INTRODUCING SPACE MISSIONS INTO THE CAREER AND TECHNICAL EDUCATION CURRICULUM VIA CONSTRUCTION OF A CUBESAT PROTOTYPE

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Freeport High School is a finalist in the U.S. Department of Education's CTE Mission: CubeSat, a national competition to bring space missions to high school students. Freeport received cash prizes, development kits and expert mentorship donated to the U. S. Department of Education by Arduino, Blue Origin, Chevron, EnduroSat, LEGO Education, Magnitude.io, MIT Media Lab Space Exploration Initiative, and XinaBox. Our CubeSat will contain an Arduino MKR WAN 1310 board, MKR GPS sensor, MKR MEM shield with a SD card, MKR IMU shield, and a lithium-polymer battery. The structure of the CubeSat was done by students in Industrial Drafting, CAD classes using AutoCAD, Sketchup, and a 3D printer. The CubeSat will be carried by a drone and its flight controlled by students in Video Media Production class. We will use this experience to teach a summer CubeSat class.

TEAM MEMBERS WILL BE AVAILABLE TO SPEAK WITH YOU ON WEDNESDAY, APRIL 28TH, AND THURSDAY, APRIL 29TH, AT 11 AM:

https://us02web.zoom.us/j/87904751067?pwd=YlV1MkYxZ2cyRzI1WTdsdFR6QVBmdz09

Introduction

To expand student interest in STEM fields, the U.S. Department of Education launched CTE Mission: CubeSat, a national challenge to inspire students to build technical skills for careers in space and beyond. High school students from across the country were invited to design and develop CubeSat prototypes, or satellites that aid in space research, bringing space missions out of the clouds and into the classroom [1]. The excitement and challenge of allowing students to do "real" things in space is a motivational experience that cannot be achieved by teaching in a classroom and represents education at its best [2]. Freeport High School was among the finalists chosen in this competition.

Mission

The primary mission of our CubeSat is to gather environmental observations to support authentic student research and create citizen scientists. For the past few years, Freeport High School students have taken part in the Global Learning and Observations to Benefit the Environment (GLOBE) program. Students from nearly 40,000 schools located in approximately 120 countries participate in this program. In our CubeSat we will use two infrared imagers in specific bands to observe the surface temperature of Earth. Students will use this data in their ongoing effort to study the urban heat island effect. If successful, our CubeSat can be employed as a dedicated satellite to the GLOBE program giving it another educational dimension. Improvements on future launches may allow us to make measurements that can challenge large-scale satellite` cost-effectiveness by capturing comparable scientific data.

Our mission will also use the CubeSat flight to study the principle of the conservation of mechanical energy. From the position and velocity of the CubeSat, students will be able to calculate the total mechanical energy. The orbit of the CubeSat will be modified by perturbations resulting from air drag. We plan to use our data to determine the drag coefficient at the initial stages of changes in the CubeSat trajectory.

Mentors provided by the U.S. Department of Education

	Names
Arduino	David Cuartielles, Co-founder Massino Banzi, Co-founder
EnduroSat	Raycho Raychev, Founder Victor Danchev, Physicist and Mission Manager
Magnitude.io	Ted Tagami, CEO and co-founder
XinaBox	Bjarke Gotfredsen, Co-founder Judi Sandrock, Co-founder William Edmonson, USA XinaBox Ambassador

Subject Matter Experts provided by the U.S. Department of Education

Organization	Names
NASA	Ali Guarneros Luna, Project Manager
DreamUp	Lauren Milord, Partnership and Outreach Manager
MIT Media Lab	Mehak Sarang, Lunar Exploration Projects Lead
Moog Space System	Robert Atkins, National Security Space Manager
Twiggs Space Lab	Robert Twiggs, Founder; co-inventor of the CubeSat

List of Webinars on Selected Space Topics

Professor Robert Twiggs	Space Environments
Robert Atkins	Space Innovation Course Lessons
Professor Robert Twiggs	Space Communications

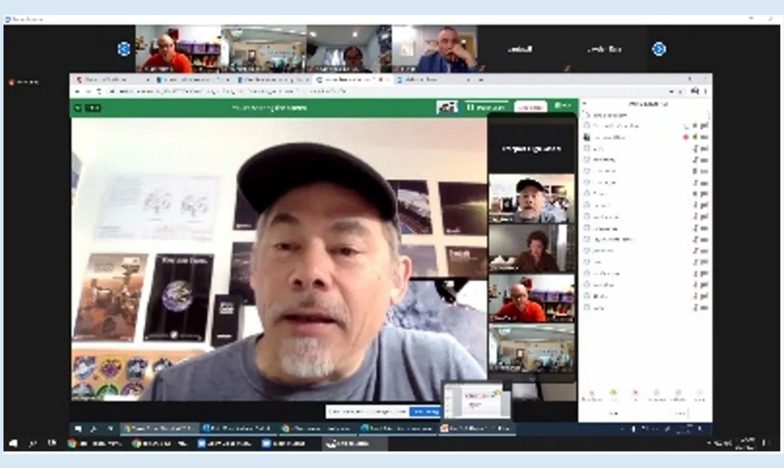


Figure 1: Ted Tagami (Magnitude.io) engaging with Freeport Students

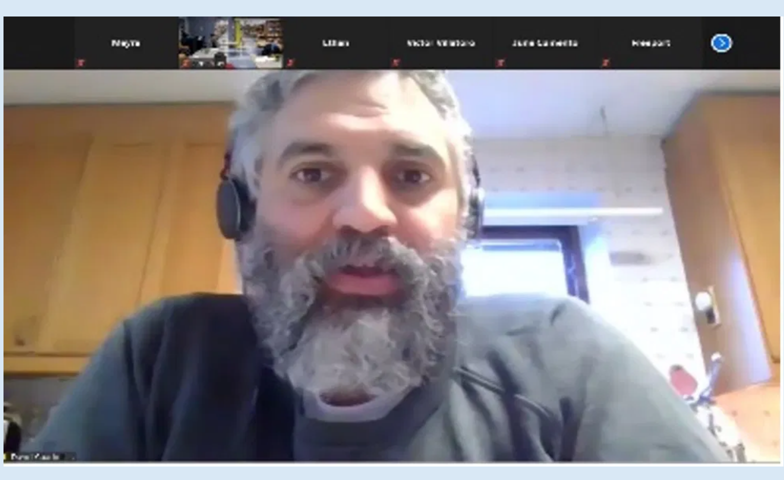


Figure 2: David Cuartielles (Arduino) engaging with Freeport Students

Science Payload

As a result of participation in the GLOBE program our students took temperatures of the concrete and grassy surfaces outside Freeport High School. These measurements were taken from the months of October to March. The maximum and minimum average temperature during these months of either surface are recorded in the Table below. We then used Planck's blackbody radiation formula to convert these temperatures into wavelengths [3].

Maximum/Minimum Average Temperature (^{0}C)	Peak Wavelength (Microns)
22.6	9.8
3.6	10.5

These wavelengths are in the infrared range and we will use infrared cameras to observe these surfaces from space. Therefore, if the infrared camera can measure the intensity of a perfect black body at a particular wavelength we can use Planck Blackbody formula to calculate its temperature [3].

There are two problems with this approach. The ground is not a perfect black body. A bigger problem is the fact that water vapor present in the atmosphere also absorbs infrared radiation. Therefore, we cannot used Planck's formula to measure the temperature of the Earth's surface. In the split window technique [4-6], we measure the radiation emitted at two wavelengths that are very near each other like 9.8 and 10.5 microns. We measure the temperature of the Earth's surface using the following Split Window formula:

$$B(\lambda_1, T_S) = I_1 + \gamma(I_1 - I_2)$$

In the above formula, B is the Planck function, I_1 and I_2 are the measured intensities at the two different wavelengths, and γ is a constant that depends on the water vapor content, viewing angle, transmittance and emissivity. The split window technique assumes that the correction due to water vapor is proportional to the difference in intensities of the two wavelengths.

Electronics and Computing

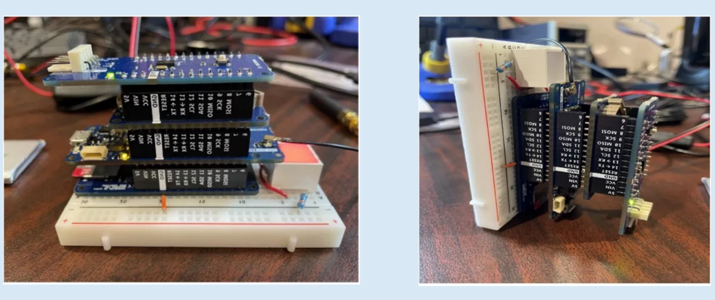
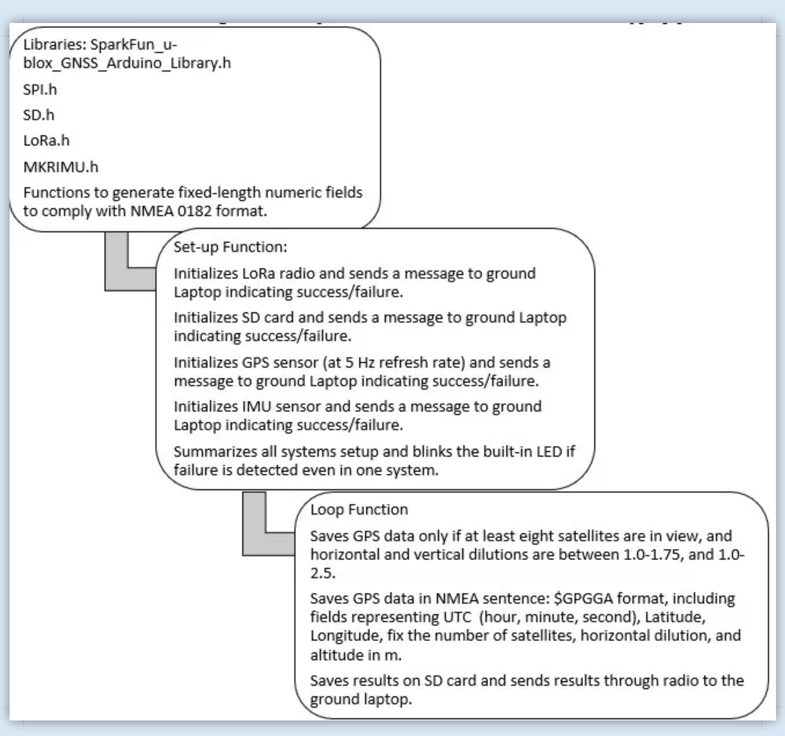


Figure 3

Figure 3 displays the electronics in our prototype. At the top is the MKR IMU shield, followed by MKR GPS sensor, Arduino MKR WAN 1310 board, and MKR MEM shield with a SD (secure memory) card and an antenna. Arduino gave the sensor, boards, and antenna. A rechargeable 1200 mAH lithium-polymer battery supplies the power. We have included a square LED for demonstration purposes, which will light up if the pitch angle is less than 70 degrees and more than 110 degrees (Figure 3 and 4). To ensure that the required current goes to the LED we have included a 330-ohm resistor.

Block Diagram of Computer Code in Arduino board inside Prototype [7]



The CubeSat will be launched by a Mavic Mini drone manufactured by DJI. There is also an Arduino MKR WAN 1310 board (also donated by Arduino) connected by USB cable to a laptop on the ground.

Structure

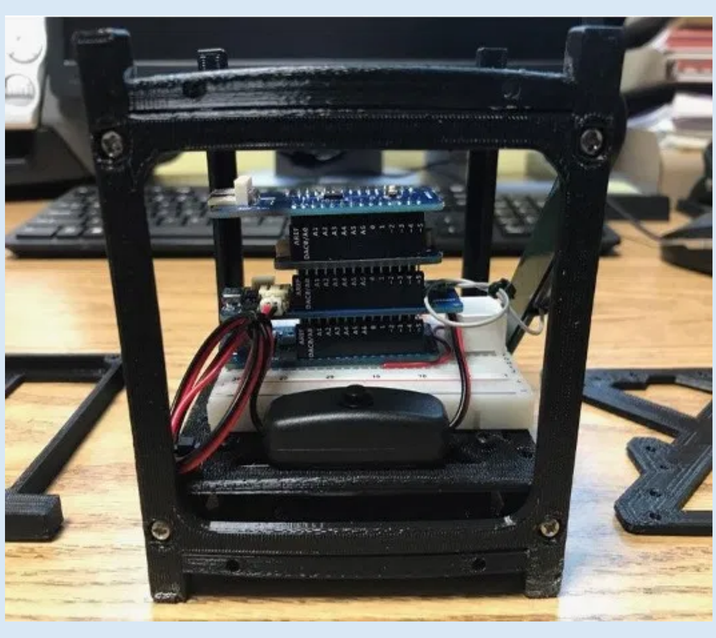


Figure 4: CubeSat Assembly

Launch

Launch Objectives

To obtain the GPS coordinates, altitude, latitude, and longitude at various time intervals. We also plan to test the accuracy of our GPS values by comparing them to the GPS values obtained by the sensors on the drone.

Determine the maximum distance digital data can be consistently transmitted via LoRa-based wireless communication links.

We want to find out if Google Earth can use our GPS data, saved as NMEA 0183 sentences, to show the terrain (towns/roads) over which the drone passed by when in flight. This information is essential because we want to find the temperature differences between cities and urban areas. Google Earth will help us identify the towns and rural areas.

Introduction to attitude control. We have included an Inertial Measurement Unit (IMU) sensor that will give us the yaw, pitch and roll angles to measure the rotation of the CubeSat. This information is required to ensure that the camera is pointing towards the ground when taking photographs.

Educational Objectives of Launch

The GPS coordinates will enable us to calculate the satellite`s gravitational potential energy and kinetic energy. We will also introduce students to the sources of GPS errors and methods developed to reduce such errors.

Introduce students to Section 25.4.8 [2]. The additional resource includes Professor Twiggs`s presentation on CubeSat Communications.

Generate excitement among the student body (including elementary students) by using VR headsets to see the Google Earth data in 3D.

Students will be introduced to rigid body rotation and their description using Euler angles. Euler angle convention of yaw, pitch, and roll will be explained to students. Students will also be introduced to the problem of gimbal lock that nearly occurred in *NASA'S Apollo* lunar missions.

CTE Connections

In the Drafting & Design program we have students working on the structure design component of the project. Students in Industrial Drafting and CAD classes have created detailed drawings of the CubeSat structure design using traditional drafting techniques and engineering software programs. These designs were then used to create working prototype models on a 3-D printer.

Students in our Electrical Engineering classes have worked to connect and test the computing, power, communication and data storage components required for the CubeSat structure to operate.

The Video Media Production class includes a Drone unit where students learn to fly a drone to record specialized video content. Students in this class are working on the launch component of the project and using the drone to fly and test the CubeSat prototype.

In the CTE Business Computer Applications program students are working to create a marketing plan to promote the CubeSat project. In the Web Page Design Class students are creating a CubeSat web page which will include details and updates related to the project

Future Work

One possible next step would be to use the IMU control code to trigger a cheap infrared camera to take a snapshot of the school's exhaust stack when the attitude is right. This would teach students much of the thermal imaging basics.

References

[1] https://www.ed.gov/press-releases/U.S. Department of Education Launches Space Mission Challenge for High School Students, August 18, 2020.

[2] Space Operations and Ground Stations by Robert Twiggs and Benjamin Malphrus, *Space Mission Engineering: The New SMAD*, Wertz, J.R., Everett, D.F., Puschell, J.J., editors, Microcosm Press, Torrance, CA (2018).

[3] Physical Chemistry, Atkins, P, De Paula, J. Oxford University Press (2010).

[4] Price, J. C., 1984 Land surface temperature measurements from the split window channels of NOAA 7advanced very high-resolution radiometer. J. Geophyys. Res. Atmos. 89 (D5), 7231-7237.

[5] McMillin, L. M., 1975 Estimation of sea surface temperatures from two infrared window measurements with different absorption. J. Geophys. Res. 80 (36), 5113-5117.

[6]. Wang, M., He, G., Zhang, Z., Wang, G., Wang, Z., Yin, R., Cui, S., Wu, Z., Cao, X., 2019. A radiance-based split-window algorithm for land surface temperature retrieval: Theory and application to MODIS dat. Int. J. Appl. Earth Obs. Geoinformation 76, 204-217.

[7] https://github.com/dbiersach/CUBESAT/blob/main/Arduino/CUBESAT_GPS/CUBESAT_GPS.ino