Joining the 18.9 Mile High Club

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In 2009, the NASA SC Space Grant Consortium (SCSGC) implemented a high-altitude ballooning program designed to involve students in NASA related research. Students were able to work with a faculty mentor on a hands-on NASA science project. The students designed their own experiments and constructed equipment "pods" to carry their experiments to the edge of space. Each of the selected student teams received a $5,000 award to design and build their own experiment. So far, experiments have ranged from measuring wind speeds, atmospheric pressures, temperatures, and radiation in the upper atmospheres, to bacteria growth, and remote sensing using digital cameras. The 2009 launch involved 5 teams of students & faculty from five different SC campuses. The 2010 launch involved 4 teams of students & faculty from four different SC campuses. The 2011 launch involved 3 teams of students from 2 different SC campuses and one elementary school. Each of the students participated fully in the loading of their experiments and launching the balloon. Comments from the students and faculty show that this ballooning activity is an exciting learning experience for everyone involved. The SCSGC is looking forward to another launch in 2012 that will involve even more students and more institutions.

I. Introduction

The South Carolina Space Grant Consortium (SCSGC) was founded in 1991 and currently has 15 member campuses across the state of South Carolina and the University of the Virgin Islands. The SCSGC has developed competitive and open programs that encourage a broad spectrum of participation in NASA related research and exploration activities. The Higher Education Programs run by SCSGC are aimed primarily at undergraduate students. The goal is to encourage student participation in contributing to NASA's goal of developing a diverse, competitive, and globally engaged Science, Technology, Engineering, and Mathematics (STEM) workforce. The programs are designed to expose students to NASA related research by immersing them in "hands on" learning experiences.

In 2009, the SCSGC was looking for a new and innovative way to get students involved in research and development. The desired activity would be one that would immerse students in "hands-on" learning while they worked with NASA related research and faculty mentors. It was decided that involving the students in a high altitude ballooning program would not only meet these goals, but sounded like a fun idea as well. (See Fig. 1) The program's purpose is to provide the students with the opportunity to "Design / Build / Fly" their own science experiments and analyze their own data and results after the experiment flight has been completed. The SCSGC's objectives and outcomes for the participating students; to gain hands-on knowledge of scientific methods and processes; to gain understanding of the importance of teamwork; to experience the exhilarating feeling of discovery; to increase the student's self-confidence; to increase written and oral communication skills; to spark an interest in continuing NASA-relevant research in graduate school; and to enter the STEM workforce by working on NASA-related endeavors.

SCSGC's program is designed around a yearly competition of student proposals. The proposals must include a 500 word essay describing their activities, interests, and future plans, a detailed description of their project along with a budget of projected costs, two faculty recommendations, college transcripts, and a resume. Those proposals are sent to faculty who have volunteered from Colleges and Universities with existing ballooning programs to act as outside reviewers. Once the reviews have been collected the top 4-5 applications are selected by the SCSGC to become part of the program. The entire application process can be found on the SCSGC's High Altitude Ballooning

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Program website (http://spinner.cofc.edu/~scsgrant/research/balloon.html). Winning students receive a $5,000 stipend to use as they see fit to design their project. Students can use the stipend entirely on equipment, as travel funds to conferences, faculty honorariums, or as money to use towards their education. The competition is open to all students who have an interest in high altitude ballooning. The SCSGC did not want to limit the competition to strictly engineering departments and wanted to cultivate the creativity and imaginations of students from a diverse range of disciplines.

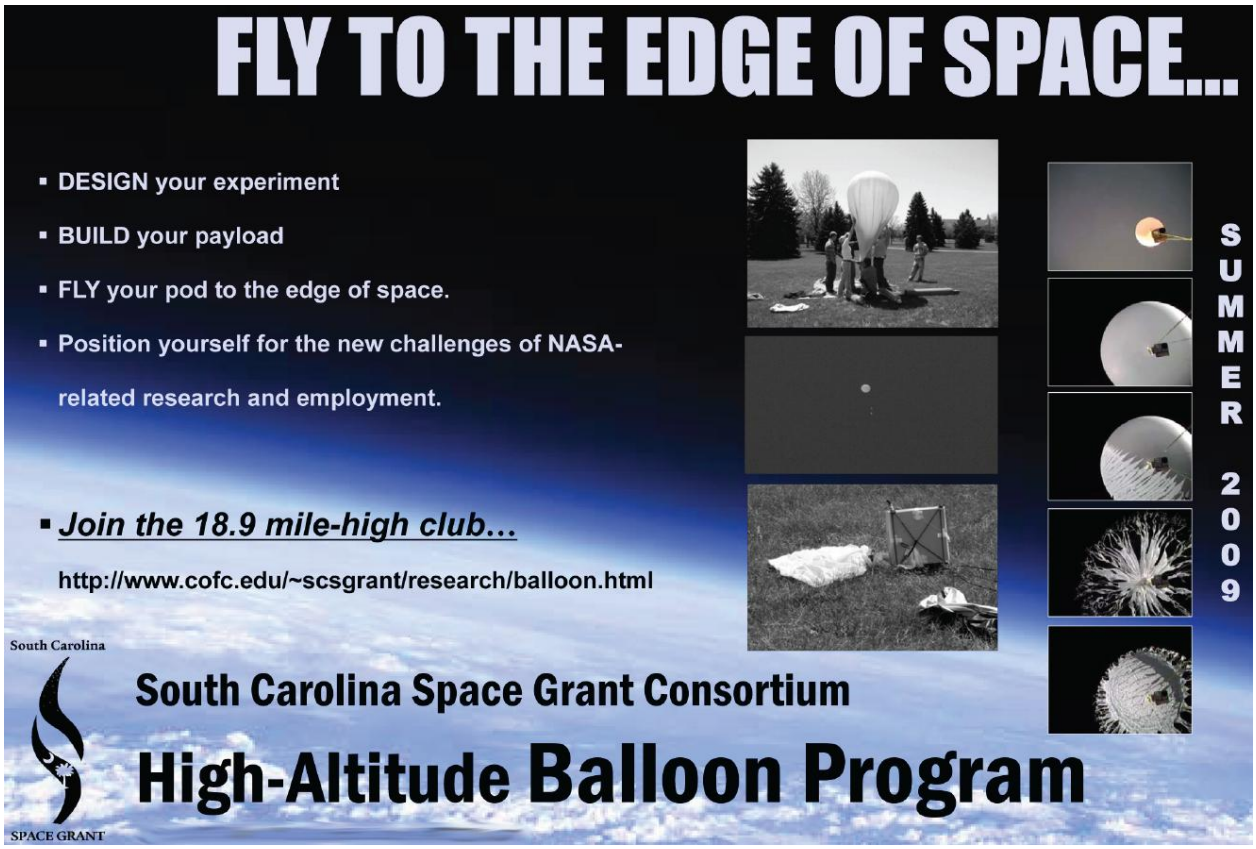

Figure 1. SCSGC High-altitude Balloon Program Poster.

The students are required to build their experiments to fit into a 6" by 6" by 6" flight pod cube, and to keep their experiment under 2 lbs. The students and their faculty mentors are involved in the entire project and fully participate in the launch, flight tracking, and recovery of the balloon. The students are only required to use their stipend for their actual experiment, so SCSGC provides all the other necessary hardware and software for the launch and recovery of the balloon.

Since SCSGC was new to the world of high altitude ballooning, we worked with StratoStar Systems to purchase our equipment and to have them travel down to Charleston, SC so that they could train our staff on managing a balloon flight. StratoStar Systems also provided technical support to SCSGC during all phases of the project. Most of the hardware purchased from StratoStar Systems is reusable, and SCSCG has used StratoStar Systems to repair damaged equipment and to provide upgrades to the payload system. SCSGC has also purchased additional equipment as the program has progressed as new lessons are learned during each flight.

This paper is designed not to discuss in detail the specifics of each student's project (SCSGC believes that it is up to each individual student to pursue publishing their own work), but to mention the different types of experiments that the SCSGC was able to fly during our high altitude ballooning program. The SCSGC recognizes that this program differs in scale and variability of other programs, and we would like to show some of the challenges that we have had in managing what has turned out to be a very popular but high risk project.

II. SCSGC 2009 Inaugural Launch

The SCSGC generated quite a bit of interest for this project and we received several abstracts for possible experiments. After the outside review process was completed, the SCSGC chose a final group to participate. Students from Clemson University, Coastal Carolina University, The Citadel, and Furman University developed, built, and launched their experiments. SCSGC also designed and flew a test experiment to be used for future research and advertisement opportunities. The experiments, students, and schools are listed below.

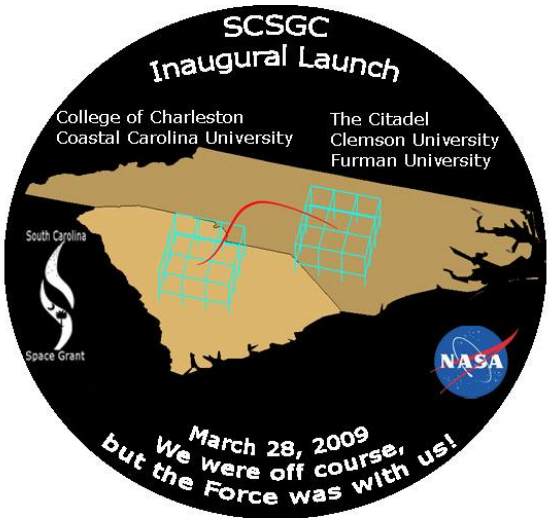

Figure 2. SCSGC 2009 Mission Patch.

1) Aerial Imaging and Atmospheric Data Collection: High Altitude Ballooning, by Matthew Torok and Joshua Summers. Clemson University

2) Measurement of Cosmic Radiation Using Electronic Digital Camera CCD Detectors, by Matthew May, Dustin Hilliard, and Daniel Woodworth. The Citadel

3) Measurement of Atmospheric Gravity Waves via Directional Thermistors, by William Graeber. Furman University

4) Getting a Glimpse at Atmospheric Turbulence, by Eric Demarco. Coastal Carolina University

5) Using a Handheld GPS to look at GPS Error and HD Video Camera to Create an Interactive Flight Path, by SCSGC. College of Charleston

SCSGC was excited about the first launch, unfortunately due to College of Charleston's close proximity to the Atlantic Ocean, an inland launch site was chosen. SCSGC with the information gathered from the Near Space Ventures, Inc. Flight Prediction Page (http://nearspaceventures.com/w3Baltrak/readyget.pl) a launch site near Camden, SC was chosen that would have made Bennettsville, SC an estimated landing zone. As luck would have it, the weather did not cooperate and due to the small launch window SCSGC has set up the balloon was launched directly into the path of an oncoming thunderstorm.

The weather ended up playing havoc with our flight, ice built up on the payloads weighing the balloon down, and heavy rain and winds buffeted the balloon during the entire flight. Our balloon ended up overshooting the predicted landing zone by 47 miles and ended up crossing the SC/NC state line. This storm system was widespread and spawned several tornadoes in the area, making what had become an already difficult retrieval more complicated. Eventually the parachute brought our payloads down into the US Army Base of Ft. Bragg in Fayetteville, NC. The telemetry signal from the balloon to the laptop was lost just before impact and the retrieval team had to use the radio beacon to search for the landing site. (See Fig. 3)

Once permission to enter the base was obtained, we were able to locate the parachute. The search took several hours, and lasted well into the night, ending at 11:30pm. The parachute missed the actual paratrooper landing zone by approximately 500', ending up in the top of a large pine tree. This presented yet another problem because this area is a known nesting site for the endangered Red Cockaded Woodpecker. Members of SCSGC had to return to Ft. Bragg two days later to meet with a biologist so he could make sure that no endangered species were nesting in the area. Once it was determined that no endangered species would be impacted and that the tree was a non-native species the biologist cut down the tree. SCSGC was able to return the experiments to the students so they could start on analyzing their data.

Even with the recovery difficulties, the students and their mentors gave glowing positive reviews about the project and SCSGC was pleased to renew the project for a second year.

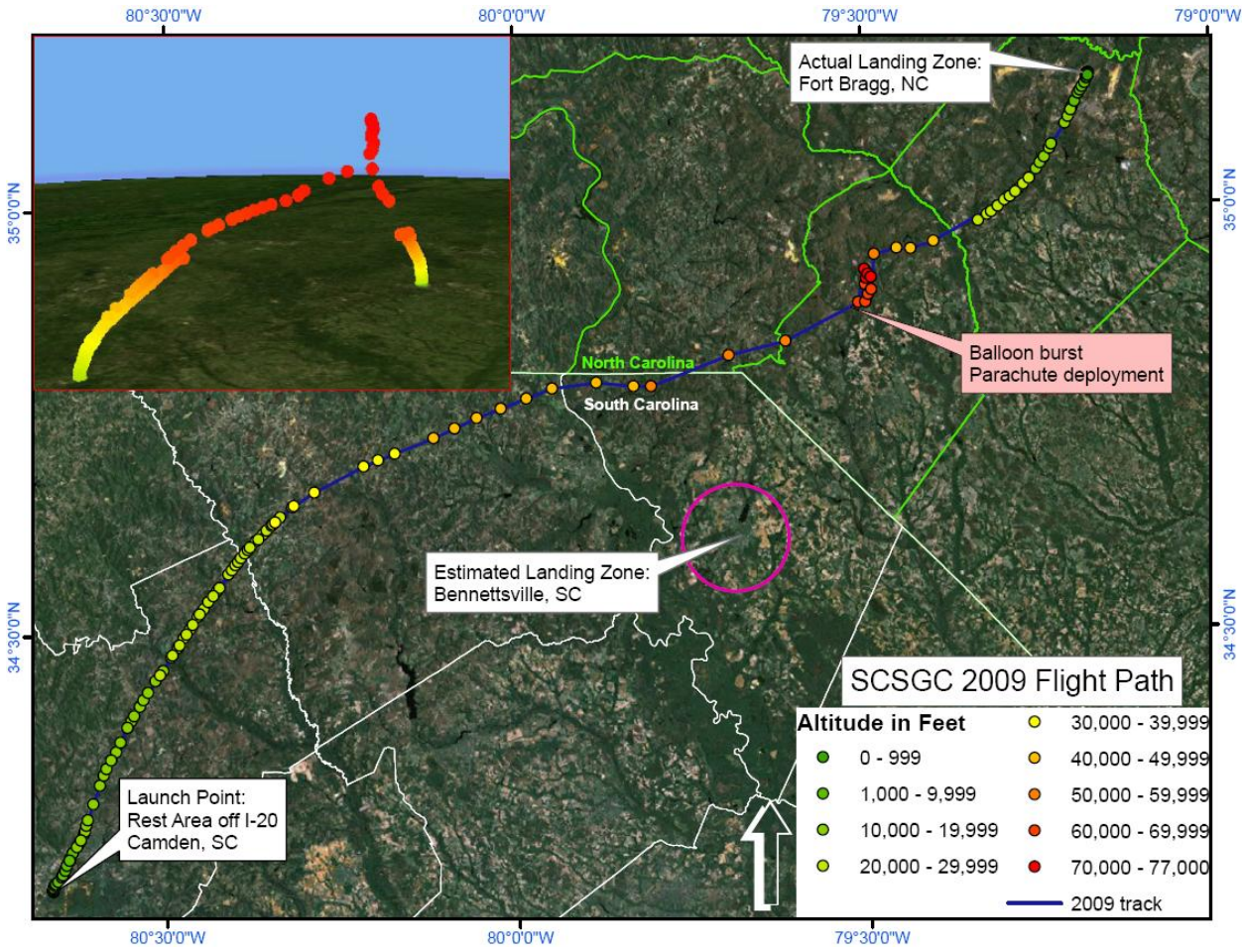

Figure 3. Map of SCSGC 2009 High Altitude Balloon Flight Path.

III. SCSGC 2010 Launch

As the SCSGC started to advertise for the 2010 high altitude balloon launch; students from the 2009 launch were spreading word of mouth how much fun the program was and SCSGC received several strong proposals. Outside reviews were conducted and once again the SCSGC chose a final group to participate. Students from The Citadel, College of Charleston, Furman University, and Francis Marion University developed, built, and launched their experiments. This year the students also demonstrated a tethered launch at the Charleston, SC Earth Day festival. The students were on hand to explain to the attendees what they were doing and why such experiments were important in helping scientist understand regional and global climate. The experiments, students, and schools are listed below.

1) A Simple Cosmic Ray Hodoscope Using Commercial CCDs, by Andrew Carnes. The Citadel
2) Thermal and Optical Remote Sensing, by, 2010 NASA Mission Class. The 2010 College of Charleston
3) Quantification of Cosmic Radiation Mutagenicity and Survivability of Bacteria and Near-Space Altitudes, by William Graeber. Furman University
4) Flying to the Edge of Space, by Philip Laing. Francis Marion University

The lessons learned from the 2009 launch were taken into account for the 2010 launch. SCSGC made additional preparations and purchased additional gear to help with the launch and recovery. A second alternate launch day was scheduled in case weather became an issue during our primary date. SCSGC also purchased field supplies such as bug spray, sunscreen, first aid kits, safety vests, and bottled water to help the students and faculty work in the field for a lengthy period of time should there be any issues such as a delay in the launch or an extended recovery effort.

Figure 4. SCSGC 2010 Mission Patch.

SCSGC started to discuss the idea of actually launching from Charleston, SC and coordinating with the US Coast Guard and local fishing captains to be on the lookout for a landing in the water. However, after studying the sheer size of the potential area that boats would have to cover, SCSGC made the decision to launch inland. With the help of the Near Space Ventures, Inc. Flight Prediction Page a launch site near Sumter, SC was chosen that would have made Lake City, SC an estimated landing zone. There was good weather for the launch date and the balloon was released on time, unfortunately, the landing zone was overshot by 20 miles and the parachute came down in the riparian swamp of the Pee Dee River. The recovery team was forced to hike into the swamp and navigate by GPS to the last received coordinates. (See Fig. 5)

The parachute once again ended in the top of a tree, unfortunately only the parachute and the command pod were visible. A general search of the swamp surrounding the tree did not yield any evidence of the experiment pods. All attempts to either climb the tree or get a line up to the parachute to pull the command pod failed and the retrieval team was forced to leave the gear in place. Several days later a farmer contacted the SCSGC office to report "this strange box I found in my yard." One of the experiment pods had been located in a field underneath the flight path of the balloon. Later that week members from the SCSGC returned to the area and picked up the pod from the local farmer. SCSGC had also enlisted the help of a professional tree climber who was able to safely retrieve the command pod and parachute. Further examination of the gear led the SCSGC theory that the loss of the payloads due to a faulty knot coming undone, or a line being frayed by one of the pods. The loss of one of the support lines then put all the stress of the pods onto the opposite line that then broke during the parachute deployment. This theory also lends itself to the explanation of why the parachute overshot the predicted landing zone.

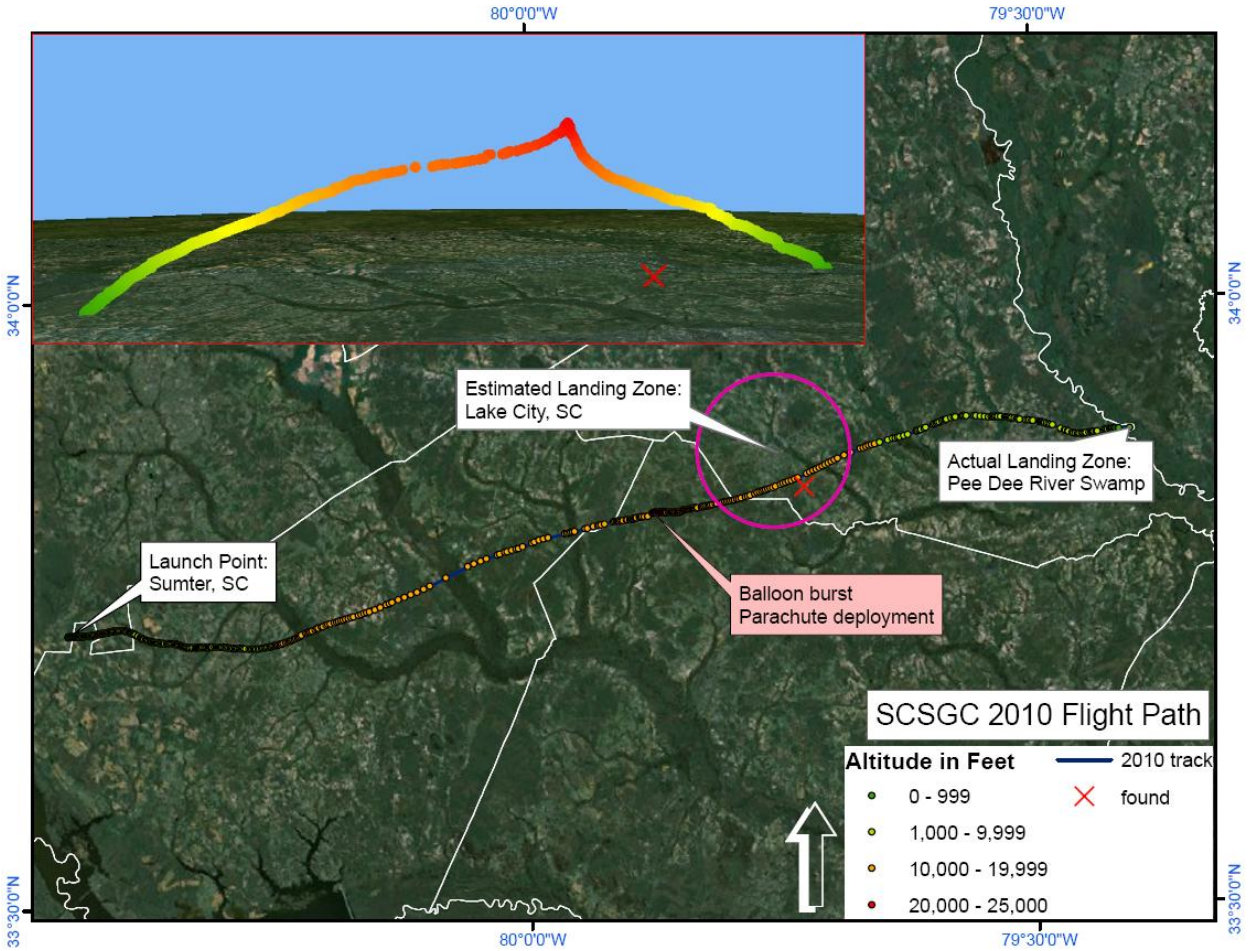

Figure 5. Map of SCSGC 2010 High Altitude Balloon Flight Path.

The recovered experiment pod happened to belong to the cadets from The Citadel and their equipment was returned to them to see if any data could be retrieved from the damaged equipment. Even with the loss of the payload students gave positive feedback to SCSGC stating that while they were disappointed in the loss of the equipment, they enjoyed working on the project.

Students from the Introduction to Geographic Information Systems (GIS) class were given the flight data and the location of the recovered pod. Since the recovered pod was at the top of the payload, the students theorized that all the pods dropped off at or near the same time. The students were able to make a map of the predicted area that the other pods might have landed. (See Fig. 6) However after a general search by SCSGC members and no other calls from residents in the area, the pods have been classified as lost.

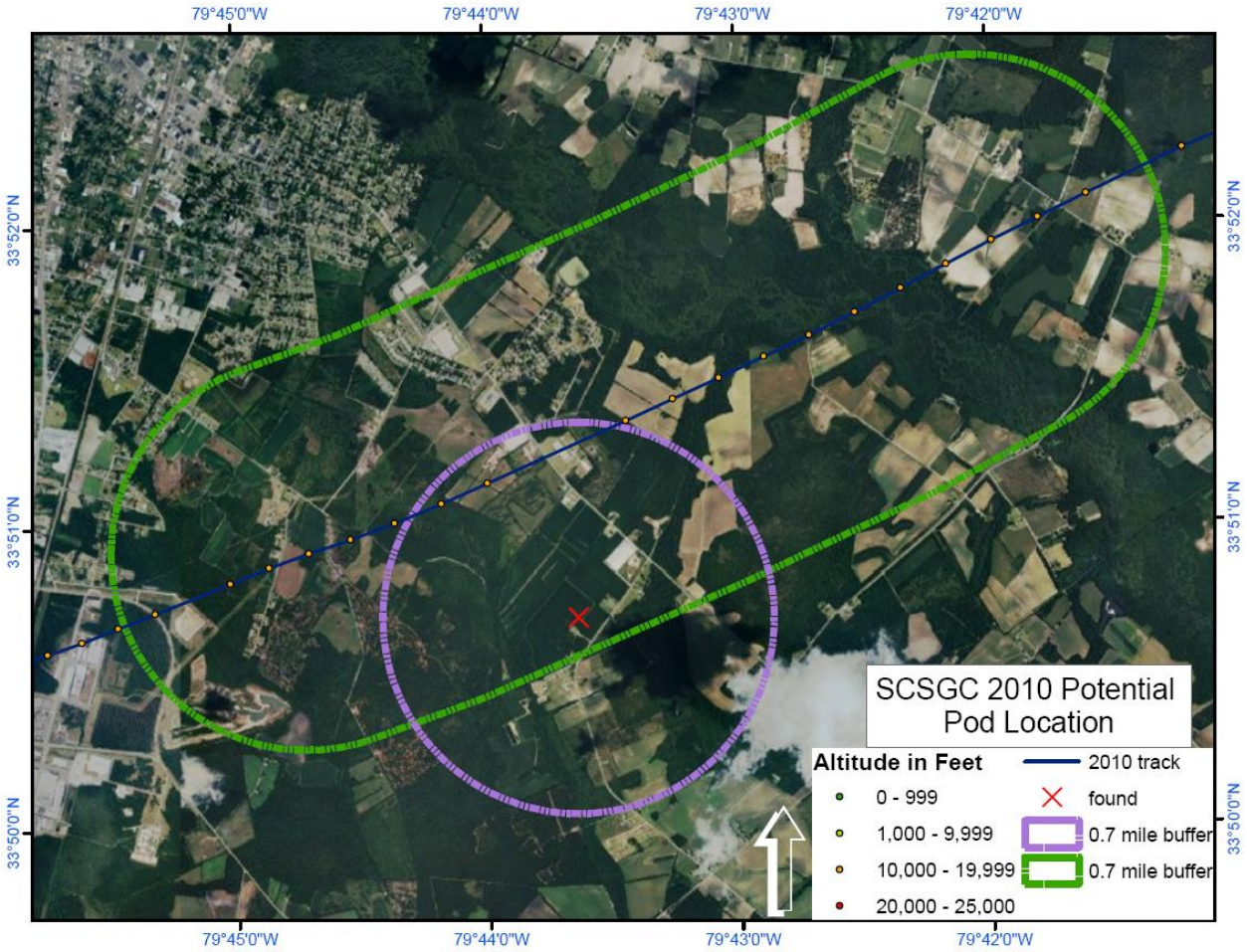

Figure 6. Map of Potential Locations from 2010.

IV. SCSGC 2011 Launch

The SCSGC was determined to have a successful 2011 high altitude balloon launch and advertised heavily across South Carolina. As with previous years outside reviews were conducted and the SCSGC chose a final group to participate. Students from The Citadel, and Furman University, developed, built, and launched their experiments. While the number of schools decreased this year, this was the first time that two different applications from the same school were accepted. The Citadel had two experiments flying increasing the number of students from their school who were able to participate in the program. The SCSGC also flew a pod that contained an experiment from an elementary school student, as well as an electric LED emergency roadside flashing beacon that was used to help with visibility during flight and recovery. The experiments, students, and schools are listed below.

1) The Citadel NERDS III (alpha) Payload, by Matthew May, Ryan Boodee, Janikula Matthew, and Michael Santos. The Citadel
2) The Citadel NERDS III (beta) Payload, by Djordon Porter, Benjamin Hall, Daniel Pittman, and Jerrod Styrk. The Citadel
3) High Resolution Image and Pressure Data Collection from a High Altitude Weather Balloon, by Matthew Arnold and Connor Jennings. Furman University
4) How Do Seeds Grow After Being Sent Up in a Balloon?, by J.T. Smeltzer. Jenny Moore Elementary (flown by College of Charleston)

After discussing with StratoStar Systems about the potential failure points from the 2010 launch, we ordered new pods that were put together with StratoStar's improved design. These pods were pre-strung with metal cables and cord and could be hooked together with swivel snaps. This design would hopefully help eliminate any potential

Figure 7. SCSGC 2011 Mission Patch.

human knot tying error, and help eliminate the friction that may have led to last year's string failure. In addition to the LED emergency roadside flashing beacon, a model rocket "screamer" (a 3oz battery operated light and noise producer) was added to the command module. These additions were put in place to help increase the chances of recovery should another forested landing occur.

The spring of 2011 was associated with strong weather conditions, and an easterly blowing wind. This forced the SCSGC to find a launch site well inland to avoid the balloon crossing over land and into the Atlantic Ocean. The Near Space Ventures, Inc. Flight Prediction Page was consulted and a launch site outside of Aiken, SC was chosen that would have made Harleyville, SC in the estimated landing zone.

The launch was picture perfect, the balloon carrying the pods almost straight up till it drifted out of site. Both the launch and the recovery team were receiving good telemetry back from the command module up till 66,000' when both teams lost all contact. While the launch team tried to follow the roads that closely matched with the predicted flight path to see if a signal could be picked up in case of a premature balloon burst, the recovery team stayed in the predicted landing zone. After 45min the recovery team reported that they had reestablished a weak signal from the command pod at an altitude of 12,000'. The recovery team was able to follow the parachute to the landing zone, which ended up almost directly in the center of the predicted area. (See Fig. 8) Following tradition, the parachute ended up in a tree. This time a student was able to climb the tree and recovery was made at that time.

Unfortunately, this flight lost the experiment pods as well. The parachute was fine, however, the command module had the antenna broken off, and while the metal cables that ran through the pods were still attached, there were no signs of the equipment pods at all. The damaged looked like the balloon had sustained an impact of some type, but due to the height of the balloon at the time the signal was lost the current theory is just strong wind shear.

Several days later, a farmer made contact with the faculty mentor from The Citadel, having found one of their two experiments in his field as he was getting ready to plow. The students were able to retrieve the data from the remains of their equipment. This pod still had the metal cables attached to it, but the clips had been pulled straight through the pod and there was evidence of heavy damage to the guide wires and the pod itself.

The SCSGC again used the Introduction to GIS class to map the flight path and the location of the recovered equipment pod. A buffer zone around the flight path and the pod was created to estimate a potential landing area for the rest of the equipment pods. The predicted area is quite large, and since no other resident has contacted SCSGC, these pods too have been classified as lost. (See Fig. 9)

V. Conclusion

One of the first issues that SCSGC had in managing this project was the logistics of getting several students and their mentors from all across the state of South Carolina into one location for the launch. The act of scheduling so many different people and having them agree on a weekend that they can get together has been a limiting factor on the ability to choose a flexible launch date. Many issues from class schedules, vacations, to mandatory school functions have caused issues in this scheduling. Another issue that our program has to deal with is the topography of our area. The Carolina's have mountains to the west, the Atlantic Ocean to the east, and are full of lakes, tree farms, and natural wooded areas that make recovery efforts a challenge.

SCSGC has done its best in finding launch locations. However, we realize that these small launch windows may be a factor in the problems we have been having in our recovery efforts. One change the SCSGC is considering in the future is having two weekends pre-chosen for potential launch dates and making the availability to participate during those dates mandatory to be able to apply for the program. This will allow for a greater flexibility to prepare for the launch in case the weather looks like it would impact either the launch or recovery efforts.

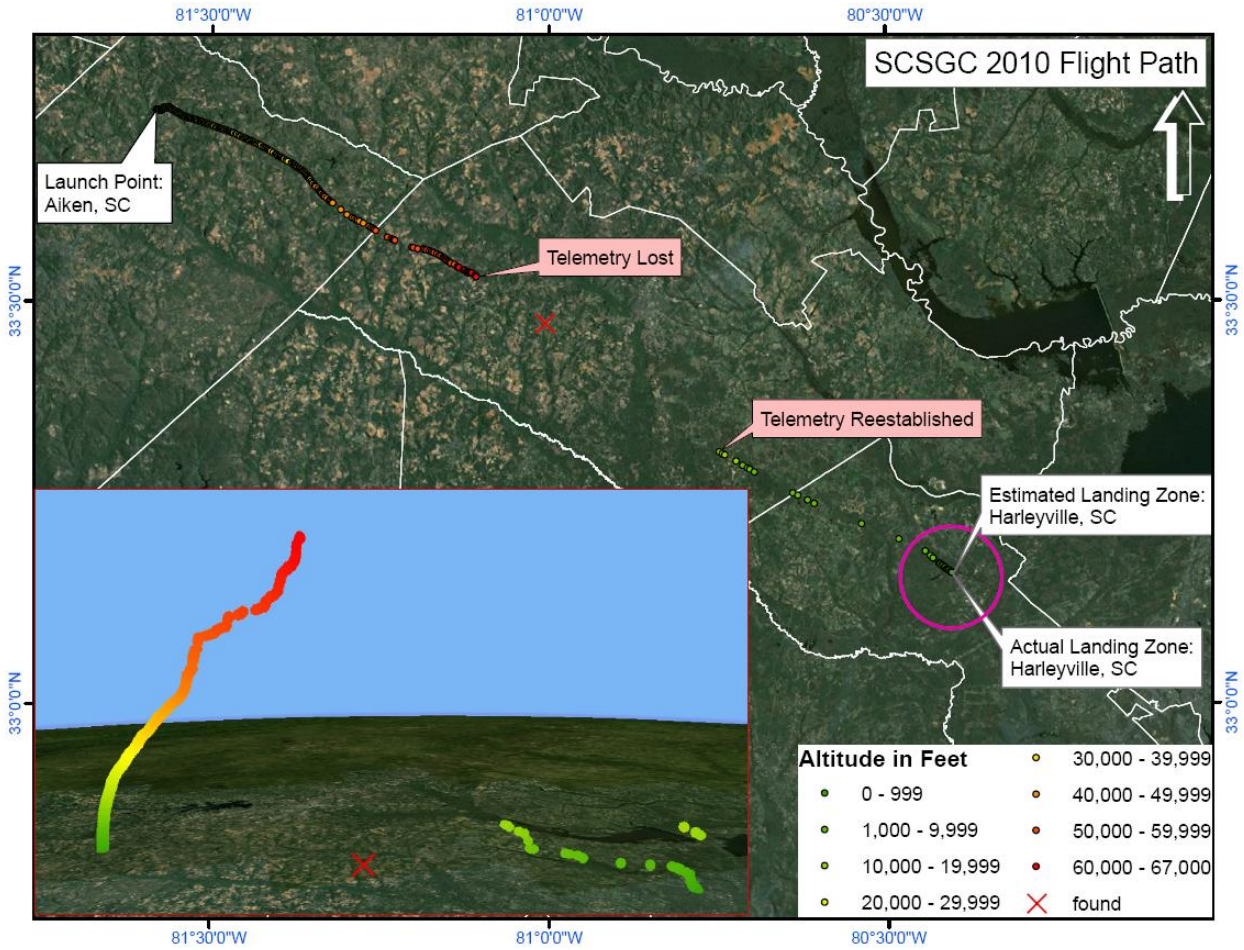

Figure 8. Map of SCSGC 2011 High Altitude Balloon Flight Path.

The SCSGC believes in these types of student participation, hands on, faculty mentored projects. However, this project is considered "high-risk" after being 3 for 3 in tree landings, and 1 for 3 in successful recoveries. (See Fig. 10) The SCSGC is currently undergoing an internal review of this project. Realizing that 3 launches still makes SCSGC fairly new to this type of work, we welcome any comments or advice from people who have been able to overcome similar problems. The SCSGC hopes that we can run this or similar student research projects in the future.

Acknowledgments

The SCSGC would like to thank NASA for providing the funding to run this project. The SCSGC would also like to thank the students and faculty who participated in this program. Special thanks go out to Dr. Briget Doyle, Dr. Norm Levine and the students of the Introduction to GIS class for helping process the flight data. The SCSGC hopes that even more students and faculty will apply for our upcoming programs in the future.

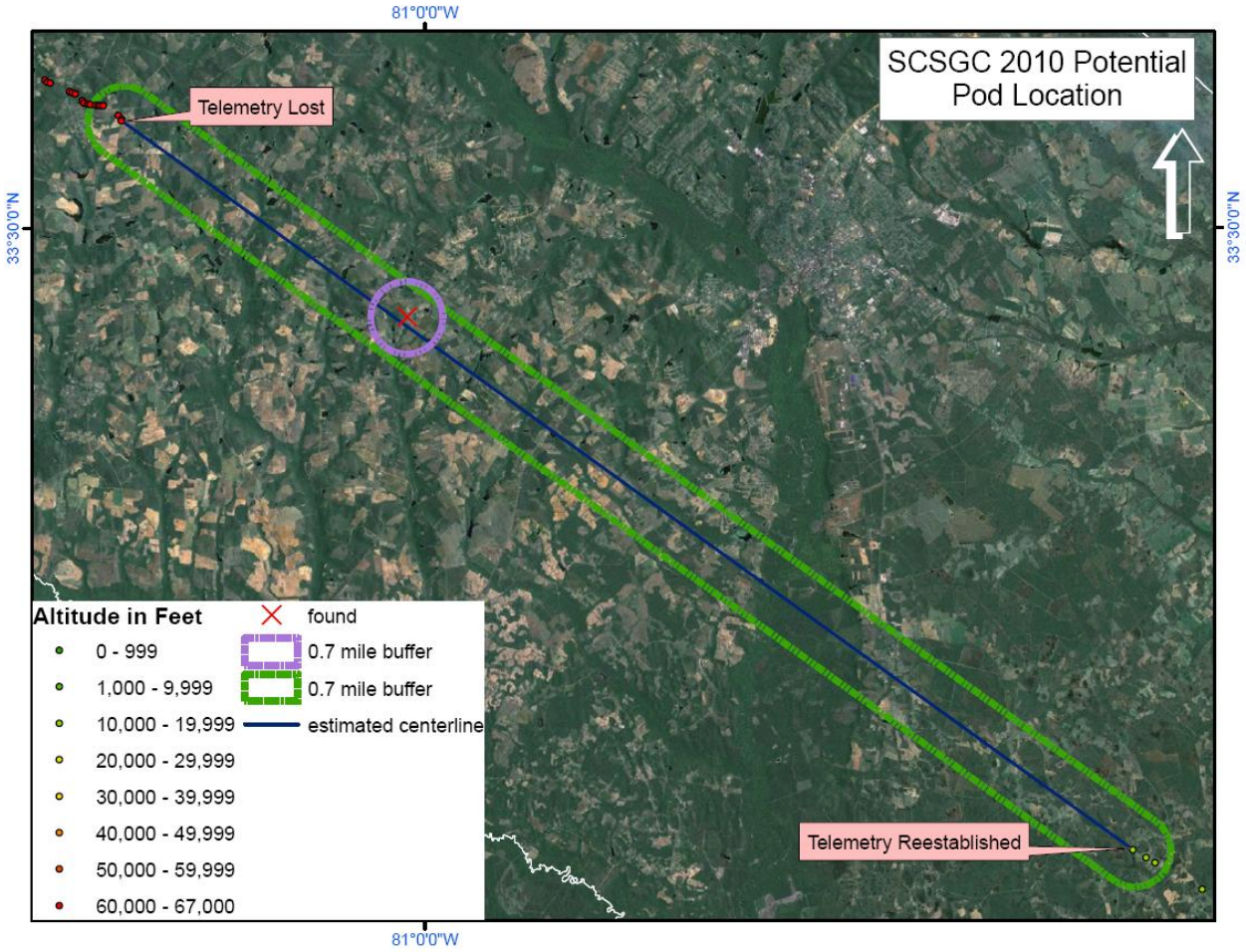

Figure 9. Map of Potential Locations from 2011.

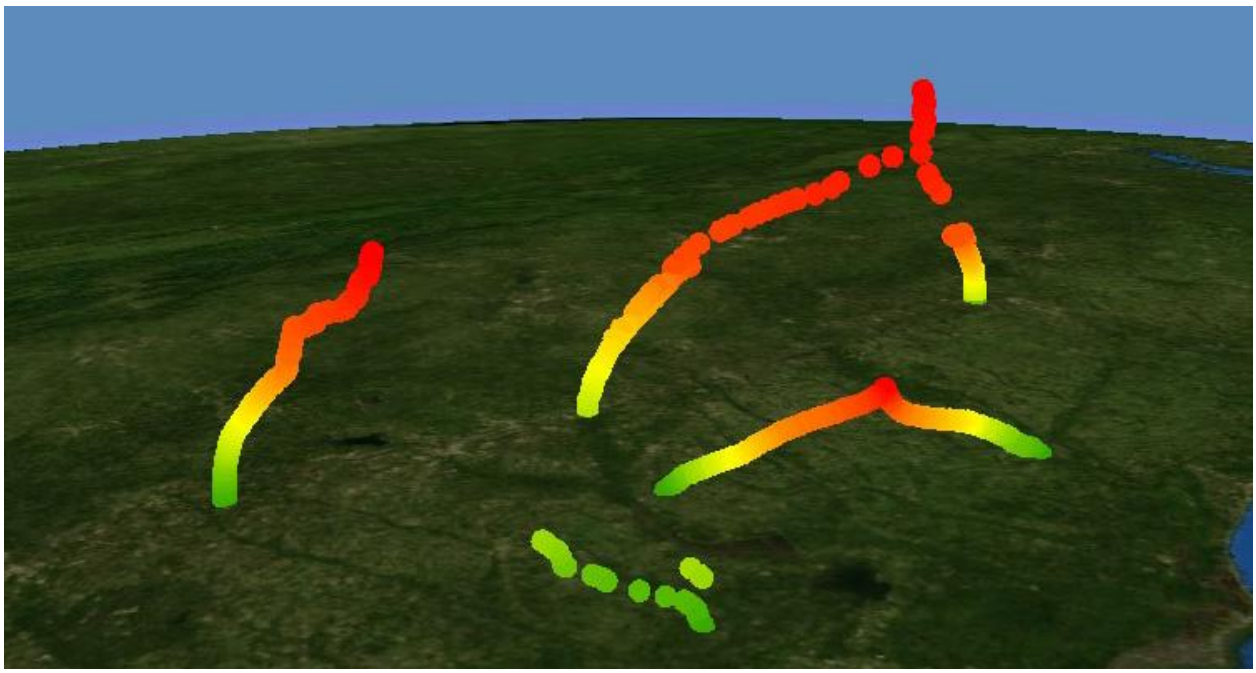

Figure 10. SCSGC 3D Image of All Launches.