

Getting Students Excited About Science with High Altitude Ballooning



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Gustavus Adolphus College



Academic High Altitude Conference

July 29, 2016 - Saint Catherine University, St. Paul, Minnesota

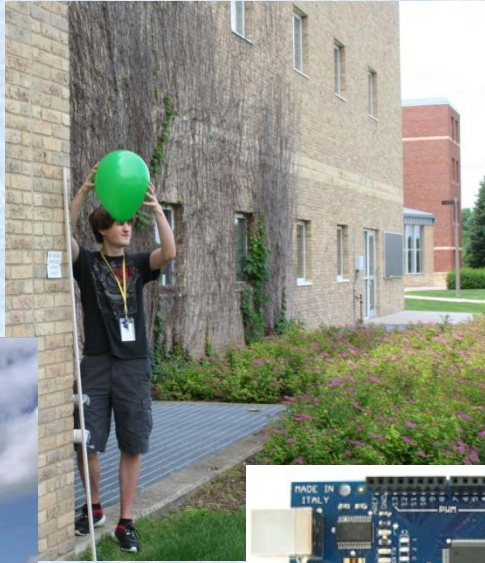
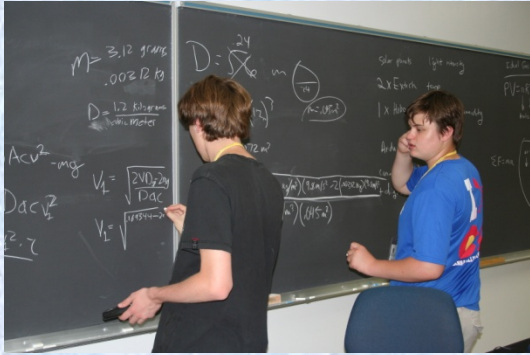
High Altitude Ballooning Summer Camp

Gustavus Adolphus College

Outline

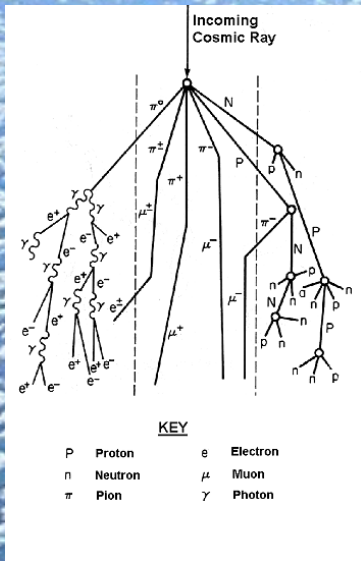
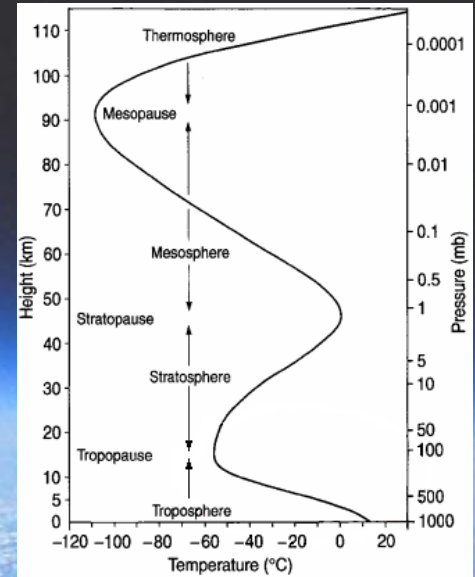
- Motivation for doing ballooning camp
- Structure of the camp
- What students accomplish in a week
- Outcomes
- Future Plans
- Acknowledgements

Gustavus' High Altitude Balloon Camp



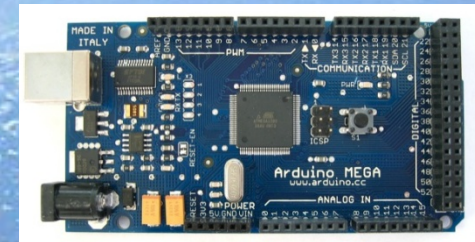
Science in High Altitude Ballooning

- Gas Laws
- Heat Transfer
- Atmospheric Science
 - Pressure variation with altitude
 - Temperature variation with altitude
 - Density variation with altitude
- Newton's Laws
- Archimedes' Principle
- Air Resistance
- Cosmic Radiation
- Magnetic Field of the Earth
 - Variation of field strength with altitude
 - Variation of field direction with altitude



Engineering and Programming in High Altitude Ballooning

- **Ohm's Law and Circuits**
- **Joule Heating**
- **Heat Transfer**
- **Determining Location**
 - **GPS Coordinates**
- **Data Collection and Recording**
- **Programming**
- **Photography/Videography**
- **Flight Path Predictions and Simulations**
- **Radio Transmitters and Tracking**
- **Graphing and Analyzing Data**

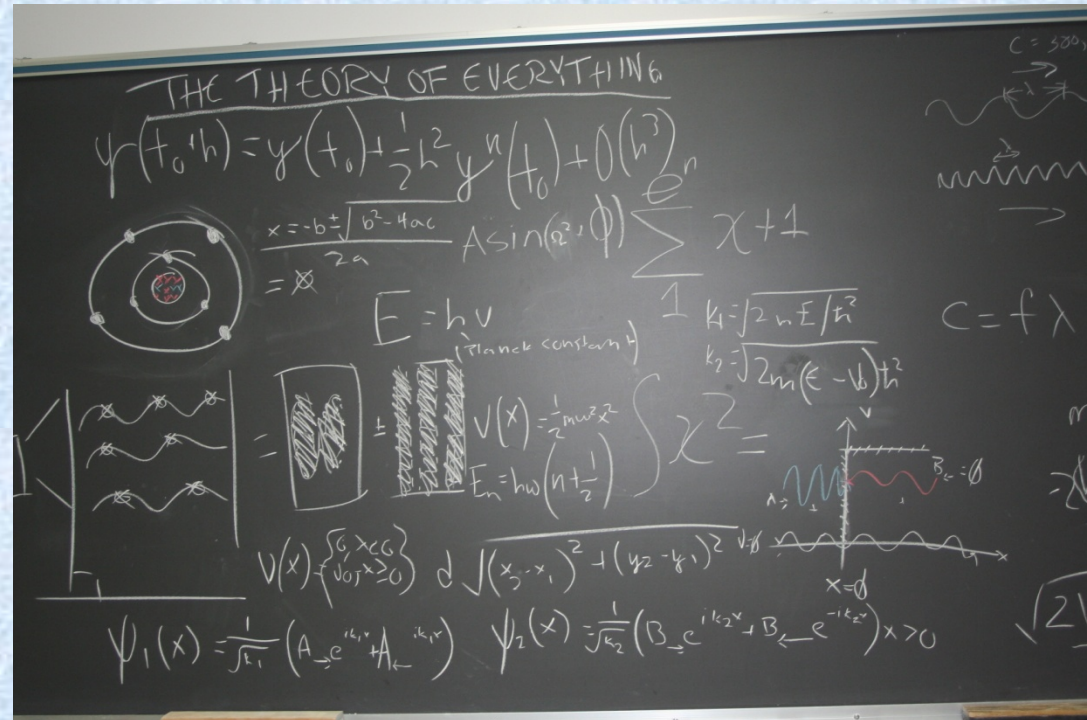


High Altitude Ballooning Summer Camp at Gustavus

| | Sunday | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday |
|------------|----------------------------|--|--|---|---|--|---|
| 7:30–8:30 | | Breakfast | Breakfast | Breakfast | Breakfast | Breakfast | Breakfast |
| 8:30-12:30 | | Atmospheric Science Thermodynamics PV=NRT Lab Archimedes Principle Newton's Laws Air Resistance and Terminal Velocity Predicting Terminal Velocity | Measuring T & P with Analog Sensors Controlling Motors Based on P I ² C and SPI Sensors CHDK Programming of Canon Cameras Time Lapse | Measuring GPS Coordinates Storing Data on microSD Card Intro to Contour Camera (with GPS) Intro to Big Red Bee | Prepare for Balloon Launch & Launch* Olin 224 | Cleaning Up Data Correlating and Graphing Data | Final Preparations Presentations Olin 224 |
| 12:30-1:30 | | Lunch | Lunch | Lunch | Chase Balloon | Lunch | |
| 1:30-5:30 | | Lift and Terminal Velocity Lab Data Loggers Introduction to Arduino Microcontrollers Programming in C | Measuring T & P with Digital Sensors Measuring Acceleration and Magnetic Field Design of Satellite Using GoPro for Videos | Putting all the Programming Together Satellite Construction Balloon Prep | Balloon Recovery* | Correlating and Graphing Data Preparing Presentations | |
| 5:30-6:30 | | Dinner | Dinner | Dinner | Dinner | Dinner | |
| 7:00-8:00 | Registration & Check-In | | | | | | |
| 8:00-9:30 | Orientation Olin 224 | | | | | | |

What we talked about:

- Gas Laws
- Heat Transfer
- Pressure variation with altitude
- Temperature variation with altitude
- Density variation with altitude
- Newton's Laws
- Archimedes' Principle
- Air Resistance
- Rate of ascent



What the students heard

Trying It Out



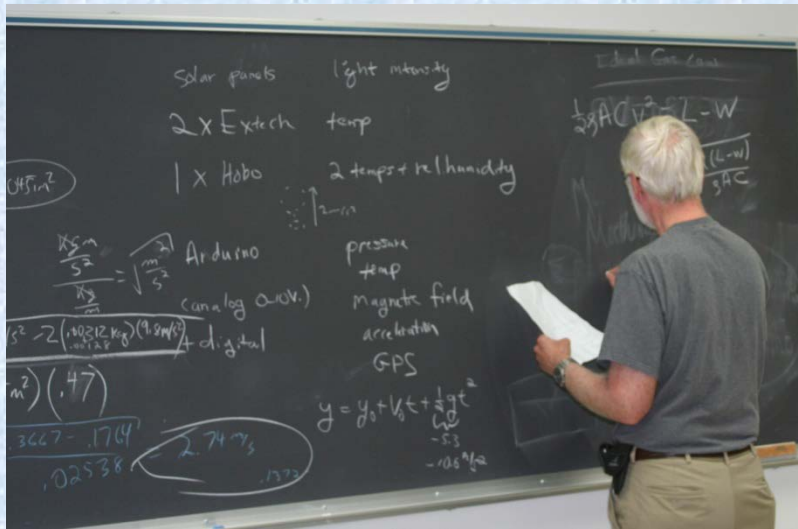
balloon data

| Best | Color | mass | Diameter | v_k |
|------|----------------------------|------|----------|-----------|
| | Teyva/John green | 2.7g | 21.5cm | 1.041 m/s |
| | Yellow Ml. San / Silvia | 3.0g | 36.5 cm | 1.536 m/s |
| | Orange | 2.8g | 30.0 cm | 1.297 m/s |

PHYSICS

So Much Data, So Little Time

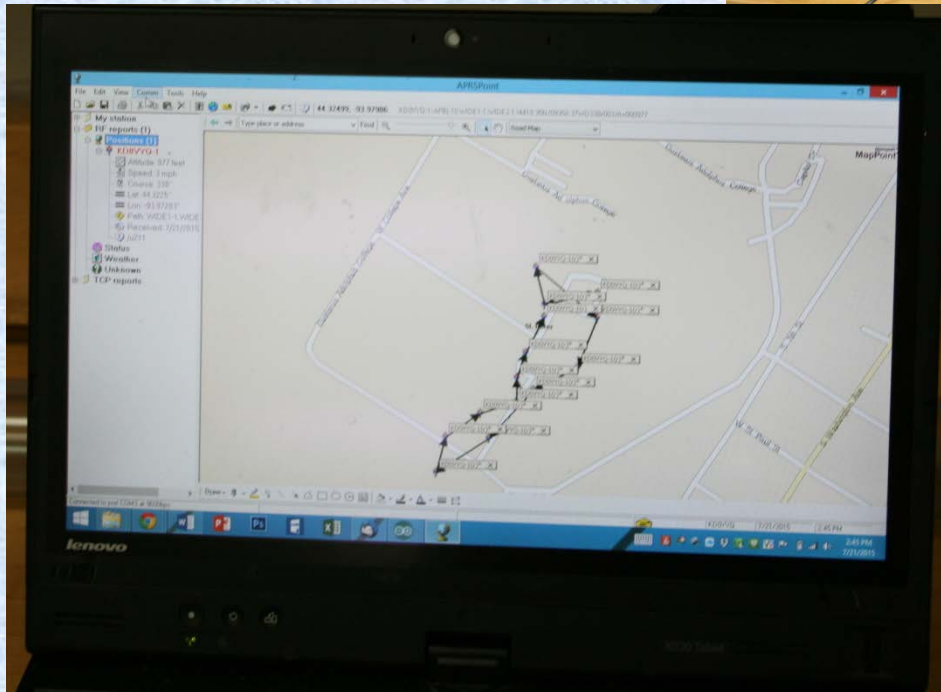
What To Measure?



- Data Logging
- Hobo
- Extech
- Arduinos
- Wiring
- Coding



Tracking The Big Red Bee



A Walk Around Campus

Flight Prediction

predict.habhub.org/#!/uuid=da45c9a8562422441dd704211353f3c28372bd23

Scenario Information
Current mouse position: Lat: 44.3994 Lon: -93.8040
Range: 18.1km, Flight Time: 2hr01
Cursor range from launch: 14.9km, land: 17.1km
Last run at 16:08 26/06/2014 UTC using model 2014062606
[Pan To | CSV | KML](#)
[Show Debug](#) | [Hide Launch Card](#) | [About](#)

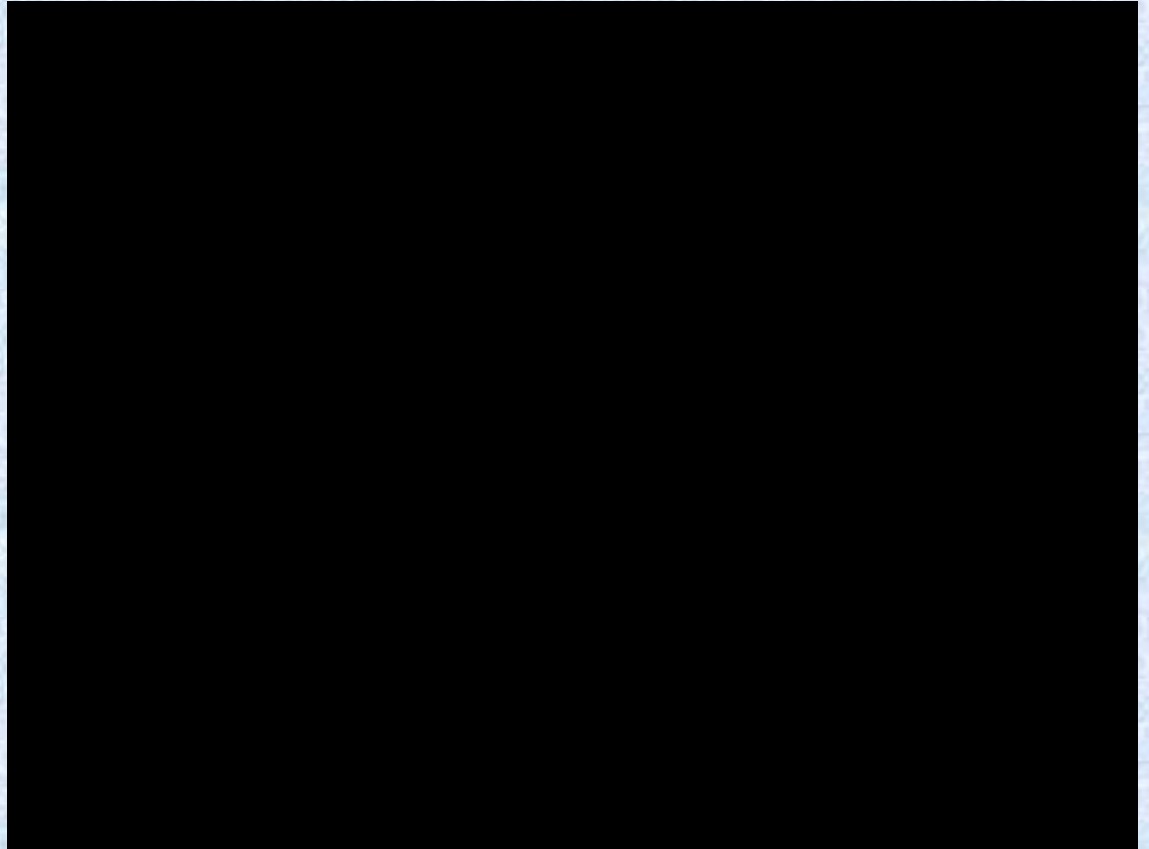
Launch Site: Custom Other
Latitude/Longitude: 44.3333 / -93.9667
[Set With Map](#) [Save Location](#)
Launch altitude (m): 300
Launch Time (UTC): 16 : 20
Launch Date: 26 Jun 2014
Ascent Rate (m/s): 5
Burst Altitude (m): 30000
[Use Burst Calculator](#)
Descent Rate (m/s): 10
[Run Prediction](#)

Map data ©2014 Google, Imagery ©2014 TerraMetrics, 2 km

11:53 AM
6/30/2014

Learning About Cameras

- Video Cameras
 - GoPro
 - Contour
- Still Cameras
 - Canon
 - Arduino based



Box Building



Coding

```
The_More_Frequently_Chosen_Ones_Code | Arduino 1.0.5
File Edit Sketch Tools Help

The_More_Frequently_Chosen_Ones_Code
// link between the computer and the SoftSerial Shield
//at 9600 bps 8-N-1
//Computer is connected to Hardware UART
//SoftSerial Shield is connected to the Software UART:D2&D3

//Edited by Teyva Chee
//Parses NMEA code returned by GPS and returns time, latitude, longitude, and altitude

#include "DHT.h"

#define DHTPIN A12    // what pin we're connected to

/*Using digital 2 to control Camera*/
/*Using digital 5 to receive sensor signal*/
#define KEY 4

// Uncomment whatever type you're using!
#define DHTTYPE DHT11 // DHT 11
DHT dht(DHTPIN, DHTTYPE);

#include <SPI.h>
#include <SD.h>

#include "Wire.h"
#include "DS1307.h"

// I2Cdev and MPU9250 must be installed as libraries, or else the .cpp/.h files
// for both classes must be in the include path of your project
#include "I2Cdev.h"
#include "MPU9250.h"
#include "BMP180.h"

const int chipSelect = 8;

DS1307 clock;//define a object of DS1307 class

MPU9250 accelgyro;
I2Cdev I2C_M;

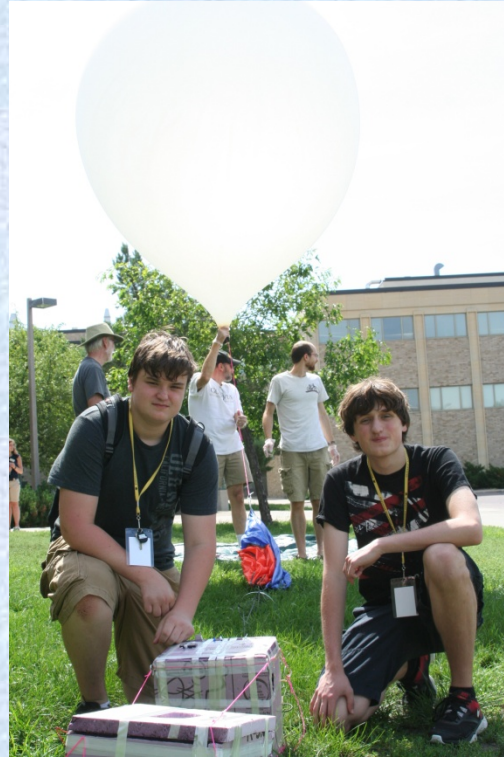
uint8_t buffer_m[6];

int16_t ax, ay, az;
int16_t gx, gy, gz;
int16_t mx, my, mz;

float heading;
<
```



Launch Day



Launch Day



The Chase



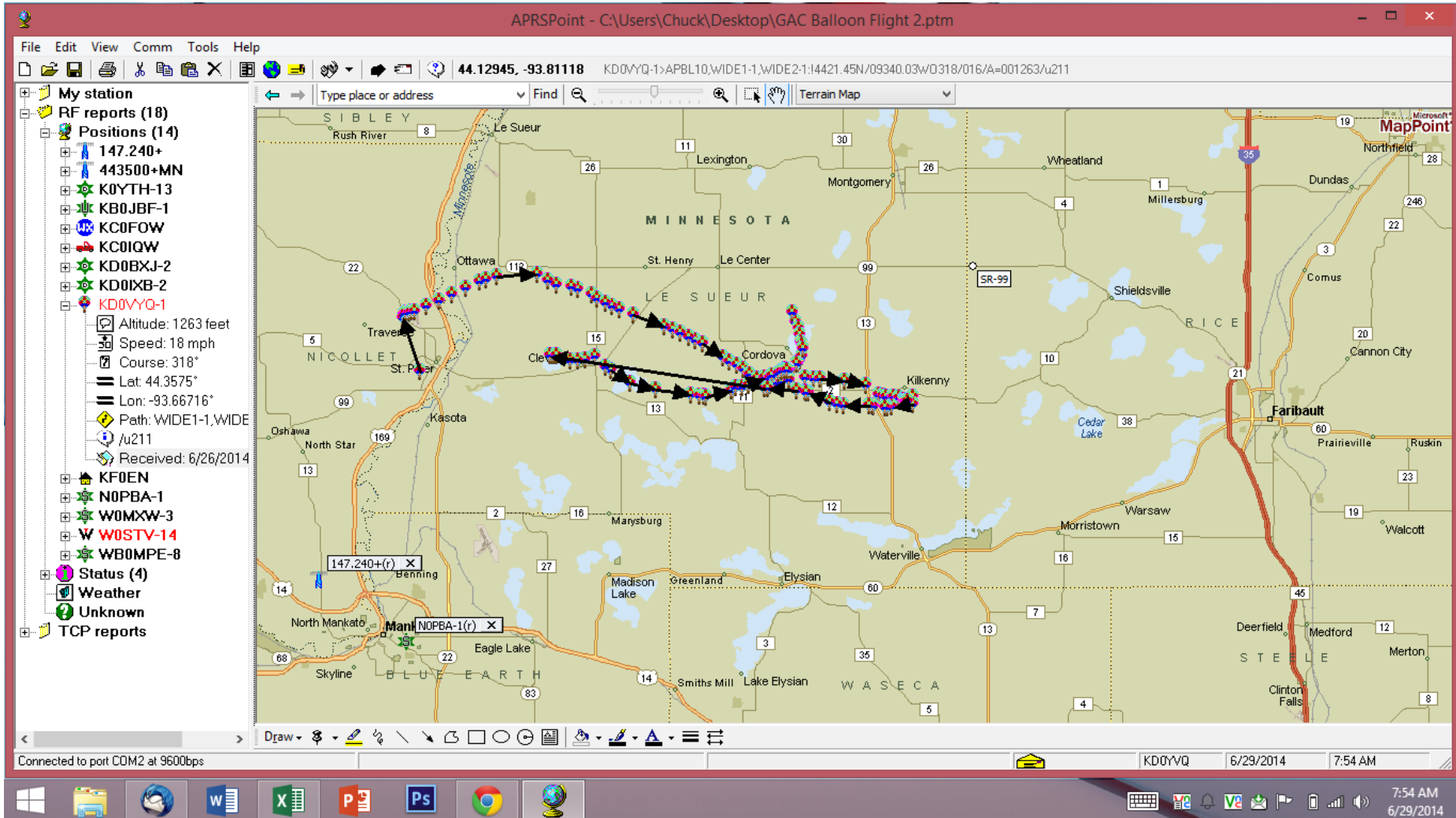
The Chase 2



Recovery



Tracking the Balloon



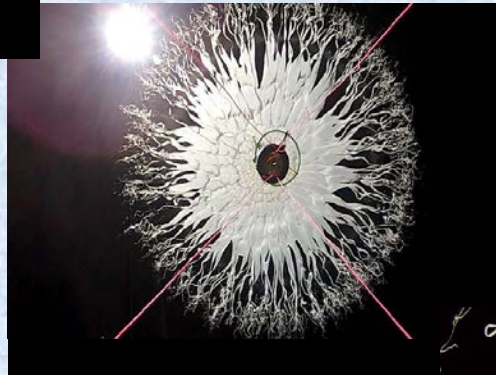
Still Pictures



Movies



Launch



Burst From Below



Launch From Side
for Video Analysis

Burst Side View



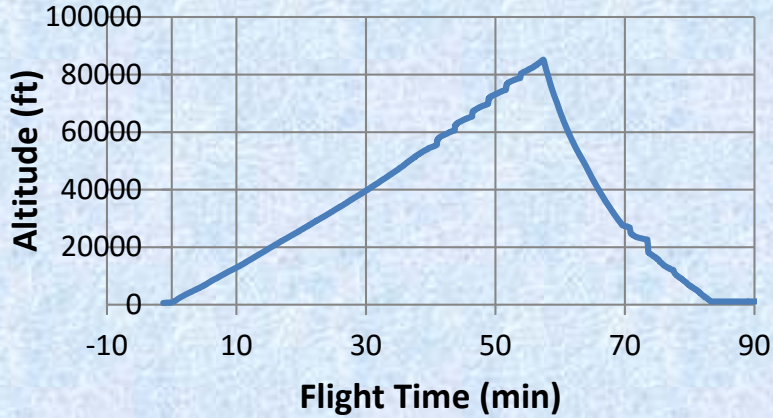
Landing



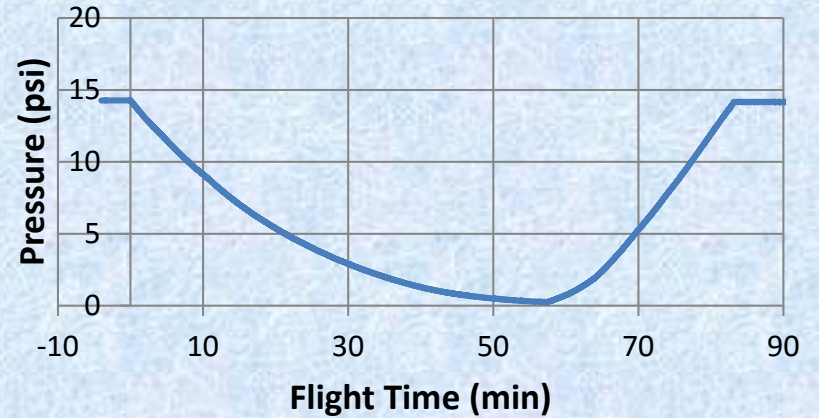
Raw Data From Arduino

| | | | | | | | | | | | | | | | | | |
|----------|----------|-------|-------|-------|-------|-------|-------|------|-------|-----|-----|------|----------|-----------|--------|---|-------------|
| 8/6/2013 | 11:40:43 | ##### | -1.32 | 14.27 | 63.66 | 20.8 | -0.98 | 0.05 | -0.22 | 327 | 587 | 1941 | 44.32332 | -93.97307 | 619.75 | 4 | 277.25 |
| 8/6/2013 | 11:40:44 | ##### | -1.30 | 14.27 | 63.97 | 20.31 | -1 | 0.17 | -0.02 | 333 | 584 | 1937 | 44.32332 | -93.97307 | 619.75 | 4 | 298.55 |
| 8/6/2013 | 11:40:45 | ##### | -1.28 | 14.27 | 64.13 | 20.31 | -1.1 | 0.14 | 0 | 336 | 606 | 1920 | 44.32322 | -93.97316 | 629.27 | 4 | 280.5 |
| 8/6/2013 | 11:40:46 | ##### | -1.27 | 14.27 | 63.97 | -50 | -1.12 | 0.13 | -0.01 | 334 | 606 | 1930 | 44.32316 | -93.97322 | 635.5 | 4 | 278.85 |
| 8/6/2013 | 11:40:48 | ##### | -1.23 | 14.27 | 63.97 | 19.82 | -1.03 | 0.16 | -0.06 | 335 | 604 | 1915 | 44.32311 | -93.97329 | 643.04 | 4 | 288.1636364 |
| 8/6/2013 | 11:40:49 | ##### | -1.22 | 14.27 | 63.97 | 20.31 | -1.08 | 0.14 | -0.02 | 338 | 608 | 1929 | 44.32308 | -93.97333 | 647.64 | 4 | 286.3090909 |
| 8/6/2013 | 11:40:50 | ##### | -1.20 | 14.27 | 63.66 | 20.8 | -1.08 | 0.13 | -0.04 | 316 | 606 | 1922 | 44.32306 | -93.97335 | 652.23 | 4 | 280.5 |
| 8/6/2013 | 11:40:51 | ##### | -1.18 | 14.27 | 63.97 | 20.31 | -1.08 | 0.15 | -0.01 | 315 | 602 | 1905 | 44.32305 | -93.97335 | 657.15 | 4 | 275.6 |
| 8/6/2013 | 11:40:52 | ##### | -1.17 | 14.27 | 63.66 | 20.8 | -1.07 | 0.14 | 0.01 | 337 | 605 | 1917 | 44.32304 | -93.97338 | 660.1 | 3 | 277.25 |
| 8/6/2013 | 11:40:53 | ##### | -1.15 | 14.27 | 63.5 | 20.31 | -1.07 | 0.14 | 0.01 | 340 | 609 | 1926 | 44.32303 | -93.97338 | 663.71 | 3 | 275.6 |
| 8/6/2013 | 11:40:55 | ##### | -1.12 | 14.27 | 64.13 | 20.31 | -1.07 | 0.15 | 0.01 | 337 | 609 | 1928 | 44.32302 | -93.97338 | 675.2 | 3 | 255.8727273 |
| 8/6/2013 | 11:40:56 | ##### | -1.10 | 14.27 | 63.97 | 19.82 | -1.08 | 0.14 | 0 | 338 | 610 | 1932 | 44.32301 | -93.97336 | 679.46 | 3 | 241.15 |
| 8/6/2013 | 11:40:57 | ##### | -1.08 | 14.27 | 63.97 | 20.31 | -1.07 | 0.14 | 0 | 340 | 613 | 1933 | 44.32301 | -93.97335 | 685.37 | 3 | 229.65 |
| 8/6/2013 | 11:40:58 | ##### | -1.07 | 14.27 | 63.5 | 20.31 | -1.07 | 0.14 | 0.01 | 339 | 605 | 1936 | 44.323 | -93.97333 | 691.27 | 3 | 213.25 |
| 8/6/2013 | 11:40:59 | ##### | -1.05 | 14.27 | 63.66 | 20.31 | -1.08 | 0.15 | 0 | 338 | 606 | 1924 | 44.323 | -93.97333 | 695.87 | 3 | 205.05 |
| 8/6/2013 | 11:41:00 | ##### | -1.03 | 14.27 | 63.66 | 20.8 | -1.07 | 0.14 | 0 | 341 | 606 | 1930 | 44.32294 | -93.97332 | 700.13 | 4 | 198.5 |
| 8/6/2013 | 11:41:02 | ##### | -1.00 | 14.27 | 63.66 | 20.31 | -1.07 | 0.14 | 0.01 | 341 | 614 | 1934 | 44.32289 | -93.97329 | 708.33 | 4 | 180.7636364 |

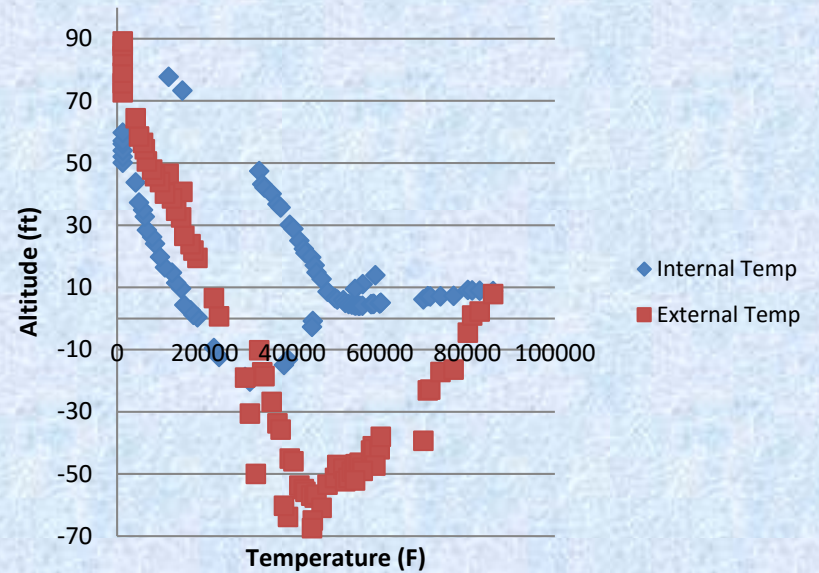
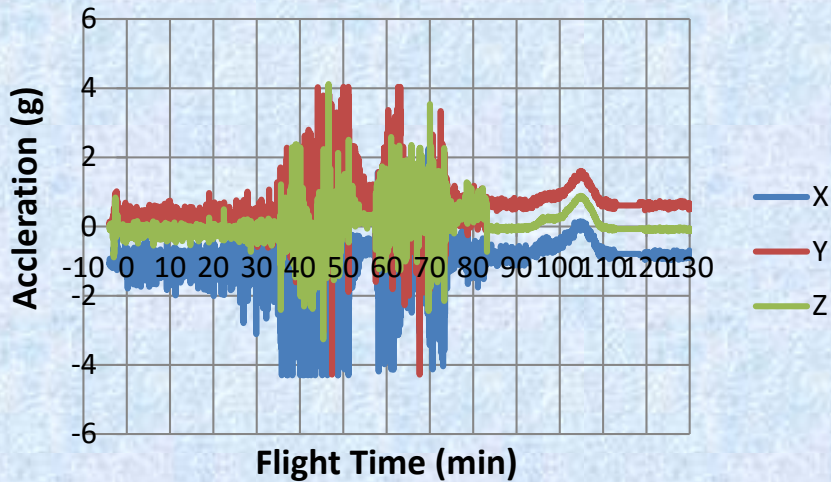
GL68A Altitude vs. Time (GPS) [Super Uno]



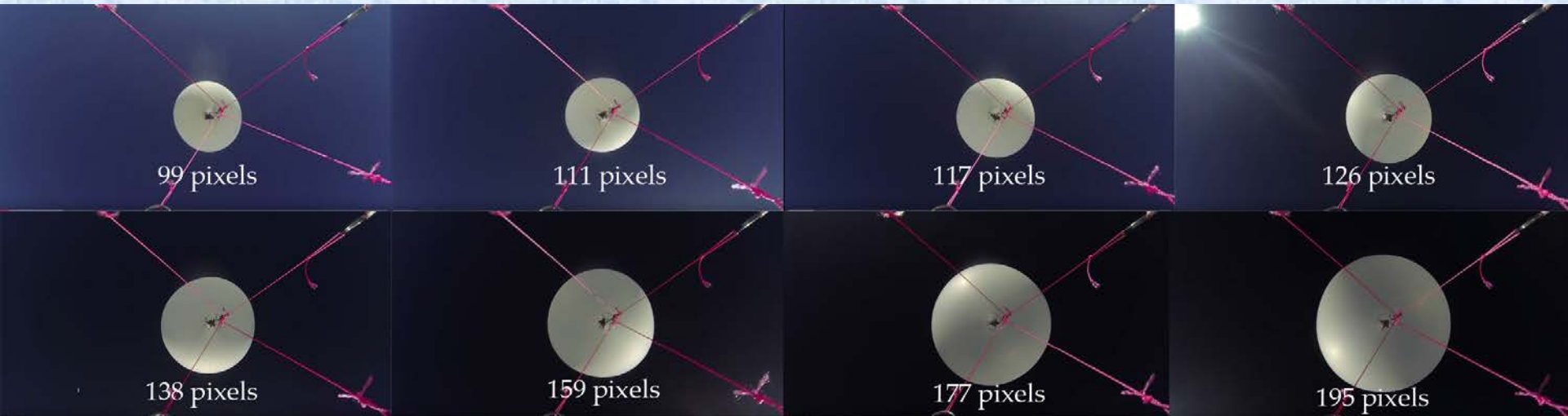
GL68A Pressure vs. Time [Super Uno]



GL68A Payload Z Acceleration vs. Time [Super Uno]

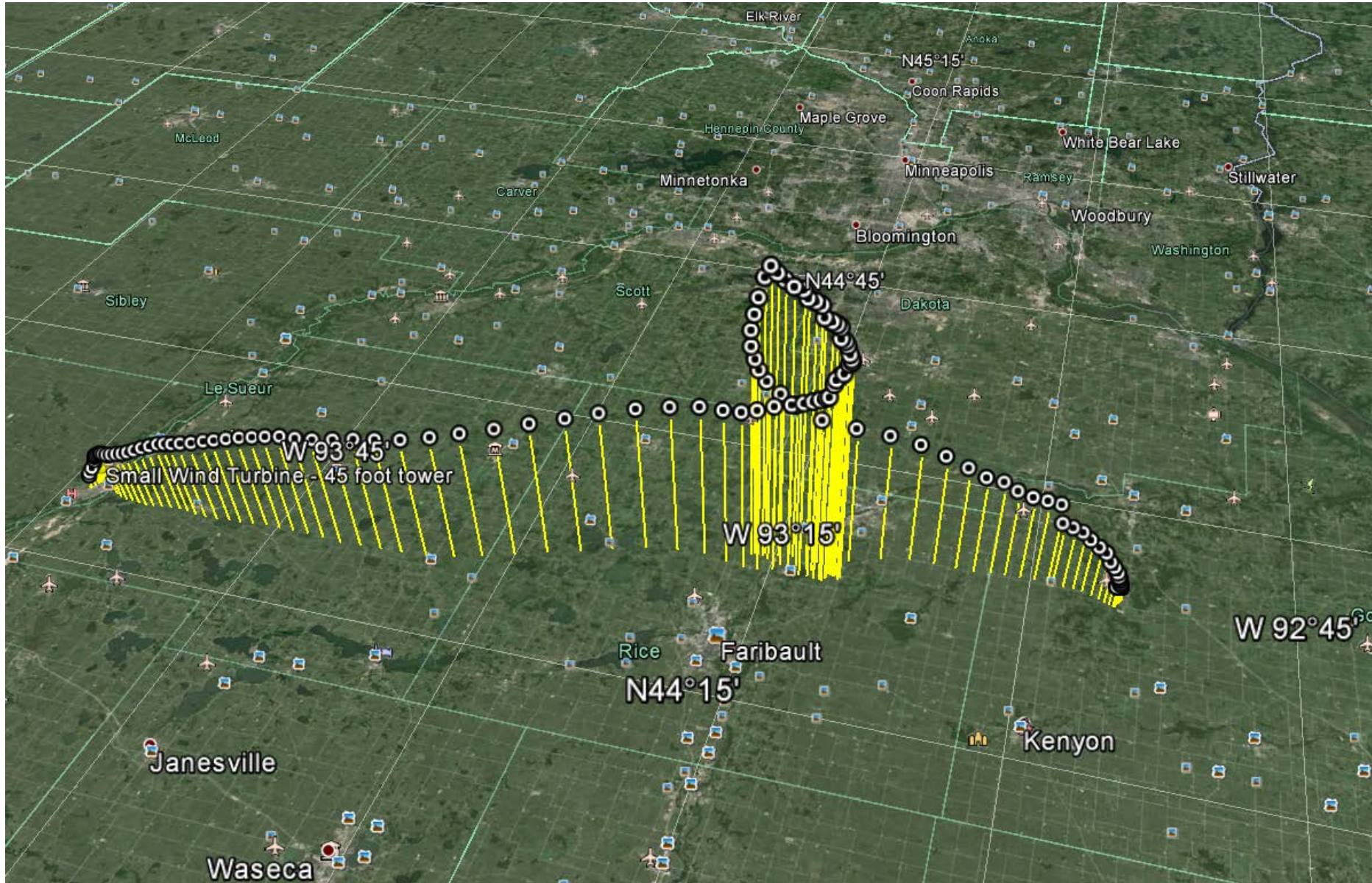


Combinations



$$PV=nRT$$

Flight Path



Follow Up



What Did the Students Learn?

- Atmospheric Science
- Designing
- Writing Code
- Wiring/Soldering
- Data Analysis



Outcomes

- Statistics of small numbers
- 2014 Camp
 - Two Students
 - One will be a senior in high school
 - Fate of second is unknown
- 2016 Camp
 - Six Students
 - Four or five will be attending college
 - None came to Gustavus

Future Work

- This summer's camp is June 10-16
- Adding more gas sensors to repertoire
- Adding a small vacuum pump to collect particulate samples
- Adding Gameduino as display/control



Conclusions

- Young People Find High Altitude Ballooning Exciting
- High Altitude Ballooning can be used to introduce young people to:
 - Scientific Concepts
 - Experiment Design
 - Engineering Concepts
 - Programming and Interfacing

Acknowledgements

- Gustavus Adolphus College
 - Physics Department
 - Provost's Office
- NASA's MN Space Grant Consortium (U of MN Twin Cities -- lead institution)