SOCIETY OF PHYSICS STUDENTS
An organization of the American Institute of Physics

SPS Chapter Research Award Final Report

Project Title	Ground Station for Small Satellites
Name of School	Sonoma State University
SPS Chapter Number	6474
Total Amount Awarded	$2000
Total Amount Expended	$2000
Project Leader	Aaron Owen

Abstract

Students at Sonoma State University propose to construct a ground station to receive radio telemetry from small satellites such as SSU's MagPocketQube [T-LogoQube], 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.

Statement of Activity

Overview of Award Activity

The project entailed building a tracking system and ground station at Sonoma State University (SSU) for the enhancement of the university's PocketQube program. The ground station's physical components include the rotator assembly, antenna system, amplifiers and radios. We are using open source software, such as Gpredict and Gqrx SDR, for tracking and packet decoding. Students working on the ground system have gained experience in both hands-on hardware, electronics, and computer applications. The primary objective of this project is to gather telemetry and serve as command center for current and future SSU satellites. Due to SSU's pocketqube T-LogoQube, launched in November of 2013, going dark in January 2014, we are unable to communicate with it any further. We were however able to receive communication data from other University satellites such as CSSWE and in the future from Montana State University's (MSU) Firebird mission due to launch at the end of January 2015. Despite setbacks, ground base testing has been performed to ensure it is ready for future SSU satellites and MSU's Firebird Mission. The next SSU satellite is due to launch later in 2015, which the ground station will be able to communicate and control, and it will be followed with additional missions that are presently in the planning stage of development. Additional future uses of the ground station will include tracking of a high altitude balloon launch to test the sensor design for a future pocketqube, in the second quarter of 2015.

The project has changed significantly from the original design and execution while maintaining the initial goals. The primary motivation for the changes has been due to logistics on the final location of the ground station hardware, in particular the antenna assemblies. Due to safety concerns and access restrictions the ground station hardware could not be located at the initial location on the roof of Darwin Hall. During the process of evaluating and working out the logistics of a new site for the installation, we assembled the basic configuration from the original plan and temporarily installed this system near the SSU Observatory. We were then able to track and take data from CubeSats and met our primary goal of the project. We then secured additional funding via the Physics and Astronomy Department to complete the final installation.

The site location of the Student Center and the logistics to access to the site were finalized in October 2014. The system had to be constructed so that all the radio and computer equipment were located close to the antenna assembly. This change required weatherproof housing for the radio and computer equipment as well as upgrading some of the hardware to industrial grade equipment to handle the harsher environment. We also had to come up with a solution for mounting the antenna mast and the housing for the hardware on the roof of the Student Center without damaging the roof or attaching directly to it. This required the use of a non-penetrating mount and pads to protect the roof. We also fashioned special brackets to attach the weatherproof housing for the hardware to the mast mount. The final installation has yet to be completed, we have been testing the new hardware and have installed the mount and weatherproof box on the roof. The temporary installation has been dismantled and removed from the SSU Observatory so it can be reassembled in the lab to test with the new hardware.

Including the original students who worked on the proposal and the midterm report as well as the students working on the project implementation are almost all members of our local chapter and eight of them are SPS national members. Aaron Owen (SPS National), with the assistance of Aman Gill (SPS National), Alyssa Afa'ese (Engineering) and a summer intern from Santa Rosa Junior College completed the installation, testing and operations of the temporary ground station at the SSU observatory. Aaron Owen with the assistance of Michael Schwartz (SPS), Tyler Whitmarsh (SPS) and Nicola Peyko (SPS National) are working on the implementation of the final design for the project at the Student Center.

Description of Research - Methods, Design, and Procedures

The original design for 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, which takes the 437 MHz signal and feeds it into a B100 receiver. A second wider-beam Yagi antenna is used to transmit and is also attached to the boom on 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 during each pass over head.

Below is a list of key components for the temporary site setup:

- Yaesu G-5500 AZ-EL Combo Rotator with the RS232 computer interface option for tracking
- Computer running Linux and Gpredict for satellite tracking and interface with the Rotator.
- Ettus Research USRP B100 radio with HDSDR (High Definition Software Defined Radio)
- Computer with HDSDR (High Definition Software Defined Radio) as well as the proprietary Jlogo and μlogo software to do waterfall plots and decoding packets.

- Custom hardware with the RFM22B, which operates with jLogo and µLogo for decoding packets and commanding our satellites.
- Advanced Receiver Research Pre-amp MSP432VDG-160 on each antenna
- An A430-11S (430-440MHZ, YAGI, 11ELE, 13.2DBI) Antenna and a smaller yagi.
- 12v Power Supplies
- LMR400 low loss cable.

With the temporary site we were able to track other CubeSats and verified successful tracking via waterfall plots of the beacon packets. We were unable to verify commanding the CubeSats because our satellite had gone dark.

With the final location, much of the functional design is the same, but due to the logistics and environment of the installation there were some significant additions to the design. In addition we decided to change the receiving antenna from the original A719B (430-450 MHZ, YAGI, 19 ELE, 15.5 DBI) to the M2 436CP42UG (430-438MHZ, Yagi, 70 cm, 42 el., Circular Polar., Satellite, 18.9 dBic). This decision was based on performance specs between the antennas allowing us to have circular polarization with a single antenna versus using two of the A719Bs. We had to use computer and power equipment that would operate in a harsher environments since the installation required all the hardware to be locate on the roof.

Below is a list of the key components for the permanent site setup:

- Yaesu G-5500 AZ-EL Combo Rotator with the RS232 computer interface option for tracking
- An industrial grade computer running Linux and Gpredict for sat tracking and interface with the Rotator as well as Gqrx SDR (GNU Software Defined Radio) and the proprietary jLogo and µlogo software to do waterfall plots and decoding packets.
- Industrial UPS
- Network remote controlled power strip
- Ettus Research USRP B100 radio with HDSDR (High Definition Software Defined Radio)
- Computer with for remote command access to the ground station computer and data analysis.
- Custom hardware with the RFM22B, which operates with jLogo and µlogo for decoding packets and commanding our satellitess.
- Advanced Receiver Research Pre-amp MSP432VDG-160 on each antenna
- An A430-11S (430-440MHZ, YAGI, 11ELE, 13.2DBI) Antenna
- M2 436CP42UG (430-438MHZ, Yagi, 70 cm, 42 el., Circular Polar., Satellite, 18.9 dBic)
- 12v Power Supplies
- LMR400 low loss cable.
- NEMA Enclosure
- Non-Penetrating Roof Mount

Discussion of Results

Even though the project has had several delays we were able to evolve the project, enabling us to obtain significant results with the temporary installation at the SSU Observatory. We successfully located, tracked and obtained waterfall plots of other CubeSats. We were unable to confirm in orbit command of T-LogoQube via the SSU ground station, but we are able to do ground simulations. We have had other successes through involving other SPS students, training them as the next group to take over operations. Through this project we have developed a new collegiate connection with MSU and have become advisers to other universities interested in building their own ground stations.

Dissemination of Results

Currently results have only been disseminated via email internally. We however have been providing advising to other universities and colleges building their own ground stations. We are in communications with UCSD (University of California at San Diego) and Santa Rosa JC (Junior College) on design recommendations and our results.

Impact Assessment:

How the Project Influenced your Chapter

The experience has been worthwhile, enabling our club members to learn how to handle a changing timeline and modifying designs to accommodate changes in the scope of a project. The challenge of obtaining a fixed location for the ground station was unexpectedly difficult. With the help from SSU Department of Physics and Astronomy and the School of Science and Technology we were able to resolve all issues and obtain a fixed location. One of the benefits of the project for the club is it has enabled us to recruit new members to our local SPS chapter. One member in specific is Michael Schwartz (physics sophomore) who has since been elected to an officer position.

Key Metrics and Reflection

How many students from your SPS chapter were involved in the research, and in what capacity?	We had six students from our chapter working on the proposal, who all are National Members; Kevin Zack, Aaron Owen, Ben Cunningham, Stephan Jackowski, Hunter Mills and Cody Johnson. We had two students from the local chapter working on the temporary ground station. Both are national members, Aaron Owen and Aman Gill. We currently have four students from our local chapter working on the final implementation. Two of the students are national members. Aaron Owen, Michael Schwartz, Tyler Whitmarsh and Nicola Peyko.
Was the amount of money you received from SPS sufficient to carry out the activities outlined in your proposal? Could you have used additional funding? If yes, how much would you have liked? How would the additional funding have augmented your activity?	The amount of money received was not sufficient because of the necessary design changes. These changes shifted the priorities on what components of the ground station the funds were used to obtain. We were then able to get the additional funds donated from the department plus hardware donations to make up for the short fall.

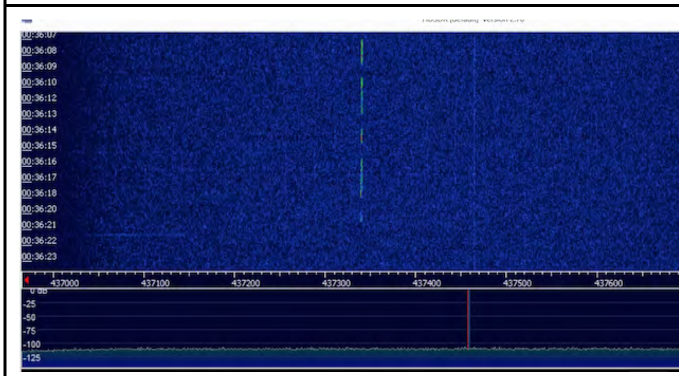
Do you anticipate continuing or expanding on this research project in the future? If yes, please explain.	The system will be expanding by adding or upgrading antennas to improve receiving sensitivity and making the system more capable. We have plans to upgrade the transmit capabilities. In addition, we plan to collaborate and take data for other universities.
If you were to do your project again, what would you do differently?	Have the installation location confirmed before requesting funding or starting the implementation.

Expenditures

Expenditure Table

See Attached for project expenditures
Items highlighted were funded by the grant.

Activity Photos

	
Temporary ground station command center located at the campus observatory running Gpredict(lt) and Gqrx SDR(rt)	Temporary ground station mast, Yaesu G-5500 rotator and 70cm yagi antenna assemblies
	
Waterfall plot of CSSWE pass. Data taken from the temporary ground station and displayed with Gqrx SDR.	Radio, rotator control and computer system staging and testing for the final design.

	
Radio, rotator control and computer system software testing for the final design.	Ground station site construction NEMA enclosure, non-penetrating roof mount w/ ballast

Quantity	Item	Description	Cost	Purchased or Donated	Note
1	Yaesu G-5500 AZ-EL Combo Rotator	Yaesu G-5500 AZ-EL Combo Rotator	800.00	D	Dr. Jernigan
1	GS-232B	Yaesu GS-232B Rotor Computer Interface	600.00	D	Dr. Jernigan
1	26-1409	GIGAWARE FEMALE-TO-FEMALE DB9 SERIAL COUPLER	14.13	D	Aaron Owen
1	26-1402	GIGAWARE 6-FT. SERIAL RS-232C 9M-9F CABLE	21.74	D	Aaron Owen
1	Dell Lat D620	Dell Latitude D620 Laptop	220.00	D	Aaron Owen
1	XL60 3601	Boschert XL60 3601 Power Supply	350.00	D	Aaron Owen
2	50 FT LMR400 N MALE to N MALE	50 FT LMR400 N MALE to N MALE cables	148.88	P	
1	250 FT 18/6C	250 FT 6 conductor 18 AWG	118.39	P	
1	M2, HD-FG FBC60	M2, HD-FG FBC60, HD FIBERGLASS CROSSBOOM KIT (11')	247.45	P	
2	N Type Female to SMA Male	Amico SMA Male to Female N Type Plug Straight RF Connector	14.02	P	
2	AIR802 CA400 Antenna Cable	AIR802 CA400 Antenna Cable Assembly, N Plug (Male) to N Plug (Male), 1 Foot (30.48 cm)	36.93	P	
1	MCA802-4-0.600	MECA, 400-800 MHz 2-Way Pwr Divider Combiner, N-Female Ports	116.95	P	
1	Gino UHF Male PL259 to N Female	Gino UHF Male PL259 to N Female Jack Straight Coax RF Adapter	6.22	P	
1	WILSON400 Ultra Low Loss Coax Cable	Wilson Electronics 952302 2-Foot WILSON400 Ultra Low Loss Coax Cable with N Male Connectors	19.75	P	
2	42200 N-Male to N-Male Adapter	C2G / Cables to Go 42200 N-Male to N-Male Adapter	14.65	P	
1	USRP B100	Ettus, Universal Software Radio Peripheral B100 Radio	1,400.00	D	Dr. Jernigan
1	A430-11S	Crushcraft, A430-11S (430-440MHZ, YAGI, 11ELE, 13.2DBI) Antenna	130.00	D	Dr. Jernigan
2	MSP432VDG-160	Advanced Receiver Research, Pre-amp MSP432VDG-160	480.00	D	Dr. Jernigan
2	DS-2002	Winegard DS-2002 Antenna Mast U-bolt Kit 2 Pcs	20.89	P	
1	M2 436CP42 U/G	M2, 42-element circular-polarized 70cm - satellite Antenna	369.95	P	
1	LMR-400 CABLE (N)MALE TO (N)MALE 3FT	LMR-400 CABLE ASSEMBLY (N)MALE TO (N)MALE 3FT	15.44	P	
1	LMR400 10 FT ULL Coax Cable N Male	LMR400 10 FT Ultra Low Loss Coax Cable with N Male Connector Ends	24.95	P	
5	SRB22A2DBBNN	Rocker Switches	5.50	P	
1	ROHJRM27510	Non-Penetrating Roof Mount 10' x 2-7/8" OD Mast	725.00	P	
1	ROHJRMPAD	JRM Series Mounts, 3/8" Thick Protective Roof Pad	246.60	P	
4	CL3000SG	Cycle 24 Galvanized Economy Saddle Clamps CL3000SG	41.95	P	
1	SCE-35VR24SCE Enclosure	SCE-35VR24SCE Enclosure	549.74	P	
1	SCE-30P24	SCE-30P24 30x24, Backpanel, Bent Lip Edge	55.50	P	
1	SCE-VRM24	SCE-VRM24 Mounting Bracket Assembly	49.67	P	
1	SCE-TEMNO	SCE-TEMNO Fan Thermostat	35.00	P	
3	DN-20-12	COTEK DN-20-12 12V, 20W SINGLE OUTPUT POWER SUPPLY	75.65	P	
2	82-202-1006	RF Connectors / Coaxial Connectors STRT PLG LMR400/7810 9913 8214 CLAMP	22.58	P	
1	SDU850	UPS - Uninterruptible Power Supplies 850VA/510W 120VAC Din Rail Mount	450.39	P	
1	UNO-2362G-3S51	AMD T40E Based Embedded Automation Computer with Mini-PCIe Expansion Slot	727.68	P	
1	Web Power Switch 7	Web Power Switch 7 - 10 outlets, Auto-Ping, Surge Suppression, LCD/Keypad, 6' Cord	142.00	P	
1	50ft 12AWG	50ft 12AWG Solid Green Cable	14.54	P	
1	12-Hole Ground Bar Kit	12-Hole Ground Bar Kit	4.50	P	
1	11" Black UV Cable ties (100)	11" Black UV Cable ties (100)	11.25	P	
1	2" Ground Bushing	2" Ground Bushing (2-Pack)	11.32	P	
1	2 Meter Stnd 35mm Din Rail	2 Meter Stnd 35mm Din Rail	13.32	P	
3	Utilitech 8-ft 13-Amp 16-Gauge Cord	Utilitech 8-ft 13-Amp 16-Gauge Cord	34.16	D	Aaron Owen
1	Utilitech 10-ft 15-Amp 110-Volt 14/3 Cord	Utilitech 10-ft 15-Amp 110-Volt 14/3 Cord	15.19	D	Aaron Owen
	Misc Hardware	Galv Hanger Tape, Lock washrs, Flt washrs, #10- 24 x 3/4-in, #4- 40 x 3/4-in, Flat Braces,	13.84	D	Aaron Owen
	Misc Hardware	2" Steel Lock Nuts, 2" Plastic Bushings, 2" Rigid Nipple,	7.06	P	

Total Donated Value	4,079.06
Total Purchased Cost	4,343.72
Project Total	8,422.78
Funds	4,900.00
Funds Balance	556.28