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COLLEGE OF LIBERAL ARTS AND SCIENCE

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# O1 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

Retain Control in Tumble

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

**03** Transmitting

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

**02** Receiving

Capable of receiving FoxTelem and Satnogs telemetry data.

**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 2

Choice, Purchasing, & Order Fulfillment

Nov 24 - Dec 17 Dec 17 Phase 4

**Testing** 

Mar 16 - Apr 19

Apr 26

Phase 1

Simulation and Design

Oct. 16 - Nov 23 Nov 23 Phase 3

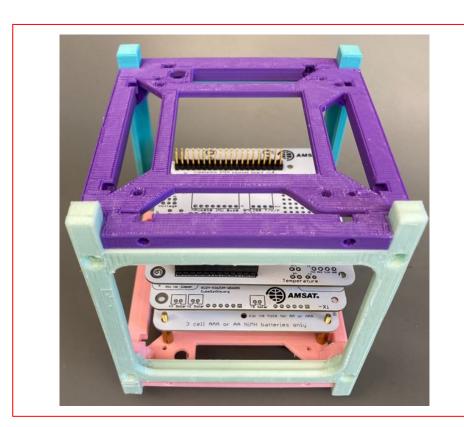
Building and Implementation

Jan 10 - Mar 15 Apr 24 Phase 5

Conclusion of Project,
Presentation

Apr 20 - May 4 Apr 28

## O2 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



## **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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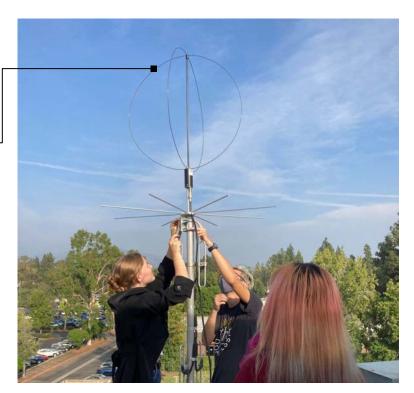
## Specifications



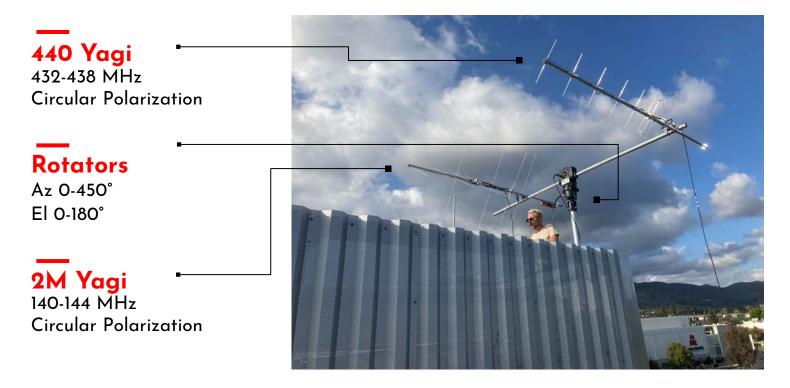
#### **Omnidirectional Antenna**

Eggbeater

140-144 MHz Circular Polarization



### **Directional Antennas**



#### **Mechanical Structure**

#### Mast

10' Galvanized Steel2" 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

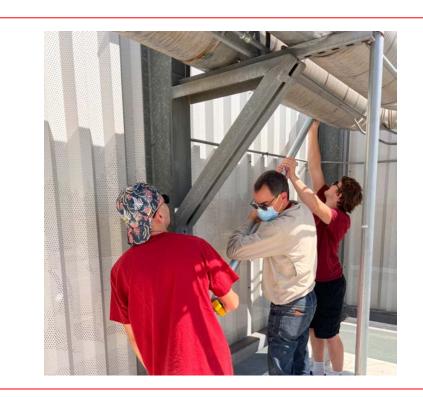
#### 440 Yagi

- 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"

# O5 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





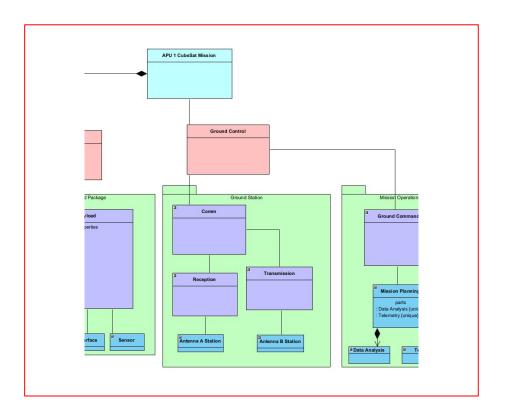
- 440 Yagi to the left of the rotators, and 2M Yagi to the right
- Both at a 45° angle
- Re-mounting omnidirectional antenna



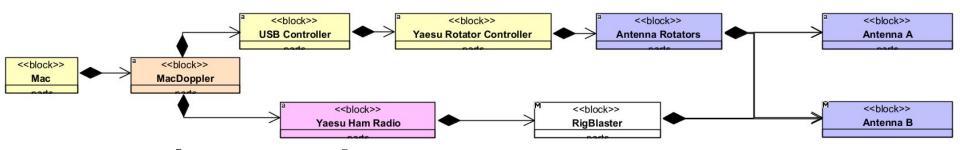


- Use MacDoppler for automated rotator control
- Use Raspberry Pis to receive satellite transmissions with FoxTelem and SatNOGS

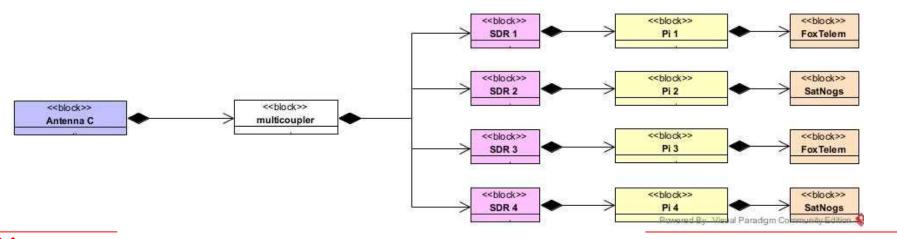
## 06 Block Diagrams

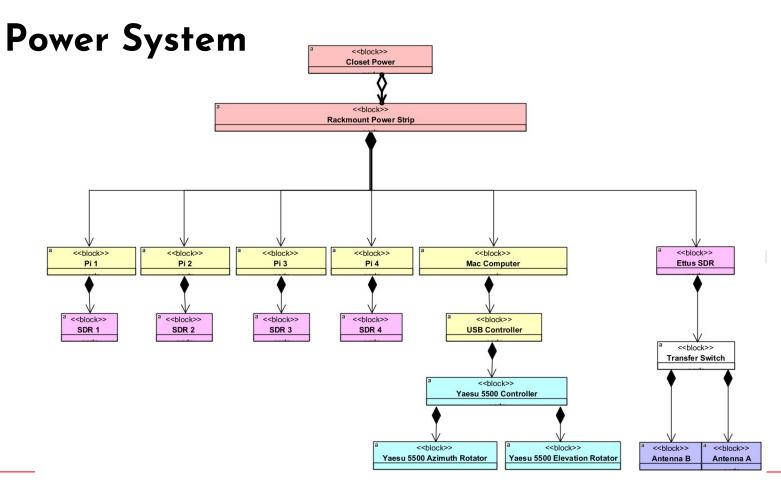


### Directional(Transmission & Reception)

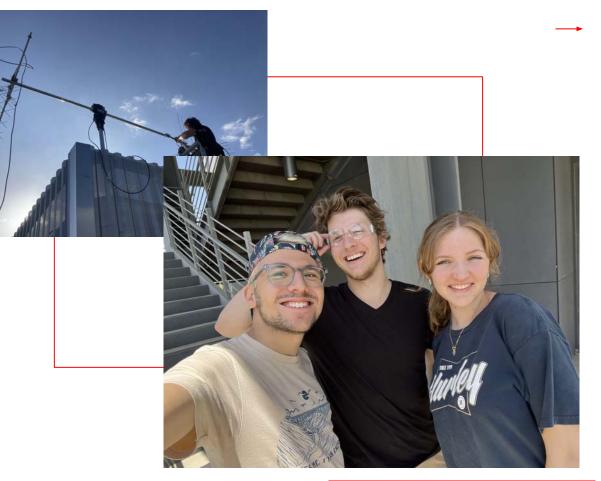


## **Omnidirectional (Reception)**





O7
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

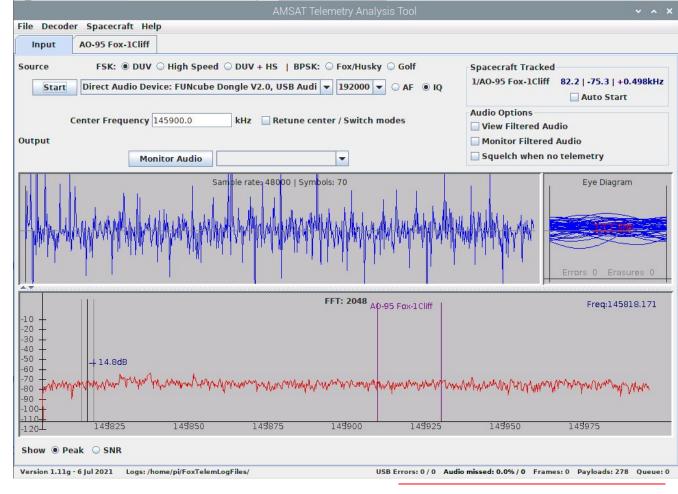
Foxtelem is capable of tracking and receiving while Satnogs has been implemented but requires testing

#### **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



## 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

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## Spectrum Analyzer

Rhode and Shwartz FPC1000