



How Close to Space Before Nobody Can Hear You Scream

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Abstract

Results are presented from a balloon-launch experiment to measure the effect of air pressure on sound transmission for various frequency ranges. Wireless transmitter/receivers mounted a fixed distance apart within a soundproof, but not airproof, enclosure measure attenuation of human screams as a function of altitude. The experiment was designed to provide real-time, qualitative data for the amusement of student observers, plus logged data from which the enclosed plots are derived. Balloon services were provided by Spaceport Indiana with a target altitude of 85,000 feet. The experiment was designed, conducted, and analyzed in just two weeks by a newly-formed student group called SEDS. After completion of the experiment, a brief survey showed a generally positive educational outcome for students involved in the project.

I. Introduction

Space activities around the world in 2012 have been historic and exciting – a good time to invigorate student interest in aerospace. This paper describes how a new chapter was formed in the SEDS organization (Students for the Exploration and Development of Space) and how a real-world experiment was conducted with both technical and non-technical students, having the goal of sparking greater interest in both. In addition to the scientific aspect, this paper also addresses the educational outcomes for the 10 participants in the experiment.

Our campus lacks an aerospace engineering department and has never had a SEDS chapter. However there is a small but engaged Space Grant organization on campus, funded in part by NASA. One of the authors of this paper is the director of the Center for Renewable Energy on campus with a strong interest in Space Solar Power (SSP), and has a history of NASA funding. This confluence of interest gave rise to the desire to found a new SEDS chapter.

Shortly after the SEDS call-out, the group was contacted by the director of the Indiana Space Port¹ inviting an experiment to be launched in a sounding balloon. By responding to this, the nascent group devised an experiment, planned it, launched it, and analyzed the outcomes. Both scientific and educational results are presented herein.

II. Student Organization

SEDS is an independent, student-based organization that promotes the exploration and development of space. SEDS was founded at the Massachusetts Institute of Technology and George Washington University in 1980 and has grown to include 36 chapters across the US, plus chapters in Canada, the United Kingdom, Asia, Latin America, and the Middle East². Starting a chapter on campus required a modest application fee to SEDS, plus the appropriate forms to be recognized as a student organization on campus. The call-out attracted 31 students, and another 6 joined shortly afterwards. The invitation to create and fly an experiment came with just over two weeks to comply.

The experiment developed by the team was dubbed “Space Scream”, and involved a test of the movie tagline: “In space no one can hear you scream”. The reason for this is space lacks an atmosphere by which to carry sound waves. However, the Earth’s atmosphere is not uniform. It becomes gradually less dense with altitude leaving no sharp border between air and space³. Our experiment meant to identify the altitude above which a scream could not be heard, or in other words: “how close to space before no one can hear you scream”.

By bringing together a multi-disciplinary and diverse team, the experiment was designed, built, flown, and analyzed. The subset of the SEDS group participating became the nucleus for the student organization leadership, elected at the second all-hands meeting. This experiment served both to focus the newly-formed student chapter, and to lower the perceptual barriers to conducting science from students who may not have otherwise participated in such an engaging activity. The next two sections describe the experiment and the analysis. Following that are results of a survey taken by participants.

III. Space Scream Experiment

Figure 1 shows a conceptual schematic of the Space Scream Experiment. Requirements for the payload were that the total mass should not exceed 1 pound, and the exterior envelope must not exceed 12 inches in any dimension. The sounding balloon was planned to fly to 85,000 feet at which point the balloon would burst and a small parachute would return the payload string gently to the ground.

Four long-range hand-held radios (“walkie-talkies”) were used in a pairwise fashion in a repeater⁴ configuration. A scream issued into radio 1 on the ground would be picked up by radio 2 in the lofted payload. Radio 3 was placed close to radio 2 and set to voice activation so that it would transmit when the sound level inside the payload enclosure exceeded a threshold volume. Radio 3 was set to a frequency as different as possible from radios 1 and 2, but the same as radio 4, which could record the scream back on the ground, but remote from the screamer. By measuring sound volume as a function of altitude, a graph could be drawn. From such a graph, one could determine the altitude at which no scream could be heard.

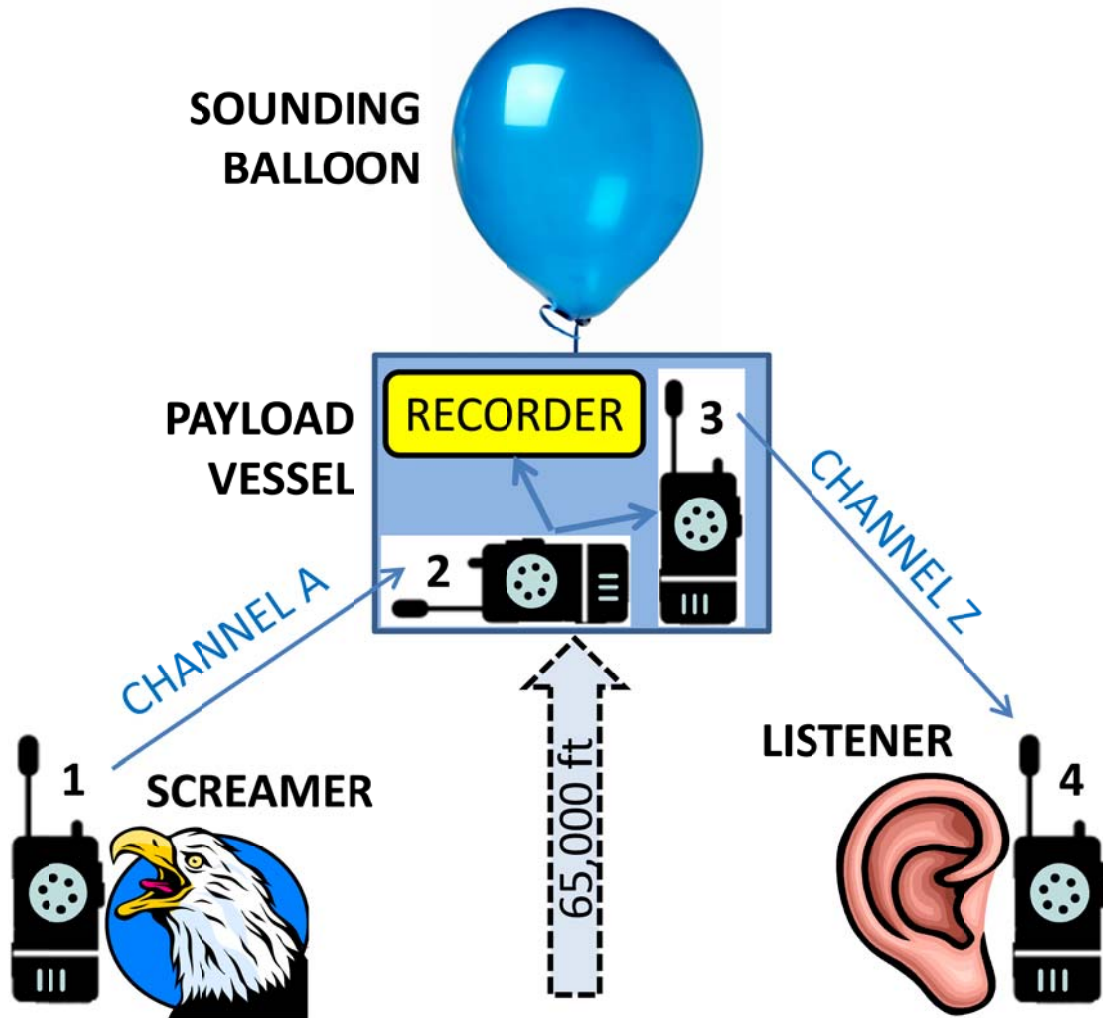


Figure 1. Schematic of Space Scream Experimental repeater setup.

Radios 2 and 3 were found to interfere when in close proximity regardless of the frequencies selected for each. This is a common phenomenon known as receiver desensitization, or “desense”⁴. By orienting the antennae at 90 degree angles, and spacing them 6 inches apart, desense was eliminated during ground testing. Niches were cut into insulating foam to hold the radios in this configuration. As a back-up, a digital voice recorder was also installed in the payload vessel to provide an independent measure of sound volume as a function of altitude. Notification information was affixed to the interior and exterior walls of the foam-enclosed payload vessel, which was held together with duct tape. The payload vessel was then mounted on the payload line hanging from the balloon, along with telemetry gear and a parachute.



Figure 2. Orientation and position of radios 2 and 3, plus voice recorder, inside payload vessel.

Global Positioning System sensors in the payload string permit on-line tracking in three dimensions of the flight and return to earth. The balloon was filled with hydrogen from a K-size cylinder until it was approximately 10 feet in diameter at ground level, 656 feet above sea level⁵.

As a third redundancy check, local amateur radio operators were on-site, and were able to record signal levels from radio 3. A hand-held Yagi antenna⁶ was used to also provide a double check on bearing and azimuth angle.

Three student teams were formed to conduct the experiment. Team 1 consisted of our “calibrated” screamer. They were positioned at a remote section of the facility to reduce the number of alarmed respondents to the screams, which were issued at 5-minute intervals into radio 1. Team 2 consisted of the ground crew with radio 4, who were set to record scream volume using voice recorders embedded in smart phones for later lab analysis of absolute milliwatt decibel (dBm) level. Team 3 was posted with the amateur radio operators, taking data on the signal strength during the experiment. The faculty advisor rode a bicycle between teams to coordinate.

IV. Experimental Results and Analysis

The sounding balloon launch is shown in Figure 3. Once released, the balloon ascended rapidly. The payload string was whipped violently, even though the wind was not especially strong that day. Within a few minutes, the balloon was no longer visible to the naked eye, and the experiment began.

Despite rigorous and repeated testing on the ground, the lofted payload never returned a signal to radio 4, even though the radios were specified as having a 20 mile range when unobstructed. Team 2 recorded a few “click” sounds, but no screams. During early design testing, similar clicking sounds were noted when the two radios experienced the interference mentioned above. One hypothesis ventured was that the violent ascent dislodged at least one of the radio units, causing receiver desensitization to occur.

Team 1 continued screaming, with the expectation that the backup digital voice recorder on board would record the sounds at altitude. Team 3 recorded only white noise and did not ever receive a scream per se. They continued to monitor signal strength, however cross talk from other sources arose; most of these were screened out by the strict timing held by all three teams so that only signals happening on the planned timeline were recorded. The Yagi antenna was used to minimize spurious signals. Results of the signal strength versus altitude, shown in Figure 4 were not those expected. No suitable hypothesis has been ventured for this data.



Figure 3. Balloon Launch, payload at end.

The balloon appeared to have entered a jet stream, and at 65,000 feet leveled off and began moving laterally at an equivalent ground speed of between 47 and 60 miles per hour. This moved the payload out of range of radio 1, so the screams were ceased when the 20 mile limit had been exceeded and the signal strength from team 3 were no longer being received.

All three teams converged indoors to monitor the trajectory of the payload on-line. The balloon finally burst, and the payload began dropping as well as continuing its lateral translation in a

southeast direction. The last signal received was from 2500 feet altitude, headed towards the Ohio River, a landmark 60 miles distant, and the only one to be avoided.

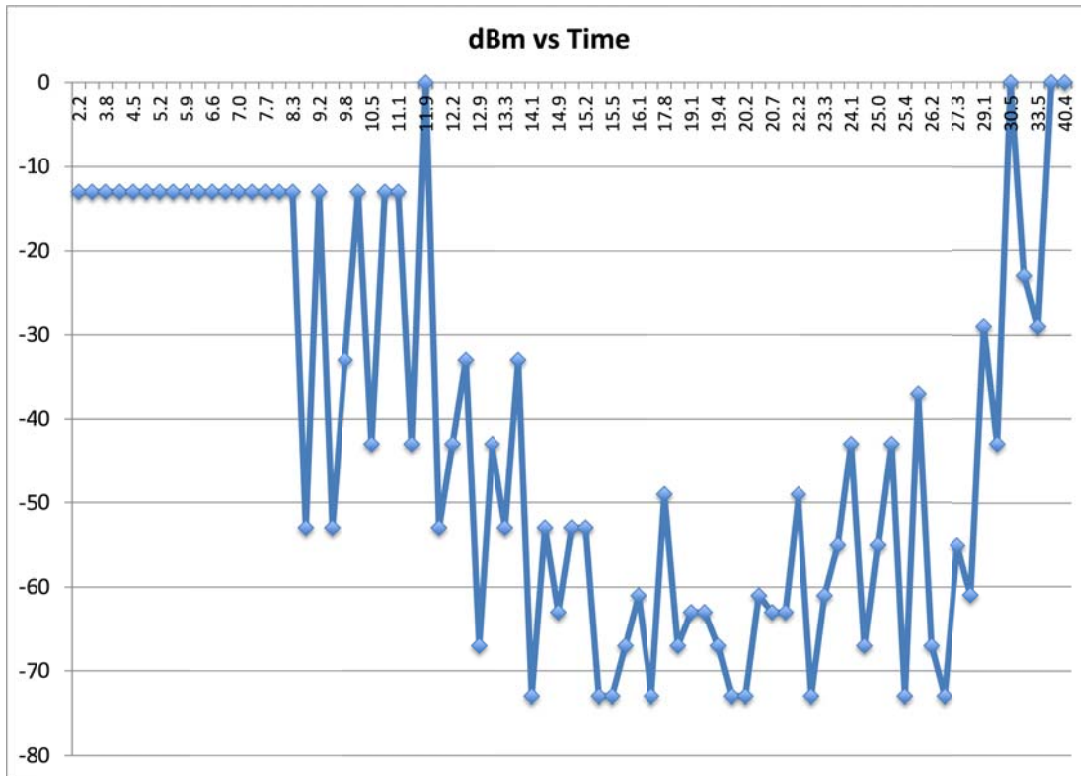


Figure 4. Data from amateur radio signal strength (Team 3) via directional Yagi antenna.

Days later a call came from Rabbit Hash, Kentucky, that a blue Styrofoam box had been found washed up on their shoreline. Local kids had stolen radios 2 and 3, but the voice recorder remained. All GPS hardware was non-functional from the dunking. Weeks after the experiment was concluded, the voice recorder was returned for analysis.

The backup digital voice recorder was dried in uncooked rice, and then powered up. All folders were empty of files, but new files could be recorded. A local company promising to recover cell phones dropped in water used a vacuum drying apparatus, but the lost data was never recovered. Thus, the primary, secondary, and tertiary means for analyzing the volume of a space scream were all rendered useless by the vagaries of the experimental and environmental conditions.

V. Student Outcomes

A survey was sent to the participating students to assess educational outcomes of this experience. Anecdotally, the bus ride home was far more convivial than the ride out. At the second SEDS meeting, all elected officers were among the 10 participants of the Space Scream experiment. Figure 5 shows the results of four key questions from the survey. All students self-identified as being in technical (as opposed to non-technical) fields of study, and all were undergraduates.

All 9 respondents answered “yes” to a question whether the experience brought them into contact with students they otherwise would not have been exposed to. The question represented in the top left of Fig. 5 addresses responses to the subsequent question: “Considering all participants, what is your perception of the degree of diversity represented?” The results labeled “Science Perception” show responses to the question: “How much did this experience change your perception of space and science?”

A majority indicated that they increased the amount they “studied, read, or followed space activities.” The bottom left graph shows responses to the question: “Did the Space Scream experiment experience influence your choice of classes for the Spring semester?” Participants were asked whether feelings of “math anxiety” or “technophobia” changed after the experience. 62 percent indicated such feelings were lessened, and 38 percent went further to indicate the experience had increased their enthusiasm for technology. The final question addresses overall perceptions.

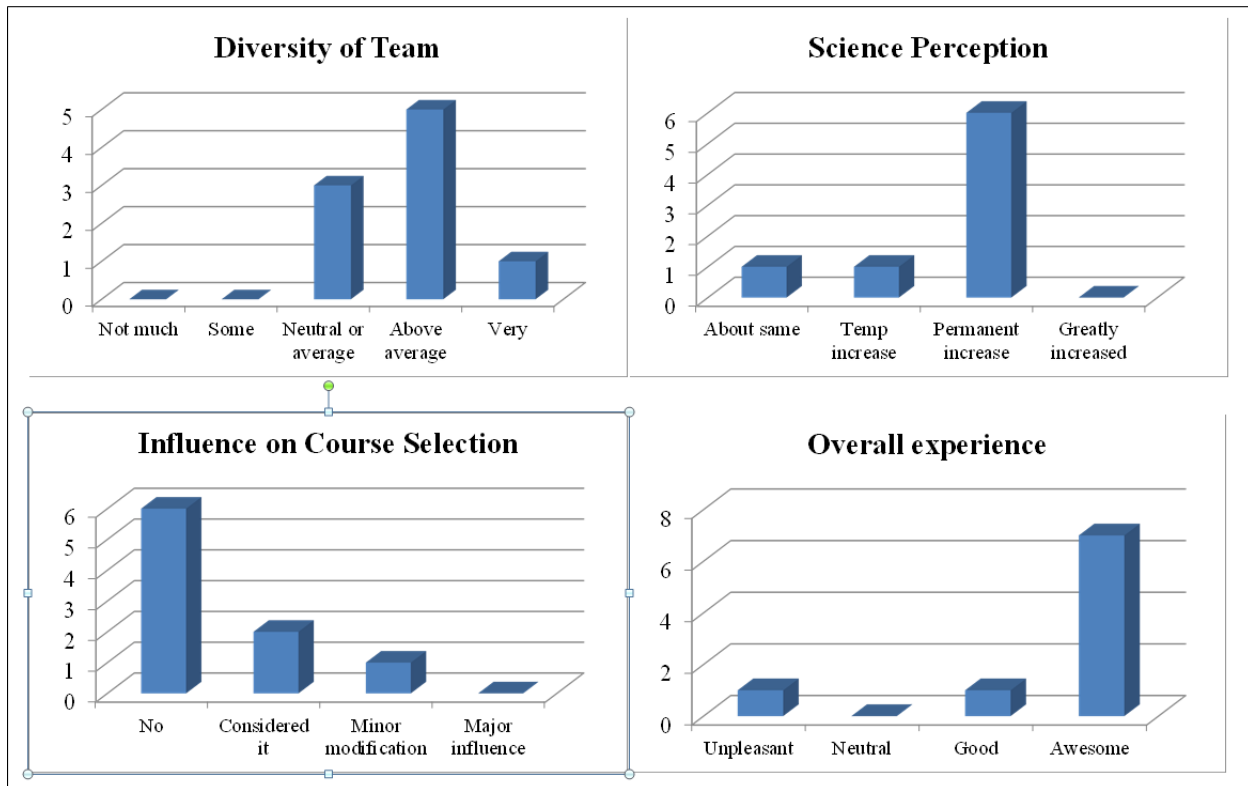


Figure 5. Educational Outcomes of Space Scream Experiment

In reviewing the results, it was not surprising to see a slightly above average perception of diversity in the team. Diversity, in this case, was referring to background and the team was comprised of several majors within the field of engineering. By not having an aerospace department, a diverse team for a SEDS chapter is necessity. The results of the second question were pleasing to see. None of the students involved had participated in a balloon-launch experiment prior. Because of this, it was expected that most students would be affected by the project. The results regarding influence on course selection were also expected. Because of how

new the SEDS team was at the time of the experiment, it was necessary to create a non-technically intensive project. This means there would not be any specific coursework necessary to have to succeed in executing or understanding what was going on. As the group grows, more technically advanced projects may become possible with using subgroups of specific majors working together. These kinds of projects would require students to reference information learned in specific courses and thus encourage students who have not yet taken these courses to do so. The final question results were, overall, very promising. It was surprising to see a student had an overall unpleasant experience. However, since the survey was done anonymously, it is impossible to ask the student for more follow up. For future projects, the student reactions survey may have a section for a brief paragraph explaining any suggestions for changes. This section will help eliminate the surprise and confusion of a response like this.

VI. Summary

The Space Scream experiment became the capstone event of Space Day 2012. All of the 350 in attendance watched the launch, and, for a while, stayed around to hear the screaming. The faculty advisor provided a verbal summary of the experiment, giving attendees an appreciation for the kind of space activities done in colleges and universities. The awareness that this came from our university may serve as a recruiting tool for future enrollees.

The SEDS organization remains strong, with plans for more field trips, rocket builds, and experiments at Space Day 2013. The next major project is to promote space solar power by enlisting the support of the entire US SEDS community.

VII. Acknowledgements

The authors gratefully acknowledge Mr. Brian Tanner and Mr. Bill Brown of SpacePort Indiana, and Mr. Jack Head of IUPUC who helped host our visit.

VIII. Bibliography

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