher manuals contain experimental results they will quickly be able to see the uses and restrictions of each of the labs. This will save a multitude of time, allowing the teachers to use previous research rather than having to experiment with the setup before using it with students. Since the teacher manuals also include objectives and Arkansas frameworks, teachers and administrators will be more likely to consider these labs for use in their classrooms. Providing the teacher manuals with student manuals makes it even easier for teachers to implement these activities in their classrooms. Many teachers strive to encourage students to take more control of their learning, they just do not have the time or money to test and create new activities for their students. The

BalloonSat and Rocket Labs will give teachers two ways in which they can get their students doing and understanding science in the classroom.

Conclusion

My goal is not just to teach students subject content, but to help students learn how to learn. Reaching this goal is not a simple one, and this is why hands-on labs such as Rocket Lab and BalloonSat are important parts of a science curriculum. These labs have been researched, tested, analyzed and written into manuals so that they can be made available to teachers around the state. They have also been presented at the state, regional, and national levels to an experienced science education community and have been well received. This response has further encouraged my confidence in the effectiveness of these labs and their potential in the classroom.

Once my students leave my classroom, they may remember some of what I have taught them in the specific subject area of the class, but it is likely that they will only remember what they did. By helping students grow through scientific inquiries of which they are in control, I hope to help them learn about the nature of science, how it affects our ever changing world, and what they can do with what they have learned. By using projects such as the Rocket Lab to interest students in science and its processes, the way is opened to engage students in further scientific endeavors. Closer to the end of a school year, a project such as BalloonSat would be appropriate to give students more control over scientific application and design. Further student involvement with scientific inquiry is desired, but the student's curiosity and aptitude should determine such endeavors. When I am teaching, I hope students feel comfortable asking questions, making mistakes, and taking their learning into their own hands. Only when this atmosphere is achieved will I be really reaching what I see as the main goal of a teacher: to inspire students to be constant learners.

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Appendix A:
Rocket Lab Teacher's Manual

Teacher's Manual
Thrust vs Time: A Rocket Lab Using Estes Model Rocket Engines

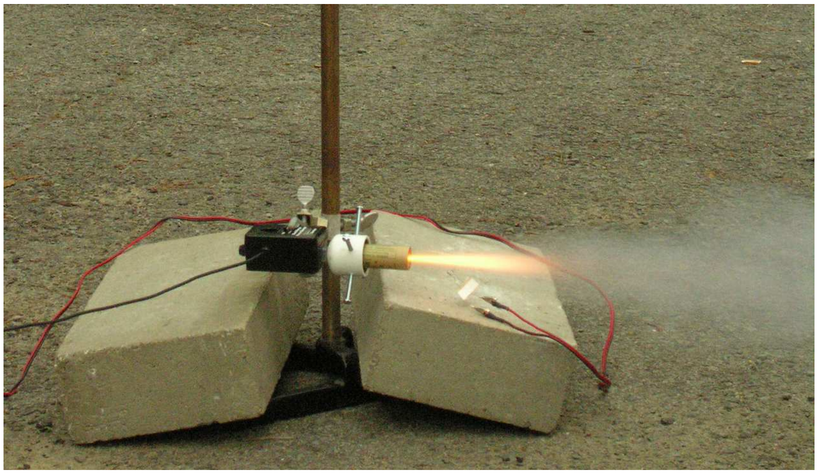
By: Kim Mason

Purpose:

- ✧ For students to understand Newton's Third Law and apply the Impulse-Momentum Theorem.

Objectives:

- ✧ Students will observe the thrust of a model rocket engine and, using the force vs. time data collected, will construct a theoretical flight plan for a rocket. Then students will compare their theoretical plan to an actual rocket launch.



Grade Level:

- ✧ 9-12 recommended

Frameworks:

- ✧ Frameworks (Arkansas):
  - ▪ Physical Science: NS.9.PS.4, NS.10.PS.2, NS.12.PS.1, NS.12.PS.2
  - ▪ Physics: MF.1.P.3, MF.1.P.5, MF.1.P.7, MF.1.P.11, MF.2.P.6, MF.2.P.7, MF.5.P.1, MF.5.P.2, NS.17.P.4, NS.17.P.2, NS.19.P.1, NS.19.P.2

Materials:

1. Vernier's LabPro or LabQuest
2. Vernier's Dual Range Force Sensor
3. LoggerPro
4. Hanging Masses to calibrate force sensor
5. Estes Model Rocket Engines
6. Estes Engine Launch Controller
7. Ring Stand
8. Cement blocks
9. Level
10. Model Rocket Engine Holder
    - o schedule 40 PVC end cap
    - o four 2-inch ¼ -20 bolts
    - o one 2-56 threaded rod and nut

Introduction:

During this lab Estes Model Rocket Engines are used along with Vernier's Dual Range Force Probe. Using a simple model rocket engine holder, the force probe can be used to measure the rocket engine's thrust vs. time. This data can then be compared to Estes Thrust Curves or Estes' predictions for a variety of variables found in their catalog.[1] The force verus time data in Vernier's LoggerPro can be integrated to find impulse. This can then be used, along with other measurable values, to do calculations, such as flight time, maximum velocity, and maximum height, to create a theoretical flight plan. The student's flight plans can then be tested by having students measure the actual time of a rocket flight. Students can also be split into groups to model the effects of the different size engines.

Procedure:

Before this lab, students should be introduced to Newton's Third Law and the impulse momentum theorem. This lab is to help them see a real life application of these two physics concepts.

When the students are ready to do the experiment, they can be broken into teams or they can work individually. The equipment should be setup as shown in Figure 1.[2] When the setup is ready to be used make sure students are wearing safety glasses, and then move outside to level ground and place the setup on concrete with the engine facing away from people and other objects. The setup should be leveled to ensure only horizontal forces will be measured.

After a engine ignition there will be an initial max thrust followed by a lower constant thrust. Then tracking smoke will be emitted during a time in which there is no measurable thrust. The end of the thrust cycle is signaled by a sudden burst, which in a normal launch condition would eject the parachute from the rocket.

The data collected from the thrust of the engine can be saved and another rocket engine can be ignited. Caution: the removing of the already ignited rocket engine should be done carefully, since it is very hot. Another of the same engine can be used to look at the differences in manufacturing, or a different sized engine can be used to allow different groups to do calculations for different rockets.

Using the thrust curve in LoggerPro, impulse and max thrust can be calculated.[3] With students who haven't had calculus, it would be best if they found the approximate area under the curve. Since the thrust is made up of a triangle and a rectangle, this can easily be done. Using this impulse, momentum can then be calculated, along with the rest of the information to compare to an actual flight.

If an actual flight is to take place other equipment is needed. Along with Estes Model Rocket Engines and the Estes Engine Launch Controller, a launch pad will also been needed. These items are also available through Estes. The time between the launch and the parachute opening should be recorded to calculate the flight characteristics and compare to theoretical data.

Calculating a Rocket Trajectory:

By the time this activity is done, students will need to have learned about forces, kinematics, and the impulse-momentum theorem to be able to do the calculations themselves. The amount of student independence on these calculations is dependent on how much the students already know as well as their intellectual level.

The data from the force versus time graphs can be integrated in the LoggerPro program by highlighting the data on the graph and clicking on the integral button at the top of the window. For some students it may be more appropriate to have them actually find the area under the force versus time curve. This should be fairly simple and accurate due to the triangle and rectangle shapes that make up the integral area.

This integral calculated through either method gives the change in momentum of the system. The momentum is equal the change in velocity times the mass. Since the mass of the rocket engine changes slightly during thrust, the initial and final mass of the engine can be measured and a linear change in mass with time can be used in the calculations. With younger students the total change in mass can be used to obtain the overall change in velocity from the beginning to the end of the thrust.

The velocities calculated during the thrust can be used to find instantaneous acceleration at different times. The final velocity can be used with the kinematics equations to find the final height of the rocket, the time the rocket should stay in the air, and if wind speed and direction are known, landing location can also be calculated.

Assessment:

Ask the students to answer the following questions:

Was the flight different than you expected?
Why was the path different from what you expected?
Were there any other forces involved that we neglected? (drag, change in mass, wind)

As an assessment of student understanding a lab report should be written. It should include what they did, what happened during the experiment, their theoretical calculations, percent difference between actual and theoretical, and why they think there was a difference.

Conclusion:

This lab is meant to make a relevant connection between the Impulse-Momentum Theorem and the real life application of rocket thrust. Hands-on activities, like this lab, allow students to actually take data and learn how to form conclusions based on the evidence they have been given. When students are taught how to ask themselves questions, draw conclusions, and defend their conclusions, they are more likely to understand what has happened. Hands-on labs make connections with the students and become a reference point for future learning.

Acknowledgements:

This research was made possible thanks to grants from

- Arkansas Science and Technology Authority
- The Undergraduate Research Committee
- Arkansas Space Grant Consortium.

Notes:

Engine Holder Assembly:

The rocket engine holder is made from a schedule 40 PVC end cap which has been drilled and tapped to accept four 2-inch ¼ -20 bolts to hold the rocket engine. The end cap is also drilled and tapped for a 2-56 threaded rod and nut, which screws into Vernier's Force Probe. (This setup is shown in Figure 1b)

Equipment Setup

The force probe will be plugged into Vernier's LabPro, which can be used remotely or used while connected to the computer. Before ignition of the rocket, make sure that you are familiar enough with the Vernier equipment to be able to change the frequency of data collection and collection time. These processes are explained in the manual for LoggerPro.

Using Logger Pro

The impulse can be calculated by highlighting the relevant data and selecting the integration button at the top of the screen. Max thrust can be found by highlighting the data and selecting the statistics button also at the top of the screen.

REFERENCES

Arkansas Frameworks
http://www.arkansased.org/teachers/pdf/physical_sci_9-12_050508.pdf
http://www.arkansased.org/teachers/pdf/physics_9-12_2005_060608.pdf
Vernier
http://www.vernier.com/
Estes website
http://www.estesrockets.com/
Estes Catalog
http://www.estesrockets.com/assets/publications/2007estescatalog.pdf
Taitt and Miller Data
Henry Taitt and Charles E. Miller, Jr, “Impulse recorder for model rocket engines” *Phys. Teach.* **18,** 315-317 (April 1980)

Experimental Data:

Engine Type	**Total Impulse (N*s)**	**Max Thrust (N)**
1/2A3	0.99	7.95
	±.05	±1.24
A3-4T	2.01	6.59
	±.17	±.14
A8-3	1.93	8.40
	±.15	±.87
B4-4	4.02	7.56
	±.23	±.38
B6-4	**4.23**	**10.50**
	±.11	**±.31**
C6-5	8.07	8.97
	±.13	±0.13
D12-3	16.31	26.29
	±.25	±.45
E9-4	25.08	20.78
	±.46	±.85

Engine Type	**Total Impulse (N*s)**	**Max Thrust (N)**
Our B6-4	**4.23**	**10.50**
	±.11	**±.31**
Taitt B6-4	**4.3**	**10.9**
[1980]	**±.3**	**±1.05**
Estes B6-4	**4.32**	**10.56**
[1980]	**±.14**	**±.90**

Table 1: The average data and standard deviations from three rocket engine launches of 8 different types of Estes rocket engines. This is compared to data from Taitt and Miller featured in *The Physics Teacher* as well as to Estes data presented in the same article.

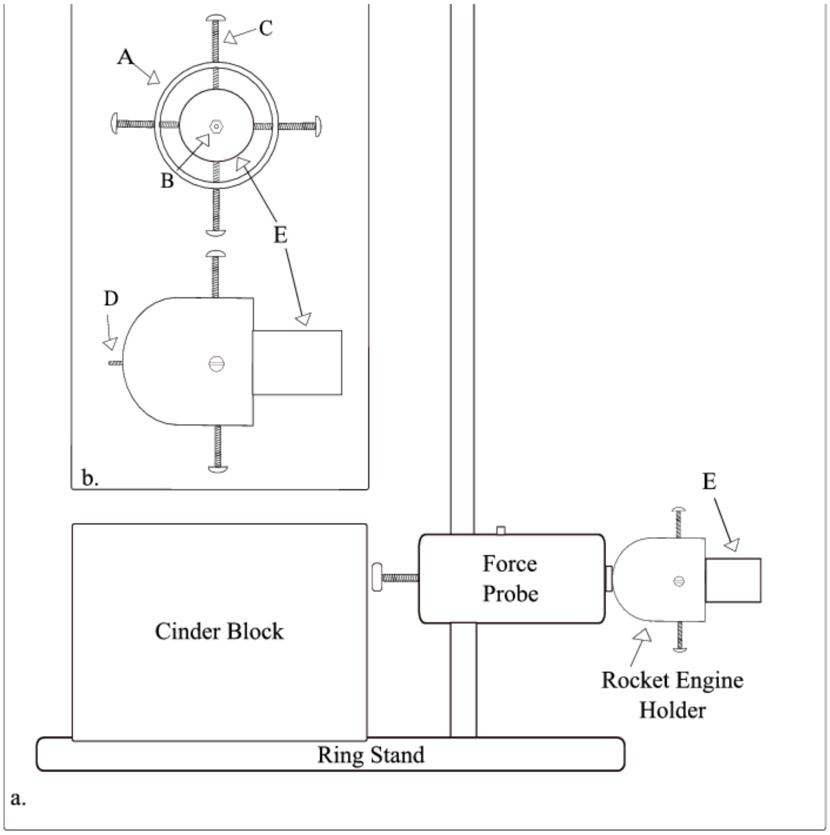


Figure 1: a) Side view of experimental setup. b) Side and front views of the rocket engine holder. A- Schedule 40 PVC end cap, B- 2-56 threaded nut, C- 2 inch ¼-20 bolts to hold engine, D- 2-56 threaded rod to mount to force probe, E- Rocket Engine

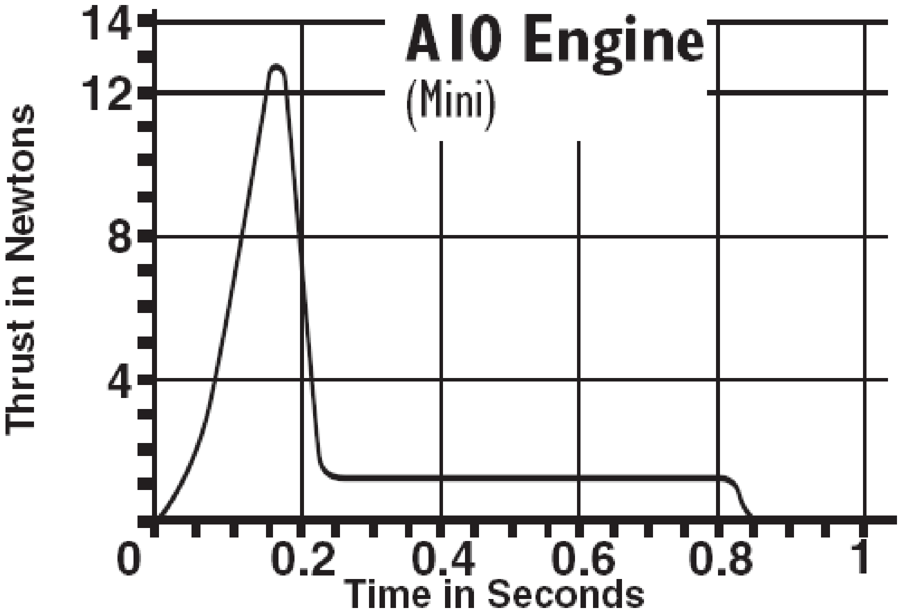


Figure 2: Estes rocket engine thrust curve for an A10 engine from Estes Catalog 2007.

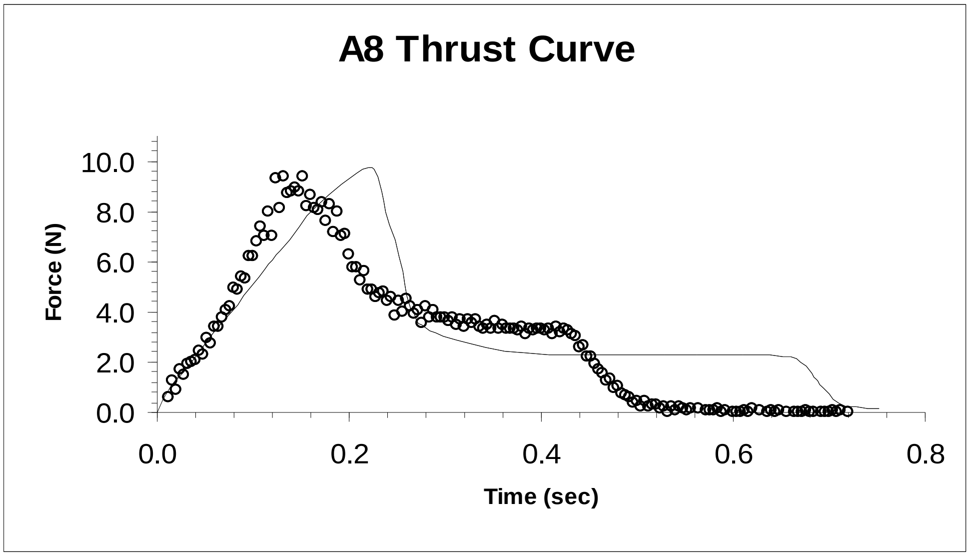


Figure 3: Force vs Time data from an A8 rocket engine. The solid line is the data from the A8 Estes Catalog Time/Thrust Curve and the data points were taken at 250 samples per second.

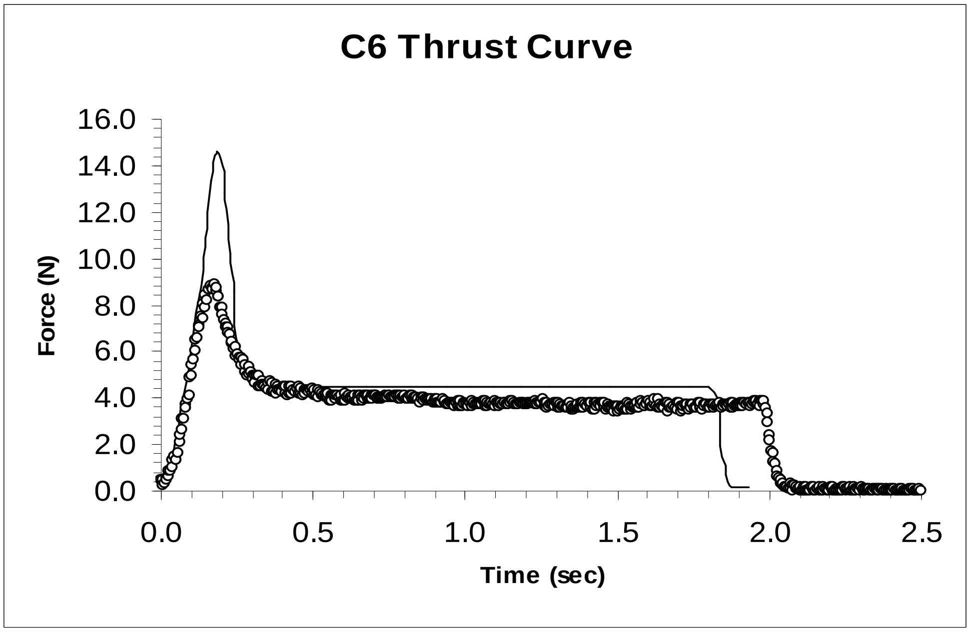


Figure 4: Force vs. Time data from a C6 rocket engine. The solid line is the data from the C6 Estes Catalog Time/Thrust Curve and the data points were taken at 250 samples per second.

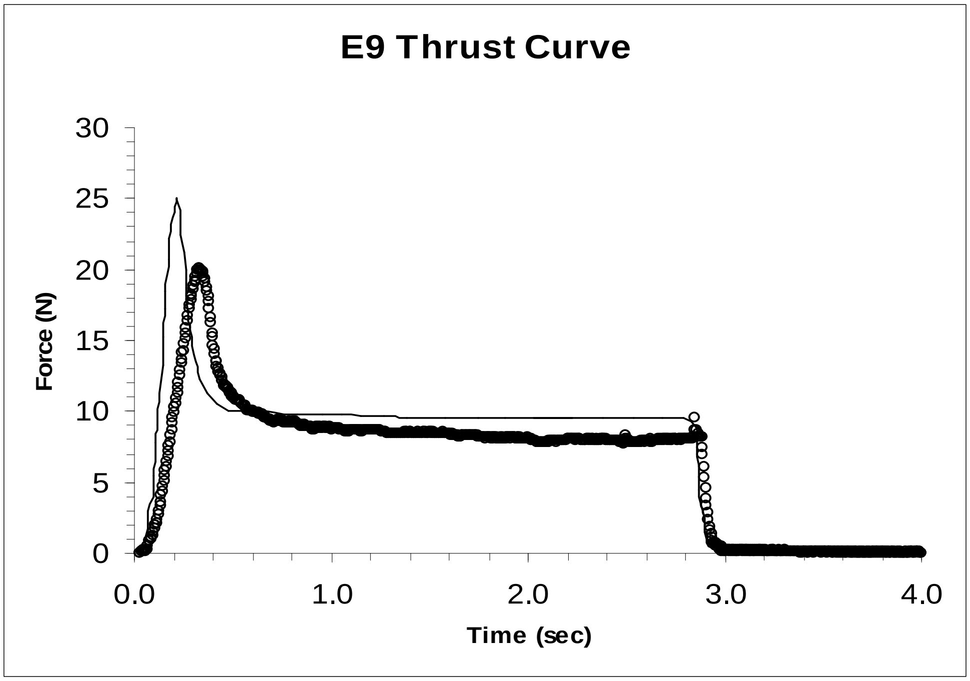


Figure 5: Force vs. Time data from an E9 rocket engine. The solid line is the data from the E9 Estes Catalog Time/Thrust Curve and the data points were taken at 250 samples per second.

Appendix B:

Rocket Lab Student Manual

Student Manual
Thrust vs. Time: A Rocket Lab Using Estes Model Rocket Engines

By: Kim Mason

Equipment:

1. Vernier's LabPro or LabQuest
2. Vernier's Dual Range Force Sensor
3. LoggerPro
4. Hanging Masses to calibrate force sensor
5. Estes Model Rocket Engines
6. Estes Engine Launch Controller
7. Ring Stand
8. Cement blocks
9. Level
10. Model Rocket Engine Holder
    - schedule 40 PVC end cap
    - four 2-inch ¼ -20 bolts
    - one 2-56 threaded rod and nut

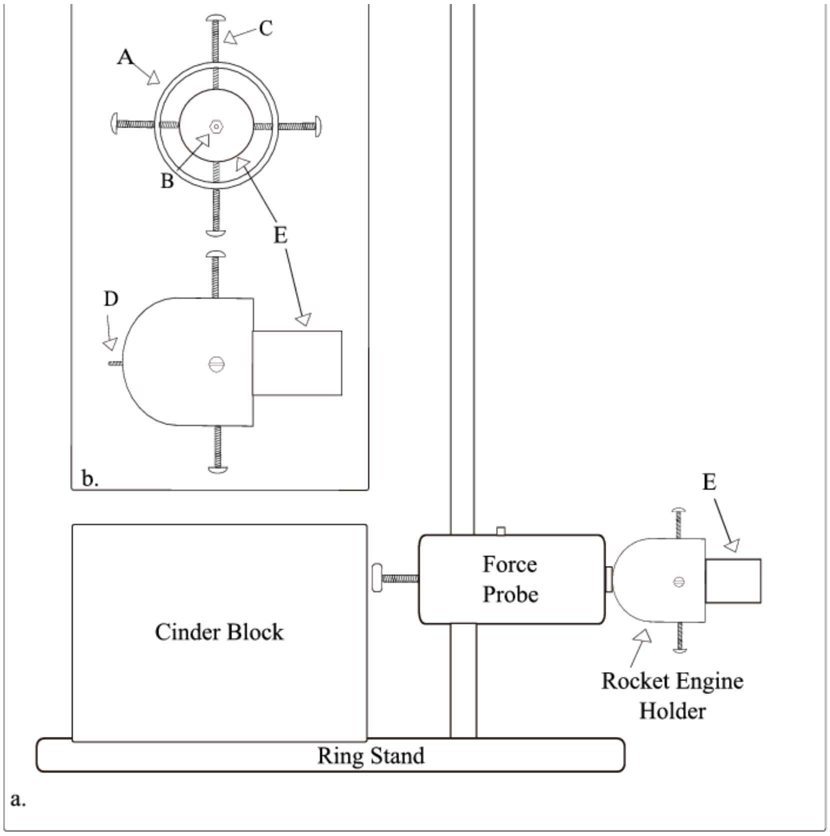


Figure 1: a) Side view of experimental setup. b) Side and front views of the rocket engine holder. A- Schedule 40 PVC end cap, B- 2-56 threaded nut, C- 2 inch ¼-20 bolts to hold engine, D- 2-56 threaded rod to mount to force probe, E- Rocket Engine

Purpose:

The purpose of this lab activity is to explore Newton's Third Law and the Impulse-Momentum Theorem. During this activity you will be able to observe an actual thrust curve of a model rocket engine and use the integral of that curve to find the impulse to calculate different aspects of a theoretical rocket's flight.

Procedures:

In this lab activity you will be working in groups to use the setup shown above in Figure 1. You will use the engine your group is assigned to measure the thrust curve. When the setup is ready to be used, **make sure you are wearing safety glasses**, and then move outside to level ground and place the setup on concrete with the engine facing away from people and other objects. The setup should be leveled to ensure only horizontal forces will be measured.

After the engine ignition there will be an initial max thrust followed by a lower constant thrust. Then tracking smoke will be emitted during a time in which there is no measurable thrust. The end of the thrust cycle is signaled by a sudden burst, which in a normal launch condition would eject the parachute from the rocket. This force pattern will be shown in the data collected using the force probe. The data collected from the thrust of the engine can be saved and another group's rocket engine can be ignited. Caution: the removing of the already ignited rocket engine should be done carefully, since it is very hot.

Using the thrust curve in LoggerPro, impulse and max thrust can be calculated. Since the thrust is made up of a triangle and a rectangle, the impulse can be calculated from the area under the curve. Using this impulse you have calculated, make predictions about what an actual flight using your engine would be like. You will be provided with the mass of the rocket to allow you to do your calculations.

In the actual flight more equipment is needed. Along with Estes Model Rocket Engines and the Estes Engine Launch Controller used in the contained launch, you will also need a model rocket and a launch pad. If you are to compare your data with other groups you will not need this equipment.

Optional Actual Launch:

The time between the launch and the end of the thrust, the time between the end of thrust and the parachute opening, and the time it takes for the rocket to come back down should be recorded to calculate the flight characteristics and compare to theoretical data.

Questions:

Was the flight different than you expected?
Why was the path different from what you expected?
Were there any other forces involved that we neglected? (drag, change in mass, wind)

Report:

In your lab report you will talk about the procedures used in the experiment, your experimental data, your flight predictions, possible sources of error, and answer the questions above.

Appendix C:
BalloonSat Teacher's Manual

Teacher's Manual
BalloonSat and LabPro: High Altitude Balloon Experiments for Arkansas Science Students

By: Kim Mason

Purpose:

- ✧ For students to learn to explore earth and space sciences

Objectives:

- ✧ The students will successfully assist in a high altitude balloon launch, on which they have a payload that contains instruments of their choosing. The data collected during the launch will be used to answer a question they had concerning atmospheric science.

Grade Level:

- ✧ 7-12 recommended (This activity can be adapted to fit many age groups.)

Frameworks:

- ✧ Frameworks (Arkansas):
  - ▪ Physical Science: NS.9.PS.4, NS.10.PS.2, NS.10.PS.6, NS.12.PS.1, NS.12.PS.2, NS.12.PS.3, NS.13.PS.4, NS.13.PS.5
  - ▪ Physics: NS.16.P.3, NS.17.P.2, NS.19.P.1 NS.19.P.2, NS.18.P.2
- ✧ Possible additional frameworks (Arkansas):
  - ▪ Physical Science:P.6.PS.3, P.6.PS.5
  - ▪ Physics: MF.1.P.4, EM.13.P.1

Materials:

1. Vernier's LabPro or LabQuest
2. Vernier Sensors:
    - o Stainless Steel Temperature Probe
    - o Gas Pressure Sensor
    - o Relative Humidity Sensor
    - o Magnetic Field Sensor
    - o Light Sensor
    - o UVA Sensor
    - o UVB Sensor
3. LoggerPro

4. 4 AA batteries
5. Materials to make a payload (also part of the student construction process)

Introduction:

As an important part of the Arkansas Academy for Space Science Education, the BalloonSat program is used by educators in Arkansas, and supported by the Arkansas Space Grant Consortium. BalloonSat helps students to be creatively and actively involved in learning science by allowing them to participate in high altitude balloon launches. Students are encouraged to build payloads that contain experiments that answer questions they have about Earth's near space environment. Since 2006 Arkansas students have studied a variety of characteristics of the Earth, including the change in temperature, pressure, humidity, UVA and UVB rays, and light intensity. Experiments involving these characteristics have been possible by using HOBO sensors and Vernier's LabPro along with its sensors. In this lab manual, information on Vernier's equipment will be given, along with how to implement the BalloonSat program in the classroom. In order to make this program accessible, the sensors explained in this lab have been tested for performance and accuracy at the extreme environment at the edge of the atmosphere. (This data is available for classroom use or for comparison to student data.)

Procedure:

Implementing the BalloonSat program in the classroom is more of an open-ended hands-on experience, hence the procedures that should be followed can vary, but a outline of what should be done with students is listed below.

Teachers should ask…

- What do students already know about the atmosphere?
- What do they want to learn about that is measurable with BalloonSat?
- What do students have questions about?

Then have students…

- research the topic they are interested in
- formulate questions relevant to them
- explain why this is an important experiment
- learn about who did the experiment originally and how and why they did it
- write a research proposal (This includes the students specifying what they will do, and why they want to do the experiment.)
- build payload*
- carry out the experiment
- summarize and present their work

*Payload specifications required by BalloonSat program: payloads are usually about 6"x6"x6" and are usually about 500grams. If more than one group shares a payload the mass and size limits can be exceeded. This will also allow multiple groups to share the same LabPro and sensors. (Up to 4 sensors may be attached to a LabPro[1])

Assessment:

There are many possibilities for student assessment in this project. Have students write a summary and do a presentation to another class of possibly younger students who have not participated in BalloonSat. Then these younger students will also benefit from the information and get excited about participating in the future.

How to get involved:

BalloonSat Website:
http://www.arkballoons.com/

Arkansas Academy of Space Science Education Outreach Director
Ed Roberts
Pottsville High School
e-mail: ed.roberts@pottsville.k12.ar.us

Arkansas Academy of Space Science Education Research Director
Dr. James Kennon
ASU Jonesboro
e-mail: jkennon@astate.edu

Arkansas Space Grant Consortium Outreach Coordinator
Ms. Sue Hawkins
ASGC Office, Phone (501) 569-8213
Minigrant application
http://asgc.ualr.edu/wp-content/uploads/miniapp.xls
Minigrant Guidelines
http://asgc.ualr.edu/wp-content/uploads/newk-12guidelines.doc

Conclusion:

Even if this activity is done by a few students outside of class time, it is worth the effort. The opportunity for students to work on a personalized hands-on project that teaches them the nature of science and integrates other curriculum cannot be taken for granted. Minigrants for equipment and supplies are available through the Arkansas Space Grant Consortium. Experimental data taken from previous BalloonSat flights is shown below to give you an idea of what data should look like using these sensors.

Acknowlegements:

This research was made possible thanks to grants from

- The Arkansas Science and Technology Authority
- The Undergraduate Research Committee at the University of Central Arkansas
- Arkansas Space Grant Consortium

Notes:

[1] LabPro has a maximum number of data points that can be collected. The maximum frequency of data collected from each sensor depends on the number of sensors and the

length of time data is to be collected. For further information on settings for remote data collection see Vernier LabPro's Manual.

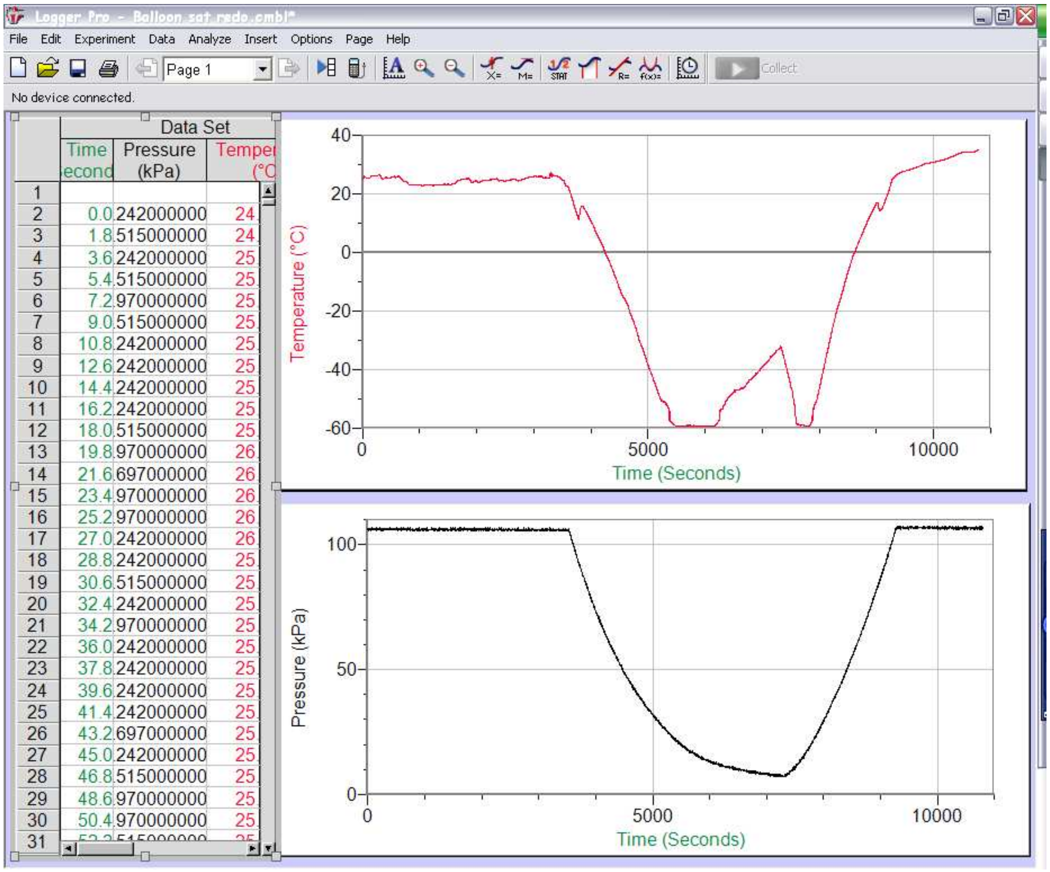
REFERENCES
Arkansas Frameworks
http://www.arkansased.org/teachers/pdf/physical_sci_9-12_050508.pdf
http://www.arkansased.org/teachers/pdf/physics_9-12_2005_060608.pdf
Vernier
http://www.vernier.com/
http://www2.vernier.com/labpro/labpro_user_manual.pdf

Our Payload:

Our payload consisted of a black travel shaving bag which was filled with polyfoam cut to fit around the LabPro and its sensors. During the flight the parts of the sensors that actually do the sensing are sticking out of the payload a short distance to be in direct contact with the air.

Experimental Data:

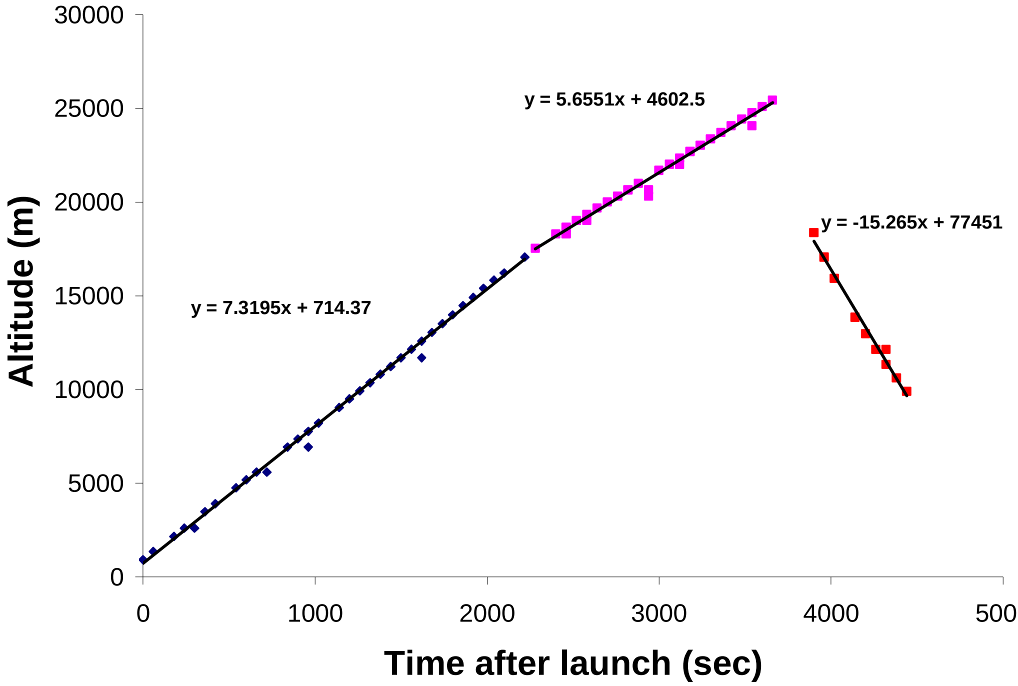
Flight 1 Data: Sept 29, 2007 flight containing a temperature sensor and a pressure sensor.



No device connected.

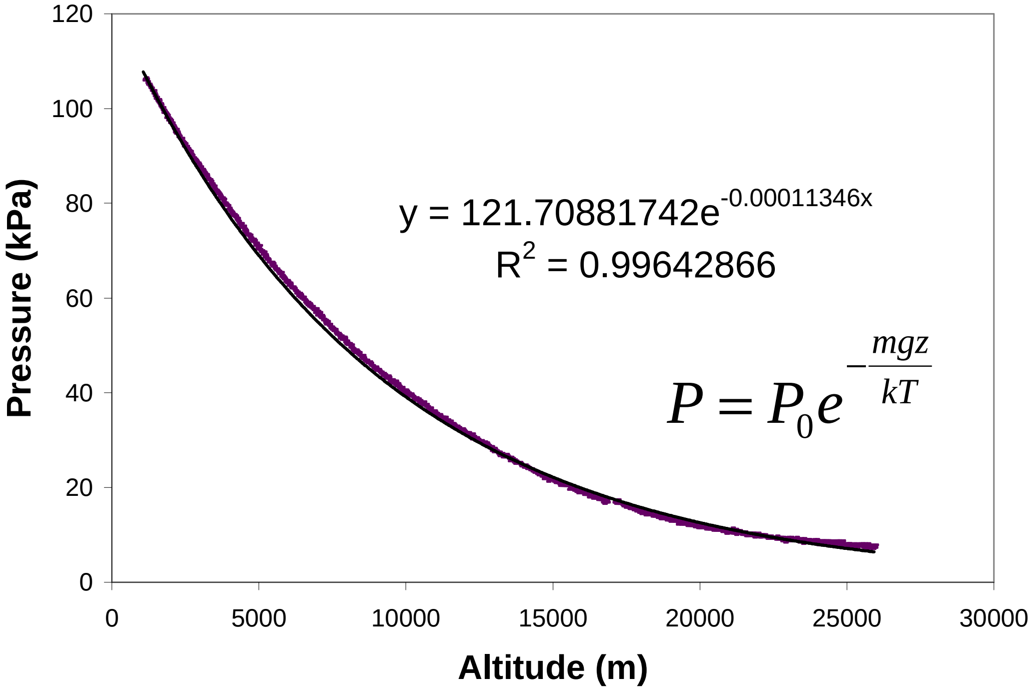
	Data Set		
	Time econd	Pressure (kPa)	Temper (°C
1			
2	0.0	242000000	24
3	1.8	515000000	24
4	3.6	242000000	25
5	5.4	515000000	25
6	7.2	970000000	25
7	9.0	515000000	25
8	10.8	242000000	25
9	12.6	242000000	25
10	14.4	242000000	25
11	16.2	242000000	25
12	18.0	515000000	25
13	19.8	970000000	26
14	21.6	697000000	26
15	23.4	970000000	26
16	25.2	970000000	26
17	27.0	242000000	26
18	28.8	242000000	25
19	30.6	515000000	25
20	32.4	242000000	25
21	34.2	970000000	25
22	36.0	242000000	25
23	37.8	242000000	25
24	39.6	242000000	25
25	41.4	242000000	25
26	43.2	697000000	25
27	45.0	242000000	25
28	46.8	515000000	25
29	48.6	970000000	25
30	50.4	970000000	25
31			

Figure 1: Original remote data uploaded from the LabPro unit into LoggerPro.



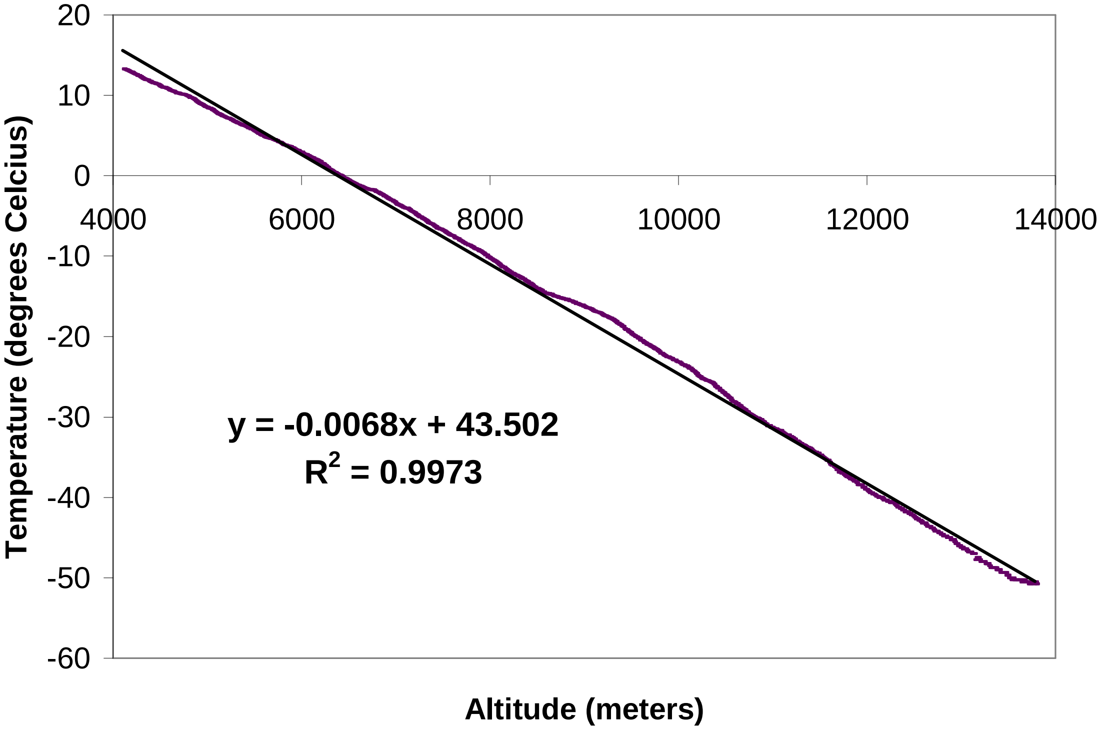
Flight 1 Data

Figure 2: Altitude data from Ed Robert's ham radio payload fit to two linear balloon ascension rates and one linear balloon descension. The slopes of the lines show the velocity of the balloon and its payloads in meters per second.



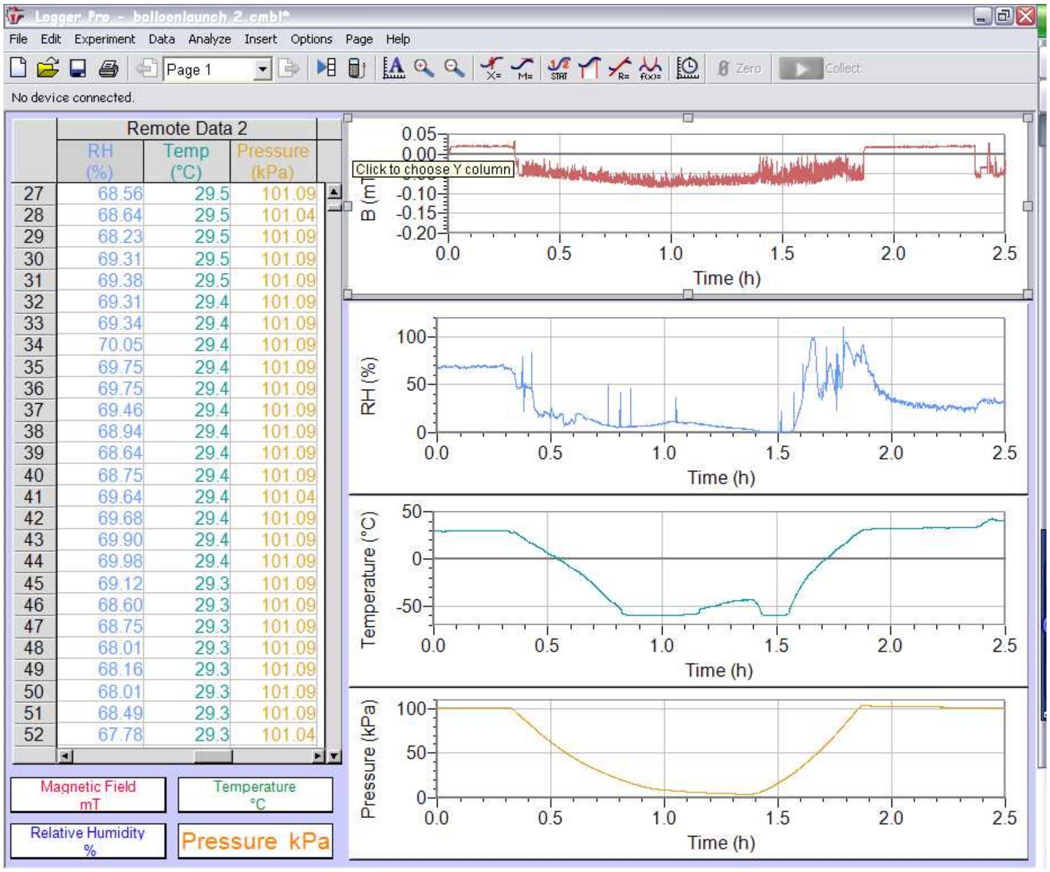
Flight 1 Data

Figure 3: Pressure vs. Altitude data plotted in Excel. The Pressure vs. Time data from LoggerPro was converted into Pressure v Altitude data using the Altitude vs. Time fits shown above. This was fit to an exponential function because as altitude increases the pressure exponentially decreases.[1]



Flight 1 Data
Figure 4: Temperature v Altitude data plotted in Excel. This was fit to a linear function because as altitude increases temperature has been observed to decrease at -9.8 degrees C/km in a dry atmosphere. Since we do not have 0% humidity, our value of -6.8 degrees C/km is comparable to the US Standard Atmosphere (1976) from CRC Handbook of Chemistry and Physics for the US wet lapse rate of -6.5 °C/km.

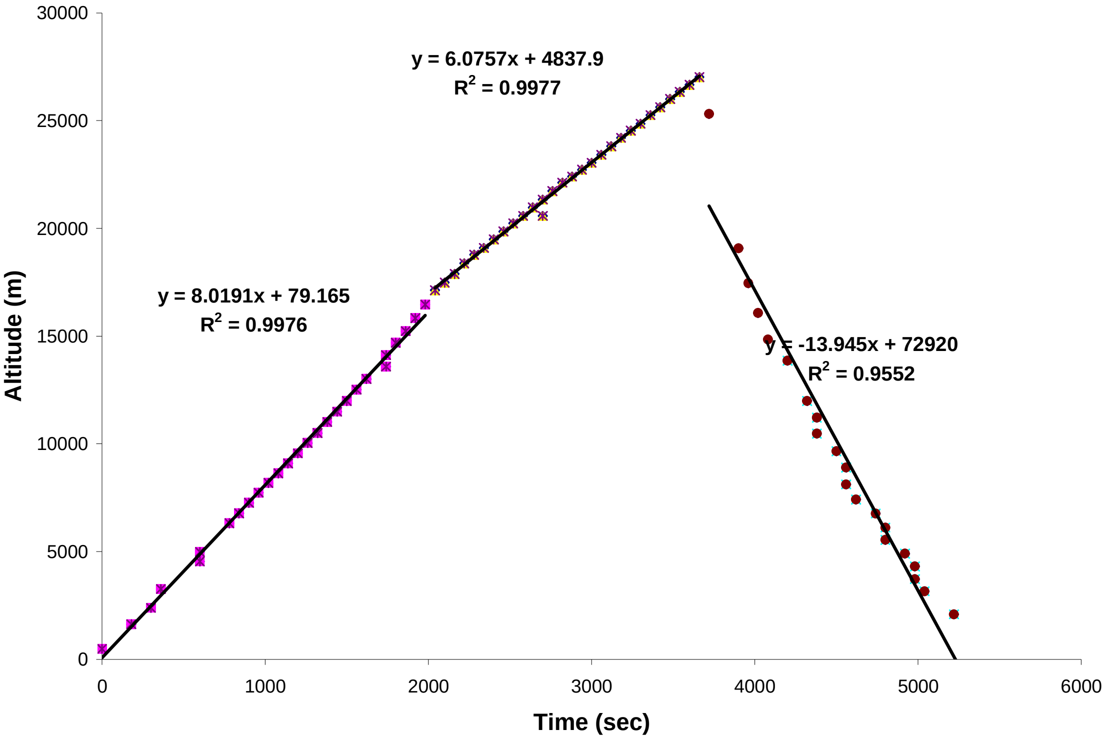
Flight 2: July 12, 2008, containing a temperature probe, a pressure probe, a relative humidity sensor, and a magnetic field sensor.



No device connected.

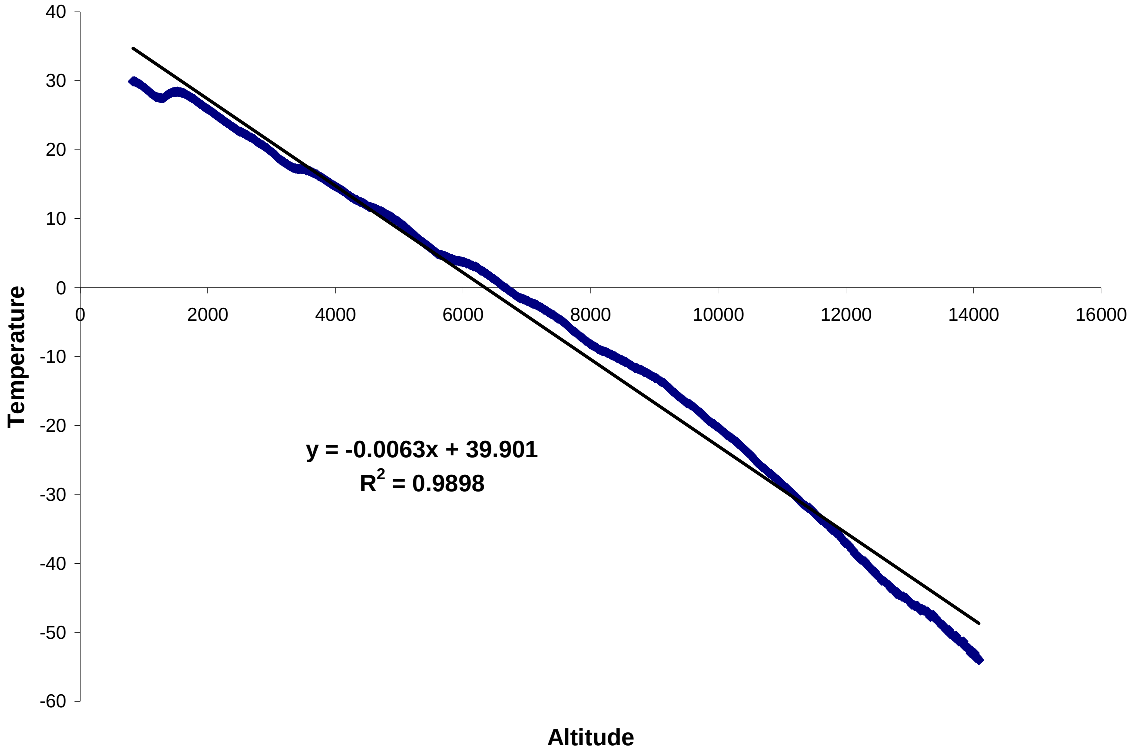
	Remote Data 2		
	RH (%)	Temp (°C)	Pressure (kPa)
27	68.56	29.5	101.09
28	68.64	29.5	101.04
29	68.23	29.5	101.09
30	69.31	29.5	101.09
31	69.38	29.5	101.09
32	69.31	29.4	101.09
33	69.34	29.4	101.09
34	70.05	29.4	101.09
35	69.75	29.4	101.09
36	69.75	29.4	101.09
37	69.46	29.4	101.09
38	68.94	29.4	101.09
39	68.64	29.4	101.09
40	68.75	29.4	101.09
41	69.64	29.4	101.04
42	69.68	29.4	101.09
43	69.90	29.4	101.09
44	69.98	29.4	101.09
45	69.12	29.3	101.09
46	68.60	29.3	101.09
47	68.75	29.3	101.09
48	68.01	29.3	101.09
49	68.16	29.3	101.09
50	68.01	29.3	101.09
51	68.49	29.3	101.09
52	67.78	29.3	101.04

Figure 5: Original remote data uploaded from the LabPro unit into LoggerPro.



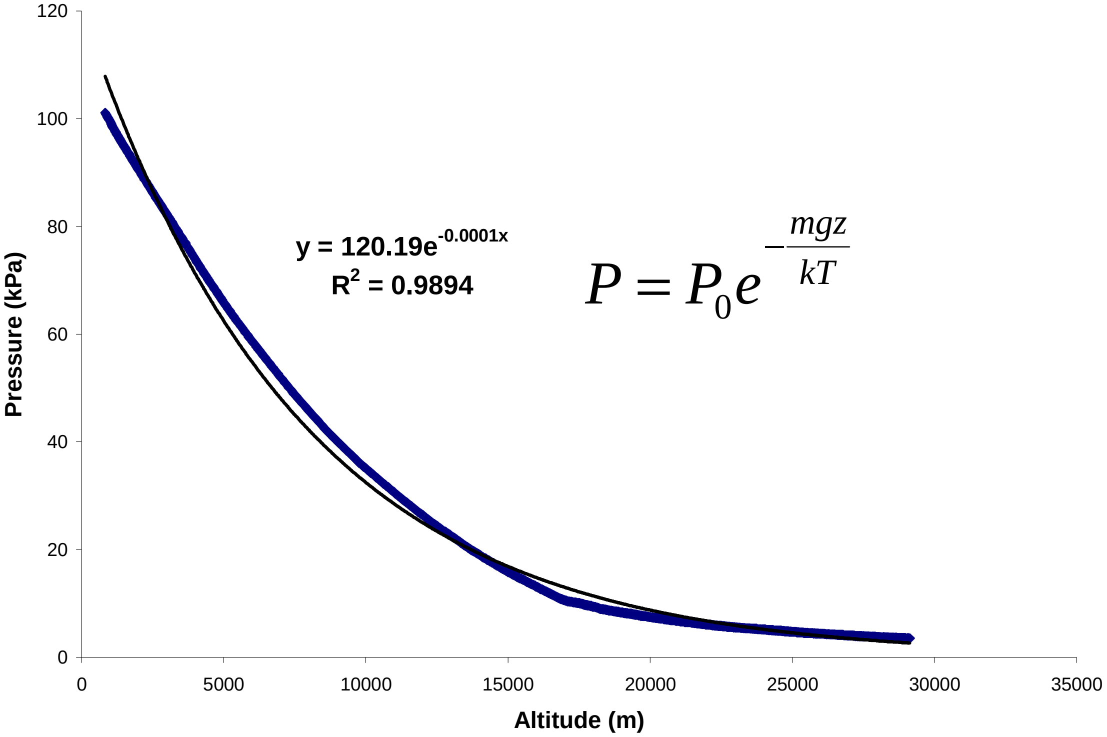
Flight 2 Data

Figure 6: Altitude data from Ed Robert's ham radio payload fit to 2 linear balloon ascension rates and 1 linear balloon descension. Again slopes are equal to the velocity of the balloon and payloads in meters per second.



Flight 2 Data

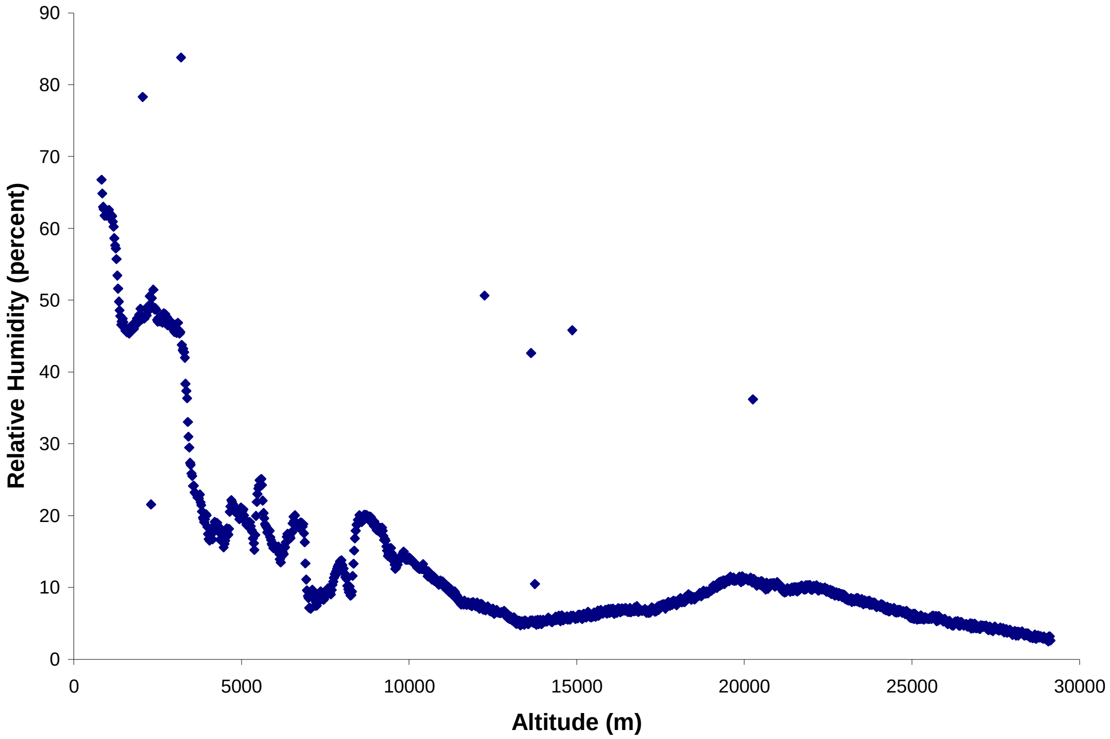
Figure 7: Temperature v Altitude data plotted in Excel. This was fit to a linear function because as altitude increases temperature has been observed to decrease at -9.8 degrees C/km in a dry atmosphere. Again compared to the US Standard Atmosphere (1976) from CRC Handbook of Chemistry and Physics for the US wet lapse rate of -6.5 °C/km, our value is much more acceptable.



$$P = P_0 e^{-\frac{mgz}{kT}}$$

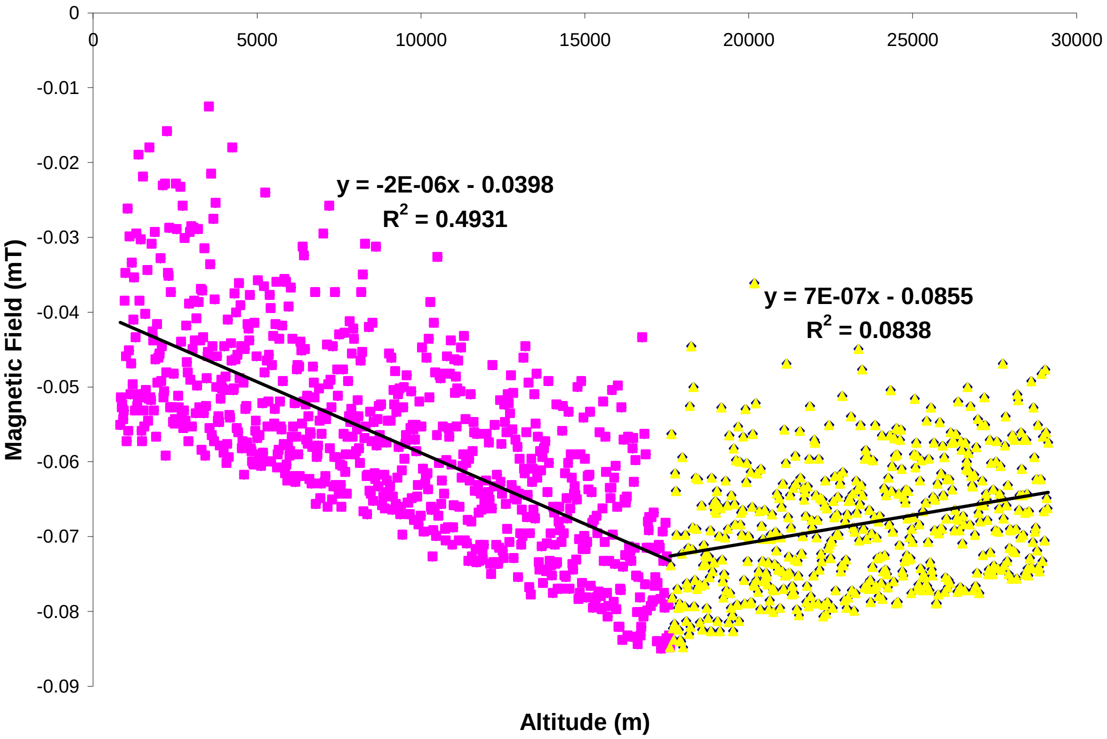
Flight 2 Data

Figure 8: Pressure v Altitude data plotted in Excel. This was fit to an exponential function because as altitude increases, the pressure exponentially decreases.[1]



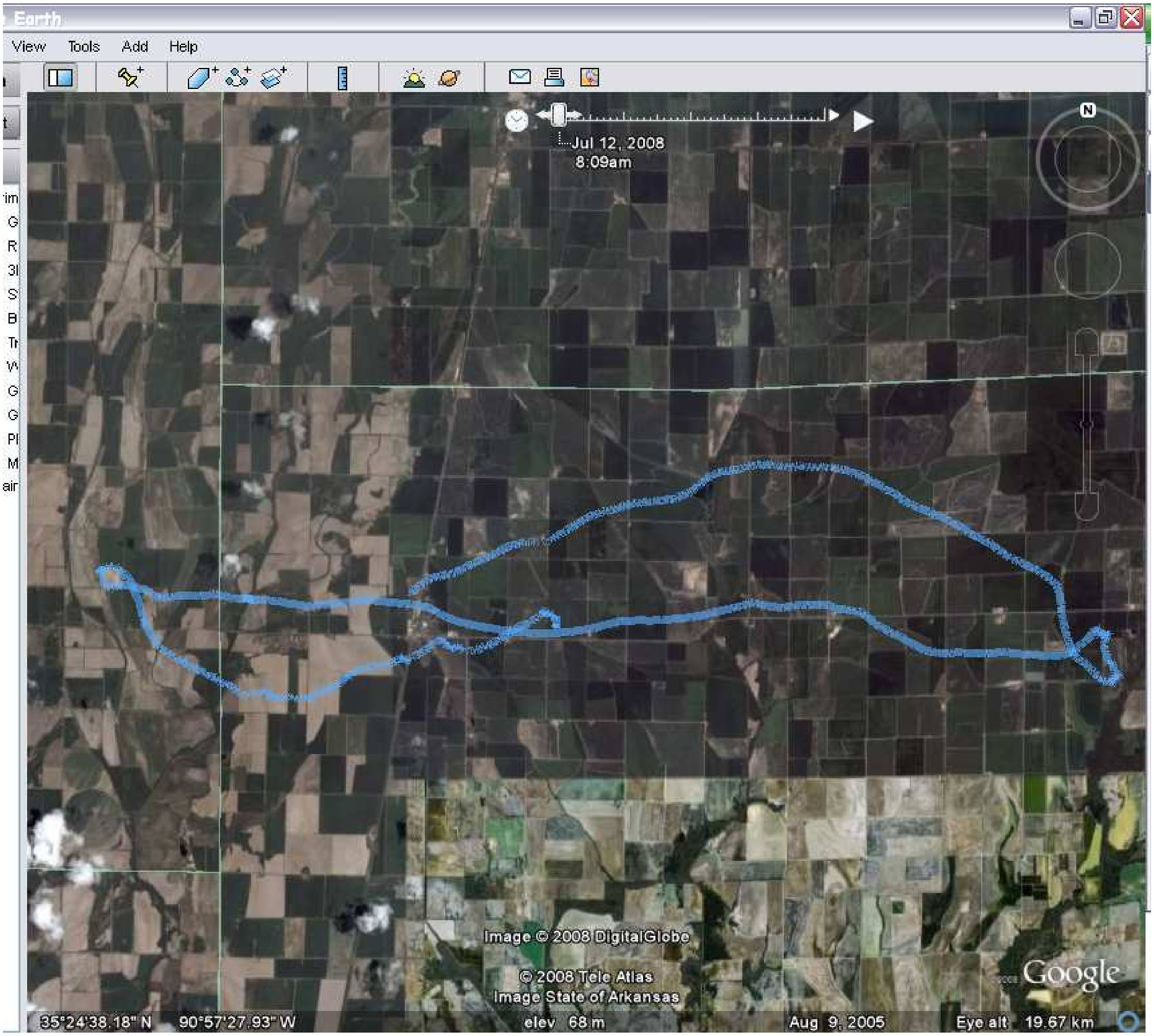
Flight 2 Data

Figure 9: Humidity v Altitude data plotted in Excel. The seemingly random data at the beginning of the graph is thought to be due to cloud cover that was present on the day of the launch. The Relative Humidity sensor is also supposed to be used at a constant temperature and in this experiment that is not possible. Also its sensing capabilities are lacking in this experiment since it has a response time of about 1 minute. In our experience with this sensor, we would not recommend it for the use in the BalloonSat program without a careful consideration of its limitations.



Flight 2 Data

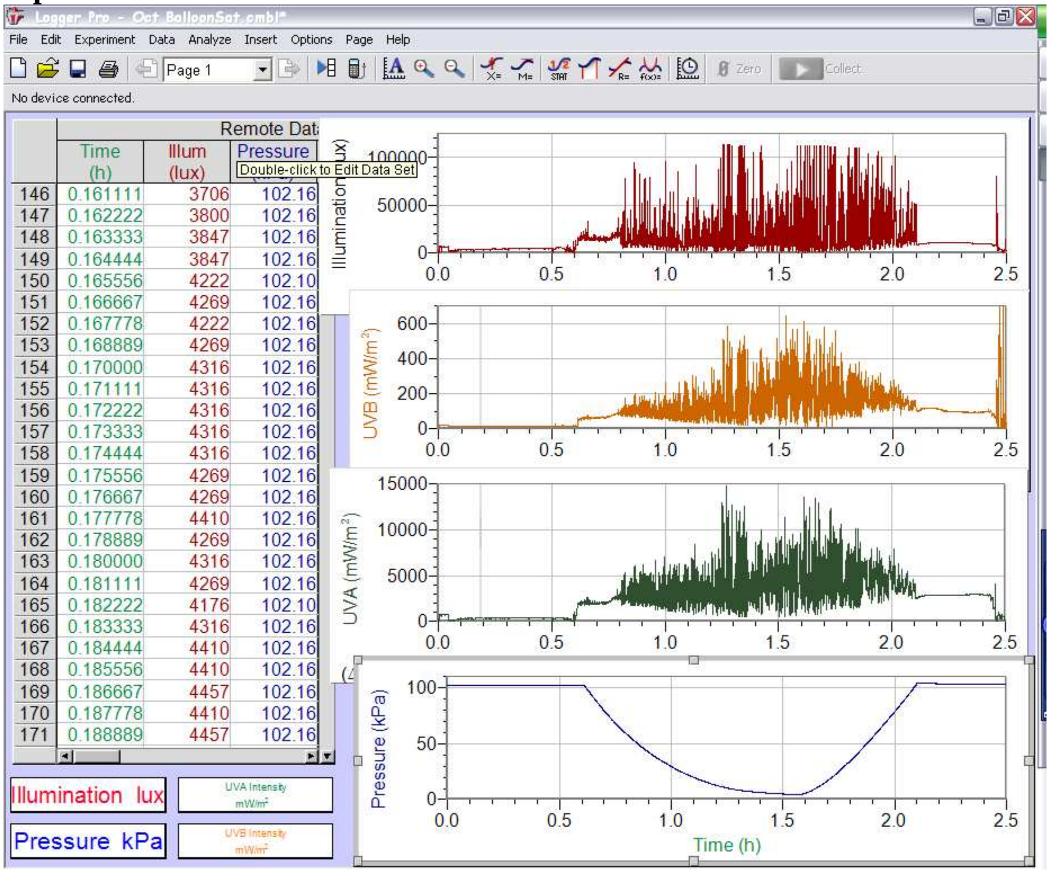
Figure 10: Magnetic Field v Altitude data plotted in Excel. This data is not clean due to the erratic motion of the payloads. The design of the Magnetic Field Sensor allows it only to take readings in a specific direction. Due to this setup, the movement of the payload during flight makes this sensor's readings in the BalloonSat program unbeneficial. In our experience with this sensor, we would not recommend it for the use in the BalloonSat program without a careful consideration of its limitations.



Flight 2 Data

Figure 11: Google Earth screenshot using GPS data from Garmin eTrex Vista Cx. The original goal was to be able to record altitude, but the unit only recorded altitude up to 30,000 ft. The longitude and latitude data from the flight were obtained using this sensor and shown above.

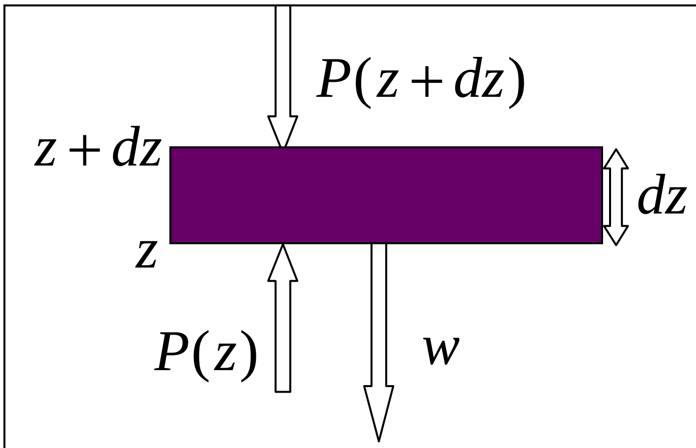
Flight 3: Oct 4, 2008 flight containing a light sensor, a UVA sensor, a UVB sensor, and a pressure sensor.



Remote Data			
	Time (h)	Illum (lux)	Pressure
146	0.161111	3706	102.16
147	0.162222	3800	102.16
148	0.163333	3847	102.16
149	0.164444	3847	102.16
150	0.165556	4222	102.10
151	0.166667	4269	102.16
152	0.167778	4222	102.16
153	0.168889	4269	102.16
154	0.170000	4316	102.16
155	0.171111	4316	102.16
156	0.172222	4316	102.16
157	0.173333	4316	102.16
158	0.174444	4316	102.16
159	0.175556	4269	102.16
160	0.176667	4269	102.16
161	0.177778	4410	102.16
162	0.178889	4269	102.16
163	0.180000	4316	102.16
164	0.181111	4269	102.16
165	0.182222	4176	102.10
166	0.183333	4316	102.16
167	0.184444	4410	102.16
168	0.185556	4410	102.16
169	0.186667	4457	102.16
170	0.187778	4410	102.16
171	0.188889	4457	102.16

Figure 12: Original remote data uploaded from the LabPro unit into LoggerPro. In this flight the Light sensor and UVA and UVB sensors act similarly to the Magnetic Field sensor since they are taking readings solely in one direction. Because of the motion of the payload and the shadow of the balloon and other payloads, this motion causes the data to look erratic. In our experience with the various light sensors, we would not recommend them for the use in the BalloonSat program without a careful consideration of their limitations.

[1] The following is the theory behind the fit of the pressure versus time graph in Figures 3 and 8. To find the theoretical values for our Pressure vs. Altitude data we treated atmosphere as a slab of air:



Using Newton's Second Law

$$AP(z) - AP(z+dz) - \rho A dz g = 0$$

$$\frac{dP}{dz} = -\rho g$$

$$\rho = \frac{mP}{kT}$$

$$\frac{dP}{dz} = -\frac{mg}{kT} P$$

$$\int_{p_0}^{P} \frac{dP}{P} = -\frac{mg}{kT} \int_0^z dz$$

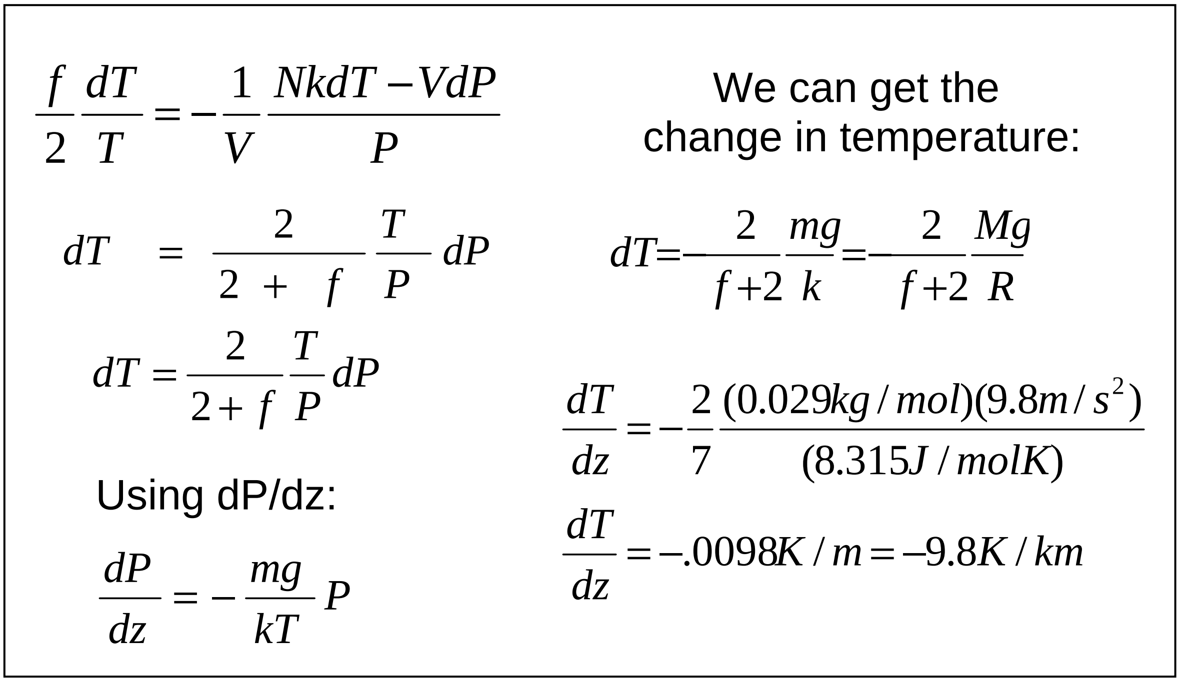
$$\ln\left(\frac{P}{P_0}\right) = -\frac{mgz}{kT}$$

$$\frac{P}{P_0} = e^{-\frac{mgz}{kT}}$$

$$P = P_0 e^{-\frac{mgz}{kT}}$$

$$P = P_0 e^{-\frac{mgz}{kT}} = P_0 e^{-\frac{(.029 kg/mol)(9.8 m/s^2) z}{(8.315 J/molK)(250 K)}} = P_0 e^{-.0001z}$$

[2] To find the theoretical values for the temperature vs altitude data, we used the Equipartition theorem, the First Law of Thermodynamics, and the differential of the Ideal Gas Law:



$$\frac{f}{2}\frac{dT}{T} = -\frac{1}{V}\frac{NkdT - VdP}{P}$$

$$dT = \frac{2}{2 + f}\frac{T}{P}dP$$

$$dT = \frac{2}{2+f}\frac{T}{P}dP$$

Using dP/dz:

$$\frac{dP}{dz} = -\frac{mg}{kT}P$$

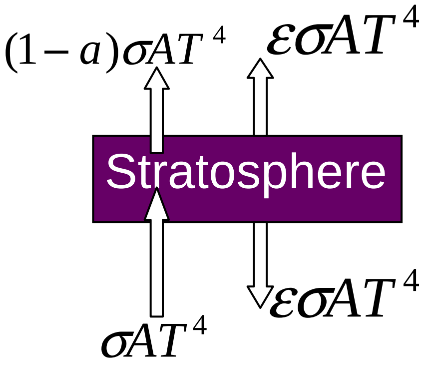
We can get the change in temperature:

$$dT = -\frac{2}{f+2}\frac{mg}{k} = -\frac{2}{f+2}\frac{Mg}{R}$$

$$\frac{dT}{dz} = -\frac{2}{7}\frac{(0.029 kg/mol)(9.8 m/s^2)}{(8.315 J/molK)}$$

$$\frac{dT}{dz} = -.0098 K/m = -9.8 K/km$$

To calculate the theoretical temperature for the tropopause, we must use the average temperature in the troposphere and Stefan's Law:



$(1-a)\sigma AT^4$ $\varepsilon\sigma AT^4$

Stratosphere

σAT^4 $\varepsilon\sigma AT^4$

Stefan's Law

$$P = A\sigma T^4$$

$$P_{in} = P_{out}$$

$$a\,\sigma AT_t^{\;4} = 2\varepsilon\sigma AT_s^{\;4}$$

$$T_s = \left(\frac{a}{2\varepsilon}\right)^{\frac{1}{4}} T_t$$

Since the absorptivity and emissivity of the stratosphere are equal:

$$= \left(\frac{1}{2}\right)^{\frac{1}{4}} \left(-21.4^{\mathrm{O}}C\right)$$

$$T_s = -61.1^{\mathrm{O}}C$$

Where *a* is absorptivity, ε is emissivity, *T* is temperature, *A* is surface area, and σ is Stefan's constant.

Appendix D:

BalloonSat Student Manual

Student Manual
BalloonSat and LabPro: High Altitude Balloon Experiments for Arkansas Science Students

by: Kim Mason

The students in this photo are helping to steady the latex weather balloon while it is being filled with helium.

Equipment:

1. Vernier's LabPro or LabQuest
2. Vernier Sensors:
    - Stainless Steel Temperature Probe
    - Gas Pressure Sensor
    - Relative Humidity Sensor
    - Magnetic Field Sensor
    - Light Sensor
    - UVA Sensor
    - UVB Sensor
3. LoggerPro
4. 4 AA batteries
5. Materials to make a payload (also part of the student construction process)

Purpose:

This experiment is meant to introduce you to atmospheric characteristics and help you further understand concepts related to Earth's atmosphere.

Procedures:

1. Research the atmospheric behaviors to be studied
2. Making a hypothesis (This is an educated and testable statement about the subject, which will be either disproved or supported by experimentation.)
3. Build a payload to hold equipment needed for the experiment*
4. Carrying out an experiment to test your hypothesis
5. Data analysis (Part of this is comparing data to theoretical and/or previous results.)
6. Drawing Conclusions (This includes making thoughtful conclusions about why your results do not match up with the theoretical data.)

**Payload Specifications:*

- ✧ Weight limit ~500g per payload
- ✧ Dimensions usually ~6x6x6", but not required
- ✧ Cannot contain hazardous chemicals or anything that could possibly break a load bearing line
- ✧ These payloads are usually made out of foam board, which can be purchased in the craft section of many local stores.

Questions to consider:
What impact do studies and discoveries concerning Earth's atmosphere have on us?
How does this type of research help us to further science and technology?

Sensors previously tested:
Temperature
Pressure
Magnetic Field
Relative Humidity
Light Intensity
UVA
UVB

Sensors that cannot be used remotely with LoggerPro:
Radiation Sensor
O2 Sensor
CO2 Sensor

Helpful Websites:

- ✧ Earth's Atmosphere
  http://www.nasa.gov/audience/forstudents/9-12/features/912_liftoff_atm.html
- ✧ UV rays
  http://www.biospherical.com/nsf/student/page3.html
- ✧ Magnetic Field with Altitude Calculator
  http://www.ngdc.noaa.gov/geomag/magfield.shtml
- ✧ BalloonSat Website
  http://www.arkballoons.com/