Undergraduate Research Award Proposal

Project Proposal Title	Ground Station for Small Satellites
Name of School	Sonoma State University
SPS Chapter Number	6474
Total Amount Requested	$2000

Students at Sonoma State University propose to construct a ground station to receive radio telemetry from small satellites such as SSU's MagPocketQube, currently due to launch in late November. At SSU, the ground station will be used for undergraduate training, research, and outreach and it can also serve other universities.

Proposal Statement

Overview of Proposed Project

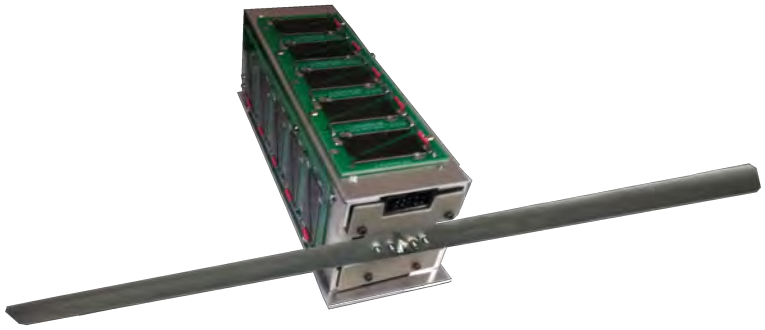
This grant will provide support for the Small Satellite program at Sonoma State University (SSU). During the summer of 2013, Sonoma State developed a small satellite, known as a PocketQube, in collaboration with Kentucky's Morehead State University (MSU). PocketQubes are small satellites that can be built by and used for space-based research by undergraduate students. The SSU/MSU "MagPocketQube" is currently installed inside a much larger Italian satellite, awaiting a November 2013 launch by a Russian rocket into a polar low earth orbit. The MagPocketQube measures 5cm x 5cm x 15cm (and is therefore considered a 3P PocketQube, as it is comprised of three cubical units, each 5 cm on a side). Subsequently, SSU students are developing a second slightly larger satellite, measuring 10 cm x 10 cm x 10 cm, known as a 1U CubeSat. This CubeSat will be capable of performing X-Ray astronomy using a Cadmium Zinc Telluride (CZT) array.

Currently the only ground station that is available to our team and capable of communicating with these satellites is at Morehead State University. The polar orbit of the MagPocketQube will result in only two passes over this ground station each day. Building a ground station at SSU will not only allow us to get twice the amount of data from the satellite, but will also be a valuable tool in training students to operate satellite tracking systems and generating the orbit equations. The MagPocketQube has the ability to change its orientation through the use of torquing coils by pushing off the earth's magnetic field. It also has a magnetometer which allows us to know the orientation and location of the satellite. We can also command it in real time by uploading new code during a pass over a ground station. Having a ground station at SSU will allow the students to command and operate the satellite, as well as acquiring the satellite's telemetry and decoding data packets.

The project will entail building the tracking system and ground station at SSU. The ground station's physical components will include the rotator assembly, antenna system, amplifiers and radios. We will use open source software which includes tracking and packet decoding software. Students working on the ground system will gain experience in both hands on and computer applications.

The primary objective of this project is to gather telemetry and command current and future SSU satellites. In addition to gathering our own data, we will also be able to decode the data from other university satellites that operate in the MagPocketQube's 70cm HAM band. This will give students experience working in collaboration with students from other universities.

The SPS at SSU will be responsible for the operation and maintenance of the ground station. SSU will benefit by improving our Small Satellite program so that we can not only develop and build the satellites, but we will also be able to operate them, acquire data and analyze the data, thereby conducting physics experiments. This project also has the potential to contribute nationally by receiving satellite data packets from CubeSats built by other universities.



The MagPocketQube as delivered for launch

Background for Proposed Project

Current SSU students have been working with a volunteer mentor, Dr. Garrett Jernigan, to learn how to build a ground station at SSU. Dr. Jernigan also oversaw the MagPocketQube development, construction and testing work done primarily by SSU student Kevin Zack (with assistance from several other students). Dr. Jernigan is a licensed Ham operator and has built a similar version of the ground station that we are proposing to build. Since the cost of the ground system is more than this grant can provide, we will either borrow some of the parts or obtain departmental funding for the balance.

Working with Dr. Jernigan, we have assembled a radio system that has an acceptable signal to noise ratio for communications with CubeSats. To date, without using a tracking system, we were able to record a radio signal from a University of Colorado, Boulder CubeSat for 90 seconds as it flew through the beam of the Yagi antenna. This radio setup has therefore proved to be a viable configuration for CubeSat communication. The rotator assembly that we will use is the same assembly used at CU Boulder. The hardware has been proven by both universities and amateur Ham operators.

Figure 1: Rotator Assembly

Expected Results

Upon completion, we expect the ground station to have the ability to track satellites, allowing us to receive and decode telemetry packets. We also expect the students working on the project to obtain the fundamental knowledge of satellite tracking and antenna systems.

This will be the final piece to the CubeSat life cycle at SSU, completing the program. So far, we have designed and built satellites and will shortly have a satellite in orbit. However, without the ground station at SSU, we will not be able to obtain our own telemetry, leaving gaps in our ability to perform satellite tracking and control, as well as data acquisition, decoding, and data analysis. This latter ability is especially important as SSU's satellites gain in sophistication from simple magnetic measurements to X-ray astronomy observations (the scientific goal of our second satellite, which is now being designed).

Description of Proposed Research - Methods, Design, and Procedures

The ground station is comprised of a rotator and a rotator controller that interfaces to a computer. Attached to the rotator is a Yagi antenna with a pre-amp. The signal is fed into a RF-daughterboard, that takes the 437 MHz signal and feeds it into the B100 receiver. To transmit, a second wider-beam Yagi antenna is also attached to the rotator. The transmitter is a RFM22B, the same transceiver as the satellite and is attached to a 50W amplifier. This enables us to communicate and command the satellite.

Figure 2 shows a screenshot of the HAM software that allows us to see a "waterfall" plot of the signal in frequency vs. time. The left side top panel shows the actual CU Boulder satellite signal. The signal is tilted due to the Doppler shift changing the frequency as it flies overhead. The right side top panel shows the signal from a ground-based engineering model of the MagPocketQube which is transmitting beacons every 20 seconds.

Figure 2

Plan for Carrying Out Proposed Project

The project will be built by the SPS at SSU and operated by the students. To build the ground station it will require at least three students to assemble and raise the mast. There will be a minimum of four people, two teams of two that will operate the ground system. The teams will be required to teach lower division students, so as they graduate there will be teams to replace them.

Student Kevin Zack, the project leader of the MagPocketQube, will lead the development of the ground system. Student Aaron Owen, who has over 15 years of IT experience, will provide computer and networking expertise and support for the project. This is necessary because the system will be designed for remote computer controlled operation. After Zack graduates, Owen will continue to lead the project in future years.

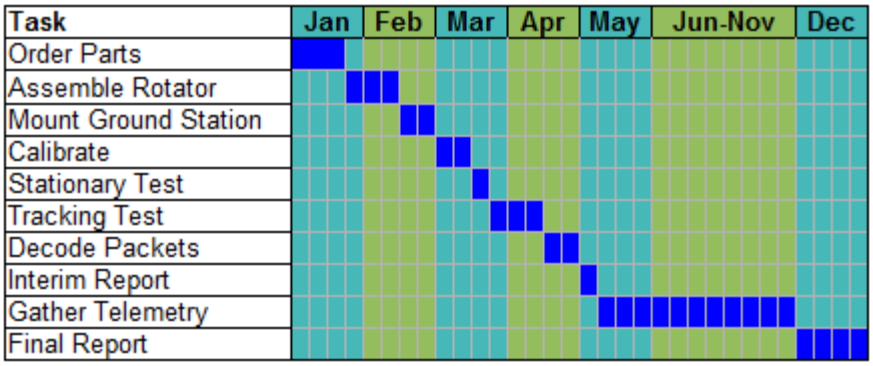
SSU has three labs dedicated to the development of the small satellites. One of the labs will be dedicated to the ground system computers. The antenna rotator system will be installed on the SSU Campus, most likely on the roof of the science building which houses the Department of Physics and Astronomy.

The computers used for the ground station will be donated by the Physics and Astronomy Department. The final parts of the ground system i.e. notch filters and RF boards, will initially be loaned to the Physics and Astronomy Department by collaborator Dr. Garrett Jernigan, but will eventually be purchased using departmental funds. Oversight of this project and additional technical support will be provided by Dr. Lynn Cominsky, the chair of the Physics and Astronomy Department, and by departmental technician Steve Anderson.

Project Timeline

In January and part of February the SSU SPS team will build and mount the ground station as well as implement the computer network. The system will be calibrated for a mid-March test. The first time we gather data, we will direct the system to go to a single point in the sky and let a satellite fly though the beam. From this information we can fine tune the tracking system. After the stationary tests we will attempt to track a satellite though the full pass. We will then decode the first packets and write the interim

report. The SSU team will continue taking telemetry from the MagPocketQube and other University small satellites. Although we will write the final report in December, this will not be the end of the project, as the ground station will be used for future satellites and will become an integral part of the CubeSat Program at SSU.



Budget Justification

The budget from this grant will pay for the rotator assembly portion of the ground system, which includes both the Rotator and the Interface between the rotator and the computer. These are the key components of the ground station.

Dr. Cominsky recently received a grant from the SSU Provost that can contribute up to $1000 to support this program by purchasing the radio system and RF-daughterboard. Dr. Jernigan will help us complete the system by initially loaning us the Yagi antenna, amplifiers and any other miscellaneous parts. The Physics and Astronomy Department at Sonoma State will provide the computers necessary to run the programs, as well as the lab space necessary to run the ground station. By June, it should be possible for the Department to find the funding to purchase the parts temporarily loaned by Dr. Jernigan.

Bibliography

http://lasp.colorado.edu/home/csswe/data/ground-station/