Ground Station Project Overview

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Introduction/Overview

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01

Project Overview

Overall Goal

To design, build, and implement an operational ground station with fully functional transmit and receive capabilities able to control a Low-Earth Orbit CubeSat

Specific Goals

01 Retain Control in Tumble

Capable of operating CubeSat in the scenario of tumbling or attitude control loss.

02 Receiving

Capable of receiving FoxTelem and Satnogs telemetry data.

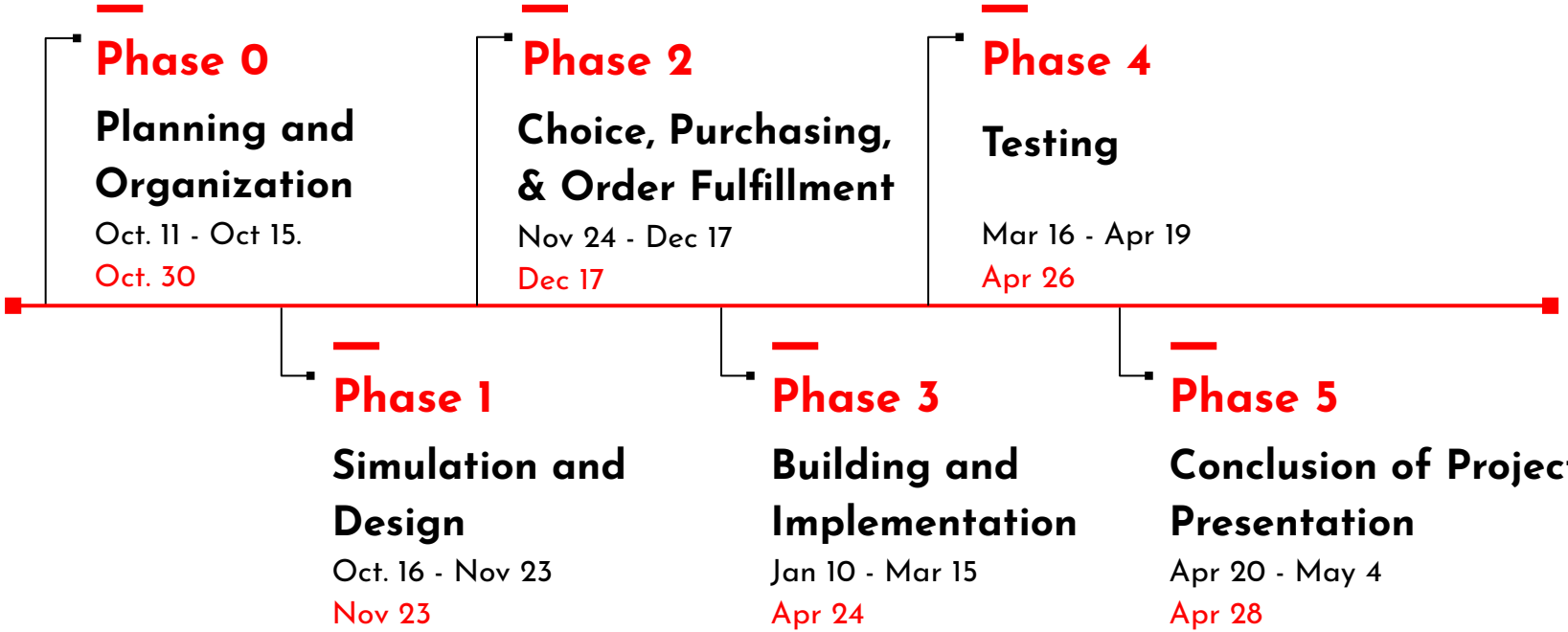
03 Transmitting

Capable of transmitting a radio signal to the CubeSat at a specific frequency and angle.

04 Life Span (5+ years)

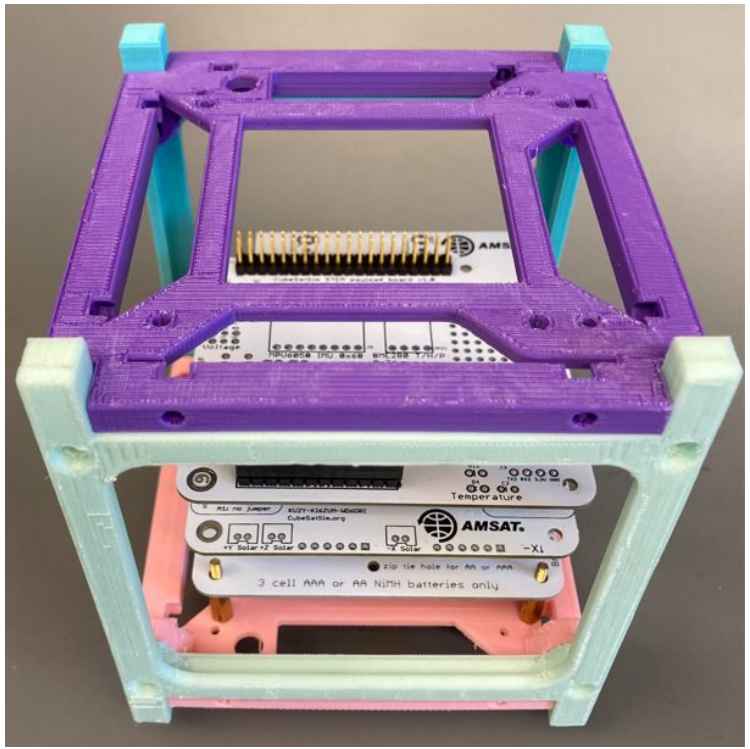
Structural integrity capable of operating for the entirety of the anticipated CubeSat mission duration.

Timeline


Phase 0
Planning and Organization
Oct. 11 - Oct 15.
Oct. 30
Phase 1
Simulation and Design
Oct. 16 - Nov 23
Nov 23
Phase 2
Choice, Purchasing, & Order Fulfillment
Nov 24 - Dec 17
Dec 17
Phase 3
Building and Implementation
Jan 10 - Mar 15
Apr 24
Phase 4
Testing
Mar 16 - Apr 19
Apr 26
Phase 5
Conclusion of Project, Presentation
Apr 20 - May 4
Apr 28

02

Customer & Impact



Stakeholders

Investors

California Space Grant, Azusa Pacific University ECS, WM Keck Foundation

Academic

University CubeSat programs (Cal Poly, University of Virginia, etc.)

Specifications

Compliance with NASA's Launch Services Program, AFSPCMAN 91-710

03
Budget


THE HOME DEPOT
Thursday 4/21/2022.
Campus Safety - yes, I meant to park like this, and yes, that's supposed to be on the roof. This is here to help Engineering Seniors align an antenna system to track Low Earth Orbit satellites.
- Professor Marshall

Budget

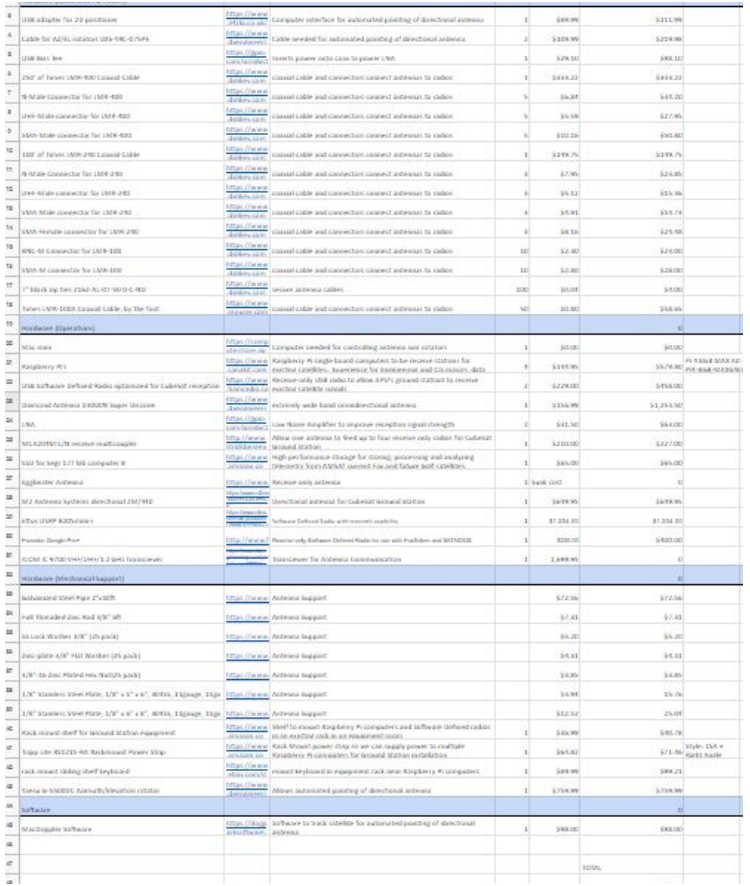
$9,300

Originally: $3,000

California Space Grant
ECS Senior Design Fund
WM Keck Grant Extension

Bill of Materials

Ettus URSP B205 Mini-i
$1350
Yaesu G-5500DC Az/El Rotator
$760
M2 Directional Antenna System 2M/440
$650



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Specifications

Omnidirectional Antenna

Eggbeater

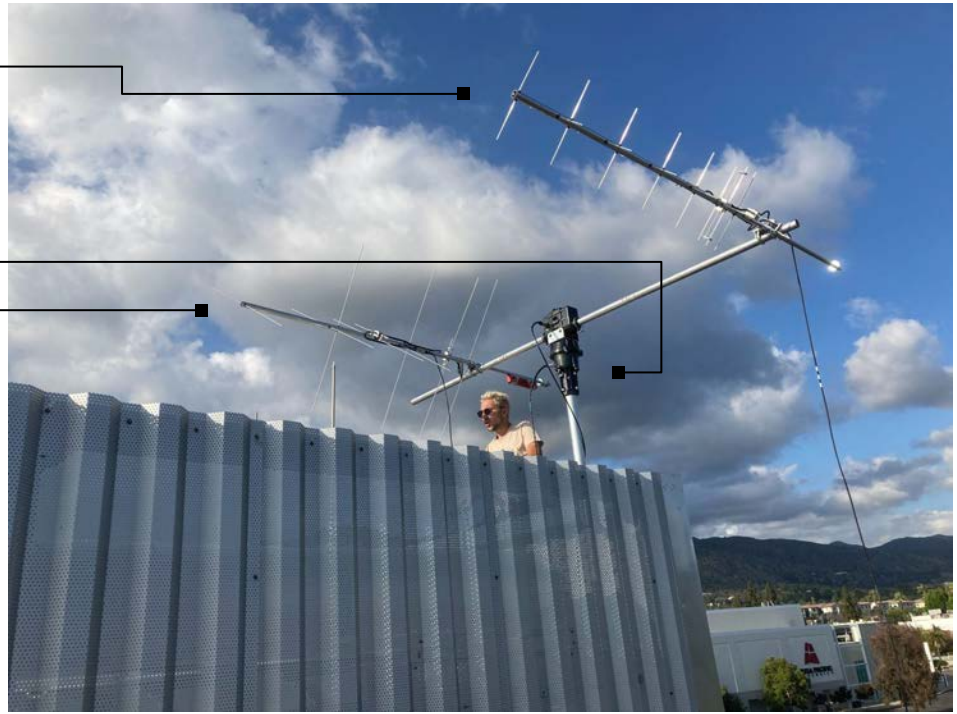
140-144 MHz
Circular Polarization

Directional Antennas

440 Yagi
432-438 MHz
Circular Polarization

Rotators
Az 0-450°
El 0-180°

2M Yagi
140-144 MHz
Circular Polarization



Mechanical Structure

Mast

10’ Galvanized Steel
2” diameter

Steel Plates

8”x 6” Steel Plate
Anti-rotation

U-bolts

2” Saddle Clamps
Lock washer, ½” bolt

Mirror Supports

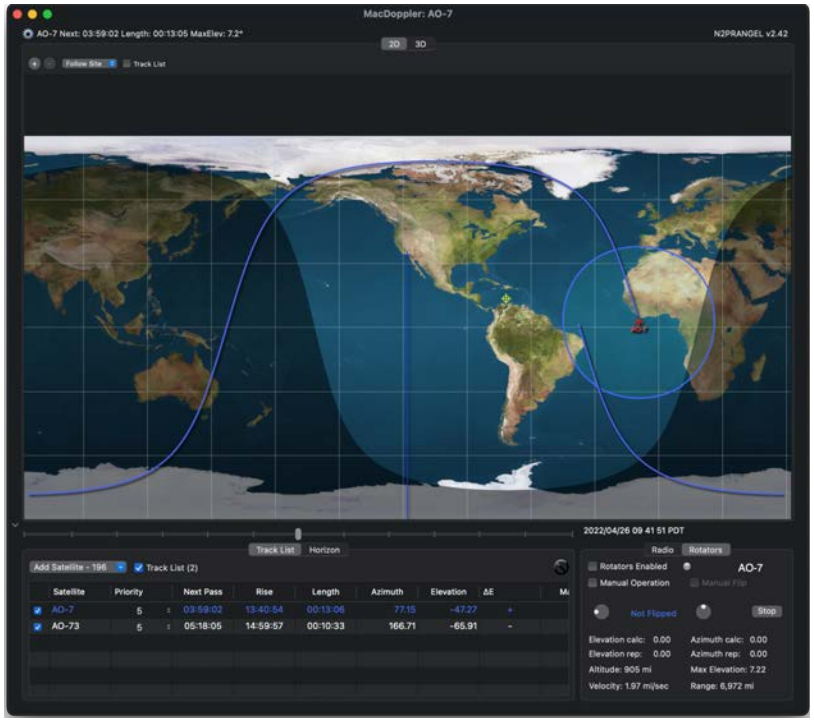
Duplicate plate structure at base and top of masthead

Antenna-Related Software

MacDoppler
Mac-based rotator control software

FoxTelem
AmSat satellite reception database

SatNOGS
Open-source ground station reception software



Electrical Components

Rotator Control Cables

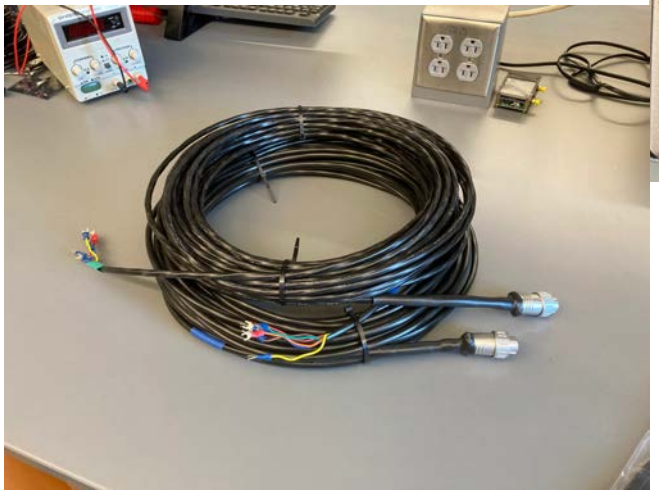
Carry control commands and position readings

Coax

LMR-240-Ultraflex and LMR-400 connects antennas to radios

USB

USB connections to radios and rotator controllers



General Specifications

Mast

- Material: Galvanized steel
- Coating: Zinc
- Length/Diameter: 10’/2”
- Complies with ANSI and ASTM A733, A53 standards
- Lifespan: 20+ years

Eggbeater

- Part Number: EB144RK2M
- Feedline Connection: UHF female, SO-239
- Frequency Range: 135-150 MHz
- Power Handling: 500 W
- Feedpoint Impedance: 50 ohm
- Weight: 4 lbs.
- Antenna Height/Width: 34”/28”
- Lifespan: 10+ years

Yaesu Rotator

- Part Number: G-5500DC
- Rotator Turning Power: 428 in.-lbs.
- Azimuth Rotation: 0°- 450°
- Elevation Rotation: 0°- 180°
- Console Input Voltage: 120 Vac
- Accuracy” +/- 4%
- Vertical Load: 200 kg
- Weight: 20 lbs
- Height/Width: 13.75”/10”
- Lifespan: 3+ years

Boom

- Material: Aluminium
- Length/Diameter: 9’/1.5”
- Composed of three 3’x1.5” pieces

440 Yagi

- Model: 436CP16
- Frequency: 432 Mhz - 438 MHz
- Gain: 13 dB
- Feed Impedance: 50 ohm
- Feed type: Folded dipole
- Power handling: 1 kW
- Maximum Element: 13.75”

2M Yagi

- Model: 2MCP8A
- Frequency: 143 Mhz - 147 MHz
- Gain: 9.2 dB
- Feed Impedance: 50 ohm
- Feed type: “T” Match
- Power handling: 1.5 kW
- Maximum Element: 41.25”

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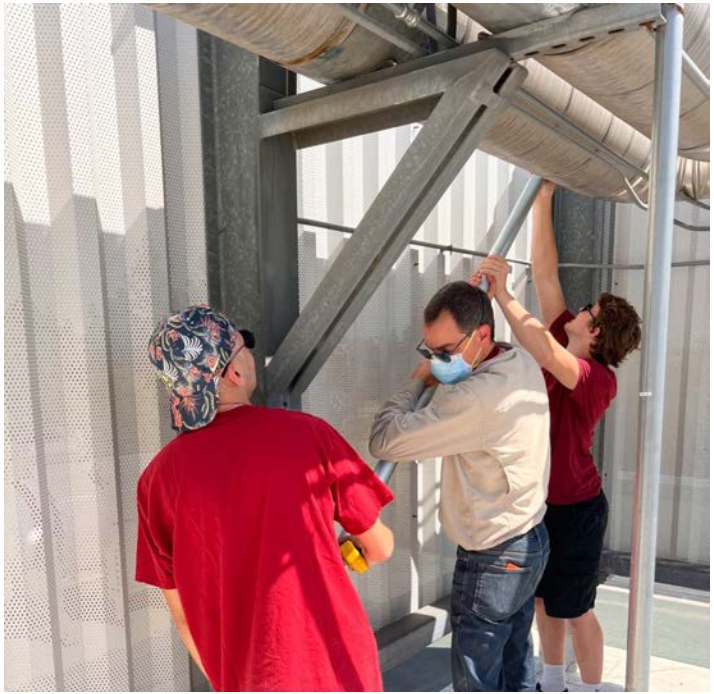
Design Choices



- Mount a non-permanent system on pre-existing rooftop structure

- Both Az/El rotators
- Vertical rotator setup

- Steel pole & zinc washer antenna counterweights secured with screws
- Maximum length CW pipe for less weight overall

- 440 Yagi to the left of the rotators, and 2M Yagi to the right
- Both at a 45° angle
- Re-mounting omnidirectional antenna

- Use MacDoppler for automated rotator control
- Use Raspberry Pis to receive satellite transmissions with FoxTelem and SatNOGS

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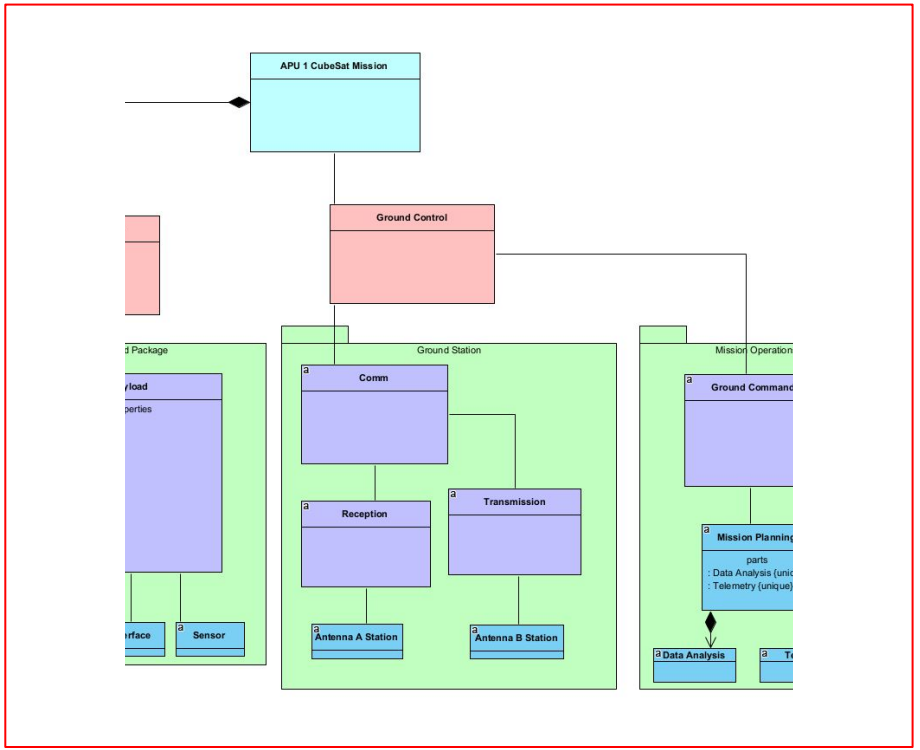
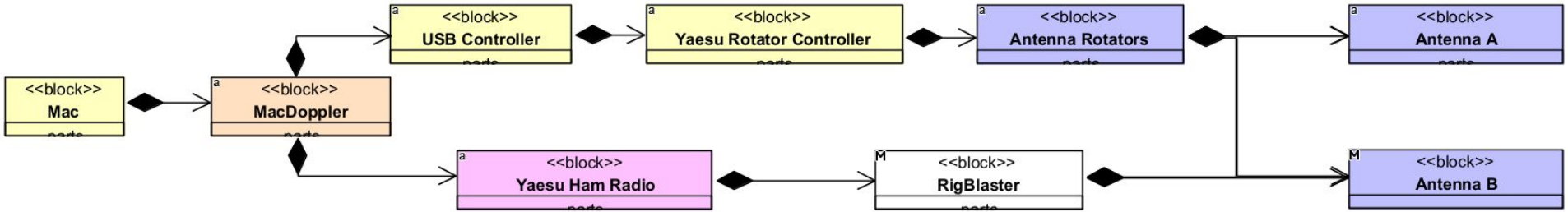
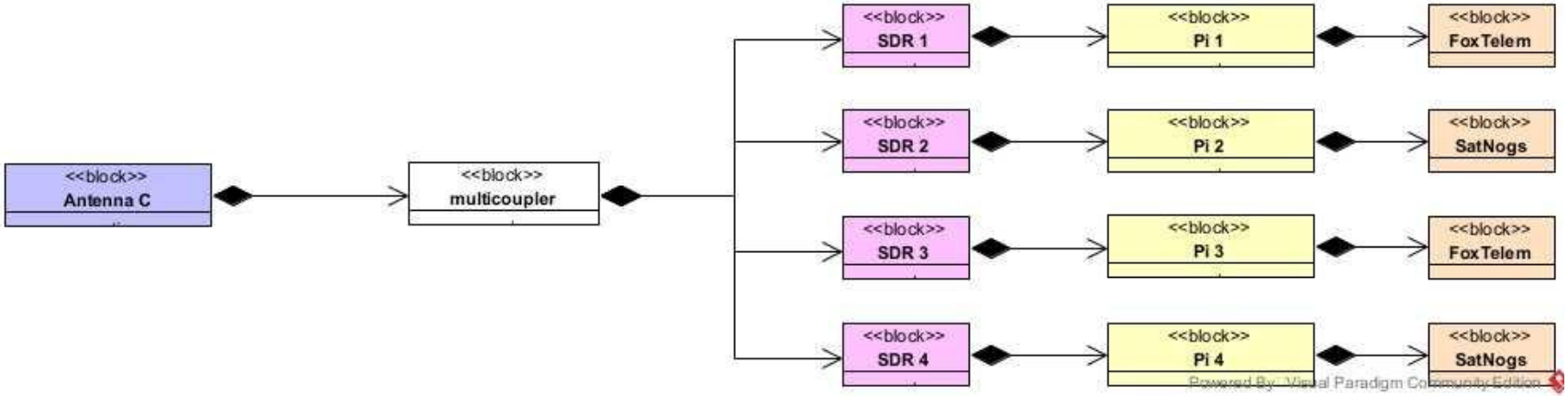
Block Diagrams



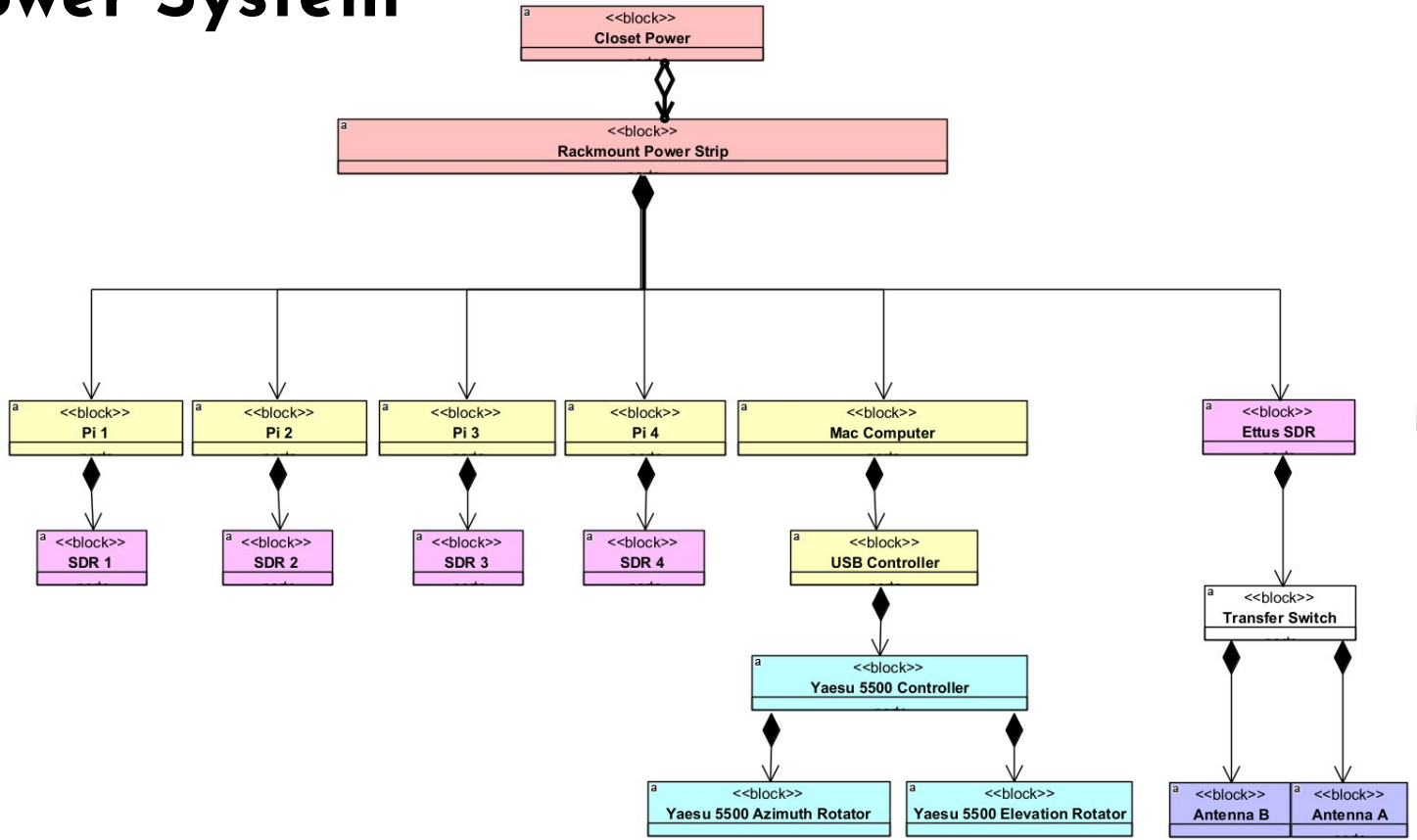
Directional(Transmission & Reception)



Omnidirectional (Reception)



Power System



07
Results/ Conclusion

Project Status

Satellite Tracking

Yaesu rotators in tandem with MacDoppler have successfully tracked AMSAT LEO CubeSats to +/- 1°

Lifespan

Estimates of critical hardware project a 5+ year lifespan with minor maintenance

Reception

Eggbeater has successfully received a signal via FoxTelem

Antenna Pointing

Rotator system is successfully able to orient towards a point to +/- 1°

Software

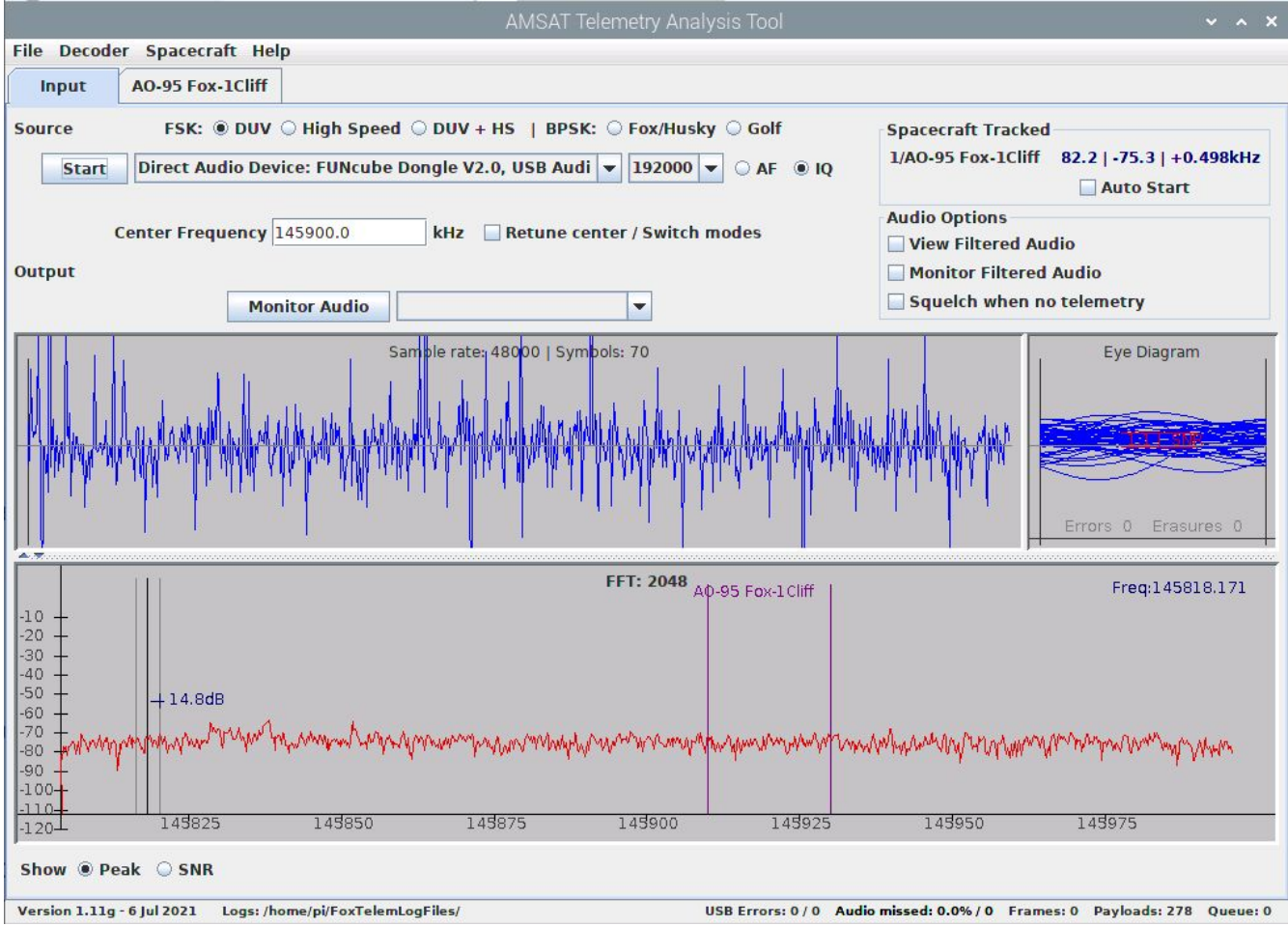
Foxtelem is capable of tracking and receiving while Satnogs has been implemented but requires testing

Transmission

Transmission testing will occur once Ettus radio arrives and is installed in existing infrastructure

Results

FoxTelem
Tracking
Fox-1Cliff
Satellite



Challenges

Pi Updates & Networking

Operating system mismatches required multiple reinstals of the operating system

Rotator Range

Software for the Yaesu rotator controller resulted in a limited elevation range

Purchasing

Purchasing permission issues caused delays amplified supply chain problems

Future Work

Switching borrowed Yaesu radio for the more versatile Ettus SDR

Installing a transfer switch between the 2M and 400 antennas

Performing additional testing to establish reception and transmission capabilities

Ensuring transmission antenna is properly set up

Determine and correct error with radio frequency

08
Acknowledgements

Acknowledgements

Dr. James Yeh

Team supervisor and consultant for project and budget requirements

Prof. JR Marshall

Team consultant overseeing technical and logistical project aspects

Neil from the U.K.

Troubleshooting correspondent for Yaesu elevation parameters

Lelani Bautista

Co-contributor in the design phase of the project

God

"Whoever abides in me and I in him, he it is that bears much fruit, for apart from me you can do nothing." (John 15:5 ESV)

Questions?

"Achievable & Challenging Goals: A fully functional receive ground station mounted on the roof of Segerstrom." (*Supras Stellas* Mission Statement 9/20/21)

Photos courtesy of members of Team *Supras Stellas*.
Diagrams developed using SysML's *Visual Paradigm*

Spectrum Analyzer

Rhode and Shwartz
FPC1000