Using Balloon Launches as a Precursor to Small Satellite High School Education

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In August 2017, Destination SPACE (Satellite Program for Aerospace-Centered Education) launched its pilot run of Satellite Week, a camp where high school students learned about satellites and remote sensing through constructing small weather stations and launching them on low altitude balloons in Asheville, North Carolina. The payloads, designed and produced by XinaBox, represented nanosatellites. Students learned about calibration, data acquisition, analysis, and interpretation, as well as how weather balloons are used to test atmospheric conditions prior to the launch of a rocket. The students will continue to use these skills as they enter the Nanosatellite Program, a three phase program that runs during the school year. Teams conduct both low and high altitude balloon launches and ultimately design and build their own Nanosatellite. Destination SPACE is manifested for launch on the second stage of a supply rocket to the International Space Station in October 2018. Destination SPACE's Nanosatellite Program is developed in collaboration with Twiggs Space Lab and Virginia Commercial Space.

I. Introduction

DESTINATION SPACE (Satellite Program for Aerospace-Centered Education) is an organization designed to promote and cultivate long term interest in STEM by providing hands-on, remote sensing educational opportunities for public high school students. Destination SPACE runs two programs annually: Satellite Week and Nanosatellite Program. Satellite Week gives students an introduction to remote sensing and engineering as participants design and build their own sensors and launch them on low altitude weather balloons. The Nanosatellite Program runs throughout the school calendar year and allows students to receive a more in-depth understanding of satellites and remote sensing. They develop their Nanosatellite satellite research projects by designing payloads and research experiments and launching low and high altitude weather balloons. A pilot run of Satellite Week took place in August 2017, followed by the Nanosatellite Program during the 2017-2018 academic school year.

Satellite Week models SpaceTrek, a STEM program for women developed at Morehead State University. Destination SPACE also collaborates with XinaBox, a South African organization that develops the sensors and data retrieval and analysis platform. In the Nanosatellite Program, which is based on curriculum developed by Twiggs Space Lab, students learn about remote sensing concepts, research sensors, design their own unique Nanosatellites (variation of a CubeSat small satellite), and ultimately launch their sensors on weather balloons with the end goal of sending them into extremely low Earth orbit. Destination SPACE's educational programs launched their pilot run in Asheville, North Carolina in August 2017 and plan to expand to include at least one school in each of the remaining states in NASA Langley's Service Region (South Carolina, Kentucky, West Virginia, and Virginia). This paper outlines the curriculum implemented by Destination SPACE, the materials and equipment used, and future goals and vision for the program.

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II.Curriculum

A. Satellite Week

The curriculum for Satellite Week was developed by Destination SPACE in collaboration with XinaBox (Table 1). This five day camp introduces students to the concepts of satellites and remote sensing. Students are given a brief history of space technology, an overview of the atmosphere, and a lesson about satellites and their applications. Following the these lessons, the students build a 'plug and play' XinaBox weather station and launch it on a low altitude balloon. The students analyze data and present findings to NOAA and NASA scientists and community members. Satellite Week includes several inspirational guest scientist and engineer speakers throughout the week.

Table 1. Destination SPACE - Satellite Week curriculum schedule August 2017

<table>
<tr><th></th><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th></tr>
<tr><td>8:00 am</td><td>Welcome speech: Mary Wohlgemuth, Director of NOAA NCEI</td><td rowspan="2">Welcome and guest presentation by Professor Bob Twiggs, co-inventor of CubeSats</td><td rowspan="2">Prepare for weather balloon launch</td><td rowspan="3">Data analysis</td><td rowspan="2">Final presentation preparations</td></tr>
<tr><td>9:00 am</td><td rowspan="3">Geodome presentation at NOAA NCEI and weather station tour</td></tr>
<tr><td>10:00 am</td><td rowspan="2">Students continue constructing weather stations</td><td rowspan="2">Weather balloon launch</td><td>The Collider's coffee hour</td></tr>
<tr><td>11:00 am</td><td>Solar eclipse presentation</td><td>Student presentations</td></tr>
<tr><td>12:00 pm</td><td>Lunch</td><td>Lunch</td><td>Lunch</td><td>Lunch</td><td>Lunch</td></tr>
<tr><td>1:00 pm</td><td>Presentation by former NASA scientist, Steve Sanford</td><td rowspan="4">Continue constructing, programming, and calibrating weather stations</td><td rowspan="4">Weather balloon launch, followed by preliminary data analysis</td><td rowspan="4">Begin preparing presentations</td><td>Awards ceremony</td></tr>
<tr><td>2:00 pm</td><td rowspan="2">Introduction to satellites and remote sensing</td><td rowspan="3">Free afternoon at the Asheville Museum of Science</td></tr>
<tr><td>3:00 pm</td></tr>
<tr><td>4:00 pm</td><td>Construct weather stations</td></tr>
<tr><td>5:00</td><td>End of day</td><td>End of day</td><td>End of day</td><td>End of day</td><td>End of day</td></tr>
</table>

B. Nanosatellite Program

The curriculum for the Nanosatellite Program was developed by Twiggs Space Lab and Virginia Commercial Space. The purpose of the Nanosatellite program is to inspire students to pursue STEM education and careers by offering engaging, exciting, and constructive projects that encourage problem solving and critical thinking. Students are divided into teams of five or six and each team develops their unique research questions and designs their own Nanosatellite. Students have full autonomy in choosing their research question, but science advisors from Destination SPACE are available for advice and suggestions. This program is divided into three phases, each with a different method of data collection: low altitude weather balloons, high altitude weather balloons, and the Nanosatellite launch into orbit. Each phase builds off of the previous phase, and all of the material is designed to prepare students for their Nanosatellite launch.

Phase I

Phase I starts at the beginning of the school year and continues until winter break. It focuses on satellites, remote sensing, and basic electronics and engineering. Students build miniature weather stations called ToastSats developed by XinaBox and launch them on low altitude weather balloons. Students develop a research question about the troposphere that may be answered using the sensors provided in the ToastSat kit. Kits contain weather and light sensors, balloons, parachutes, long range radio transceiver, monopole antenna, GPS Unit, battery module, Wi-Fi module, nine degrees of freedom unit, and burn wire module [1]. Examples of proposed experiments for Phase I include analyzing the correlation between ultraviolet light and altitude and measuring atmospheric conditions at different proximities from a river. When students launch their weather balloons, data are automatically synced to the Science Data Dashboard, where they can view live updates. This dashboard serves as a tool for analyzing the data; students may also access data from all the launches across the participating Nanosatellite schools. This phase culminates each team submitting a scientific research paper to their teachers.

Phase II

Similar to Phase I, students design research questions and collect data from weather balloon launches. This time, students work with a Nanosatellite Engineering Model on a high altitude weather balloon that mocks the Nanosatellite they construct in Phase III, focusing on the ozone layer and stratosphere. Teams are given a budget to purchase space-hardened sensors, and decide which materials are necessary to successfully answer their research question. Students also receive a Nanosatellite printed circuit board, 3-axis accelerometer, 3-axis magnetometer, 3-axis gyros, and a 3-D printed frame. Before the launch of their high altitude weather balloon, students integrate physics and math problem solving into their projects, as they figure out payload weight constraints and helium requirements. Post balloon launch, each team writes a scientific paper discussing design process and data analysis.

Phase III

In Phase III, students leverage their knowledge and lessons learned from the first two phases and apply their experience to developing their own Nanosatellite. As with Phase I and II, teams devise research questions and implement a plan for carrying out research. This time the scientific question must address characteristics of the thermosphere. Students will also engage with course material related to space debris, rocket launch protocol, and the magnetosphere. The curriculum will focus again on electronics and engineering design process as students create an electrical circuit schematic of their Nanosatellite. Nanosatellite teams communicate with other teams, sharing ideas and providing feedback on project plans. Each team submits a schematic and research proposal to Twiggs Space Lab for approval. The completed Nanosatellites are sent to a clean room at Morehead State University to become flight-ready before heading to Wallops Island, Virginia. The Nanosatellites are manifested for launch on the second stage of an Orbital ATK Antares rocket destined for the International Space Station. The Containerized Satellite Dispenser will eject the Nanosatellites at an altitude of approximately 250 km. Nanosatellites orbit Earth every 90 seconds with a lifespan of approximately five days. Teams again submit a final paper and give a formal presentation on their three-phase project to teachers, Destination SPACE staff, and, depending on location, NASA and NOAA affiliated scientists and engineers.

III.Continuity and Future Goals

The Nanosatellite program intends to increase the number of participating schools each year across NASA Langley Research Center's five state service region. The Nanosatellite Program spans approximately one year; however graduates of the program will be invited back to act as peer mentors to upcoming Nanosatellite Program teams. Peer mentors provide assistance to teams through project design and to teachers in lesson facilitation. The second annual Satellite Week, scheduled for July 2018, is planned as a one-week residential camp located at a local college dormitories. Peer mentors will act as teaching assistants during class time and will lead students in fun science-related crafts and games in the evenings.

The Nanosatellite Program also has the potential to contribute to pertinent scientific knowledge. The area of the atmosphere 250 km above the Earth's surface is too high for weather balloons and too low for traditional satellites. Therefore, this region is underrepresented in scientific research. By sending large constellations of Nanosatellites into extremely low Earth orbit each year, the Nanosatellite Program has the opportunity to coordinate experiments to add to and improve a scientifically valuable dataset.

IV.Conclusion

The mission of Destination SPACE is to create engaging STEM education opportunities for students to inspire a long term passion for science and engineering. Satellite Week and the Nanosatellite Program achieve this mission by offering students the opportunity to design their own experiments and launch a satellite into orbit while they learn applied math, physics, engineering, and atmospheric science. Students also develop teamwork skills, presentation skills, scientific writing, and learn about the engineering planning process. Students will graduate from the Nanosatellite Program with scientific research experience and will have a head start on planning career paths and educational goals.

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References

[1] Twiggs Space Lab. “An Exciting Opportunity to Advance STEM Education with Femto-satellites,” Twiggs Space Lab. Morehead, KY, 2017 (unpublished).