Balloon Experiment Manual table of contents

Introduction

So you want to you want to do balloon experiments with your students? Good for you. Balloon experiments are fun, interesting and most importantly give students a taste of real-life science. They take data in the field, analyze it, and report their findings (either with a write-up, paper or power point presentation). Because the atmosphere is always different, so too are there results. That's real science. This manual and the accompanying website
http://scipp.ucsc.edu/outreach/balloon/index.html
is designed to help you and your students get started. The experiments contained in this manual have all been tested and work well, but they will be perfected by you and your students as you rewrite them to your liking. When in doubt I put in extra instructions, however I plan to take out many of the instructions before I give them to my students so that they will have to tinker and come up with their own ideas on what is the best way to do some parts of the experiment.

What I suggest: Do each experiment on your own or (better) with a few students, then decide what instructions can be left out (so that the students can do some thinking and figuring), what needs to be added/cut, what new idea you want to input into the experience. The labs are meant to be done somewhat in order. For example because the barometer will be your altimeter for many of the experiments, the first lab has students use the barometer to make a contour map of their neighborhood. This way when the come to the Buoyancy lab or cosmic ray lab, it is like 2nd nature to them on how to get the height of the balloon that corresponds to their data. Also timing is a main source of error (not just for balloon experiments but also for many other high school experiments) so there is a lab in the beginning on getting the error on the stopwatch.

How to determine the altitude of the balloon: This is an essential component to almost every experiment. It is most accurately done using the barometer. For educational purposes (and for the pressure lab) there are also instructions on how to determine the altitude using a range finder and/or the line length with protractor (using right triangle method).

Where to find/purchase materials:
http://scipp.ucsc.edu/outreach/balloon/index.html
This website is a huge resource to you and your students on balloon experiments.

FAA regulations: Also see our website and, of course, the FAA website, but basically you can tether a balloon up to 1,000ft. as long as the string is well marked and the diameter of the balloon is 6ft. or smaller.

Good luck, have fun and contact me (jdann@siprep.org) with your comments, suggestions and questions.

James Dann

Making an Altitude Contour Map of Your Neighborhood

Equipment: Lappro, Ti-83 calculator, Barometer probe, good shoes.

Big Idea: Use the barometer (pressure meter) as an altimeter (altitude meter) in order to make a contour map of a San Francisco neighborhood or the area around your house. Your map will contain street names and contour lines that specify height readings. Note that altitude is the height above sea level.

Procedure:

Your teacher will handout the equipment and show you how to use the Lappro and Barometer probe (i.e. pressure detector) with your Ti-83 calculator.
Follow the instructions in Appendix III in order to convert the pressure readings into altitude readings.
Take data in your neighborhood at every street intersection.
Make a detailed table of your data that has 3 columns (what street intersection, pressure reading, altitude corresponding to the pressure reading). Take at least 50 different readings.

Example:

Where you are	Pressure (atm)	Altitude (m)
24^{th} and Douglas	0.9839	135m

Sketch out a map (with street names of the area). Put a key at the bottum (so many cm equals so many meters).
Now draw in the altitude contours on your street map of the neighborhood.

Grading: Your grade will be based on how accurate and how extensive your map is. I will check your numbers.

Reaction Time Error with a Stopwatch

Equipment: string, mass, stopwatch, photo-gates, brain

Big Idea: Determine how accurately you can time things with a stopwatch. You will do this by comparing the time taken by you with a stopwatch to that of the photo-gate (which is extremely accurate, so we'll assume it's the 'true time').

Procedure: Make a 1m long pendulum (i.e. tie a meter long string to a mass). The stopwatch time of one period (i.e. how long it takes to go back and forth) of the pendulum will be compared to the time obtained by the photo-gates. The pendulum is used because the period is independent of where you release it (for <u>small</u> amplitudes, say less than 5°)*. Place the photo-gate at the bottom of its swing, making sure it is triggered when the mass swings through. Start the pendulum program found on the desktop of the computer. Think of how you will do the experiment and write down exactly (including who times, releases pendulum, etc.) who does what and how. Justify why.
The pendulum program times one cycle. Run this program while timing periods with the stopwatch. Take the photo-gate numbers as your 'true time'. Pull the pendulum back and record the times from the photo-gate and stopwatch for that cycle. Repeat. Take at least 30 measurements recording your data in a table. Make a data table of times from the photo-gate and stopwatch. Subtract each of these from the 'true time' in order to find the difference. You can do this part really fast, but you need to be focused and organized.

Analyzing the Data:

Make a histogram** of the data with the x-axis being 'true time – stopwatch time'. Choose a bin size for your histogram that gives you about 5 or 6 entries in the peak area.

Do for each

What does your histogram look like? Is it approximately 'Bell shaped'?

Follow the picture below to find the error (the error is the 'half-width, half-height' of your histogram).

Write your results as '$time \pm error$'. Show all your histograms and your work on each.

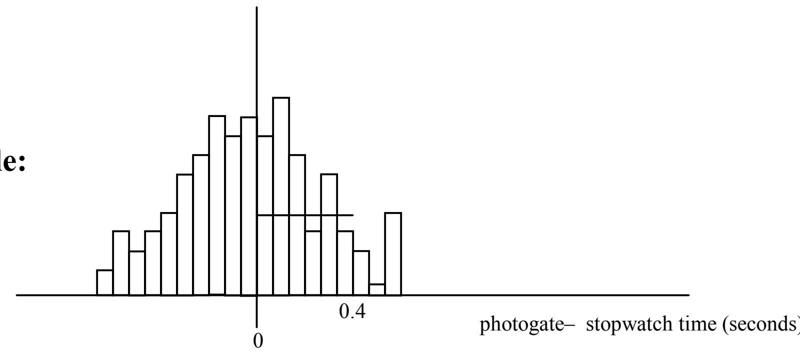
Write a sentence (as if writing to your English professor dad who knows no math or science) what this means.

If time, Repeat for the other two members in your group and compare the reaction time error for the 3 different people. Who's your best timer?

* The difference in time between 3° and 5° is ______________________

** You can do this part by hand or Type your data into Graphical Analysis program (it's similar to Excel), found on the desktop of your computer

Example:



The Bell-shaped curve drawn over the histogram is called a normal curve. When the data has approximately this shape, you can simply take the half-width at the half-height (ok it's actually 0.607 of the height, but 0.5 will do) and this is your error. The length of the error above is your reaction time error. In the example above the error is 0.4 seconds. From now on if you measure, for example, 5 seconds with your stopwatch the true time is 5 ± 0.4 seconds.
Also note that if you try to time something that takes 0.01 seconds, it is useless because your error is 0.4 seconds, so much bigger than the measurement. The stopwatch is just not accurate enough to time this.
Draw the normal curve that 'best fits' your data. That is the curve that has as much overlap as underlap with regards to the bars.

Questions:
Now that you know the accuracy of your stopwatch timing, consider these questions

1. Can you use a stopwatch to measure the time it takes for light to reach your eye from the light bulb?
2. Can you use a stopwatch to measure the time it takes to drive to Tahoe?
3. Can you use a stopwatch to measure the time it takes to drop a rock off the roof of SI? Justify your answer.
4. What would be the shortest amount of time you could measure with the stopwatch and feel confident? Justify.
5. Was it appropriate to use a stopwatch on the football field? Why or why not?

Extensions: Do same experiment by releasing a mass from a certain height and letting it drop through two photo-gates. Questions: what's main source of error in this method?

Extensions: Repeat the experiment for two other lengths (say 0.1m and 0.5m). The different length pendulums will give different periods, thus you can check your accuracy for different time measurements (slow, medium, fast)

Extensions: Determine if there is a shift in the stopwatch times (this is indicated by the center of the curve being different from zero. How would you adjust for this in future measurements by the stopwatch.

Measuring Variations in Temperature and Pressure

Equipment: Labpro, temperature probe, barometer

Big Idea: Study how temperature and pressure vary with altitude. Then compare your graphs of T vs. h and P vs. h to the exponential models

Procedure:

1. Connect a Temperature Probe to Channel 1 of the LabPro and the Barometer (which measures pressure) to channel 2.

2. Go to the Setup Sensor menu. Click on Sensors. Make sure that the correct probes are selected for both channels (i.e. Temperature for channel 1 and Barometer for channel 2, also choose what units you want for pressure).

3. Use the Window menu to setup one tall window for table data, and two horizontal windows for graphs. Setup one graph for pressure and the other for temperature.

3. Use the Experiment Sampling menu to record for 3600 seconds (60 minutes), recording data every 1-second and over sampling 3x.

4. Save this setup as an experiment file.

5. Use the Remote menu to Setup LabPro.

6. Disconnect the LabPro from the computer, attach to the balloon, and when ready to start collecting data, press the Start button. Record the time.

5. Allow the balloon to rise by letting out 100 ft of line. Hold at station several minutes to allow probes to reach equilibrium. For each 100ft. of line record the times and the height (the height is obtained from a range finder or by measuring the angle with a protractor and using right triangle methods). Repeat until the balloon reaches maximum height and then repeat the steps bringing it back down.

6. Reattach the LabPro to the computer. Use the Remote menu to retrieve data from the LabPro.

7. Analyze the data using the Logger Pro software or Export the data as a text (.txt) file that can be imported into Excel for more advanced analysis and graphing.

Analyzing the Data:

Make a graph of T vs. h (temperature vs. height)

Make a graph of P vs. h (pressure vs. height)

Graph the function $T = T_0 (1 - h / h_1)$ for temperature over your graph and comment on how well the two curves agree. This model is valid at low altitudes lower than 11 km.

Graph the function $P = P_o e^{-h/a}$ for Pressure over your graph and comment on how well the two curves agree. This is the adiabatic model for pressure.

Note: h = Height about sea level,

T_0 = 288 K = 518 R absolute (= 15°C = 59°F), &

h_1 = 145 400 ft = 44 330 m

P_0 = 101 325 N/m^2 = 2 116 lb/ft^2 = 14.69 lb/in^2 = 29.92 in of Hg,

a = 8420m

Atmospheric models: see http://scipp.ucsc.edu/outreach/balloon/index.html and click on atmosperic models. There you will find the constant temperature and adiabatic models for temperature and pressure that are listed above as well as the NASA empirical model.

How to graph a function over your data:

See Appendix IV of this manual.

Buoyancy Force

Equipment: One helium filled balloon, a force scale (or probe), a scale to weigh the string, altimeter (range finder or pressure probe to use as altimeter (see Appendix III), or plumb blob and protractor).

The Big Idea:

The buoyancy force equals the weight of fluid (air in this case) displaced by the object (balloon in this case). Using this fact and Newton's 2^{nd} law we can do a number of calculations and then check them with an experiment.

Procedure:

Measuring the net force: Set the labpro* to take data every 5 seconds (and over sample 3) for a period of time of one hour. Synchronize a stopwatch with the start of the Labpro. Take data at your designated heights (for example every 100 ft.) by stopping the balloon for about 2 minutes and noting the start time and stop time at the height using the synchronized stopwatch

*see Appendix II on Labpro

Height: Stand directly under the balloon and use the range finder to get the height. And/or use the barometer to measure the pressure and then use the formula in Appendix III to calculate the height.

Height Estimate: Know how much line is let out, use plumb blob and protractor to write down angle for each stop, in order to estimate height.

Preliminary Calculations (show all work):

1) Calculate the weight of the air displaced.
2) What is F_B?
3) Draw Free-body diagram for the balloon.
4) Fill balloon to 6ft.-7ft. diameter (get the diameter of balloon by measuring diameter of the shadow)
5) Find the mass of the balloon when filled with He. (Using the volume and the known density of He, calculate the mass of the He in the balloon. Then add this to the mass of the balloon.)
6) Using your measurement for the Net force of the balloon and the weight of the balloon, calculate the buoyancy force.

Analyzing the data:

Retrieve the data from the labpro and study the net force vs. time graph.
Use the graph of net force vs. time and the table you made of height vs. time to make a table of <u>net force vs. height.</u>
Use your table of net forced vs. height to make a graph of net force vs. height.
Draw the free-body diagram for the balloon and write Newton's 2nd law
$\sum \vec{F} = m\vec{a}$.
Calculate the buoyancy force (F_B) for different heights (don't forget to take into account the mass of the string) using the equation above (this is the measured F_B)
If F_B varies significantly with time, graph it.

Questions:

1) What's the percent difference between the measured F_B and the predicted F_B?
2) and compare it to measurement.
3) Does F_B depend on height?
4) How can one increase F_B, without changing

Measuring the Acceleration and Comparing to Theory

Equipment: Helium balloon, Labpro, 3-axis accelerometer, scale, altimeter (range finder or pressure probe to use as altimeter (see Appendix III), or plumb blob and protractor).

The Big Idea: To compare the measured acceleration of a freely-ascending balloon to the theoretical acceleration as predicted by Newton's 2nd law ($\sum \vec{F} = m\vec{a}$)

Procedure:
Measure Buoyancy Force(F_B): Use the force probe on the balloon while it is on the ground. The force probe measures the tension in the string which equals F_B minus the weight of the (balloon+payload). Take an average of the force probe reading to average out the effects of the balloon bobbing up and down.
Measuring the acceleration: Set the Labpro to take data 10 times a second and oversample by 10) for a duration of 5 minutes (although the experiment itself is only 20 seconds at the most, this gives you time to do it two or three times without resetting the Labpro. Connect the 3-axis accelerometer to the Labpro and tape it to the Labpro or gondola. Calibrate the 3-axis accelerometer. Tape the accelerometer with one of the axis pointing down. When you release it, try to eliminate any bobbing back and forth of the gondola as much as possible. If you have a better idea do it! Otherwise, one way to get the 'free-ascent' acceleration is to release the balloon for 10 seconds or so, letting it ascend, then slowly (you don't want to lose the balloon) add friction to the string slowing it to a stop. Then bring it back down.

Analyzing the data:

- Compare measured F_B to calculated F_B (see Appendix III for help on calculating F_B). Find the percent difference.
- There should only be acceleration in one direction (the vertical), but due to the accelerometer swinging back and forth you will get acceleration in all directions. The vertical acceleration is then equal to the sum of the squares of the 3; i.e. $a_{vertical} = \sqrt{a_x^2 + a_y^2 + a_z^2}$. This is the *r* column.
- The vertical acceleration graph should be fairly constant, Take the average of the acceleration while it is in free accent.
- Use $\sum \vec{F} = m\vec{a}$ to calculate the theoretical acceleration (forces to consider: buoyancy force (F_B), weight of balloon, weight of payload (gondola, Labpro, etc.)). Second order forces are the varying weight of string, air resistance, and wind.

  Extra-credit: Use the acceleration graph and your knowledge of physics to calculate the expected height for the free ascent. You have big errors so just see how close you get.

Questions:

1) Note that the string will add mass as it rises. Do you predict this to cause a decrease in the acceleration or an increase or no change? Justify your answer and see if you observe your prediction on the acceleration graph.
2) Use the acceleration of the balloon to predict the velocity of the balloon at the half-way point in time and (harder) at the half-way point in distance.
3) Use the acceleration of the balloon to predict the velocity of the balloon at the very end of it's 'free' ascent.
4) Calculate the balloon's maximum height.
5) Find the percent difference from the calculated height and the height determined by the range finder.

Cosmic Ray Radiation

A word on cosmic rays
Cosmic rays are simply particles (two examples are the beloved electron and proton) that are flying around throughout our universe. They originate from and get their kinetic energy from various sources (examples: super nova explosions, quasars, even the Big Bang!). Anyway, we are constantly being bombarded by these little guys. When they enter the atmosphere they often interact with the gas molecules in our atmosphere creating more particles (often called ‘secondary cosmic ray particles). Depending where you are in the atmosphere (i.e. how high you are from the surface of Earth) there will be more or less particles flying around. So in other words <u>the number of particles flying around depends on how high you are in the atmosphere</u>. This experiment works best the higher you go and the longer you take data at each altitude.

Equipment: Helium balloon, Labpro, radiation probe, altimeter (range finder or pressure probe to use as altimeter (see Appendix III), or plumb blob and protractor).

The Big Idea: Determine how the atmosphere effects the number of cosmic ray particles by charting the average number of particles detected vs. altitude. You will then compare your graph to a similar one made by a NASA experiment.

Procedure:
Measuring cosmic ray radiation: Set the Labpro*, so that the experiment length is at least ten minutes and a total time of about 240 minutes (more than you’ll need most likely). Thus, every minute the Labpro will record how many particles (actually only ionizing particles can be detected by this device) passed through the radiation detector in the last minute. Set the Labpro to take data remotely. At the ground, start both the stopwatch and the Labpro at the same time.
Take data at your designated heights (for example every 100 ft.) by stopping the balloon for 3 minutes and noting the start time and stop time at the height using the synchronized stopwatch. The reason for 3 minutes is that there will definitely be one minute of recording at that exact altitude.
*see Appendix II on Labpro

Height: Use the barometer to get an accurate height estimate.

Analyzing the Data:

- Graph a number of particles vs. Altitude.
- Compare your numbers and graph with that of the GLAST balloon experiment located at http://scipp.ucsc.edu/outreach/balloon/glost/index.html

Acceleration of San Francisco Elevators

Equipment: Labpro, accelerometer, and some good excuses or knowledge of backdoors to get in the elevators.

The Big Idea: Contest to find the elevator in San Francisco that a) has the largest acceleration on the way up, b) has the largest acceleration on the way down, c) the elevator that has the smallest acceleration, and d) the elevator with the longest acceleration graph. The winner is awarded 10 points for each category won.

How to interpret your data:
The accelerometer reads the acceleration on the object, which is normally $-9.8\ m/s^2$, so when the elevator accelerates up, for example, it will read something larger than $-9.8\ m/s^2$, like $-8.0\ m/s^2$. So the difference is the acceleration of the elevator (i.e. the elevator is accelerating $1.8\ m/s^2$ upward)

Requirements: Must have graph and data table printed out and give a short (one or two minute) power point presentation to the class explaining how you did the experiment and the location of the elevator. Another graph or two of other elevators tried is also recommended. Don't cheat, because the winners will have their elevators tested to verify the graphs.

Labpro settings: Set the Labpro to take data 10 times a second and oversample by 10) for a duration of 240 seconds. Tape the accelerometer to the wall so that the arrow points down (it should read $-9.8\ m/s^2$ before the elevator moves).

Elevators to use: All elevators in San Francisco are open game. The building must be at least 10 floors high.

To Do:

Print out the acceleration graphs, labeling the start time, end time and anything else you deem important.

Use the your above a vs. t graph and your knowledge of kinematics to sketch the velocity vs. time graph and the height vs. time graph.

Calculate the total height obtained using the data in these graphs and compare to your estimate obtained by measuring one floor and multiplying it by the number of floors you went up. The errors are big in this experiment, so you're hoping to be in the ballpark only.

Appendix I: Labpro Instructions

Remote data taking:

I. First determine how much data to take and how often the Labpro should record data. Do this by choosing the *Setup* tab and selecting *Data Collection*. Then choose the *Sampling* tab from the pop-up window. Experimental length is how long you want to take data for after you hit the start button. Sampling speed is how often you want to record data from the probes (i.e. so if you want to record the acceleration 10 times a second –every 0.1 second, then you type in 10 here). Over Sampling means do you want to record more data then selected in the Sampling speed, and then average over the extra data. Talk to your teacher about this one. Note that the maximum amount of data the Labpro can take is 12,000 points. So if you have 4 probes attached then you divide by 4 (i.e. each probe can record 3,000 data points). Note that oversampling does not change anything because these points aren't recorded.

II. Click on the *Remote* tab, then choose *Set up Labpro* , follow the instructions on the computer.

III. You know you're ready to go when the yellow light is on. Hit the start button on the Labpro just before you want to start taking data.

IV. To download the data onto the computer, simply reconnect the Labpro to the computer and click on the *Remote* tab, this time choosing *Retrieve Data from Labpro*.

Miscellaneous Instructions:

Setting the decimal places for the data table and graph:

Double click on the data table. In the pop-up window set the number of decimal places you want.

Selecting which graph shows what when have more than one probe:

Simply double click the graph window, and click the data you want displayed.

Max Sample rate: (same for all 3 probes): max. is 2.67 samples per second for 50 minutes we'll do 1 sample per second. Will average over 3 samples for a data point.

Trouble Shooting

Resetting Labpro for remote data taking:

If having trouble resetting Labpro, try clicking on the 'retrieve data' under the remote sensor tab <u>once for each probe</u>.

Appendix II: Using the Barometer as an Altimeter

Set up Labpro:
Connect the barometer (which measures pressure) probe to the Lappro. The settings aren't terribly important, but a setting of 10 sample/second with an over-sampling of 3 should be fine (and of course set the experiment length for a little over the time the balloon will be in the air). Refer to Appendix II on how to set the Labpro for remote data taking.

How to get the height of the balloon from the pressure reading:
Use the exponential formula for pressure vs. height, $P = P_o e^{-h/a}$, where P is the pressure reading at the height of interest, P_o is the pressure at ground at sea level and equal to 1 atm=101325 N/m^2 =101.325 kPa = 2116 lb/ft^2 = 14.69 lb/in^2, h is the height of the Pressure reading (i.e. height) and a = 8.42 km. -this is the height the atmosphere would have to have if its density were *constant* with height, and equal to r_0 (r_0 = 1.225 kg/m^3), in order to maintain pressure P_o at sea level. So, one can use this formula, the pressure reading P and the known value for P_o to find h. Here's how it's done. First decompose the equation, $P = P_o e^{-h/a}$ to solve for h. This is done by taking the natural log of both sides of the equation and solving for h.

$$P = P_o e^{-h/a}$$
$$\ln P = \ln(P_o e^{-h/a})$$
$$\ln P = \ln P_o + \ln(e^{-h/a})$$
$$\ln P - \ln P_o = -h/a$$
$$\ln\left(\frac{P}{P_o}\right) = -h/a$$
$$h = -a \ln\left(\frac{P}{P_o}\right)$$

Example: Let's say you measure the pressure at the ground to be 0.9841 atm (thus, P_o=0.9841atm) and you measure the pressure at a certain height to be 0.9724 atm (thus, P=0.9724 atm), in order to find the height the balloon was at simply use the above equation, plugging in the values.

$$h = 8240\text{m} \cdot \ln\left(\frac{.9724}{.9841}\right).$$
$$h = 101\text{m}$$

Note: if you want to find your height above sea level (altitude), simply plug in 1.0 atm P_o, this is the pressure at sea level.

Accuracy: The barometer is accurate to ± 0.0001 atm, which roughly corresponds to ± 1 m accuracy in height; see below for a detailed check with a range finder.

One can also use the empirical model from NASA (this formula is derived from fitting a function to data). However, the exponential model only differs with the NASA empirical model by $\pm 0.04m$ at 1000m altitude, and even less for smaller altitudes.

At altitudes (see GLAST website, classroom resources tab) below 11km, here are the following fits for the atmosphere.

$T = T_0 (1 - h / 44329 \text{ m})$

$r = r_0 (1 - h / 44329 \text{ m})^{4.255876}$

$P = P_0 (1 - h / 44329 \text{ m})^{5.255876}$

Appendix III: Lift due to Helium

Density of Helium: $D_{He} = 0.18 \frac{gm}{liter}$

Density of Air: $D_{air} = 1.30 \frac{gm}{liter}$

Buoyancy Force: $F_B = (D_{air} - D_{He})Vg$

Lift per Volume (Buoyancy Force per volume)*:

$$L = (D_{air} - D_{He})g = (1.30 \frac{gm}{liter} - 0.18 \frac{gm}{liter}) \cdot 9.81 \frac{N}{kg} \cdot \frac{kg}{1000\,gm} \cdot \frac{liter}{m^3} = 10.98 \frac{N}{m^3}$$

* assume same pressure inside and outside the balloon

Appendix IV: Data analysis instructions

Pressure vs. Altitude data

1) Open the Graphical Analysis program located on the desktop of the computers in the physics lab.
2) Enter your Pressure vs. height numbers into the spreadsheet. Note: this is not a copy of the data from the Labpro. You need to find the plateau's that correspond with the given altitudes, then take the average of that plateau and enter that one number for pressure for the given height. Note it'll make a graph for you as you type in the data.
3) Hit the tab at the top on the far right ('curve fit')
4) Scroll down to natural exponential and choose the equation of the form Aexp(-x) + B. Which corresponds to the exponential model for pressure.
5) Click on the 'define function' tab and erase 'B', and plug in your P_o for A. Now you have an equation that agrees with the pressure equation for atmosphere.
6) Click on 'try fit'
7) Printout graph (make sure to move dialogue box so it doesn't block the graph) and record the values for A,B,C.
8) Write down your equation for pressure (i.e. plugging in A,B,C for P_o and a).
9) How close are P_o and a to the expected values? How good a fit is it (RMSE should be as small as possible)
10) Compare your graph with your data fitted to the linear model (the tab just to the left of the curve fit) –if |correlation| < 0.98 , it's not a good fit. Also use your eyes to judge.
11) Try fitting your data to the NASA model
12) Now repeat process for the Temperature data.

In order to copy the graphs into a power point presentation, click on the print tab and use the acrobat distiller to make a .pdf file. This is a universal document.

To make a new column of data (for example $a_{vertical}$ from a_x, a_y, a_z)

Click on 'Data' tab

Go to 'New Column', then to 'formula'

Type in long name and short name and the units for this new column (names that make sense are vertical acceleration, etc.)

Click on 'Definition' tab.

From function tab choose sqrt().

From variable tab choose a_x

Type ' ^2 ' after a_x variable then repeat two times for a_y and a_z.

Click 'OK' and a new column of verticle acceleration should appear.

Graph it.

Note: follow the same steps if using 'Graphical Analysis' program.

Appendix V: Calculator Instructions

TI-83 and TI-83 plus instructions:
First connect the calculator to the labpro using the graph link. Set the calculator to receive data by punching the '2nd' key and the 'x,T,θ,n' key (this gives you the 'link'key). Now use the arrow keys to move to 'RECEIVE' and hit enter.
All that is left to do is to hit the transfer key on the Labpro and be patient while it uploads the program DATAMATE.
TI-83: this program is stored under the 'prgm' key.
TI-83 plus: this program is stored under the 'APP' key (easy to find because it's the only blue key.
Note: you might have to delete some programs in order to make room for this program as it is rather large.

In order to change settings of data taking time:
On your calculator with the Labpro attached (and the probe attached to the Labpro), hit either the prgm key or APP key and hit enter on 'DATAMATE'
Wait as the calculator shows the intro screen and then moves to the main screen (with the channels and what's plugged into them and the main menu below (with setup, start,graph, etc.) Hit the '1' key for SETUP. Be patient as the calculator moves slowly. Scroll up by one to go to 'MODE:Time Graph', hit enter. Then choose 'Time Graph' by hitting the '2' key. Then hit the '2 ' key again in order to change the settings. Now you can choose how often it takes data ('time between samples') and how long it takes data for ('number of samples' multiplied by 'time between samples' gives total time).
Note: the calculator can only store so much data in the lists, so if you demand to much list one (with the time intervals) will be deleted as it goes, so you won't get a graph as you run it. In that situation either increase 'time between samples' or decrease 'time between samples'.

In order to setup probe:
The calculator should automatically detect the probe, and list it in whatever channel it is plugged into. If it does not recognize the probe, make sure the probe and calculator link are firmly connected and restart the program. If that doesn't work try going to SETUP as above, choose the channel where the probe is connected, hit enter and change to the correct probe.

Appendix VI: Labpro instrumentation spec.s

These units are Data Acquisition Devices (DAQ) they record voltages (range =± 10V, resolution = 4.9mV) from attached sensors at programmed intervals or other trigger conditions. They may also convert the raw data to measurements, average it, or filter it.

	LabPro
On-board Data Display	No
Max # of data Points	<12,287 (limited by memory)
Sample Time Range (seconds/ sample)	10^{-4}s to 16,000s
Sample Time Rules	Multiple of 100µs
Max # of probes: Analog vs Digital	4 Analog, 2 digital
Data collection and analysis: Realtime vs Non-realtime	both
Setup: Remote, Calculator, Computer	All three modes
Connection: I/O port (Calculator to calculator link cable), Serial port, USB port	All three

Software

DataMate : A calculator program (transferred from LabPro) that allows any probe or combination of probes to be setup, calibrated, collected and graphed.

Logger Pro: A computer program that will setup, calibrate, collect, graph, store, and analyze data from all probes on the LabPro.

TI-Graph Link: A computer program that allows programs and data to be transferred between the calculator and the computer. It requires a special adapter cable from the computers serial port and the calculator's I/O port.

Graphical Analysis: A computer program that allows data to be retrieved directly from the calculator and then graphed and analyzed.

Sensors

Many sensors are available. They return a voltage (V) that is linearly proportional to the desired measurement (M). This voltage must be "calibrated" by getting a slope (K_1) and intercept (K_0) for the following equation.

$$M = K_0 + K_1 V$$

Standard Calibration Coefficients:

Sensor	ID	Units	Equ Type	K_0	K_1	K_2
Stainless Steel Temp	TMP-BTA	°C	12	0.001021	0.0002225	0.0000001333
Barometer	BAR-BTA	Atm	1	0.8093	0.077	
		mBar	1	819.52	78.001	
		mmHg	1	614.84	58.52	
		inHg	1	24.215	2.292	
CO_2 Sensor	CO2-BTA	ppm	1	0.0	2000	
O_2 Sensor	O2-BTA	%	1	0.0	6.658	
Relative Humidity	RH-BTA	%	1	-23.8	32.9	
Magnetic Field (low)	MG-BTA	Gauss	1	-80.63	32.25	
		mTesla	1	-8.063	3.225	
Light Sensor –600 lux	LS-BTA	lux	1	0.0	154.0	
-6000 lux		lux	1	0.0	1695.0	
-150000		lux	1	0.0	38424.0	
Radiation Monitor (G-M)	RM-BTA	Counts	1	0.0	1.0	

Sampling Interval Limitations:

LabPro S cannot be less than 0.0001 sec nor more than 16,000 seconds. S must be a multiple of 0.0001 sec.

TI-83 specs:

Memory: 27K bytes

Lists: L_1 thru L_6, plus unlimited additional named lists (5 chars). Each list may contain up to 999 elements. However, since 9bytes are required per element, one is usually limited to about 512 data points because of memory.

Appendix VII: HiBall Program

<u>TI – CBL - LabPro</u>

Purpose

This is a program for the TI-83 to control the LabPro DAQ with a barometer, a thermometer, and one other instrument to investigate our lower atmosphere.

Experimental Plan

The balloon and equipment is prepared and ready to fly.
The operator runs this program, checks and/or modifies any settings, and then presses start. The basic cycle runs until stopped or until memory is exceeded. The progress and number of data points and photographs taken will be displayed real time.
The user then downloads the TI-83 data to a laptop using Logger Pro software and either the TI GraphLink cable or a USB connection.

Basic Cycle

The LabPro takes N samples, at an interval of T seconds before being retrieved by the TI-83, averaged and recorded as a **data point.** The Ti-83 records M data points before a photograph is taken and then the cycle repeats.

Control Structure

HIBALL Menu and display

- ⇒ S1INIT Initialize the DCU
- ⇒ S1Set Prepare the LabPro for data collection
- ⇒ S1Get Retrieve & average the data from the CBL or LabPro for analysis
- ⇒ S1Snap Take a picture using the DCU

Data Dictionary:

T = Sample interval (sec) (default = .25s)
N = Number of samples to be averaged for each recorded data point. (default =20)
M = Number of data points between each photograph. (default = 12)

R = User responses
[C] = Calibration coefficients (4x3 matrix)
I = Counter for current data element in list

Lists of Sampled Data (N)		Lists of Averaged Data Points (M)			
D1 =	Chnl 1, temp	L_1 =	Chnl 1, SS temp probe,	°C	TMP-BTA
D2 =	Chnl 2, pressure	L_2 =	Chnl 2, Barometer,	Atm	BAR-BTA
D3 =	Chnl 3	L_3 =	Chnl 3,		
D4 =	Chnl 4	L_4 =	Chnl 4,		
D5 =	Time coordinates	L_5 =	Time coordinates (sec)		

L_6 = CBL commands and returned data

CBL / LabPro Command Strings

(use the Send() command to send the following lists to the LabPro, use the Get() command to retrieve lists of data in the following order: chn 1, chn 2, …, time)

Setup LabPro

{6,0}	System setup, abort any sampling
{0}	Reset all channels
{7}	Request system status
{102, -1}	Power always on (disables APD)
{6,3}	System startup, turn off sound

Setup analog channels with Auto ID, no d/dt, calibration equation is on

{1,1,1,0,0,1}	Setup Channel 1, Stainless Steel Thermometer
{1,2,1,0,0,1}	Setup Channel 2, Barometer
{1,3,1,0,0,1}	Setup Channel 3, (CO_2, O_2, Magnetic Field, etc.)
{1,4,1,0,0,1}	Setup Channel 4

Setup Calibration Equations (type 1: K_0+K_1x or type 12: $K_0+K_1(\ln 1000X) + K_2(\ln 1000X)^3$

{4,1,12,[C](1,1),[C](1,2),[C](1,3)}	Calibrate channel 1, K_0 = [C](1,1), K_1 = [C](1,2), K_2=[C](1,3)
{4,2,1,1,[C](2,1),[C](2,2)}	Calibrate channel 2, K_0 = [C](2,1), K_1 = [C](2,2)
{4,3,1,1,[C](3,1),[C](3,2)}	Calibrate channel 3, K_0 = [C](3,1), K_1 = [C](3,2)
{4,4,1,1,[C](4,1),[C](4,2)}	Calibrate channel 4, K_0 = [C](4,1), K_1 = [C](4,2)

Setup Sample times and start trigger

{3,T,N,0,0,0,0,1,1}	Setup Sample and Trigger Interval = T # of samples = N Trigger type = immediate start Time = record absolute time (as 5th list) Filter = 5 point filter

Disable analog channels

{1,1,0}	Disable Channel 1
{1,2,0}	Disable Channel 2
{1,3,0}	Disable Channel 3
{1,4,0}	Disable Channel 4

Setup DCU (digital control unit) with a sequence of line D1 ON and then OFF.

{1,31,2,1,0]	Setup DIG/SONIC1, DCU

Trigger DCU with cycle time of 1 second for two steps, immediate start

{3,1,2,0]	Trigger DCU (and all other active probes)