Paper ID #18661

A Near-space Research Experience for High School Students

Dr. John E. Post P.E., Embry-Riddle Aeronautical University, Prescott

John. E. Post was born in Midland, Texas in 1958. He received the B.S. degree in electrical engineering from Texas Tech University in 1981, the M.S. degree in engineering from the University of Texas at Austin in 1991, and the Ph.D. degree in electrical engineering from Stanford University in 2005. He was commissioned a second lieutenant in the United States Army in December, 1981 and served on active duty until his retirement as a lieutenant colonel in June, 2006. His military service included two tours as an Instructor and later Assistant Professor with the Department of Electrical Engineering and Computer Science at the United States Military Academy, West Point, NY. His final military assignment was as Chief of Engineering with the Defense Threat Reduction Agency's Test Division at Kirtland AFB, NM. After retiring from the military, he joined the Computer, Electrical, and Software Engineering Department at Embry-Riddle Aeronautical University, Prescott, AZ, where he is an Associate Professor and currently serving as Chair. His research interests include design and optimization of planar microwave circuits and devices, optimizing the design of low-noise microwave amplifiers, and engineering education. Dr. Post is a member of Eta Kappa Nu and Tau Beta Pi. He is currently serving as the faculty advisor for the Embry-Riddle IEEE Student Chapter. He is also a Registered Professional Engineer of the Commonwealth of Virginia.

A Near-space Research Experience for High School Students

John E. Post
College of Engineering, Embry-Riddle Aeronautical University, Prescott, Arizona

Abstract
A near-space research experience for high school students was created at Embry-Riddle Aeronautical University in Prescott, Arizona in 2011, and held each summer since then with the goal of exposing high school students to advanced STEM topics, specifically those topics relevant to the fields of computer, electrical, and software engineering. During this intensive week-long experience students are exposed to fundamental concepts involved in researching the near-space environment through the launch, flight, and recovery of a high-altitude balloon carrying student-built balloon satellites, or, "balloonsat" payloads. This is the only research experience of its kind that the author is aware of outside of one conducted by NASA's Glenn Research Center in Cleveland[1]. This paper provides details of the topics, schedule, enrollments, and student evaluations of the most recent Near-Space Research Experience conducted at Embry-Riddle Aeronautical University in Prescott, Arizona during June, 2016.

Introduction
With graduates well-placed throughout the aerospace industry, and with a nearly a century-long track record in the field of aviation. Embry-Riddle Aeronautical University continues to lead the way in aviation, aerospace, and engineering. On the Prescott campus, the College of Engineering specializes in excellence in undergraduate education and strives to provide students with opportunities for hands-on learning and intensive interaction with the faculty, both inside and outside of the classroom.

Due to the hands-on nature of the engineering curriculum, the College has many well-equipped laboratories that are available to undergraduate students during the regular school year. During the summer, however, reduced demand for laboratory facilities by undergraduate students provides the opportunity to repurpose the laboratory space for other activities—such as outreach to K-12 students. Additionally, Prescott has a relatively mild summer climate that is conducive to engaging in outdoor summer activities, unlike most of the rest of the state of Arizona. For these reasons, the College has a well-established record of hosting a variety of summer experiences for high school students[2,3].

Most outreach programs fall into one of the following categories[4]: the development of classroom material, including Web-based resources; the professional development of teachers; conducting outreach activities at the local school; conducting or sponsoring engineering contests; sponsoring teaching fellowships or offering service-learning courses; conducting outreach activities on the college campus. This paper discusses a Near-space Research Experience for high school students, which is covered by the final category in the list—an outreach activity conducted on the college campus. Review of the literature reveals a number of institutions that conduct outreach on their campus during the summer. However, none of these attempt the technical depth or level of project complexity that is reported here[5,6,7,8,9].

It is important for outreach programs to support what is happening in science education in the student's classrooms back home. As one example of a standard, the Next Generation Science Standards (NGSS) provides content standards for K-12 science education[10]. The NGSS Executive Summary states that "Science and engineering are integrated into science education by raising engineering design to the same level as scientific inquiry in science classroom instruction at all levels, and by emphasizing the core ideas of engineering design and technology applications[11]." This standard supports the idea of this outreach program that provides high school students with a research experience that integrates science and engineering and introduces them to foundational concepts in engineering design and technology.

A Near-space Research Experience

Few subjects capture the interest of young people more than the idea of exploring space. Although the outer space environment is difficult and expensive to reach, near space—defined as the region of Earth's atmosphere between 65,000 and 328,000 feet[12]—is relatively accessible through the use of meteorological or "weather" balloons. High-altitude ballooning provides a unique opportunity to engage high school students with an experience that will expose them to fundamental science and engineering topics. During this carefully structured week-long experience, students are introduced to basic concepts involved in researching the near-space environment through the launch, flight, and recovery of a high-altitude balloon carrying student-built balloonsat payloads.

Table 1, the schedule for the research experience, is quite intensive due to the need to complete the many tasks necessary for a successful flight. The students were kept busy from arrival Sunday evening (not shown) through the graduation luncheon held at noon on Friday. Sessions were normally held from 8 - 5 with an hour provided for lunch at the campus dining facility. Additionally, several technical presentations were provided in the evening during which a faculty member provided presentations on engineering entrepreneurship and a history of the computer.

During the morning of the first day students meet the instructors and overview the schedule for the camp shown in Table 1. Additionally, students learn about the near-space environment, are introduced to balloon flight procedures, and watch a video recording that introduces all the steps necessary for a successful flight. The purpose of these activities is to provide students with an overall context within which to learn the many concepts that are introduced during the week.

Next, students learn about the microprocessor-based sensor system they will build that records the data taken during the ascent and descent of the balloonsat payload during a high-altitude flight[13]. The sensor data recorded during the flight includes the voltage of the battery supply, internal and external temperatures, and the ambient atmospheric pressure. Students quickly realize that analyzing and plotting the hundreds of measurements taken during the flight requires a computational aid, such as the software package Matlab. This combination of hands-on use of technology to obtain and analyze scientific data corresponds closely to NGSS science and engineering standards[10].

<table>
<tr><th>Monday, 6/13/16</th><th>Tuesday, 6/14/16</th><th>Wednesday, 6/15/16</th><th>Thursday, 6/16/16</th><th>Friday, 6/17/16</th></tr>
<tr><td>Wake Up Call 6:30AM</td><td>Wake Up Call 6:30AM</td><td>Wake Up Call 6:30AM</td><td>Wake Up Call 6:30AM</td><td>Wake Up Call 6:30AM</td></tr>
<tr><td>7:15-7:45AM Breakfast , Earhart's</td><td>7:15-7:45AM Breakfast , Earhart's</td><td>7:15-7:45AM Breakfast , Earhart's</td><td>7:15-7:45AM Breakfast , Earhart's</td><td>7:15-7:45AM Breakfast , Earhart's</td></tr>
<tr><td>8AM - 11AM Intro to Balloon Operations, Payload design and construction, and Intro to Matlab/Processing sensor data, Instructor Crabtree and Instructor Post,</td><td rowspan="2">8AM - 11:30AM Payload Construction, Instructor Crabtree, King 117/130,</td><td rowspan="4">8AM - 3PM, Payload launch and recovery, Soccer Field, Instructor Crabtree Boxed Lunches on the Road</td><td rowspan="2">Data Analysis, Instructor Post, King 130, 8AM - 11:30AM</td><td>Introduction to Electronics, Instructor Kodimer, 8AM - 11AM, King 128</td></tr>
<tr><td>11AM - 12PM Free time/Dorms (SP Staff)</td><td>11AM - 12PM, Dorms, packing, check out</td></tr>
<tr><td>12PM - 1PM, Lunch, Earhart's</td><td>12PM - 1PM, Lunch, Earhart's</td><td>12PM - 1PM, Lunch, WOW Cafe</td><td>12PM - 1PM Graduation Lunch, Hangar</td></tr>
<tr><td>1PM - 3PM, Intro to Soldering, Instructor Post, King 130</td><td>1PM - 3PM, Payload Construction, Instructor Post, King 117/130</td><td>Prep for Presentations 1PM - 3PM, King 126, Instructor Crabtree</td><td>Check out of Dorms, Hall 7, 1PM - 3PM</td></tr>
<tr><td rowspan="2">3PM - 5PM Soldering Kit Construction and Troubleshooting, Instructor Post, King 130,</td><td rowspan="2">3PM - 5PM Vacuum Chamber Testing, Instructor Crabree, location AXFAB,</td><td>3PM - 4PM Free time/Dorms (SP Staff)</td><td rowspan="2">Present Results, Instructor Crabtree King 126, 3PM-5PM</td><td rowspan="2"></td></tr>
<tr><td>4:15PM - 5:00PM Admissions DLC Auditorium</td></tr>
</table>

Table 1. Daily schedule for the Near-space Research Experience.

Because most high school students have not been exposed to mathematical software packages like Matlab, a brief introduction is necessary. Students spend about an hour working individually through a self-paced tutorial that introduces the basic capability of the Matlab programming language. Then, with the instructor's assistance they work through the process of constructing a Matlab script file capable of analyzing and plotting the hundreds of measurements taken during the flight. Finally, students plot sample sensor data to verify the functionality of their software program and practice the steps involved in downloading and analyzing their data.

These days few students have practical skills in soldering and circuit construction, so prior to constructing the electronics it is necessary to introduce these skills and provide an opportunity to practice them. Students spend several hours in the afternoon learning and practicing these skills constructing a commercially available soldering practice kit like the SP1A Practical Soldering Project Kit available from Elenco[14]. Because they are beginners, mistakes are frequent and troubleshooting an inoperative circuit is another skill they are exposed to during this session.

At the end of the first day, the instructors survey the students to determine who has developed the best skills in soldering and circuit construction, Matlab programming skills for analyzing the data, or craft skills for constructing the balloonsat structures. Then, the students are divided up into teams of three or four students with a mixture of skills sufficient to construct their sensor system payloads, the balloonsats that will carry them, and the software that will analyze their data. The students are challenged to spend time during the evening brainstorming a name for their balloonsat payload that captures the spirit of the research adventure they are undertaking.

During the morning of the second day two students from each team begin construction of their balloonsat structure and associated payload electronics. The microprocessor-based sensor system and its associated analog signal processing circuitry is assembled on a custom printed circuit board designed and manufactured specifically for this purpose. It is important to verify circuit functionality periodically during construction to catch any mistakes that are made during this phase. For this reason, the assembly instructions include frequent opportunities for the instructor to assess student learning by verify circuit operation during the assembly process.

While two members of each team are assembling the electronics, the other team members are constructing the balloonsat structures from 3/8 inch thick foam-core board cut out in a cross-shaped pattern. The pattern is then folded up to form a cube approximately 6 inches on each side and the interior filled with pieces of ½ inch thick foam containing voids cut out of the foam to fit the payload. The joints of the cube are secured with hot glue and the outside of the cube is wrapped with aluminum tape to form a rigid structure suitable for flight in the near-space environment.

After lunch, students are introduced to the concept of testing. Each completed electronics assembly is powered up and inserted into a balloonsat structure for this step. The first test involves cooling the balloonsat payloads to approximately -20^{o}C to simulate the sub-zero temperatures encountered during flight in the troposphere. Next, to simulate a flight from ground level to the stratosphere and back the balloonsat payloads were placed in a vacuum chamber. Upon closing the door and sealing the chamber a vacuum pump evacuates the air from the chamber simulating a "flight" to an altitude of approximately 100,000 feet. At the conclusion of this test the vacuum pump is switched off and a small valve opened in order to repressurize the chamber to ambient atmospheric conditions so it is possible to open the door of the chamber and retrieve the payloads. Finally, as the concluding activity for the day the data recorded during the test is downloaded and analyzed as a final verification of the functionality of the electronics and sensor system.

The morning of the third day the students apply power to their payloads, assist with inflating the balloon with hydrogen, and then launch the balloon with its balloonsat payloads during the designated launch window. The balloon train typically includes one or more Amateur Radio APRS (Automatic Packet Reporting System) beacons whose GPS data packets are received by digital repeaters (digipeaters) at ground stations, transferred to Internet gateway stations (iGates), and displayed graphically on a map on a web page[15,16]. This enables students to monitor the progress of the balloon flight in real-time on their smart phones during the balloon chase. Once the balloon has burst and the payloads return to earth by parachute the students travel to the landing location to recover their payloads and retrieve their data.

During the fourth day of the camp the students spend the morning reviewing and analyzing their flight data: battery voltage, internal and external temperatures, and atmospheric pressure. Upon reviewing their data students observe the decline in the air temperature that occurs as the balloon climbs through the troposphere. Paradoxically, temperature increases climbing through the stratosphere[17]. The most observant students are quick to note that this temperature reversal denotes the boundary between the two layers. The temperature pattern is reversed after burst because the temperature first decreases as the payload parachutes through the stratosphere and then increases as it continues through the troposphere. Review of pressure data reveals that the balloon ascends at almost constant rate of around 900 ft/min until the balloon bursts. After burst the balloonsat payloads plummet through the stratosphere due to the limited effectiveness of the parachute in the thin air. The parachute is increasingly effective as the payloads fall through the troposphere so that landing is accomplished with minimal damage to the balloonsat structures.

After lunch each of the student teams prepare and deliver a final oral presentation of their results to an audience consisting of the students and the instructors, as well as interested members of the local community. This provides the students with an opportunity to communicate what they have learned and practice the soft skills that are important for success in technical fields.

On the morning of the final day an instructor leads the students through several digital circuit labs that are modeled after those required for our freshmen engineering students. This provides them with the opportunity to sample college-level instruction with a hands-on focus and deepens their understanding of several of the technical concepts presented during the week.

The final event for the Near-space Research Experience is the graduation luncheon. This event reunites students with their families and provides the instructors an opportunity to recognize the student's hard work and the attention to detail necessary to accomplish a successful flight.

Participant Information and Program Evaluation

Summer 2016 was the fifth summer that the Near-Space Research Experience was offered on the Prescott campus. The camp was designed for a maximum of sixteen students and sold out well in advance attracting thirteen male and three female students. ERAU advertises summer camps nationally, so the camp typically attracts attendees from around the US, as shown in Table 3. The ages of the students ranged from fourteen to sixteen years, as shown in Table 4.

The Summer Programs Department on campus attempts to survey attendees to determine their satisfaction with the overall program outside the classroom. Table 5 contains the survey questions and responses for the Near-Space Research Experience for the nine out of the sixteen students who responded to this survey before their departure. The rating scale is Likert-like and ranges from high satisfaction or extreme enjoyment to very dissatisfied or very disappointed.

Additionally, the instructors surveyed the students at the end of the camp to determine their satisfaction with the technical elements of the curriculum, as shown in Table 6. Table 6 reports the number of responses on a Likert-like scale that ranges from strongly agree to strongly disagree from the fifteen out of sixteen students who completed the survey.

Table 3. Student States of Residence

AZ, CA, ,CO, TX, WA

Table 4. Ages of Attendees

14 (3), 15 (5), 16 (4), 17 (4)

Table 5. Summer Programs Survey Questions and Results

Questions/Statements:	Very Satisfied	Satisfied	Neutral	Somewhat dissatisfied	Very dissatisfied
1. How would you rate your overall experience with the program?	5	4			
2. How would you rate your overall experience with the professors?	5	4			
Please rate your experience/enjoyment on the following classes:	Extremely Enjoyed	Enjoyed	Neutral	Disappointed	Very Disappointed
3. Payload design	4	5			
4. Soldering	4	3	1		1
5. Circuit design	2	6	1		
6. Payload construction	5	4			
7. Chamber testing	3	4	2		
8. Data analysis	3	3	3		
9. Presentation	1	4	4		

Table 6. Results of Student Evaluation of the Near-space Research Experience

Statements:	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. The activities conducted during the week met or exceeded my expectations for the camp.	8	6	1		
2. The class on balloon flight operations provided sufficient background for me to understand how the balloon flight would be conducted.	10	4		1	
3. The class on sensors, electronics, and data analysis provided sufficient information for me to understand what the payload was designed to do.	8	6	1		
4. The soldering class was sufficient for me to understand how to follow directions, assemble, and test electronic circuits.	8	6	1		
5. The Matlab class was sufficient for me to understand how to write a Matlab program to analyze the data.	7	4	2	2	
6. The team presentations provided me an opportunity to communicate what I had learned to an audience.	7	5	3		
7. I am more interested in studying computer, electrical, or software engineering as a result of this camp than I was before.	3	7	4	1	
8. The evening presentations were informative and educational.	4	8	3		
9. I would recommend this camp to others.	7	6	1	1	

The student evaluations contained in Table 5 and Table 6 support the assertion that the Near-space Research Experience has succeeded in exposing students to advanced STEM topics related to the fields of computer, electrical, and software engineering. As shown in Table 6 ten out of fifteen students *Agreed* or *Strongly Agreed* with the statement "I am more interested in studying computer, electrical, or software engineering as a result of this camp than I was before." This is an encouraging result give that few students had any previous exposure to programming, circuit design and construction, or any of the other technical topics covered during the week.

Lessons Learned

The instructors have learned several important lessons since the Near-space Research Experience began in the summer of 2011. One lesson is the requirement to identify specialized tasks that students need training on, and then completing this training before the skills are needed for payload construction. An example of this preliminary training is first having the students build a solder practice kit to gain sufficient construction experience before they attempt to assemble the payload electronics.

Another lesson learned is the need to maximize student productivity to accomplish the many tasks that are required to complete a successful flight in the limited time that is available. As one example, the payload electronics are packaged in the form of a kit with step-by-step assembly instructions. To facilitate assembly the electronic components are adhesively fastened on each page of the instructions in the order that they are needed. This procedure serves to minimize the possibility of incorrectly installing, and possibly damaging, a component during assembly along with the concomitant student frustration and dissatisfaction that can occur.

Finally, prior to payload launch and recovery it is important to make adequate preparations, and take appropriate precautions, as the students transition from a controlled classroom environment to a potential inhospitable outdoor setting. Vehicles should be well-stocked with basic items like water, sunscreen, snacks, a first-aid kit, etc. Additionally, students should be properly clothed and wear good shoes so they can hike cross-country, if necessary, to the balloon's landing location so they can successfully recover their payloads.

Summary

This paper reports the results of the fifth year of an intensive week-long experience where students are exposed to fundamental STEM concepts involved in exploring the near-space environment through the construction, launch, flight, and recovery of high-altitude balloon payloads. Student responses appear to confirm the success of the camp as an outreach activity designed to increase student interest in technical fields—specifically computer, electrical, or software engineering. Feedback from students and lessons learned by the instructors will be applied to improve the next Near-space Research Experience scheduled for June, 2017.

Bibliography

1. https://www.nasa.gov/centers/glenn/technology/explorers_balloons.html
2. Lanning, D., Helbling, J., and Lestari, W., "An Aerospace Engineering Summer Camp for High School Students", Proceedings of the PSW 2011 Regional ASEE Conference, March 31-April 2, 2011, California State University at Fresno, CA.
3. Post, J.E. "An Arduino-based Summer Camp Experience for High School Students," Proceedings of the 2016 ASEE Annual Conference, June 2016, New Orleans, LA.
4. Jeffers, A., Safferman, A., and Safferman, S. (2004) "Understanding K-12 Engineering Outreach Programs," *J. Prof. Issues Eng. Educ. Pract.,* ASCE 130(2):95-108.
5. Fry, C., Davis, J., Shirzi-Fard, Y., "Recruitment and Retention of Females in the STEM Disciplines: The Annual Girl Scout Day Camp at Baylor University," Proceedings of the 38th ASEE/IEEE FIE Conference, October, 2008 at Saratoga Springs, NY.
6. Weston, V., Bonhivert, A., Elia, A. Hsu-Kim, H., and Ybarra, G., "Work in Progress: A STEM Education Outreach Day for Young Females," Proceedings of the 38th ASEE/IEEE FIE Conference, October, 2008 at Saratoga Springs, NY.
7. Stapleton, W. Asiabanpour, B., Stern H., Gourgey, H., "A Novel Engineering Outreach to High School Education," Proceedings of the 39th ASEE/IEEE FIE Conference, October, 2009 at San Antonio, TX.
8. Yilmax, M., Ren, J., Custer, S., and Coleman, J., "Hands-on Summer Camp to Attract K-12 Students to Engineering Fields." *IEEE Trans. on Education,* Vol. 53, No.1, February 2010.
9. Gieskes, K., Brennan, D., Cavagnetto, A., Gal, S., Jones, W., McGrann, R., and O'Brien, T., "Work in Progress-Introducing Engineering to Middle-School Students During a Green Summer Institute," Proceedings of the 40th ASEE/IEEE FIE Conference, October, 2010 at Washington, D.C.
10. URL. https://www.nextgenscience.org/get-to-know [cited 20 April 2017]
11. URL.https://www.nextgenscience.org/sites/default/files/Final%20Release%20NGSS%20Front%20Matter%20-%206.17.13%20Update_0.pdf [cited 20 April 2017]
12. URL: http://www.globalnearspace.com/definition.shtml [cited 7 March 2017]
13. Post, J.E., "A Simple Sensor Package for High Altitude Ballooning," QEX, May/June 2012.
14. URL: www.elenco.com [cited 9 Feb 2017]
15. URL: http://www.arrl.org/automatic-packet-reporting-system-aprs [cited 9 Mar 2017]
16. URL: aprs.fi [cited 10 Feb 2017] (Search N7ERU to view data from recent flights)
17. URL: http://www.srh.noaa.gov/srh/jetstream/atmos/layers.html [cited 9 Mar 2017]