Oklahoma State University / Tulsa Technology Center

Balloon Satellite Mission: ASTRO-08

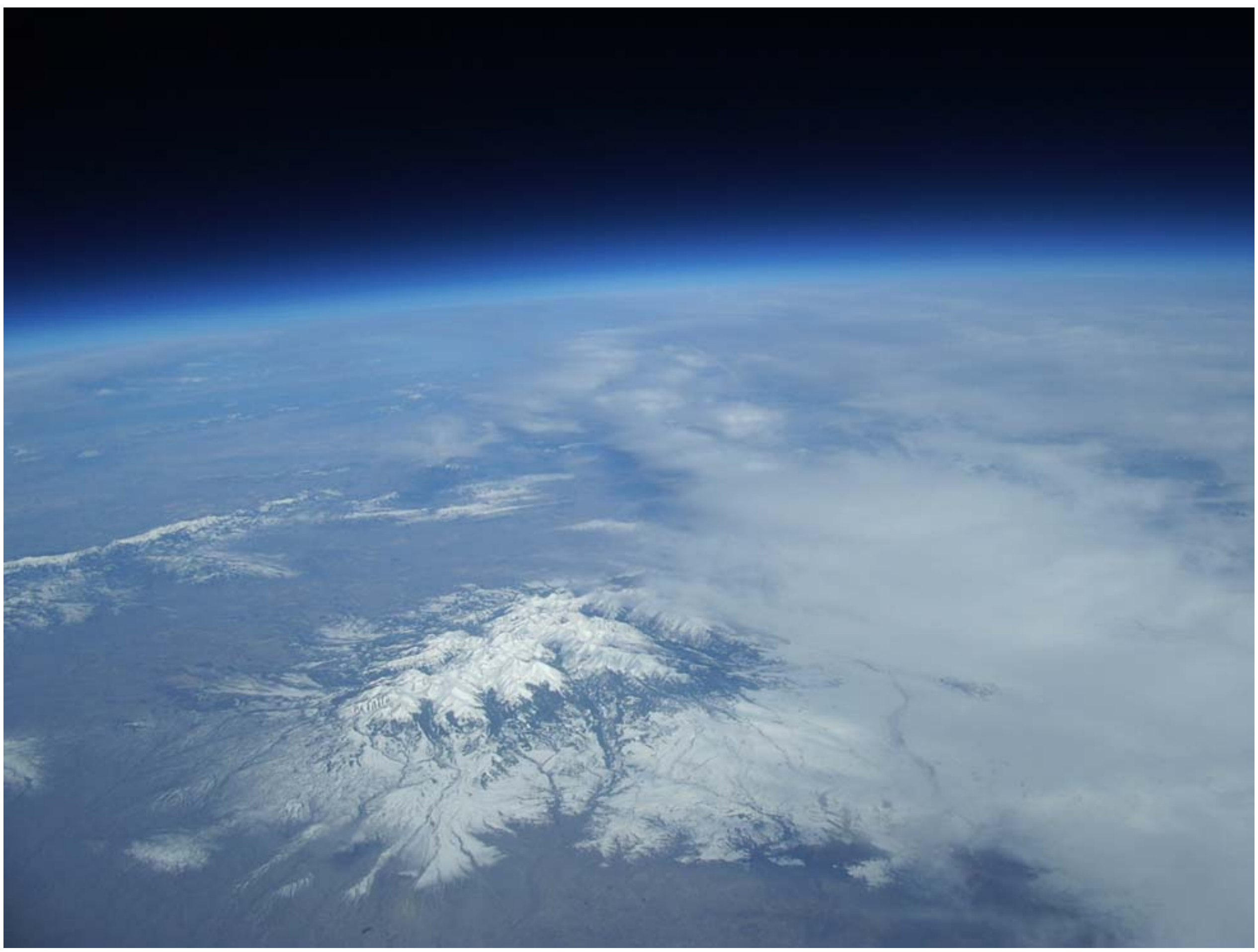


Photo Taken on April 2005 Borealis Flight; Montana State University

Project Background

There has been much debate over the past few years concerning the supply of engineers and high-tech technicians in this country. Many of us believe that the roots of this dilemma are found at the high school level. Due to a lack in preparation or a lack of interest, our young adults are not competing in the engineering curriculums at our country's major research universities. Various national initiatives have been underway for the past two decades to recruit and develop aspiring young pre-engineers at the high school level, with the hope of refreshing our aging high-tech workforce. Recently, these initiatives are being taken more seriously due to increased indications that the US is loosing its role as the world's leader in innovation and technology. Here in Tulsa, Oklahoma, bridges are being built to span the academic gap between our teenage talent and our engineering colleges.

Under the mentorship of Dr. Andy Arena (Oklahoma State University), Mr. Joe Conner (Oklahoma State University), and Mr. Harry Mueller (Oklahoma Research Balloons), Tulsa Technology Center's *Introduction to Aerospace Engineering* class built payloads to fly on the ASTRO-08 mission, which was successfully flown on February 22, 2008. The mission objective was to carry student payloads and experiments to the near-space altitude of 100,000 feet MSL, to track and recover the payloads, and then to download and process the data. Student payloads consisted of cameras and temperature data acquisition equipment. The experimental payloads, built by OSU's PhD candidate, Joe Conner, consisted of two video cameras, with a third experiment to test a *Dual-Tone Multi-Frequency* (DTMF) activated cut-down device. This article will primarily focus on the educational aspects of this project, from the perspective of the Tulsa Tech students and instructor.

Since this type of coursework and activity is new in Oklahoma at the high school level, many technological and logistical details needed to be ironed out. All the normal challenges associated with a startup program were encountered this year. For this mission, the students and the instructor set modest goals. Many lessons were learned through trial and error. And, as wisdom would dictate, we learned far more through our failures than we ever could if everything worked the right first time. The class objectives for the payloads were to develop reliable and inexpensive technologies for: 1) photographing the earth at near-space altitudes; 2) gathering atmospheric data; and 3) processing *Automatic Position Reporting System* (APRS) packets and tracking the payload. *Objectives 1 and 2* were reasonably successful, while *Objective 3* needs further development within the Tulsa Tech class.

Camera Circuit

Based on feedback from multiple sources, we chose the adjustable *Interval Timer* kit, manufactured by *Velleman*, to trigger an *Aiptek* *PocketCam* on a 20 to 30 second cycle. We found the timer kits easy to assemble, convenient for school purchasing, and inexpensive. At room temperatures the 12-volt kits worked fine. However, we had problems with our kits when they were exposed to even moderate drops in temperature. Specifically, while at room temperature, the timer kit was set for a 1 second pulse and a 30 second pause. Then after the temperature dropped to around zero degrees Celsius, the pulse would extend to over 2 minutes with the pause remaining at the original 30 seconds. This drastic increase in the cycle time would, in turn, cause the cameras to go into sleep mode prematurely and cause battery life to decrease. A fix was incorporated by placing a transistor on the output pin of the 555 timing chip to drive the relay (*Figure 1*). With this change in place, the timer kit functioned properly at and below zero degrees Celsius. The instructor observed this modified circuit working fine for over 1 hour in a freezer without insulation or supplemental heat. Next year's class will use a different, smaller timing circuit. A transistor will be used to switch the camera's trigger, as opposed to a relay switching the camera's trigger.

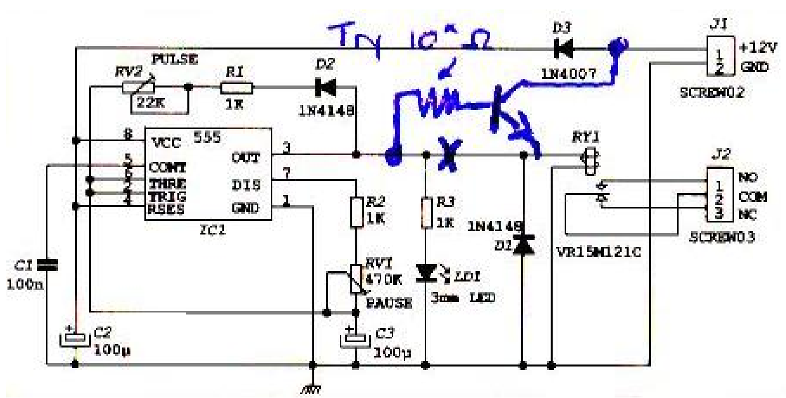


Figure 1: *Velleman's MK111 Interval Timer kit modified circuit. Modification courtesy of Mr. Barry Lazzer, Tulsa Technology Center's Digital Electronics instructor.*

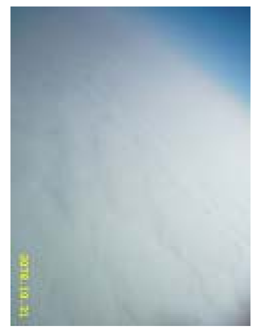
The *PocketCams* were inexpensive enough; costing approximately $30 each. They were lightweight and easy enough to integrate with the timing circuit. The resolution of the photos taken at altitude was acceptable given the extreme temperatures and the low cost. However, two out of the three student payloads' cameras quit taking pictures early during the flight. We have multiple theories as to why the cameras malfunctioned and it will fall to the next year's class to resolve this problem. The following photos (*Figure 2*) were taken at random intervals on the flight up. The atmosphere was very cloudy, resulting in unimpressive photos for this mission. Notice that we need to turn the *date-time-stamp* off for the next mission and we need to turn our cameras 90^{o} (landscape orientation).

ASTRO-08
Student Photos

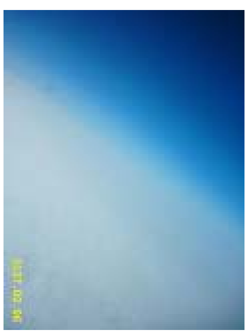
Approx Alt: 1,900 feet

(View of OSU's new stadium)

Approx Alt: 7,500 feet

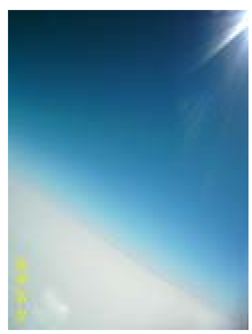


Approx Alt: 13,500 feet

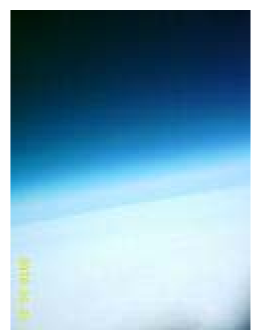


Approx Alt: 18,000 feet

Approx Alt: 27,000 feet



Approx Alt: 32,600 feet



Approx Alt: 99,000 feet

***Figure 2**: Selected Mission Photos*

Heater Circuit & Temp Data

The Hobo Data Logger, by Onset Computers, was used to gather temperature information for the mission. This is a great device. It's lightweight, easy to use, and will collect temperature and relative humidity data. The price is moderate at approximately $130, with another $25 going towards software. We developed a simple and lightweight thermostat circuit (*Figure 3*) to latch-on the "heaters" (two power resistors) at a preset temperature. The thermostat and heater circuits with the 9-volt battery had a combined weight of 67 grams. This heater circuit in conjunction with the data loggers will continue to be a nice educational resource. The students will be exposed to more electronics as they build the circuits and they will be able to collect data on their experiments related to the satellite's thermal conditions during flight. The thermostat will allow the students some flexibility in choosing the start conditions for the satellite's heater.

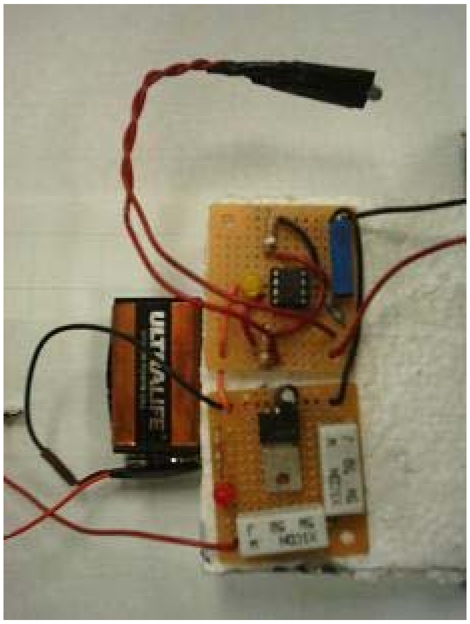


Figure 3: *Thermostat and Heater Circuits. A 741 Op-Amp is setup as a comparator, which triggers a Silicon Controlled Rectifier (SCR). The SCR "latches-on" the heater circuit. The 9-volt battery is drained through the two resistors (5-watt, 5-ohm).*

Since this was the first mission for the Tulsa Tech class, temperature data was collected on the interiors of the satellite boxes, as opposed to collecting the atmospheric temperature data. We were more concerned about the adequacy of our small heaters. Below is a chart of the temperature data collected on the inside of one of the satellite boxes (*Figure 4*). You can see that the heater circuit turned on at 18^{o} F, approximately 15 minutes before apogee. We believe the 5^{o} shift in temperature produced by a single battery and two small resistors is adequate for our purposes. Again, our goal is to keep things cheap and lightweight. (The elevated temperatures from 15:00 to 18:00 are due to the box being stored with a hand-warmer accidentally enclosed in the box.) A possible improvement for next year's class would be incorporating in the circuit a large amount of hysteresis to turn off the heater when the temperature reaches a level 20^{o} higher than the trigger temperature.

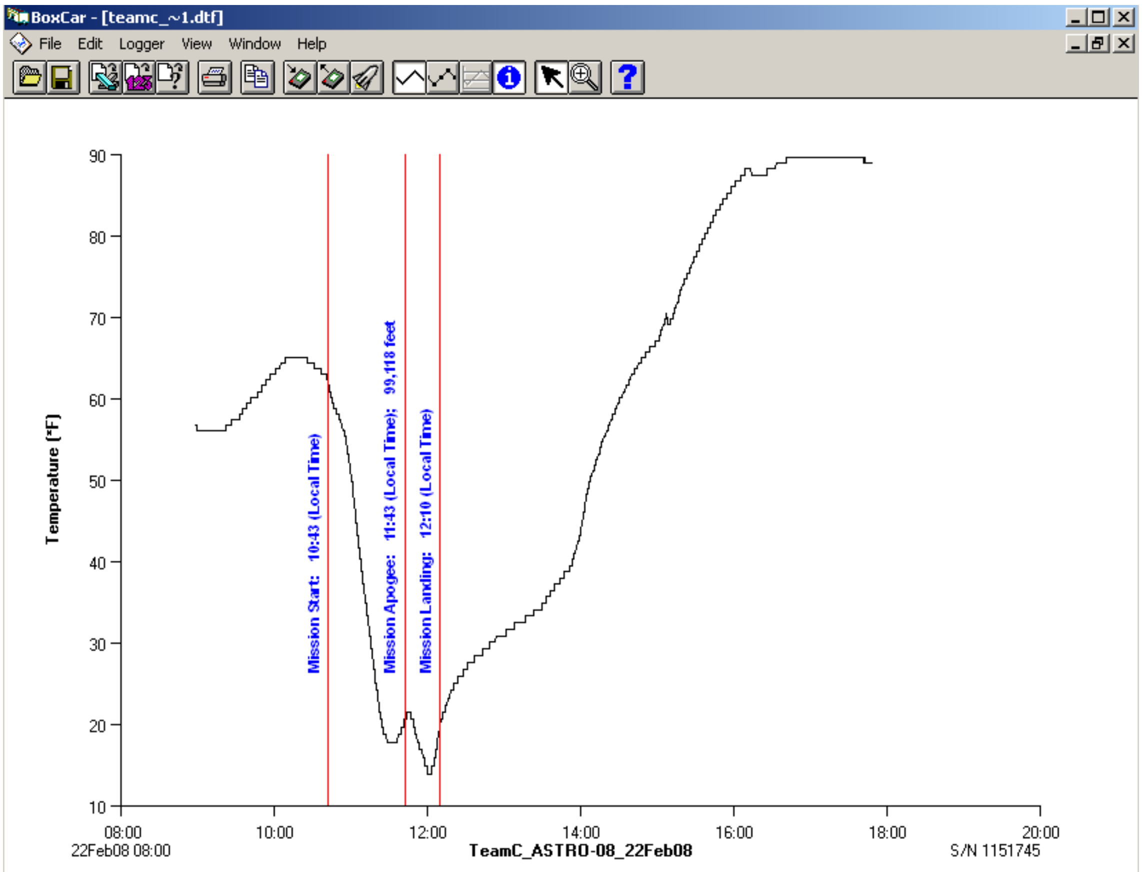


***Figure 4**: Temperature profile of box interior*

Tracking System

Joe Conner built the tracking module for this mission, which consisted of three independent tracking systems. The first system, transmitting on 144.360, used a Kenwood TH-D7A to transmit APRS packets containing position information generated by a Garmin GPS 18. The second tracking system, transmitting packets on 144.390, used a PocketTracker to transmit information generated by a second Garmin GPS 18. And the third system, transmitting CW ID beacons on 147.475, was a K12 CW Beacon Kit fabricated by Harry Mueller (call sign KC5TRB). All three systems were used in previous ASTRO missions and were already proven reliable. Both the Tulsa Tech instructor and Mr. Conner used mapping software to track the satellite positions on a laptop in real-time. The Tulsa Tech instructor has a goal of building these tracking systems and incorporating them into the class learning activities in the near future.

Educational Benefits

Realistic problem-solving is the one aspect of Project-Based Learning that truly prepares a student for life's challenges. No one would probably question that assertion. However, the problem for us educators is choosing projects that are: 1) skill-level appropriate for the student; 2) skill-level appropriate for the instructor; 3) feasible within the school's budget; and 4) logistically feasible based on factors local to the school (i.e., geography, transportation, FAA controlled airspaces).

Various aspects of the balloon-sat project are skill-appropriate for a high school junior or senior, provided some prerequisite skills are addressed. The student must be able to solder and read simple electronic schematics before starting the project. Most likely, the high school student should not be expected to make decisions concerning most electronics; at least, not at the start of the school year. All aspects of this project need to be well organized and thoroughly communicated before hand to the teenage student. Certain sub-systems need to be taught pedagogically in order to develop a good intellectual foundation for the students. In the early part of next year's class, it's my intention that the students will build, step-by-step, an astable 555 circuit (oscillator), a mono stable 555 circuit; and a thermostat circuit; all in a pedagogical manner, in order to build a quick foundation in analog electronics. Later, they will be shown how to integrate these circuits. As for telemetry, possibly future classes will build something similar to the TinyTrak kit. But for the near term, until the instructor acquires a ham license and gains more confidence in using the tracking technology, construction of the tracking systems will not be a major part of the in-class learning activities.

***Figure 5**: Dr. Andy Arena (OSU) inflating the sounding balloon.*

The skill-level of the instructor is an important aspect of this project's educational effectiveness. The instructor needs some background in electronics and Ham radio technology to make this project a success. In general, most high school students need a high level of structure to be successful in building these electronics projects. Only when the instructor has a solid foundation in electronics can this structure be provided to the average teenage student. Otherwise, even the above average student will lose motivation and then class discipline tends to become an issue. In addition, adult decisions need to be made concerning FAA regulations. This all requires mature supervision, sound engineering judgment, and good shop organization.

The school's budget will also determine whether this project gets off the ground. For one student satellite box with an Aiptek PocketCam, a Hobo Data Logger, and a small heating circuit, the cost was approximately $230, with another $200 of soldering supplies. If three students worked on one box, then we arrive at approximately $145 per student per satellite box per year. Additional items include a

1500 gram balloon (Kaymont: ~$95); Radios (Kenwood: ~$325); Antennas (~$50); and Lithium batteries (~$50). A rough estimate for 4 satellite boxes, balloon, tracking equipment, and miscellaneous supplies is approximately $1500 for the first year and $500 each year after.

Lastly, there will be a myriad of external factors that may effect local decisions. Some other considerations might be:

- Geography – western and central Oklahoma is a great place to recover weather balloons due to the lack of trees and people;
- Transportation – the fewer students to transport to the launch and recovery sites, the simpler transportation becomes;
- FAA Controlled Airspace – the launch and recovery sites should not be located near busy airports;
- Available mentors – if a large number of students are involved with launch and recovery, the instructor will need assistance supervising the teenage students.

As interest increases in the *Introduction to Aerospace Engineering* courses at Tulsa Tech, all of these logistical challenges will increase. It remains to be determined how next year's 32 students will all participate in launching and tracking one or two balloon-sat missions.

Figure 6: *The Launch Crew enjoying the view of their first mission launch.*

Summary

Incorporating high-tech, challenging projects into the high-school environment is difficult. We want to stretch the students without breaking their motivation. We want to push them to acquire deeper math, science, and engineering skills so they compete well in their early college years. But, we don't want to push them away from the hard sciences either. It's a tough balancing act. Add to the mix, teens behaving like adolescents and a market pulling well-trained technical professionals away from the classroom. Most high schools are not equipped to handle the more in depth technical projects. Fortunately, Oklahoma has a well-developed *CareerTech* system that has made a commitment to the pre-engineering curriculum. Many of Oklahoma's Technology Centers are in a strong position to fund these projects and to hire instructors with the appropriate experience to lead these projects.

Equally important to our project-based learning efforts is mentorship by our community's professionals. On this project, we had help from *Oklahoma State University*, *Oklahoma Space Consortium*, *Oklahoma Research Balloons*, *CQ Magazine*, and other *Tulsa Technology Center* instructors (Barry Lazzer, Jim Snow). The message is out; our community's engineers are getting involved with raising-up new engineering talent. These types of practical relationships are critical for incorporating challenging projects at the high school level. The question is: Do we have enough of these processes in place to grow enough engineers in the next decade?

Genuine problem solving skills were necessary for the completion of this project. The mistakes made in the course of this first balloon-sat project at Tulsa Tech were priceless. Both the students and the instructor were forced to adapt and overcome technical difficulties. In the end, this project was a great specimen of what Project-Based Learning should look like. In our next phase at Tulsa Tech, we will turn our sights toward organizing this project and making it accessible to a broader scope of students, with a hope of challenging the next generation of engineers.