Development, Installation, and Operation of a Small Satellite Ground Station at a Public High School

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Abstract

For the past three years, the FIRST robotics team at Perkins High School (PHS) has worked to prepare for an educational CubeSat mission. The name of the mission is Foras Promineo, coined by a high school Latin teacher to mean "outreach" or "pushing beyond previous limits." The goals of the mission are (1) to provide a fun, educational experience for the public by giving them real-time control of a robot arm carried by the satellite with very low resolution "live video" (100X100 pixel four color images), and (2) to give PHS students the opportunity to work on an actual space mission. One of the primary tasks PHS has undertaken to support the Foras Promineo mission has been building a ground station that will provide communication to the satellite, in turn controlling its robot arm.

Introduction

CubeSats are often touted as excellent educational tools for students and younger members of the workforce. Small size, relatively low cost, and a large variety of educational resources are making development of CubeSats more accessible to high school, middle school, and elementary school students. To date, over 50 high schools have attempted to develop CubeSats [1]. However, high school teams face significant challenges due to lack of strong technical expertise of most students, loss of most experienced team members to yearly graduation, limited time commitment of each team member, and lack of appropriate assembly, integration, and test facilities [1].

To help make up for the student members' general technical inexperience, the Foras Promineo team decided to base its CubeSat on the PyCubed architecture, an open source educational satellite system. PyCubed uses LoRa, a low power, low bandwidth amateur band communication protocol capable of "extremely long distance communications" [2]. LoRa is also "routinely used… by the Starlink constellation and in the TinyGS project" [2]. To support mission operations using LoRa, the Foras Promineo team opted to install a LoRa ground station at Perkins High School (PHS). To date, the students and mentors at PHS have spec'd out, purchased, assembled, installed, and performed limited functional testing of the PHS LoRa ground station.

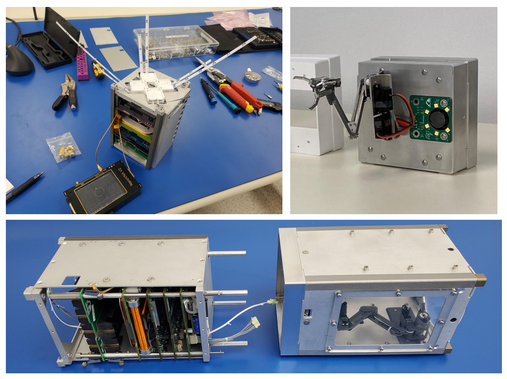

Figure 2—The Foras Promineo satellite mission is to provide a fun and educational experience through real-time control of a robotic arm in space.

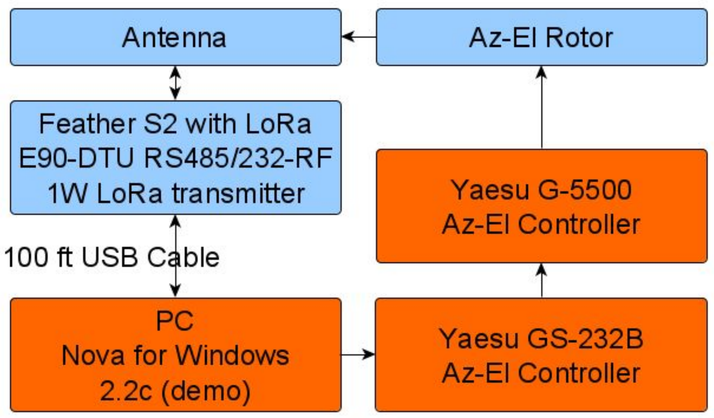

Figure 1—Foras Promineo ground station block diagram.

Configuration

The ground station is configured as shown in Fig. 1. The Yagi beam antenna with rotor assembly is mounted to a 20 ft. tall aluminum mast attached to the high school building such that the antenna is approximately 10 ft. above the roof line.

Nova for Windows, a satellite tracking program, calculates the direction to aim the antenna and sends signals to control the Az-El rotor; Nova has a built-in interface for the Yaesu Az-El controllers.

Data and command packets from/to the satellite are received/sent via the Feather S2 LoRa module. A terminal-based program, custom-designed by Sierra Lobo, runs on the PC and is used by ground station operators to send commands to the satellite. The program also relays data between the satellite and a website the general public can use to operate the robot arm onboard the satellite.

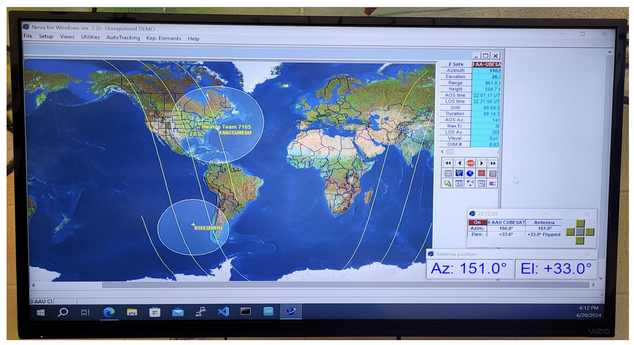

Figure 3—Nova for Windows provides the ability to track Foras Promineo satellite and control the antenna rotors.

References

[1] Ribeiro, L., et. al, "Identifying and Overcoming Challenges in High School CubeSat Programs," 36th Annual Small Satellite Conference, Logan, UT, 2022.
[2] Büttrich, S., "CubeSat Lora Module," University of Copenhagen, February 2024. [https://dasya.itu.dk/for-students/proposals/current/jucp-cubesat-lora/. Acc. 7/23/24.]

Figure 4—The Foras Promineo ground station antenna is installed at Perkins High School in Sandusky, Ohio.

Testing

Preliminary functional tests verified the ground antenna is able to track and receive signals from orbiting satellites. We used Nova for Windows with the rotor controller setup in Fig. 1 to track existing spacecraft in the TinyGS network. We used the Feather radio in Fig. 6 connected to the antenna in Fig. 4 to receive data from spacecraft in the TinyGS network.

Additional functional testing verified the ground station is able to communicate with the type of LoRa radio used on Foras Promineo. A standalone LoRa Feather Radio with a simple passthrough script attached to a laptop running a terminal program was used to send/receive human typed/readable messages to/from the ground station.

Future functional testing will verify the ground station is able to communicate with Foras Promineo using our mission-specific command and control packet structure. The Foras Promineo EDU (and Flight Unit), running flight software, will communicate with the ground station from the PHS parking lot.

Logistics/Hurdles

- Required an amateur radio license to communicate with a satellite in space using LoRa
  - Applied for FCC license via Nanoracks
  - Used license of a mentor for application (KA8VDW)
- Coordinated with the school (administration, custodial, maintenance, and IT) to maintain safety and compliance with school regulations during the installation of the antenna mast and cabling
  - Submitted a work order to the PHS Buildings and Grounds department to mount the mast on the school
  - One of our mentors installed the antenna on top of the mast and ran the cabling
- Set up the PC and rotor controls in our lab in the high school

Figure 5—The Foras Promineo ground station PC and antenna control electronics reside in the PHS robotics lab.

Figure 6—The Foras Promineo ground station radio is a Feather S2 integrated into the system in a weatherproof box adjacent to the antenna at the top of the mast.

Results and Future Work

A ground station (GS) for the Foras Promineo (FP) mission has been established at Perkins High School (PHS) in Sandusky, Ohio. The antenna mast, antenna azimuth and elevation drive motors, antenna, and radio have been successfully installed on the PHS building. Permitting and licensing for the GS and mission has been successfully established. The GS PC and drive motor electronics have been successfully installed in the robotics lab at PHS. The GS antenna has been verified to track satellites using the Nova for Windows program. The GS has also been verified to receive information from satellites currently in orbit and verified to send and receive information to/from a radio similar to the FP flight radio.

Preliminary RF communication testing between the GS and the FP EDU is planned for the next two months. Following successful RF communication and command and control debugging with the EDU, RF communication and command and control between the GS and the FP Flight Unit will be verified. During the mission, PHS students will participate in operation of the GS under the guidance of mentors.

Foras Promineo is scheduled to be delivered to Nanoracks in January 2025, launched in April 2025, and deployed from the ISS in mid-2025. We expect to be fully operational within a few weeks of deployment.

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