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# Tracking High Altitude Balloons in an EE Projects Class

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# Tracking High Altitude Balloons in an EE Projects Class


## Abstract

EE 380 is a required junior level projects class in electrical engineering. Each student must design and implement three open-ended projects in three different EE areas, such as electronics, microcontrollers, linear systems, electromagnetics, etc; in addition a fourth team-based project is also required which typically covers two or more areas in EE. This paper describes the team project which has been done for the past three years along with the software that has been developed to predict the balloon flight path and track it in real time.

A high altitude balloon is typically 10 to 12 feet in diameter, filled with helium or hydrogen, and carries a 12 pound payload to an altitude of about 100,000 feet – near space. At this altitude, the balloon will have expanded to about 25 feet in diameter because of the reduced air pressure. It eventually bursts and a parachute allows the payload to survive the trip back to earth. A part of the payload includes two radio transmitters and a GPS tracking device. The transmitted radio signal is decoded and the data is placed on the internet. Software on the ground uses the data along with Google® maps or Microsoft® MapPoint to track the balloon's flight in real time.

A typical student project requires a team of two or three students to design and implement an instrumentation package for the balloon's flight. A balloon can carry six two-pound instrumentation pods. We put two (typically) student-built instrumentation packages in a pod allowing us to handle 12 to 18 students per flight. Instrumentation for each project varies but typically requires photographs, and the periodic measurement of altitude, air pressure, temperature, g-force, or sunlight. The environment is severe with temperatures down to -70º F, nearly zero air pressure, and often high g-forces.

This paper is in two parts: The first part presents the mechanics of the projects and provides examples and results. The second part provides the details of the software which we developed for use in forecasting the balloon's flight and tracking it in real time.


## Introduction

A high altitude weather balloon makes an excellent vehicle for an electrical engineering instrumentation design project. A typical balloon project will have two to three students on a team. Their assignment is to design an instrumentation package which will travel to about 100,000 feet by way of a balloon, and return to earth by way of a parachute to be recovered by the students.

The balloon launch is not difficult to accomplish. The mechanics of the launch have been presented in detail elsewhere[1, 3]. The near-space environment provided by the balloon is harsh, including temperatures down to -70 ºF, high g-forces, and exposure to very low pressure. The balloon, once launched, can carry up to six two-pound instrumentation packages over a ground distance of 10 to 100 miles. An onboard GPS and radio transmitter allow real-time tracking of the balloon, but final recovery of the balloon is not always easy. Recovery works best when an accurate forecast can be made as to where the balloon will land, so the "chasers" on the ground can be close to that location when the balloon arrives. A radio transmitter on the balloon broadcasts its location, but the transmitter range is typically "line-of-sight", or about 40 to 50 miles. When the forecasted landing site is not accurate, it can take several hours of hunting for the balloon in often rough terrain to find it.

The current forecasting software is free and comes from Near Space Ventures Inc.[2] It is web-based. The forecast is created by obtaining the current forecast for the upper level winds and the estimated balloon ascent and descent rates. As the balloon rises, the upper level winds are typically moving in different directions and at different speeds. It is not at all unusual for a balloon's ground path to change by 180 degrees as the balloon passes through a wind shift. Although in most cases, the forecasting software is accurate to within about 5 miles of the actual landing site, we have had several cases where it was more than twenty miles off.

To remedy this problem we have created our own tracking software. This software differs from what is currently available in that it reforecast the balloon landing site based on real-time data from the balloon's current location. The final landing site for the parachute is thus continuously updated based upon GPS data of the current location and current wind forecast.

**Part 1: The balloon project**

At the University of Evansville, high altitude balloons have been the focus of senior design projects. We have completed several tethered launches which provides aerial movies of campus in the Engr 101 class. The most successful balloon project however, has been the one that is used in the junior level Intermediate Project Design Lab, EE 380, in which students are expected to design a sequence of open ended projects in a variety of areas such as electronics, microcontrollers, linear systems, etc. For the past four years, EE 380 has included a team-based project in which students design and implement an instrumentation package for a balloon launch.

The balloon launch is the highlight of the EE 380 class and most students eager to participate in the project. The project gets outstanding reviews. The main features of this project are:

- Teams are limited to no more than three students. Each team builds an instrumentation package with strict size and weight restrictions. Typically, two team projects are fitted into one "pod" and a balloon carries up to six pods to a height of about 100,000 feet – near space.
- Each team creates an independent project. Teams which share a pod may share batteries but not other resources such as sensors.
- Temperature, pressure, humidity, g-forces, and altitude are good candidates for measurement as the balloon rises and parachutes back to earth. Small, still cameras are often included, as are movie cameras that make short movies at various altitudes.
- All data collected must be stored on board to be retrieved when the balloon is recovered. Commercial instrumentation is included in a "master pod" and is used to determine the accuracy of the student data.
- The teams sharing a pod must work together on final packaging. Batteries are particularly vulnerable to low temperatures and insulation is critical. Likewise, g-forces can be severe in wind shifts, so pods must be securely tethered together.
- All instrumentation is ground tested before the launch and any instrument that isn't working doesn't fly.

We provide shuttle vehicles to transport team members to the launch site. Typically the team divides its members so that some students participate in the launch and others participate in the recovery. In addition, the entire balloon flight can be viewed online from any computer with an internet connection. A large screen TV in the engineering building lobby displays the flight online.

The EE 380 class is limited to 12 students per section. For this number, a single balloon is sufficient. Each team gets an 8-bit microcontroller which supports a memory card for data storage. For each item being recorded the teams must choose a sensor from several that are available. The software is written in C and must acquire the data, preprocess it, and save it on the memory card. The microcontroller may also trigger a camera or receive commands to take data from another module (at a particular altitude, for example). In some cases, each student module will be assigned a different time or altitude for data collection.

The balloon typically uses two tracking devices both of which make use of GPS data. The first of these sends a radio signal burst to a ground station every ten seconds. This data may also contain information from the sensors. The radio broadcasts at 900 MHz; any correctly configured receiver within the line of sight of the balloon can receive the data. The second tracking unit also broadcasts over a radio channel but uses an Automatic Packet Reporting System (APRS). The data is picked up by the amateur shortwave radio network, decoded and uploaded to `http://APRS.fi`. This data is updated about every five minutes. The APRS is used as a backup recovery system if real-time communication is lost or interrupted.

A 900 MHz transceiver, APRS receiver, GPS receiver, and a laptop computer are located in each chase vehicle and in a remote base station. The computer has the software to translate the location data to an onscreen map for balloon tracking. The existing commercial version of the software is limited in that it can plot only the location of the balloon and chase vehicle on Microsoft Map Point. This allows the driver of the chase vehicle to determine the relative location of the balloon and to follow as best he can. The remote base station is used to receive and upload current tracking data to a university server via the internet. Anyone with an internet connection can watch the balloon flight in real time. Figure 1 shows the flight path for a balloon launched in July, 2012.

The flight path of the balloon is forecast, as software from Near Space Ventures Inc., is available free from `http://nearspaceventures.com/w3Baltrak/readyget`. This software accepts the ascent rate, descent rate, and the GPS coordinates of the launch site. It accesses the current weather forecast for upper level winds and provides a map with the predicted balloon path and landing site. This is typically accurate to within a five mile radius although, in a few instances, it has been as far off as 20 miles.

The software from Near Space Ventures, Inc. is reasonably accurate if the forecast is done in the hour or so prior to the launch and the atmosphere is not stirred up by a passing storm front. It is this software which we have rewritten as a real time Android app. The revised software provides an updated forecast every five minutes based on the present position and current ground speed of the balloon.

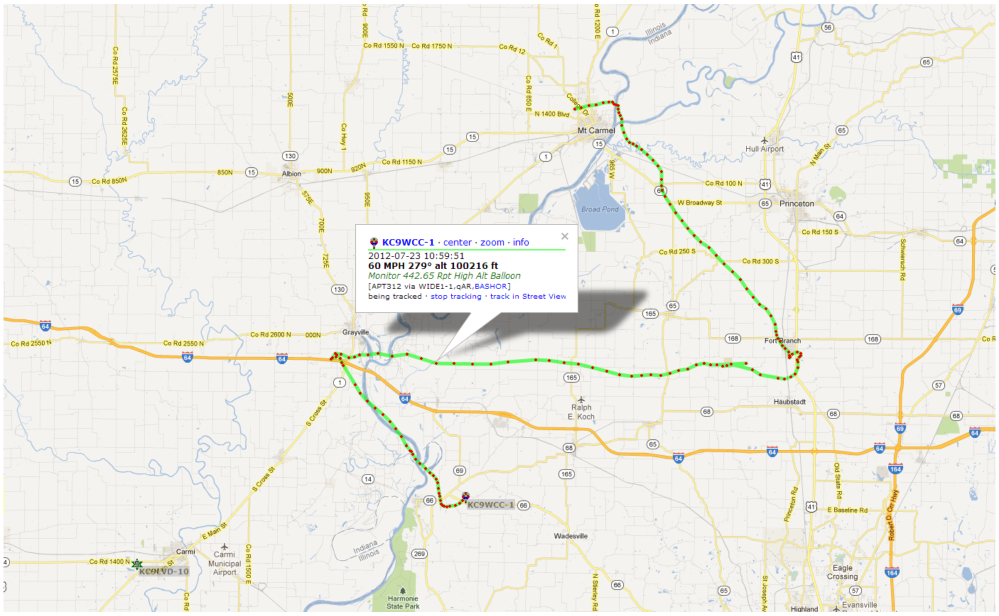


**Figure 1**

The green line marks the path of a balloon launched in July, 2012. The red dots on the line indicate data points where altitude and velocity data was collected and transmitted. The white text box indicates the point where the balloon burst at 100, 216 feet.

**Part 2: The tracking software**

The rewritten software to track and predict the path of the high-altitude balloon was developed as a senior project by a computer science student. It runs on the Android 2.3.6 platform and initially forecasts the balloon's landing point based on upper level wind forecasts and balloon characteristics. After the flight begins, the software tracks the current balloon position and updates the predicted landing point every five minutes in real-time.

The Android platform was chosen for two primary reasons. First, it is commonly implemented on tablets and smartphones. This allows the chase teams to have easily portable devices that are relatively inexpensive, with long battery lives. The second reason is that Android is an open platform and allows direct access to the Bluetooth framework within the operating system. The Bluetooth framework allows easy interfacing with the tracking radios mentioned in the previous section. The iOS platform was also considered for implementation but, due to the restrictions that Apple has imposed on accessing the Bluetooth framework, it is not feasible at this time.

One additional advantage of using the Android platform is the ease with which geo-location data can be integrated with map data. Android provides simple access to the Google Maps data which allows the chase teams to see the balloon track and prediction information overlaid on any of the standard Google Maps views.

To predict the flight of the balloon, the software uses the upper-air data from the Global Forecast System (GFS) forecast model run by the National Oceanic and Atmospheric Administration (NOAA). This model is computed 4 times per day and produces forecasts up to 16 days in the future. The wind velocity at various altitudes is the key parameter used by the prediction model.

The flight model used by the software is the same model that is used by the Cambridge University Spaceflight Landing Predictor. However, we have made a couple of useful modifications in the way that this model is accessed. The modified model can predict a launch site when the user determines a desired landing site. A balloon can be launched from almost anywhere. We have launched balloons from city parks, baseball fields, small airports, public picnic areas, and even from the wide-shoulder of a country road. Choosing a landing site that is relatively tree-free and using the forecast to find a launching site is easier than arbitrarily choosing a launch site and hoping for a good landing site.

Real-time tracking of the balloon is not too difficult since the balloon telemetry sends position data via 900 MHz radio every 10 seconds. This data is captured by a radio receiver in the chase vehicle and then transmitted via Bluetooth to the Android device. One of the new features of the tracking software is that it will re-compute the predicted landing zone based on the current position of the balloon using the same flight model as the initial prediction. This provides continual updates to the chase crew as to where to expect the balloon to land. As the flight progresses, this prediction will approach 100% accuracy.

One future enhancement (which will become a future senior project) is to measure the actual flight parameters (e.g. ascent rate and wind velocities) during the ascent and then use them to compute the landing zone during the descent. This should yield more accurate landing predictions since they will be based on current observations rather than forecast models.

This software is open-source and can be downloaded at:
`http://haballoons.evansville.edu/Research.htm`

**Summary**

Launching a high altitude balloon provides an effective mechanism for team based projects in electrical and computer engineering. Once initial costs have been covered, a balloon launch for a class can take place for as little as $500. (The Stratostar[4] website provides instructional videos and has much of the equipment available to complete a launch.) The design and implementation of instrumentation for the balloon payload is an excellent project involving realistic constraints including software, hardware, packaging, power requirements, and reliability – all in a relatively harsh environment that is difficult to reproduce in a lab setting.

The software developed for this project simplifies the recovery process and reduces the amount of time the chase teams spend looking for the payload. The ascent/descent prediction models used in this software are not new, but the real-time feedback which is used to modify the track prediction is new and significantly improves the track forecast.

The Android-based software developed for this project is available to the public and provides an effective way to recover a balloon payload.

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4. http://www.stratostar.net/ This site sells a complete turnkey system.