Earth and Spce Science: Making Connections in Education and Public Outreach
ASP Conference Series, Vol. CS-443, p340, ©2011
Editor Jenson: ISBN 978-1-58381-766-7.

High-Altitude Balloon Launches and Hands-On Sensors for Effective Student Learning in Astronomy and STEM

Hank D. Voss, Jeff Dailey, and Steve J. Snyder

Taylor University, Physics Dept., Psychology Dept ., 236 Reade., IN 46989

Abstract. Students creating and flying experiments into NearSpace using a low-cost balloon High-Altitude Research Platform (HARP) greatly advance understanding in introductory astronomy and advanced classes across several disciplines. Remote sensing above 98% of the uncharted atmosphere using cameras, intensifiers, IR and UV sensors provide access to the heavens and large regions of the earth bellow. *Insitu* and limb atmospheric gas measurements, near-space stratosphere measurements, and cosmic rays engage students in areas from planetary atmospheres to supernova acceleration. This new capability is possible by exposing students to recent advances in MEMS technology, nanotechnology, wireless telecommunication systems, GPS, DSPs and other microchip miniaturizations to build < 4 kg payloads. The HARP program provides an engaging laboratory, gives challenging STEM field experiences, reaches students from diverse backgrounds, encourages collaboration among science faculty, and provides quantitative assessment of the learning outcomes Over a seven-year period Taylor University, an undergraduate liberal art school, has successfully launched and recovered over 230 HARP systems to altitudes over 30 km (100% retrieval success with rapid recovery) with flight times between 2 to 6 hrs. The HARP payloads included two GPS tracking systems, cameras and monitors, a 110 kbit down link, an uplink command capability for educational experiments (K-12 and undergrad). Launches were conducted during the day and night, with multiple balloons, with up to 10 payloads for experiments, and under varying weather and upper atmospheric conditions. The many launches in a short period of time allowed the payload bus design to evolve toward increased performance, reliability, standardization, simplicity, and modularity for low-cost launch services. Through NSF and NASA grants, the program has expanded leading to over 52 universities trained at workshops to implement high-altitude balloon launches in the classroom. A spin-off company, StraoStar Systems LLC, now sells the turn-key high-altitude balloon system and another spin-off company, NearSpace Launch, now offers a low cost ride-for-hire into near-space.

1. Introduction and Balloon Platform

High–altitude balloon launches provide low-cost access to near space and give general education and upper level students the opportunity to experience firsthand the excitement of real science in a relatively unexplored region of the stratosphere. Small balloons achieve heights of 30 km and can carry payloads up to 4 kgs without needing special FAA waivers. The flight passes through the troposphere, tropopause, most of the ozone layer, and up through 98-99% of the atmosphere (see Figure1). A balloon travels for about 2-6 hours and covers a horizontal distance of 0 to over 200 km (see figure 2 map). To date we have launched over 230 balloons and have recovered each one due to the reliable and redundant GPS flight computer transceiver system, the ideal launch conditions in Indiana, and motivated student recovery teams.

Figure 1. Video camera photo of student twin balloon ascending while also showing the atmosphere, the curved limb-of-the- earth, and black heavens.

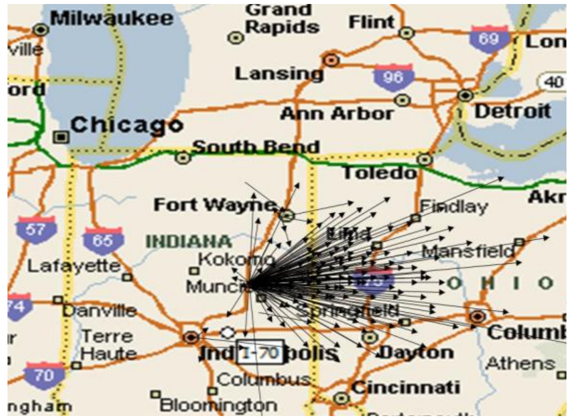

Figure 2. Flight paths of over 200 launches in Indiana over the past 4 years

Typically, an introductory astronomy 101 class with 120 students will fly their instruments on a single balloon. Students fly many types of low-cost Basic sensors: Temperature, pressure, humidity, visible light, solar cells, video cameras, UV and IR sensors, spectrometers, Geiger counters, accelerometers, gas sensors, wind sensors, and field sensors. In our 101 curriculum 5-6 students are grouped together to develop two types of experiment packages. The group must choose one or more Basic sensors (ensures good data) and also develop a Creative group experiment. Example creative experiments include recording sound with altitude, imaging cockroach survivability, studying greenhouse gas heating in soda bottles, and many other ideas. Student groups develop and build their payload during two labs (2hr/lab), launch and collect data for one lab, and plot and interpret data for presentation in the fourth lab.

2. Balloon Experiment Objectives

The use of balloons for real projects significantly invigorates and expedites development and teamwork, teaches problem solving and instructor mentoring, drives schedule and creativity, uncovers unexpected problems, permits end-to-end testing, gives a real environmental check (significant thermal vacuum and freefall vibration test), and forces completion and validation of the flight and ground station software. Figure 3 illustrates some of the program operational logistics.

Specifically, the HARP balloon experiment helps students 1) learn the Scientific Method (hypothesis, test, observe, analyze, interpret, predict, repeat, document), 2) learn some hand-on technical skills (design, soldering, fabrication, electronics, assembly, and team work, 3) learn engineering principles (heat transfer, sensors, GPS, communication links, optics, remote imaging, and data processing), 4) learn atmospheric variables (pressure, temperature, wind, troposphere, stratosphere, humidity, windows, and others), 5) obtain physics knowledge (fundamental equations, radiation, acceleration, Archimedes principle, etc.), 6) apply data analysis skills (using Excel, handling noisy data, plotting profiles, creating log plots, and applying different plot formats), and 7) documentation (Wiki, team report, presentation, and resume). The objective is for students to have fun, efficiently learn, value science, improve in STEM, and advance in critical thinking skills.

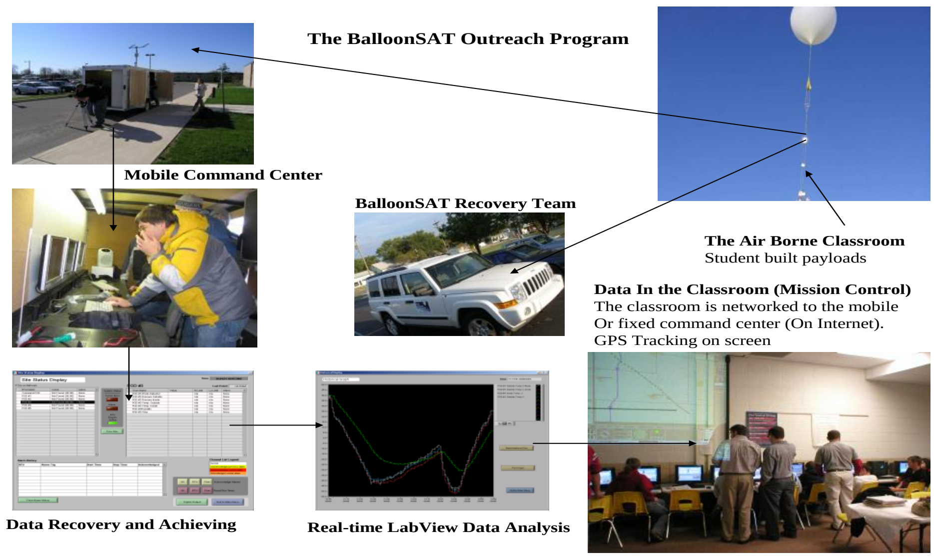

Figure 3. Real experience and real data as student sensors transmit their data in real time and student teams monitor data, track flight path, and chase for the GPS landing.

3. Assessment of HARP Program

The first objective of the assessment portion was to develop reliable and valid instruments to evaluate the students on key educational variables. Pre and Posttest student assessments instruments were developed to measure intrinsic motivation, application knowledge, cognitive skills, metacognitive processes, valuing science, and content knowledge. A pilot study was conducted and the instruments were found to be reliable and valid.

The Introduction to Astronomy class was evaluated over two years (4 semesters). After each semester constructive feedback on how to improve the teaching strategies for particular educational variables in implementing the HARP program into their curriculum was discussed from the assessment data. This provided a good model to other universities implementing HARP into their science classes, not only in strategies used, but also in the attitude of continual improvement. After 4 semesters of implementation and feedback on how to improve, all major educational variables measured were both statistically and practically significant when comparing their students' improvements from pre to posttests. The statistical and practical significance of the students improvement during the semester occurred in Intrinsic Motivation ($p<.001$; $\eta^2 = .418$), Valuing Science ($p<.001$; $\eta^2 = .559$), Application Knowledge ($p<.001$; $\eta^2 = .602$), Metacognitive Knowledge ($p<.001$; $\eta^2 = .492$), Cognitive Skills ($p<.001$; $\eta^2 = .738$), and Content Knowledge ($p<.001$; $\eta^2 = .738$). See Figure 5 and Table 1. When each of the semesters in which the professors in the Introduction to Astronomy implemented the HARP program into their curriculum was compared the last intervention was statistically superior to the rest of the earlier implementations.

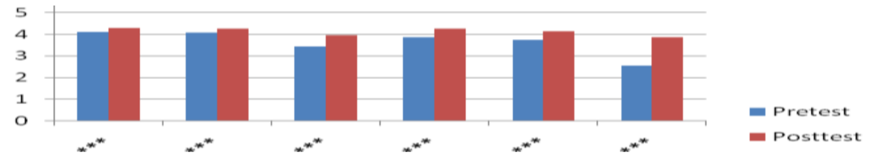

Figure 5. Assessment for Astronomy (note 6 columns match numbers 1 to 6 in Table 1)

Table 1. Spring 2010 Introduction Astronomy Class Assessments

1)Intrinsic Motivation*	4)Metacognitive Processes*
a. Contextualization	a. Metacognitive Planning*
b. Curiosity	b. Metacognitive Assessing*
c. Challenge*	c. Metacognitive Monitoring**
d. Control*	5)Cognitive Skills**
e. Cooperation*	6)Content Knowledge**
2)Valuing Science**	a. Primary Technical Knowledge**
3)Application Knowledge**	b. Learning Cycle Knowledge**
a. Apply Problem Solving*	c. Operations Knowledge**
b. Process of Prototyping**	**Practical Significance Levels:**
c. Process of Evaluation*	*** Significant**
d. Documentation and Reports*	**** Medium Significance**

4. Launch Your Experiment

To get started you can 1) get involved in a NSF-Taylor or StratoStar Systems sponsored workshop, 2) purchase a complete launch system from StratoStar Systems, 3) contact a local amateur or professional, if available (e.g. Edge of Space or local university), or 4) mail your payload box to NearSpace Launch and for a small fee you remotely launch and collect your live data online. A simple/quick way to get started is to purchase a payload kit and let NearSpace Launch take responsibility for launch, recovery, returning, and collecting your data for a ride-for-hire (turnkey system, GPS tracking, supporting T, P, H sensors, video, near real time data to your classroom, liability insurance, FAA/ FCC regulations, safety, and more). After your experience with a few low risk payload launches more sophisticated launch options are available (Voss personal communication, 2010).

Acknowledgements. Support includes NSF CCLI Grant Award 0717787, NASA Indiana Space Grant Program, and the Taylor University Center for Research & Innovation (CRI) internal support. Also, appreciated is the help of many students and the encouragement and help from Dr. Don Takehara, Jason Krueger, and Sue Gavin for management and much other assistance.

References

Voss, H. D., personal communication**,** 2010, many small balloons have been launched for research, weather, educational, industrial, and government use over the past 80 years and are available via a simple internet search. Please email hnvoss@taylor.edu for more information.