Critical Design Review (CDR)

February 10, 2024

SilverSat’s CubeSat and Mission Details

Success Criteria for the Review

- All Board design changes have been identified for the Flight Model
- Flight Software development is well underway and has been tested as part of the Prototype 2 test campaign
- Prototype testing demonstrates Level 1 requirements
- Mechanical fit check is complete and successful

Logistics

- Welcome to APL’s B201 Auditorium!
- Bathrooms are outside and to the right of the Auditorium double doors
- Food is in the back of the room, please help yourself
- Please silence your cell phones
- For the attendees on the Google Meet, please mute your microphone
- The CDR is scheduled to run from 2:30 - 5:30 PM, but there is a lot of material to cover. At ~3:30 PM, we will do a time check to see where we are at in the presentation

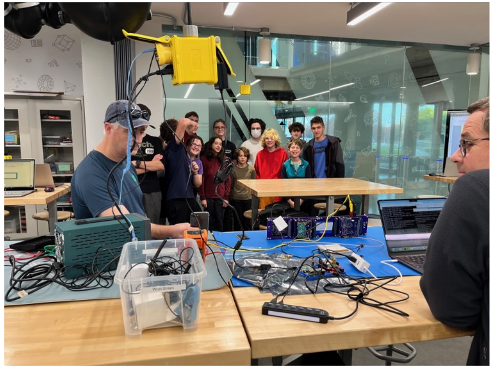
Overview of SilverSat Limited

- Multi-year community-based non-profit serving Silver Spring area tweens and teens
- Goals include STEM enrichment “to discover and expand knowledge”* and leadership development among tweens and teens, including those from underrepresented and underserved groups in STEM fields
- Diverse student participation -> different perspectives on the different challenges we face throughout this program
    - ~15 Students in grades 6-12 as well as in college
    - Mix of public, private, and home-schooled students
    - Greater Silver Spring area: DC, Maryland, and Virginia
    - Many different personal interests and aspirations

** NASA 2018 Strategic Plan, NASA Vision - p.6*

Outline

- Overview & Mission Concept
- Systems Engineering
- Critical Designs (Major Components)
  - Power, Avionics, Radio, Payload, Mechanical, Ground
- Prototype 2 Results
- Flight Model (FM) Integration and Test Flow
- Programmatics
- Conclusion/Outbrief



SiLVER SAT

Mission Concept

SilverSat is a CubeSat that…

Takes photos of Earth during its orbit and, when in contact with a ground station, logs into X (formerly Twitter) and posts its photos and mission data as posts (formerly Tweets).

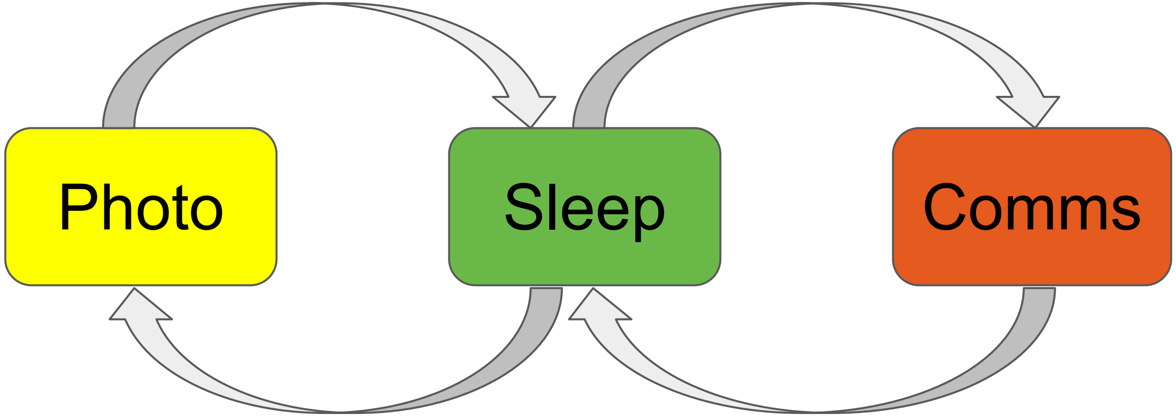
Updates Since the Preliminary Design Review (PDR)

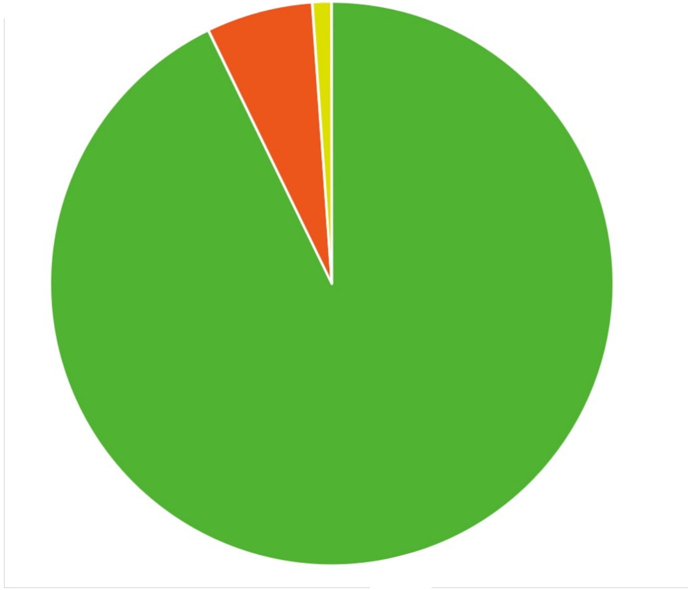
- Completed designs of printed circuit boards (PCBs)
- Finished Prototype 2 testing
- Began ordering and receiving Boards and parts for the Flight Model
- Implemented, tested, and integrated the Payload, Avionics, and Radio Boards Software
- Established and prototyped the Ground Station
- Found a new location for building the CubeSat
- Established alternatives to X (formerly Twitter)

PDR Action Items

Action	Status	Notes
Come up with ideas of how we could use our extra mass margin.	Closed	Team conducted trade study, decided to pursue a backup battery. Ultimately did not incorporate due to heater power.
Find out what other CubeSat missions have used the uCAM camera from 4D Systems. Ask them how well the camera performed, if they had any issues, and what did they do about direct sun illumination.	Closed	Identified five other missions that have used this camera. No additional information on how they avoided direct sunlight. Payload Team met with Dr. Dan Moses for input, and conducted independent assessment of possible Sun damage.
Put together ideas for load shedding. What could our CubeSat do if it needed to turn off loads to save power? Does the EPS already have this function? Decide what if any design changes to make from these ideas.	Open	EPS will shut off bus supplies if Batteries fall below threshold. 5V and 3.3V can be powered down separately.
Try to determine soon what the ground station will be and test it with the AX5043.	Closed	Ground Station Radio is a copy of the CubeSat Radio with external PA, LNA, and switch. Prototype testing conducted with an AX5043 Prototype Board as the Ground Station.
Contact Dave Kubalak concerning ideas for 3-D printing the camera's lens housing, and about possible lens that are better suited for flight.	Closed	Payload Team contacted Dr. Kubalak after PDR.

Concept of Operations





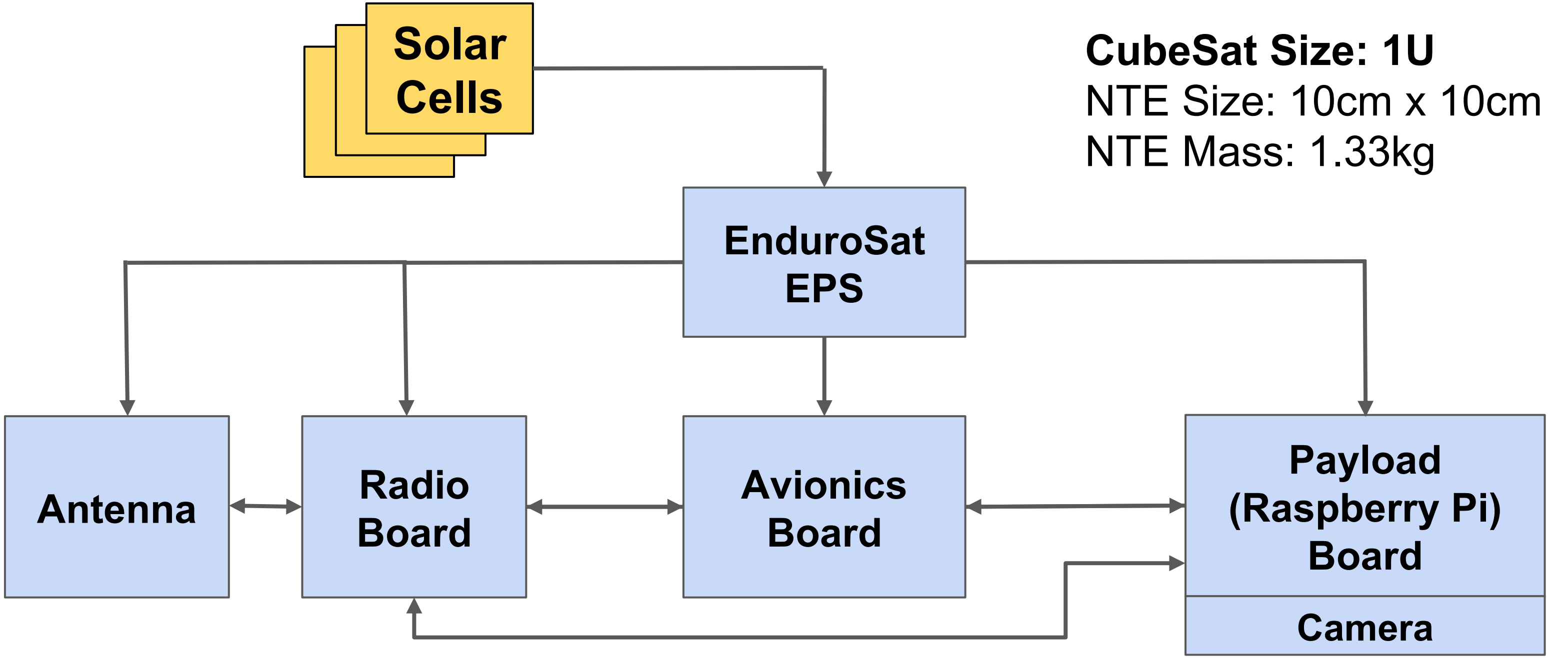
Total: 90 minutes
(1 Orbit)

Photo: Take pictures of the Earth from Space

Comms: Communication with Ground Station, automated tweet of photo, status

Sleep: Idle, conserve power, wake for photo or communication, beacon

CubeSat Block Diagram



CubeSat Size: 1U
NTE Size: 10cm x 10cm x 11cm
NTE Mass: 1.33kg

SiLVER SAT

Outline

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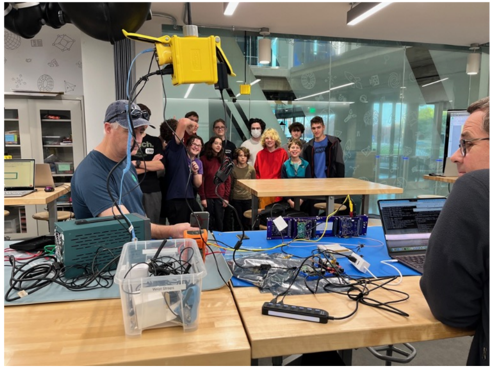


Level-2 Requirements

Take a picture of Earth

- Shall have a camera
- Shall point the camera towards Earth in the northern hemisphere
- Shall know when to take a picture
- Shall know whether it is stable/not spinning
- Shall know if it has enough Battery power to take a picture
- Shall implement file management

Level-2 Requirements cont.

Post photos and data to X (formerly Twitter)

- Shall know when it is able to connect with the Ground Station
- Shall tweet
- Shall be able to compile information and form it into a text tweet
- Shall be able to create a tweet with a photo taken from the file system

Fly in Low Earth Orbit (LEO)

- Shall be launched into LEO
- Shall conduct the mission from LEO
- Shall be able to track the orbit of the CubeSat
- Shall be able to know where the CubeSat is at all times

Level-2 Requirements cont.

Meet CubeSat Design Specification Requirements:

- Shall conform to the CubeSat Design Specification
- Shall conform to the Nanoracks Flight Acceptance Test Requirements for Lithium-ion Cells and Battery Packs
- Shall conform to the Nanoracks CubeSat Deployer (NRCSD) Interface Definition Document (IDD)

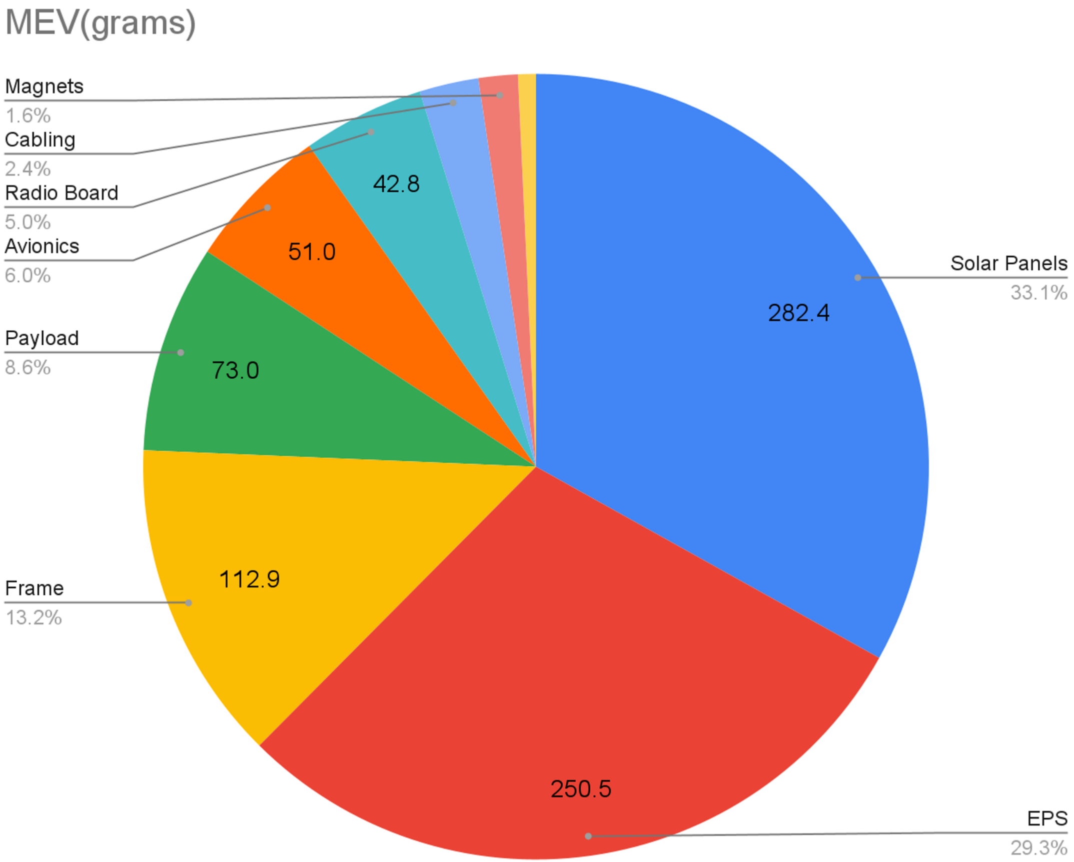
Mass Budget

Total CBE: 823 g

Total MEV: 853 g

NTE Mass: 1.3 kg

Average Contingency: 4.6%



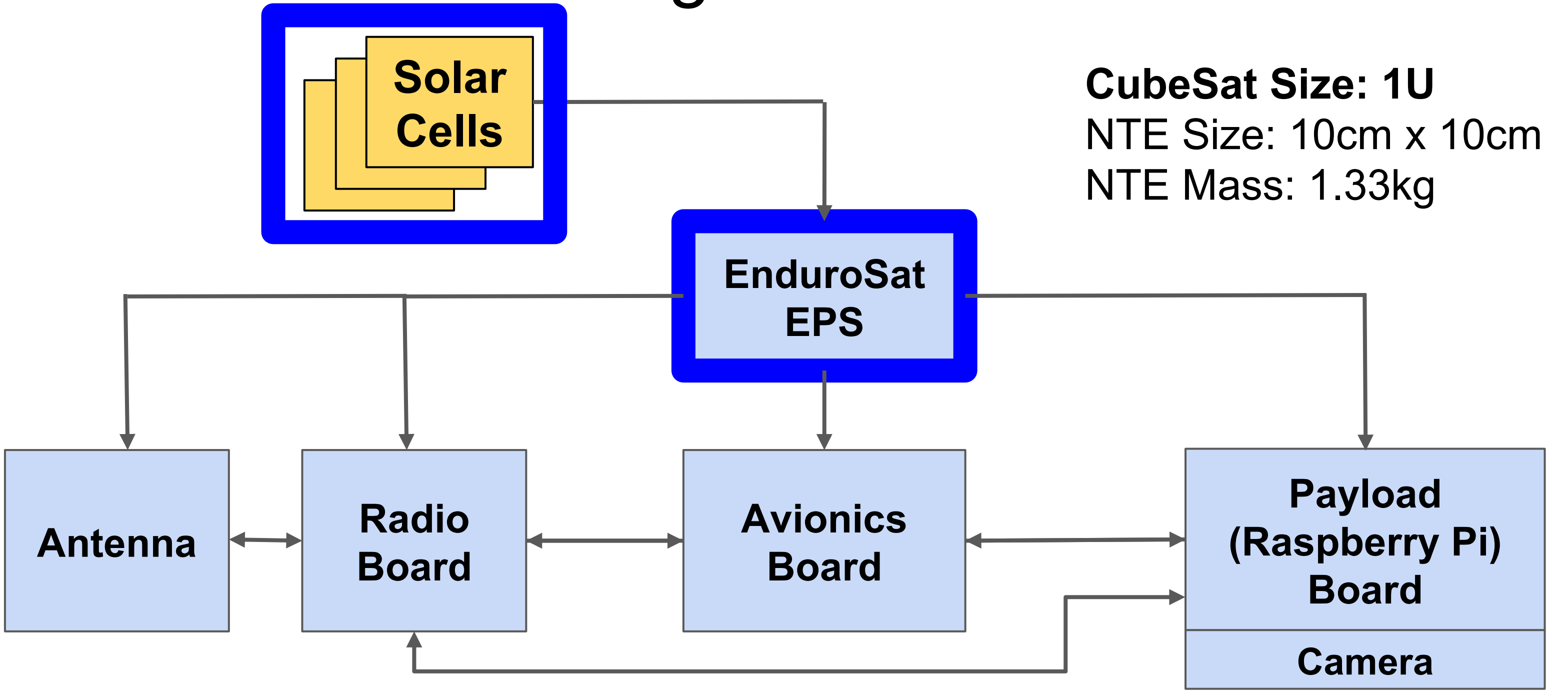
Mass Budget

We have a comfortable margin of 446g or over 50%. The heaviest components (solar panels) have had their final mass measured.

Components	CBE (g)	Contingency	MEV (g)	BOE
Frame	107.5	5%	112.9	Measured - Engineering Model
EPS	238.5	5%	250.5	Measured - Engineering Model
Radio Board	40.8	5%	42.8	Measured - Engineering Model
Payload Board	69.5	5%	73.0	Measured - Engineering Model
Avionics Board	48.6	5%	51.0	Measured - Engineering Model
Solar Array PCM10A2-R11102201	43.0	0%	43.0	Measured - Flightware
Solar Array PCM10A1-R11102212	43.3	0%	43.3	Measured - Flightware
Solar Array PCM10A1-R11102211	44.1	0%	44.1	Measured - Flightware
Solar Array PCM10A1-R11102213	43.4	0%	43.4	Measured - Flightware
Solar Array & Antenna	108.6	0%	108.6	Measured - Flightware
Coax	6.0	5%	6.3	Data Sheet
Magnets	12.0	15%	13.8	Estimation
Cabling	18.0	15%	20.7	Estimation
Total weight:	823.3	4.6%	853.4	Measured: 85%

Power Board

CubeSat Block Diagram



CubeSat Size: 1U
NTE Size: 10cm x 10cm x 11cm
NTE Mass: 1.33kg

Driving (Derived) Requirements

- The Board shall use five solar panels to charge the Batteries during the mission.
- The Board shall provide the correct voltage power to the Avionics Board.
- The Board shall provide the correct voltage power to the Payload and be able to switch the latter on and off.
- The Board shall provide the correct voltage power to the Radio System.
- The Board shall be able to give diagnostic reports to the Avionics Board.
- The Board shall have a reasonable difference between the amount of power generated by board as compared to the usage of the satellite over a cycle.
- The EPS Battery shall be compliant with Nanoracks requirements for ISS launch.

Final Design

- The EPS design was halted after consultation with Nanoracks over concerns about Li Ion Battery qualification, and suggested we use a qualified EPS.
- We selected the EnduroSat EPS based on lowest overall cost that met or exceeded requirements. Other EPSes considered were GomSpace and Clyde Space.
- This EPS has been successfully flown and Nanoracks was familiar with the product and the product was qualified for ISS launch.

EnduroSat EPS Board Overview

Key Features

- Includes Li Ion Batteries and Battery Heaters, Stores up to 10.2 Watt Hours
- Draws current through three independent maximum power point trackers, from diode or'd pairs of solar cell sides.
- Outputs at 5 V and 3.3 V with additional and latch up protected outputs (LUP) tripping at 2 Amps
- Acceptable input voltage range from solar cells (up to 5.5 V)
- Battery voltage typical 3.7 V
- All outputs short circuit protected
- I2C interface

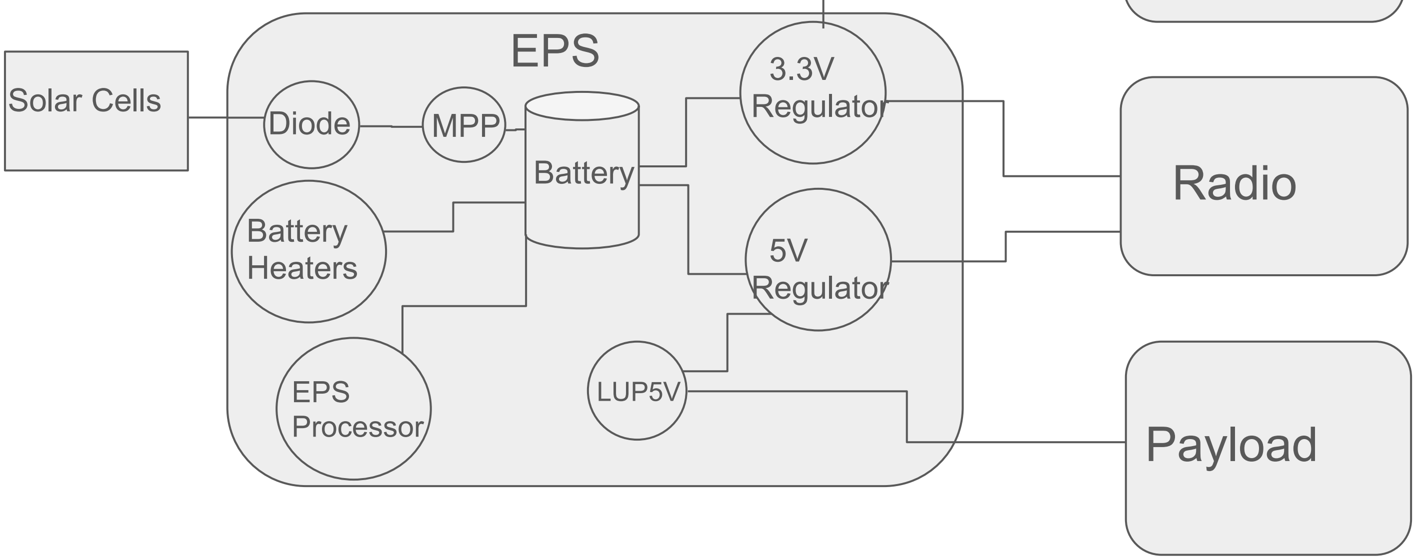
EnduroSat Customized the EPS in These Ways…

- Our design requires the EPS to be in the center of the stack. EnduroSat modified the housing and H1/H2 pins to provide a stacking connector.
- EnduroSat's base design does not include Battery inhibits
  - They add roller switches, which are hard-wired internally (no connectors)
- EnduroSat altered the H1/H2 pinout, adding outputs to pins which were unconnected on earlier designs
  - Caused a conflict with our pin assignment
  - Made modifications to the prototypes to verify the changes
  - The H1/H2 definition will be revised on the flight board designs

Power Budget Model

Each circle represents an energy sink

The EPS has multiple internal energy sinks

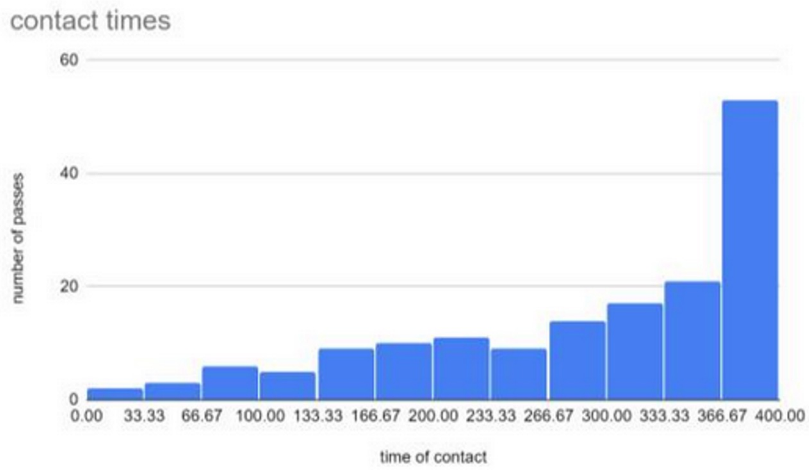


The **margin** is the difference between the Input Energy (square) and the sum of the energy sinks (circles)

Power Budget Assumptions

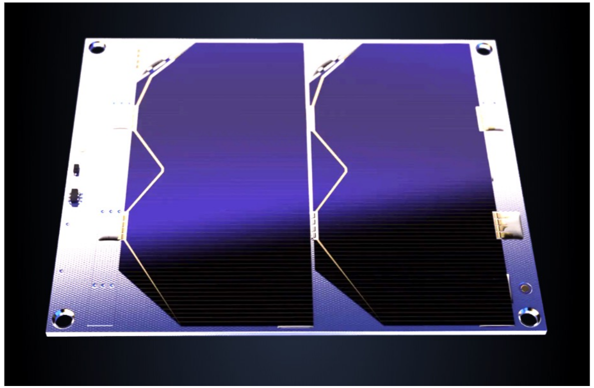
- Solar panels on only 5 of 6 sides.
- We will not attempt a tweet unless a pass is greater than 300 seconds (5 minutes). See graph to right.
- Avionics will shut down an active tweet if it takes longer than 600 seconds.
- Baseline Assumption*: Input power contributed only from one side at a time
But analysis of all Cubesat solar cross-section at angles provides margin.
- Antenna can be switched off after it is deployed.
- No energy captured from Albedo or other IR radiation sources (Earth).
- Beacon time base is 100mS (time to transmit a dit).
- Beacon interval is 90 Seconds.

*This simplified assumption is very conservative and we believe we get more power



⅓ of contact times are roughly 400 seconds

Input Side Baseline Power Budget: Solar Cell Power



EnduroSat solar cell on 5 sides of the cube

Based on 1353 W/m² insolation,
power with one side illuminated broadside
(2-3 sides may be illuminated - total on next slide)

Endurosat panels			
area	60.36	cm^2	2 cells in series
each cell	30.18	cm^2	
efficiency(max)	29.5	%	4.8 V, 0.502 A mpp
Max power (based on efficiency)	2.41	**Watts**	using Solar (A14) only
Orbital average	1.22	**Watts**	3360 of 5520 sec. light per orbit

(1.22 W includes a ⅚ factor for one missing side)

Power Budget Includes Evaluation of Total Sun the Cubesat Receives at Various Orientations

- The amount of sun received depends on the angle of the Cubesat.
  - **Note that the camera side does not have a solar cell.**
- One, two, or three sides may be illuminated at any given time.
- Total intercepted sunlight by a cube equivalent to that of a cross section of a sphere of equal surface area.

$6s^2 = 4\pi r^2$ — equating sphere and cube area

$r^2 = 3s^2/(2\pi)$ — finding r^2 of sphere

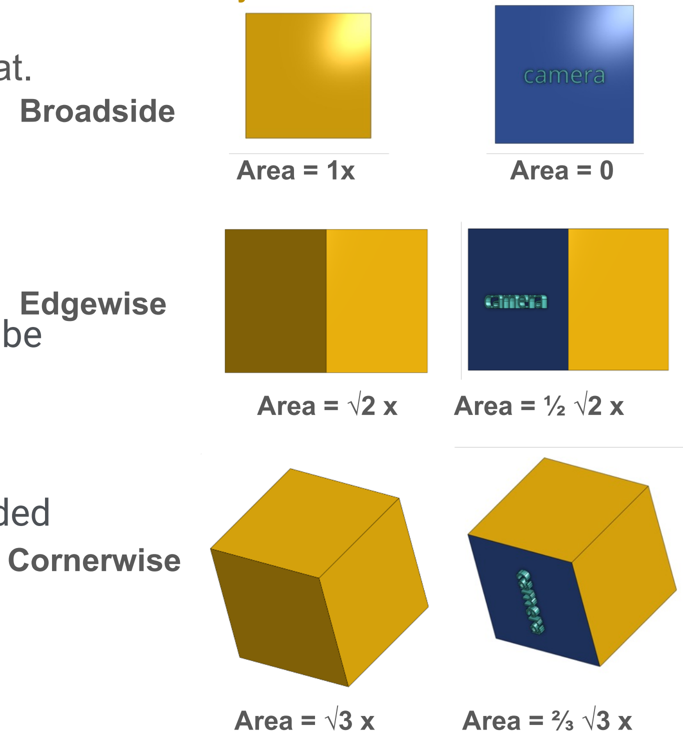
$\pi r^2 = \pi * (3s^2/(2\pi)) = 1.5s^2$ — cross section of sphere

$A = (5/6)*1.5s^2 = 1.25s^2$ — average solar cross section of 5 sided cube

Average sun exposure of randomly oriented 5 sided cube is 25% higher than broadside illumination of one side.

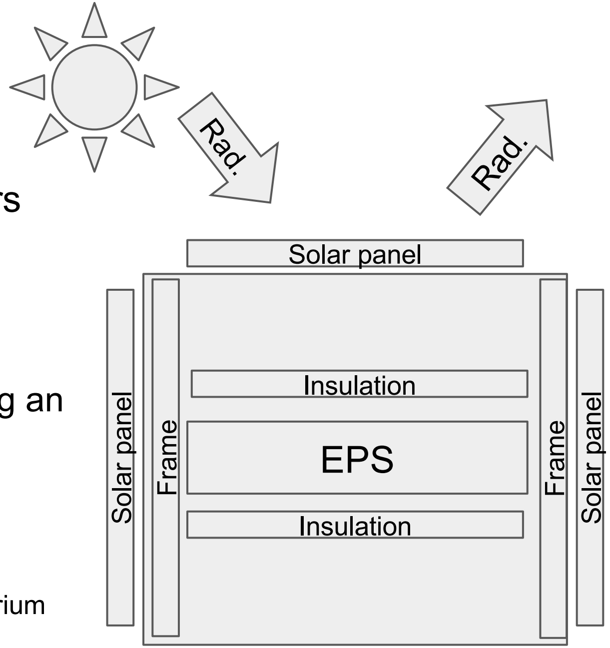
Six cases and useful illuminated area fraction

Only Solar Cell sides | **With Camera side**



Available Orbital Averaged Power and Energy				
Calcualated as 5/6 of one side (old baseline)	1.22	Watts	6746	Joules
Calculated across rotation of 5 sided cube	1.83	Watts	10119	Joules

Battery Heaters



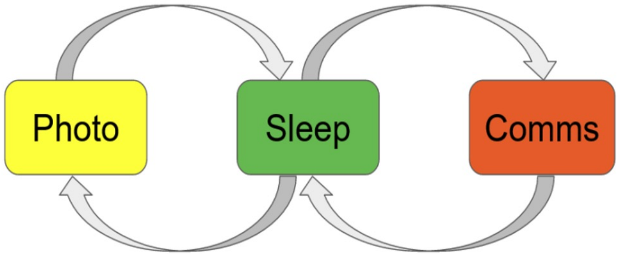
- Heater energy was identified as a risk
- We need to estimate the energy needed to run the Battery Heaters
  - Final results are pending a full thermal model of the Satellite
- Heater energy estimate uses a simplified thermal model for the Satellite and EPS
  - We want the Batteries to be at or above 0 C
  - We have to supply the equivalent amount of energy is lost during an orbit
  - Assume there's an insulation layer around the EPS
    - 5mm thick layer of cryogel insulation, top/bottom
    - EPS is thermally isolated from frame
    - Assume conduction from EPS top/bottom to outside through insulation
    - Outside temp of Satellite varies between -88 C and +35C (based on equilibrium temps)
    - No assumption of Battery to case conduction (i.e. Tcase=Tbattery)
- Net loss estimate is about 127 joules

$$\underbrace{A_1 \epsilon \sigma T^4}_{\text{THERMAL EMISSION}} = \underbrace{A_2 \alpha F_s}_{\text{SOLAR RADIATION}} + \underbrace{A_3 \alpha \overset{\text{Earth visibility factor}}{f} F_s \overset{\text{Earth albedo}}{A_E}}_{\text{EARTHSHINE (VISIBLE)}} + \underbrace{A_3 \epsilon F_{E,IR}}_{\text{EARTHSHINE (IR)}} + \underbrace{Q_i}_{\text{INTERNAL FLUX}}$$

SiLVER SAT

Power Budget

- The budget is based on system states representing a day in the life of the Satellite
  - Beacon (beacons only)
  - Photo (photo w/ beacons)
  - Comms (tweet w/ beacons)



	"SLEEP"	"PHOTO"	"COMMS"
	Beacons Only	Photo w/Beacons	Tweet w/ Beacons
Number of beacons (per orbit)	61	61	57
Input Energy	10119	10119	10119
Input Diode	464	464	464
MPP Charger	965	965	965
Net input to battery	**8689**	**8689**	**8689**
Heaters	127	127	127
EPS	408	408	408
Payload	0	342	855
Radio (receive)	1156	1156	1156
Radio (beacons)	1392	1392	1301
Radio (tweet)	0	0	883
Avionics	847	847	847
Net out of battery	**3930**	**4272**	**5578**
watts(OAP)	0.712	0.774	1.010
Net Excess Energy	**4759**	**4417**	**3112**
MEV Net Excess Energy per Orbit	**3532**	**3121**	**1674**

Largest risk remains heaters

Next Steps

- Consider replacement of 3.3V regulation scheme for lower overhead current
- Complete measurements of required currents
- Verify time taken to tweet/take a photo*
- Revise H1/H2 definition pins

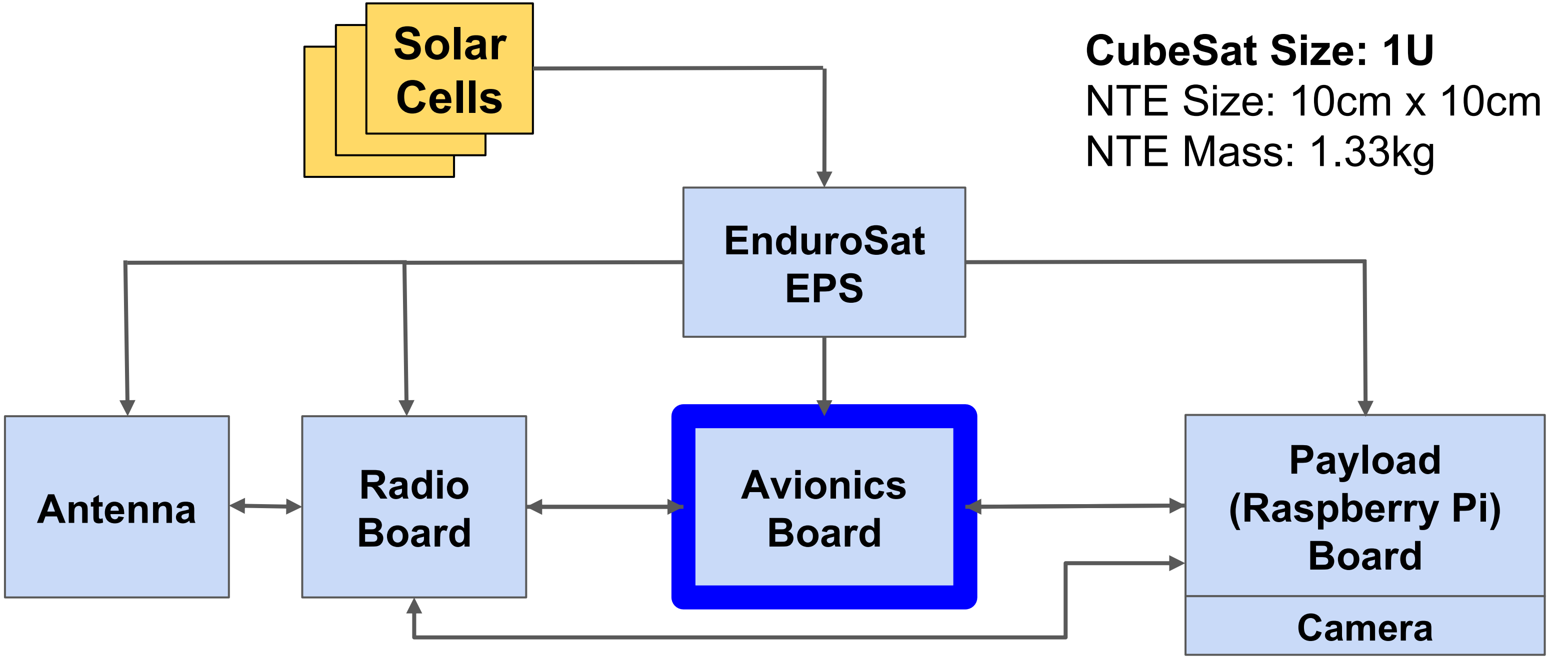
*Timeline affects how much energy is needed to tweet

Currently Working On? Going into Flight Model Build…

- The EnduroSat EPS 3.3V regulator is extremely inefficient at our current level
- Considering placing linear 3.3V regulators on Avionics and Radio Boards and regulate down from the raw Battery voltage

Avionics Board

CubeSat Block Diagram



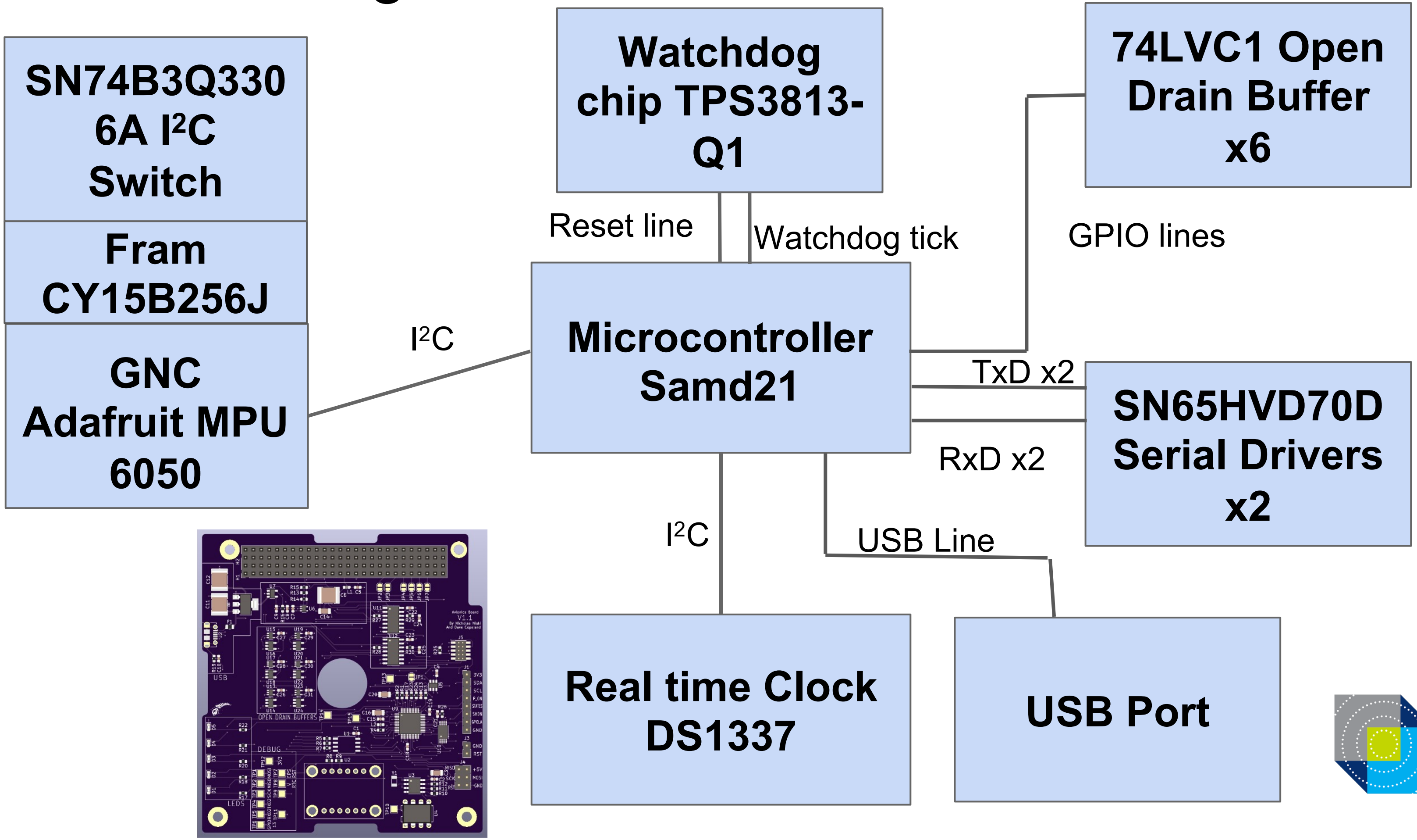
CubeSat Size: 1U
NTE Size: 10cm x 10cm x 11cm
NTE Mass: 1.33kg

Driving (Derived) Requirements

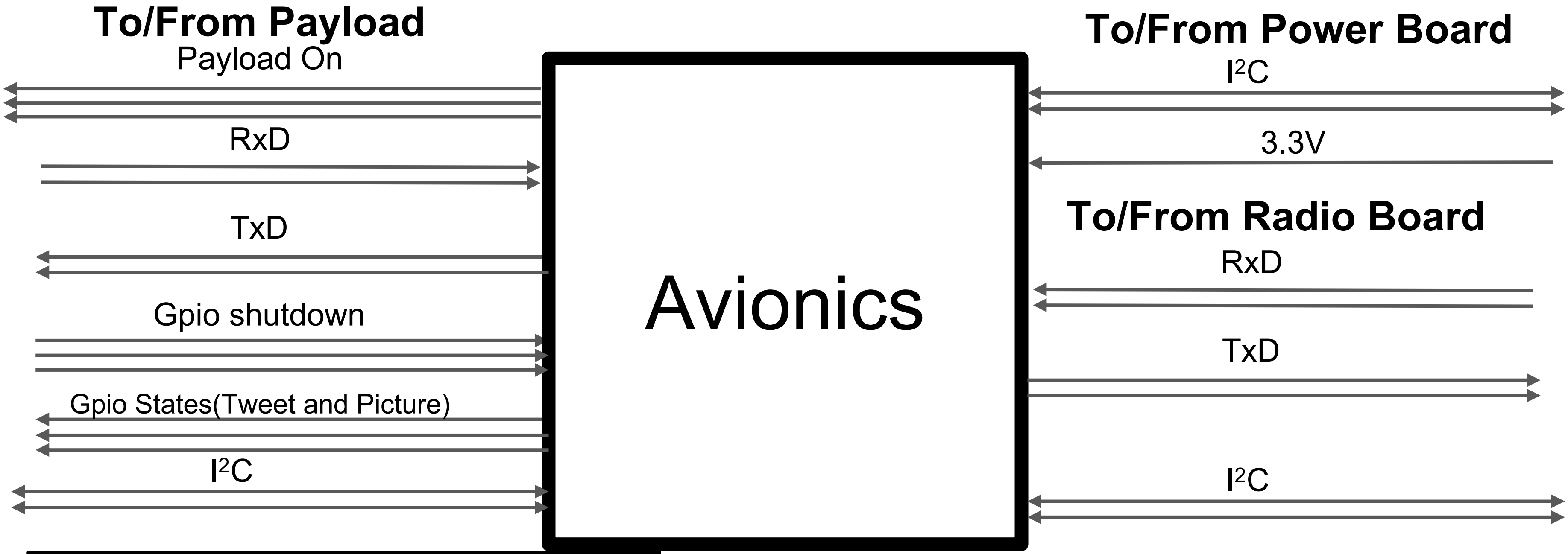
The Avionics Board shall…

- Keep track of time using a real time clock
- Formulate the beacon message
- Determine the time at which the CubeSat should transmit a beacon message
- Communicate the beacon message to the Radio Board at the time determined for beacon transmission
- Collect and process power measurements from the Power Board
- Generate the Power Board beacon character based on Power Board performance measurements
- Determine the Avionics beacon character pertaining to the Avionics Board state of health
- Receive and process uplink commands via the Radio Board
- Be in control of the power state of the Payload Board
- Be able to communicate what state the Payload Board shall be in when it beats what.
- Be able to acknowledge a received command
- Be able to check GPIO shutdown pin
- Protect itself from software bricks using the watchdog tick
- Give information on the status of the other boards
- Give telemetry information.

Avionics Diagram - Connections Inside the Board



Avionics Diagram - Connections to Other Boards

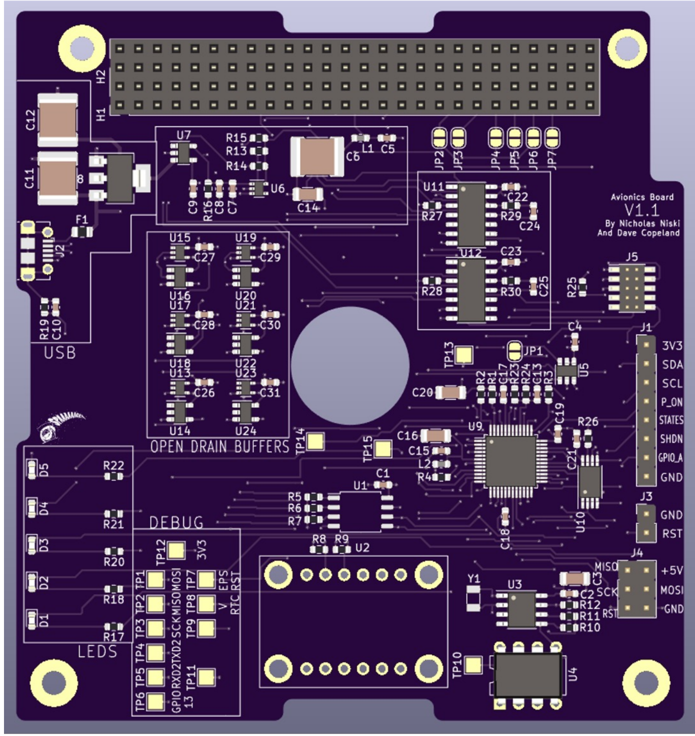


Payload On 0=on 1=off
Shutdown 1=shutdown possible 0=Pb on
States 1=tweet 0=photo

Final Design

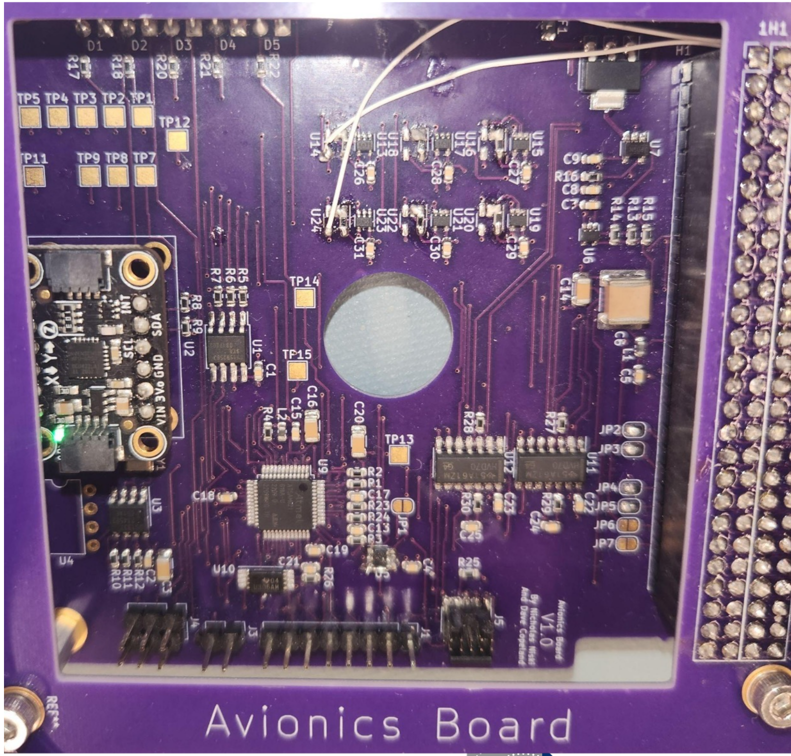
The Flight (V2.0) version of the Avionics Board will include

- Revised Hardware that complies with New EnduroSat Header Definition.
- New Graphics allows for easier identification of Regions on the Board and Other Headers and Test Points.
- Original THT LEDs replaced with New SMD LEDs.
- Pull Up Resistors added to Open-Drain Buffers.



Avionics Board V1.0

- The Avionics Board V1.0 was very successful, with no major hardware issues present.
- Minor issues did present, for example, the open drain drivers required pullup resistors to prevent Payload from accidentally starting up on boot.



SiLVER SAT

Code

- Made the first prototype codebase to test the software for different components
- Made the second prototype codebase that started to integrate the different parts of the codebase together
- Made the third prototype codebase which fully integrated the parts of the codebase
- Flight Model will get rid of unnecessary code that was used for testing and try to optimize the code as much as possible

Code cont.

- Codebase had a few main parts to it
    - Code for the different hardware components
        - Watchdog timer
        - Ds1337 real time clock
        - Antenna
        - FRAM
        - Communications with other CubeSat Boards
        - IMU to detect the orientation of the Satellite
    - Code for the different commands
    - Code for the beaconing
    - Code for determining photo time
    - Code for controlling Payload
    - Code for receiving commands from Radio

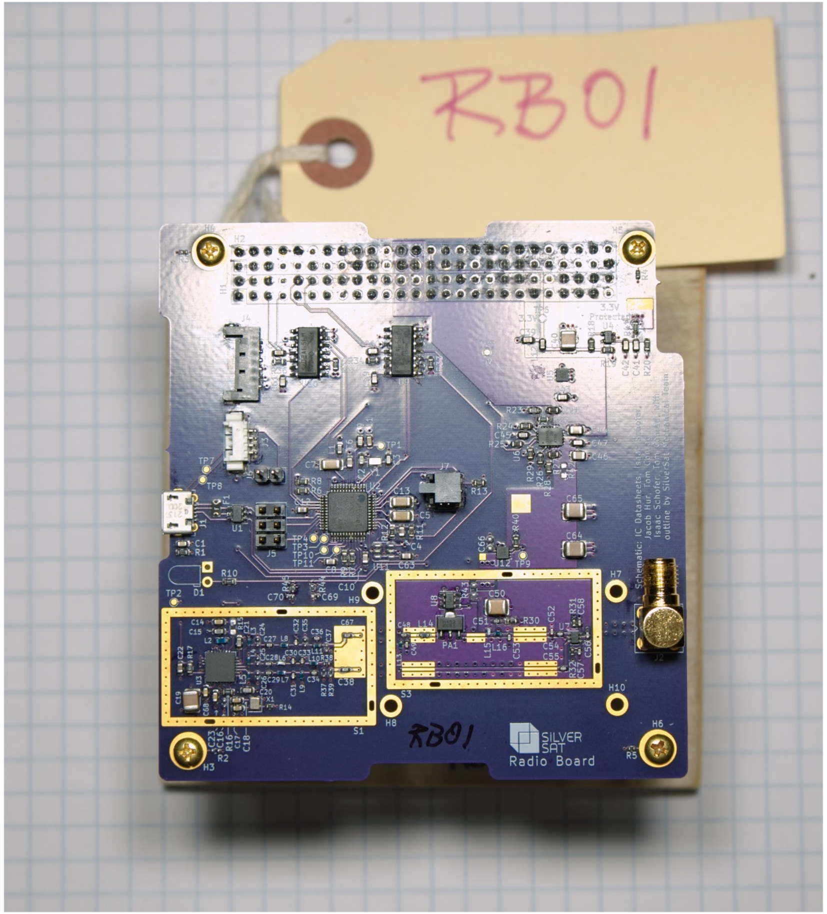
Prototype 2 Test Results

- Avionics Board header pin reassignment tested successfully (no collision issues)
- Open-Drain Buffers pull down resistors functioned as expected (Payload did NOT boot up on power on)

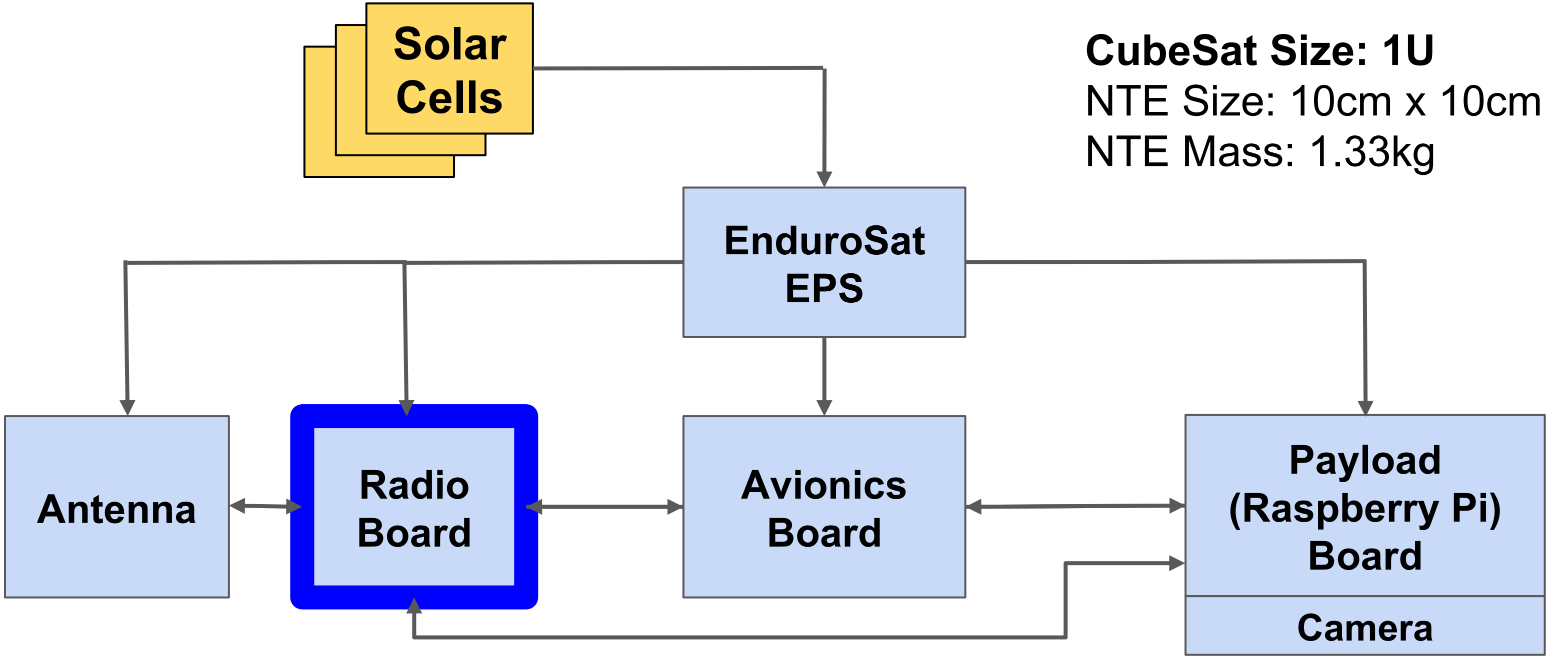
Currently Working On? Going into Flight Model Build…

- Fixing Issues: Header pin assignments changed in response to allow synergy with the EnduroSat EPS. Pull-up resistors connected to open-drain buffers to prevent Payload from booting on power on.
- Adding helpful graphics: Drawing boxes around different regions of the Board to help identify circuits and other test points and headers
- Replacing LEDs: Non-functioning THT LEDs replaced with SMD LEDs, and resistors replaced to obtain proper voltage drop

Radio Board



CubeSat Block Diagram



CubeSat Size: 1U
NTE Size: 10cm x 10cm x 11cm
NTE Mass: 1.33kg

Avionics and Payload UARTs pass through H1/H2.
The Antenna has a dedicated connector.

Driving (Derived) Requirements

<u>The Radio Board shall</u>…

- ✅ provide an Internet connection to and from ~~Avionics~~ Payload
- ✅ provide basic status for the beacon
- ✅ tx. beacon and rx beacon info from avionics every one and a half minutes, but no more than 10
- ✅ transmit a beacon using Morse code every one and a half minutes
- ✅ receive beacon information from Avionics
- ✅ receive signals from the ground
- ✅ transmit signals to the ground
- ~~transmit data using AX25.~~
- ✅ exchange data with the rest of the CubeSat using KISS
- ✅ send commands from the ground station to avionics.
- ✅ receive commands
- ✅ communicate with Avionics using the KISS protocol
- ✅ transmit at a frequency near 438 megahertz (operating range 400 to 520 MHz)
- ✅ receive signals at a frequency near 438 megahertz
- ❌ transmit with an output power of no less than 30 dBm (28 dBm measured)
- ✅ transmit signals with a standard data speed of no less than 9600 baud
- ✅ receive signals with a standard data speed of no less than 9600 baud
- exhibit a noise figure of no greater than 2 dB (✅ ground only)
- ✅ exhibit an implementation loss of no greater than 3 dB
- ✅ have a mass of no greater than 112.8 grams (40.77 g measured)
- ✅ consume no more than 2.574 watts while transmitting (2.37 watts measured)
- ❌ consume no more than 82.5 milliwatts while receiving (90 mW measured)
- ✅ receive data from the raspberry pi
- ✅ receive configuration commands
- ✅ be fast enough to carry a full TCP/IP connection, but still conserve power and bandwidth

SiLVER SAT

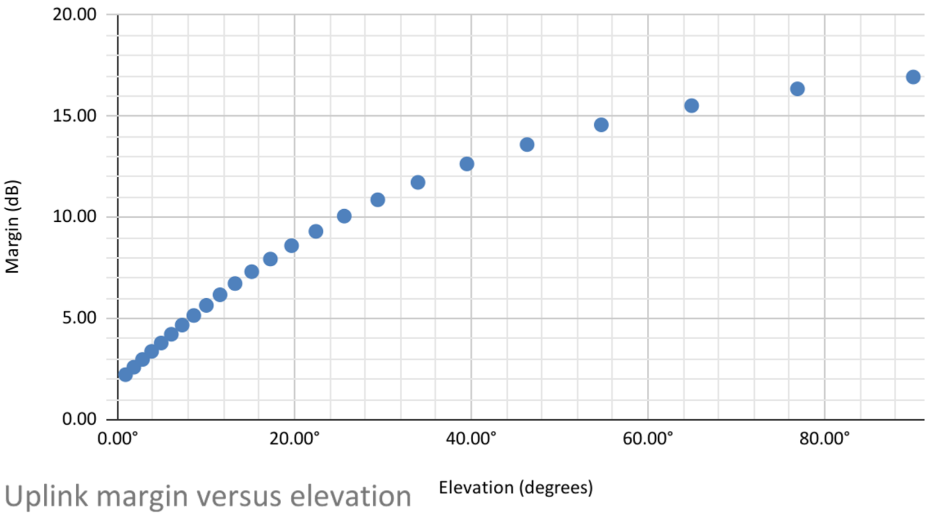
Link Budget

Downlink	
Transmitter Output Power (dBm)	28.00
Cable Losses (dB)	-0.50
Antenna Gain (dBi)	0.00
Output EIRP (dBm)	27.50
Receiver Power (dBm) at 1 570 km (12.09°)	-110.19
Margin (dB) at 1 570 km (8.97°)	**5.78**

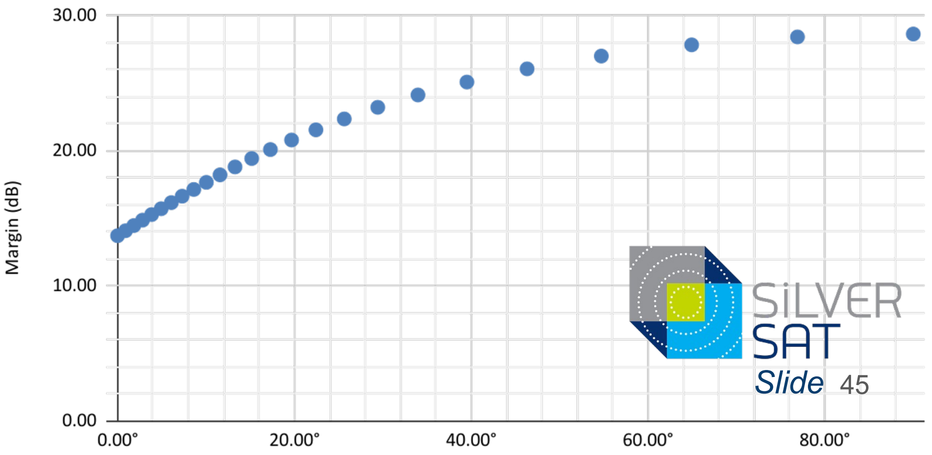
Uplink	
Transmitter Output Power (dBm)	40.00
Cable Losses (dB)	−1.00
Antenna Gain (dBi)	15.5
Output EIRP (dBm)	52.30
Receiver Power (dBm) at 1 570 km (12.09°)	−98.69
Margin (dB) at 1 570 km (8.97°)	17.28

Required BER = 10^{-7}

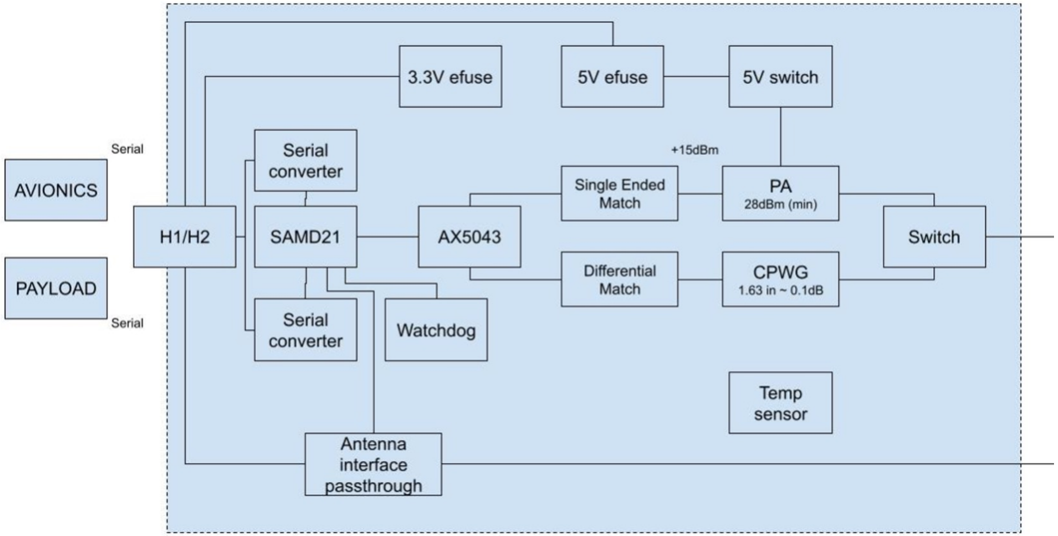
Downlink margin versus elevation

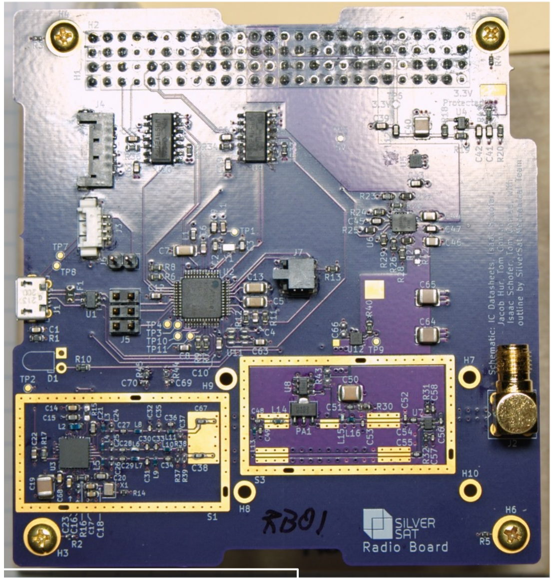


Uplink margin versus elevation



Reference: Satellite Radio Block Diagram with Detail





Proto had no major hardware issues.
Revisions for final will include:

- An attenuator was added to the receive path, but it should be on the transmit path
- Power amplifier was saturated

Bit Error Rate Testing

- The variable attenuator was adjusted to provide between -114 to -128 dBm

(LNA included in the second test)

0 dBm
Transmitter

50.7 dB

Shielded box

60 dB

0 to 30 dB

24 dB gain

DC block

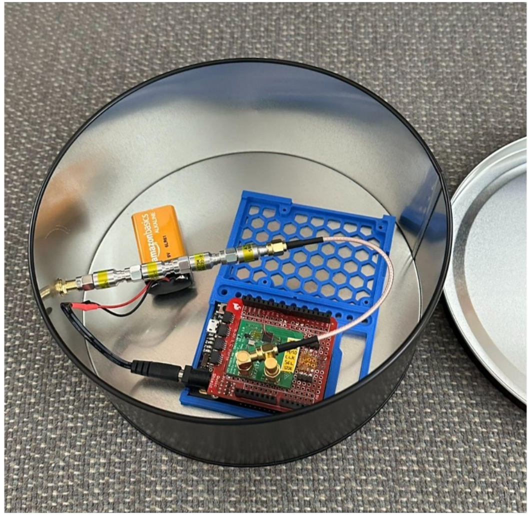
nooelec LNA

DC block

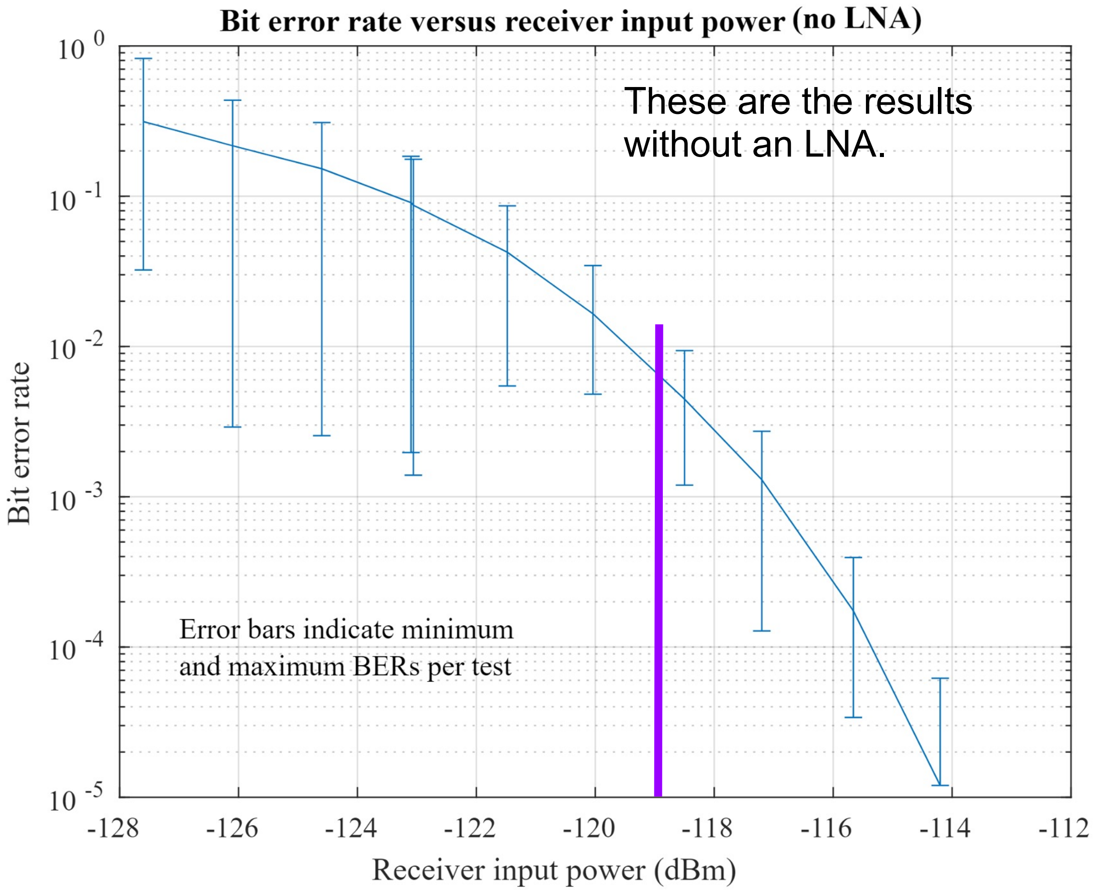
SilverSat Radio Board

Laptop

“Cookie tin shielded enclosure”



Bit Error Rate Testing cont.



But how well does our receiver perform?

Given a required Eb/No of 13.3dB @ 10^{-5} BER (Non-coherent FSK), and using the AX5043 receiver BW (14.4 KHz), the minimum detectable signal should be -119 dBm (0 dB NF).

Our measurements show a 5dB deviation, split between receiver front end noise and implementation losses.

Subsequent measurements with an external LNA showed an improvement between 4 to 5 dB.

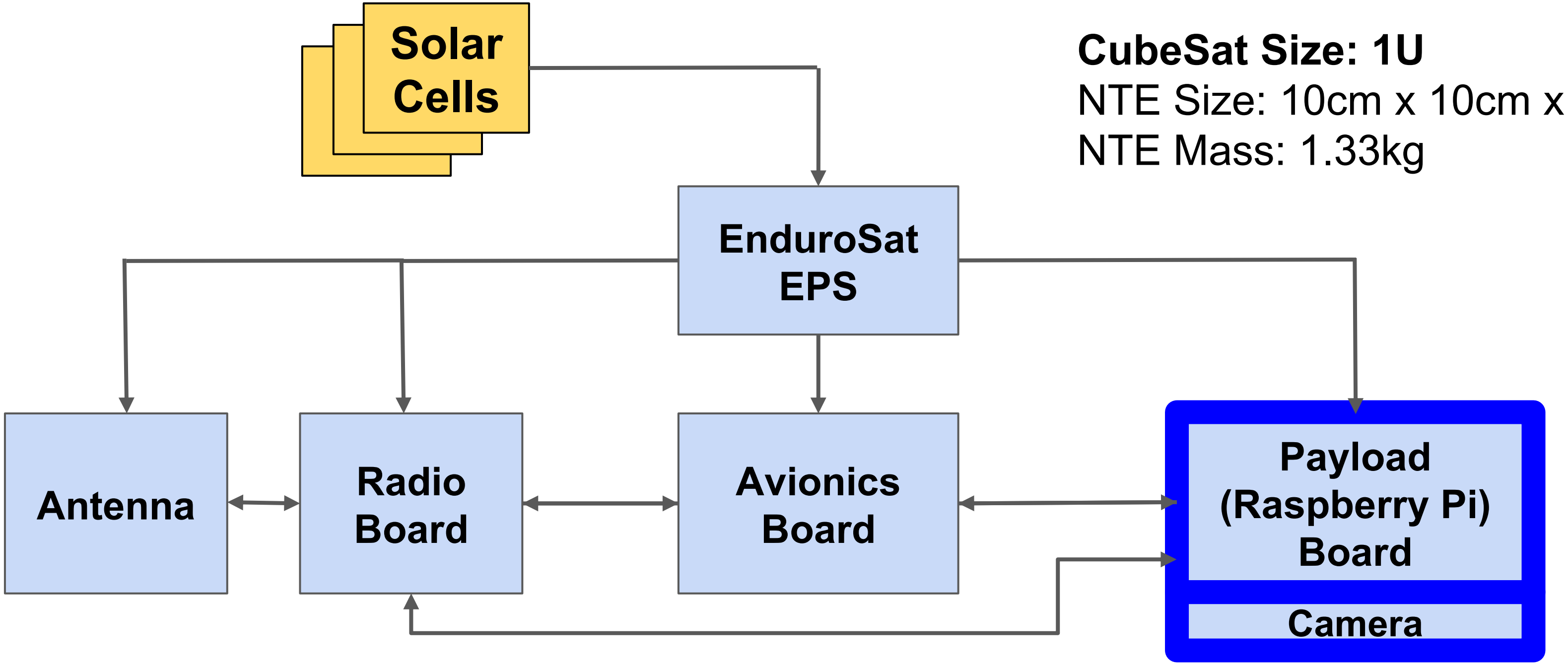
Things We Might Want to Add

- Improving Link Margin
  - We’re barely getting +28.5dBm right now (should be 30)
    - current PAE is roughly 28% (should be closer to 50), but haven’t played with tuning
  - Can improve to +32-34 dBm at cost of more DC power draw (at peak output)
    - 4dB improvement on downlink margin where we’re tightest
    - GRF5504 or HMC453 (drop in replacement)
  - If PAE numbers are to be believed, this would cost an additional 700 J per tweet
- Add an LNA
  - The decision is to include the LNA on the ground side, but probably not include the LNA on the satellite
  - This isn’t the link that is power limited and more likely to have strong in-band interferers, but there is room in the power budget
  - We would need to add/design a front-end filter
  - MAX2650, 0.7dB NF, 3.5mA typ @ 3.3V
  - Filter for LNA
  - SAW based filter, TA1808A, 440MHz, 20MHz BW, 2.4dB IL
  - Or design our own ;)
  - May want to have a filter regardless due to adjacent channel interference
  - Still need to do a proper survey once we have a frequency
- Secondary radio
  - Adds full duplex and redundancy
  - Needs another 435 to 438 MHz frequency; a request AMSAT may not grant
  - Potentially include an Iridium SBD module for AMSAT compliance, but that will require an additional Antenna

All items, except beacon characters, require approximately six months to implement. LNA and filter require frequency allocation before they can start.

Payload Board

CubeSat Block Diagram



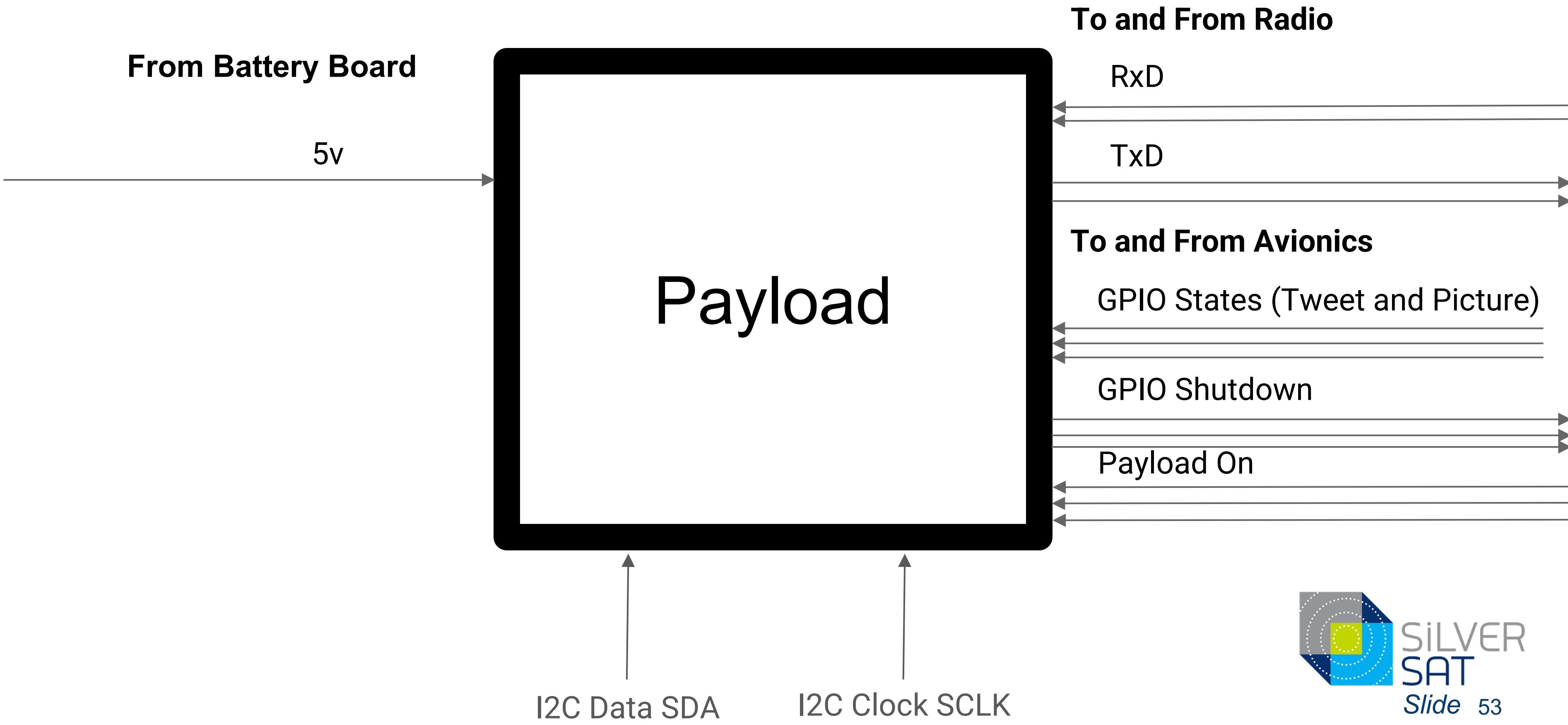
CubeSat Size: 1U
NTE Size: 10cm x 10cm x 11cm
NTE Mass: 1.33kg

Driving (Derived) Requirements

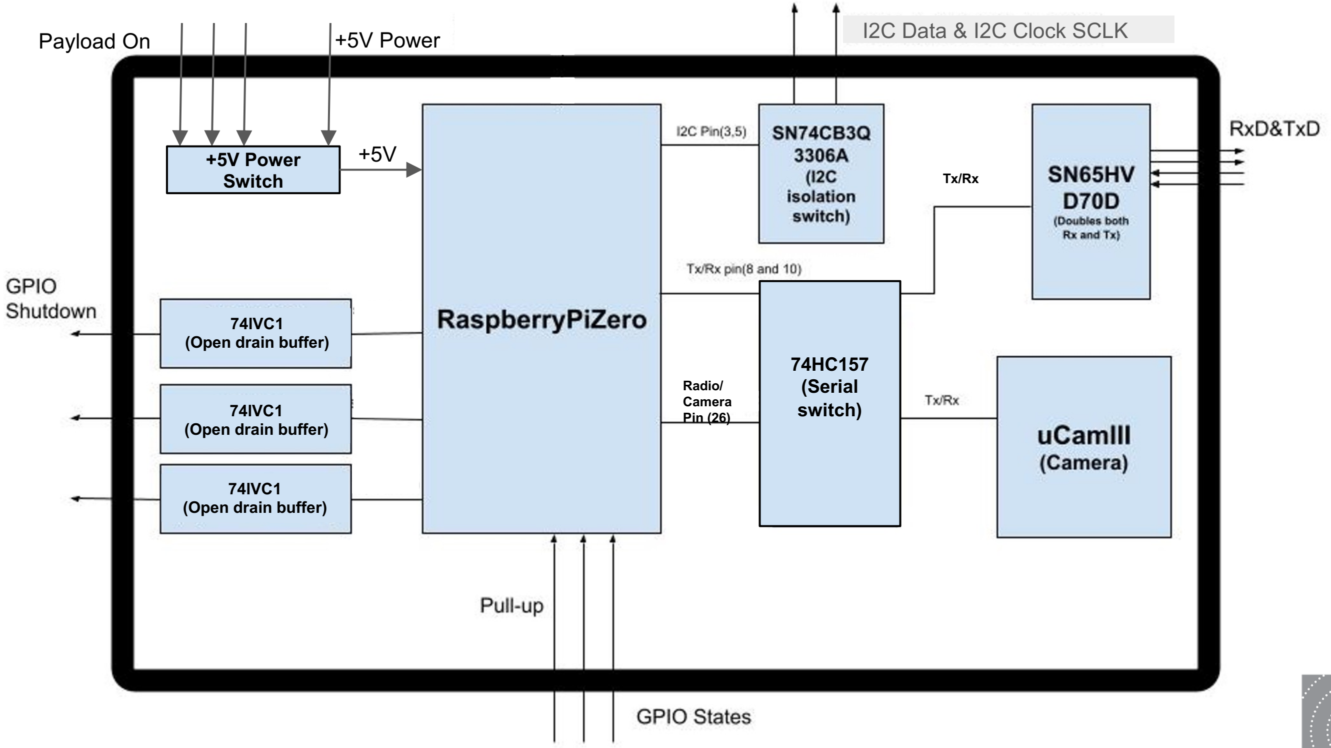
- Input/Output
  - Board Power switch (Input from Avionics, +5VLUP from Power)
  - Photo/Tweet (Input from Avionics)
  - Running/Shutdown (Output to Avionics)
  - Differential Serial (Input/Output Radio)
- Take Photo
  - Switch RPi Serial to Camera****
  - Use Camera to take photo
  - Save photo to filesystem
- Send Tweet
  - Switch RPi Serial to Radio****
  - Set up network, run startup scripts
  - Login to Twitter and tweet text or photo if present
  - Remove photo if successful

**** New since PDR

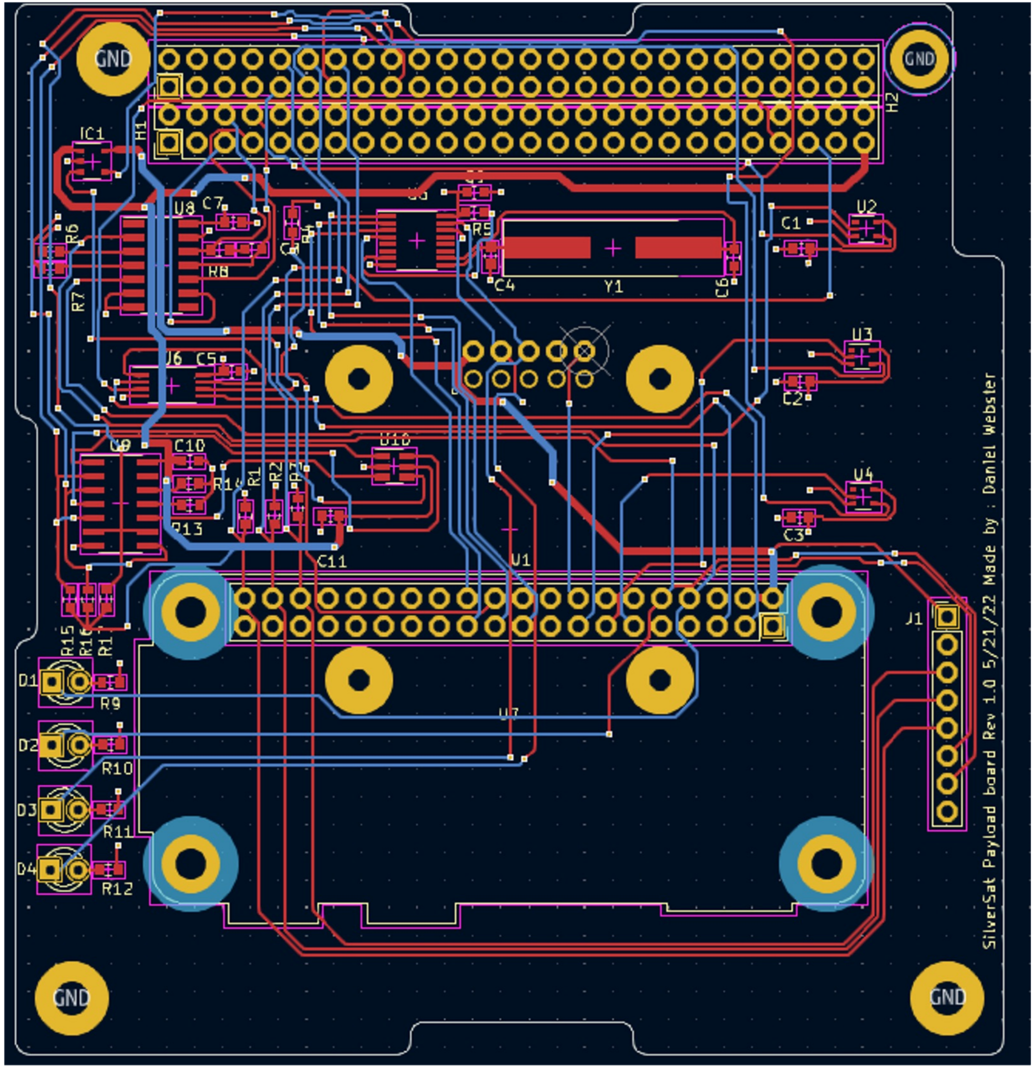
Payload Board - Connections



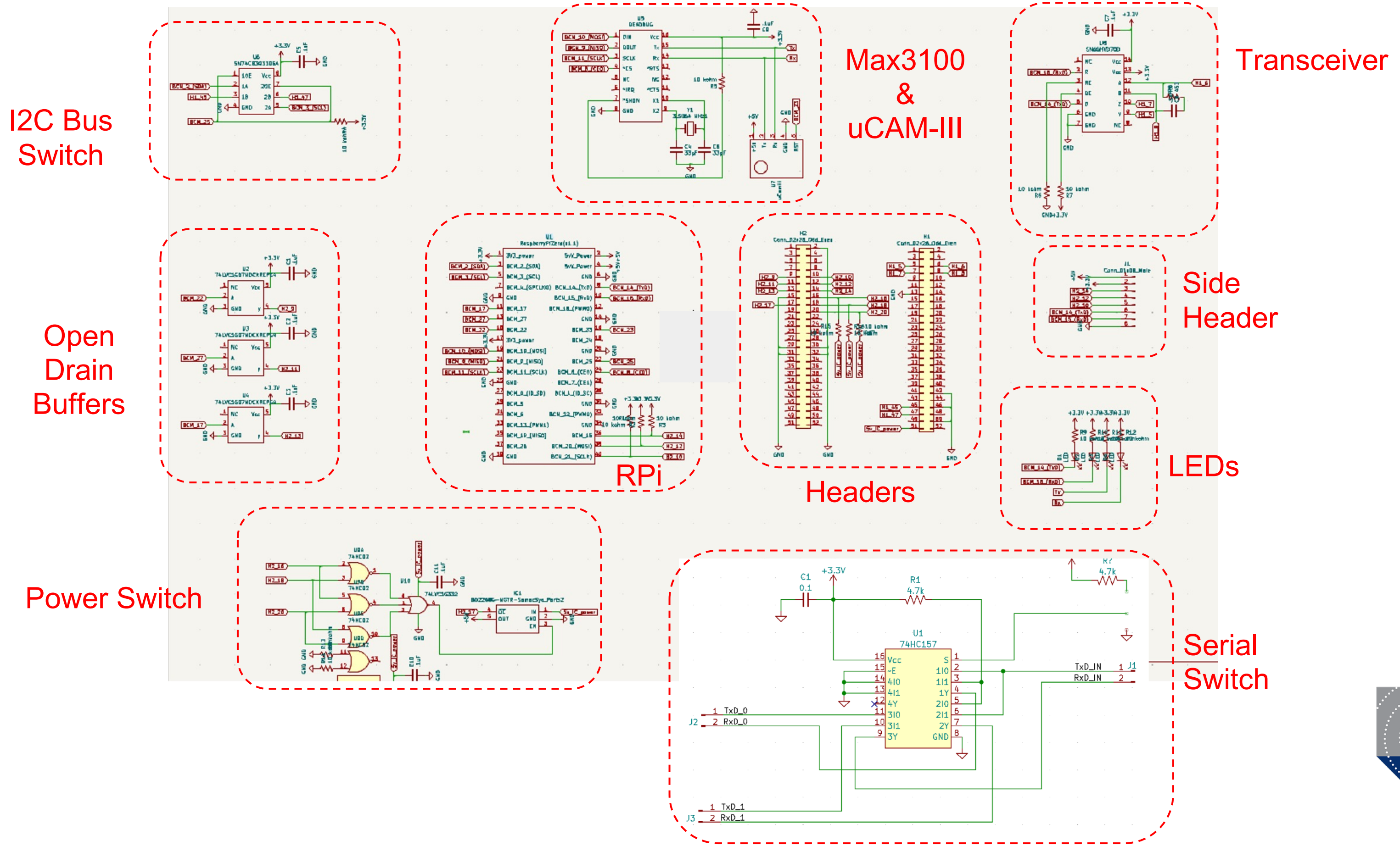
Payload Board - Block Diagram



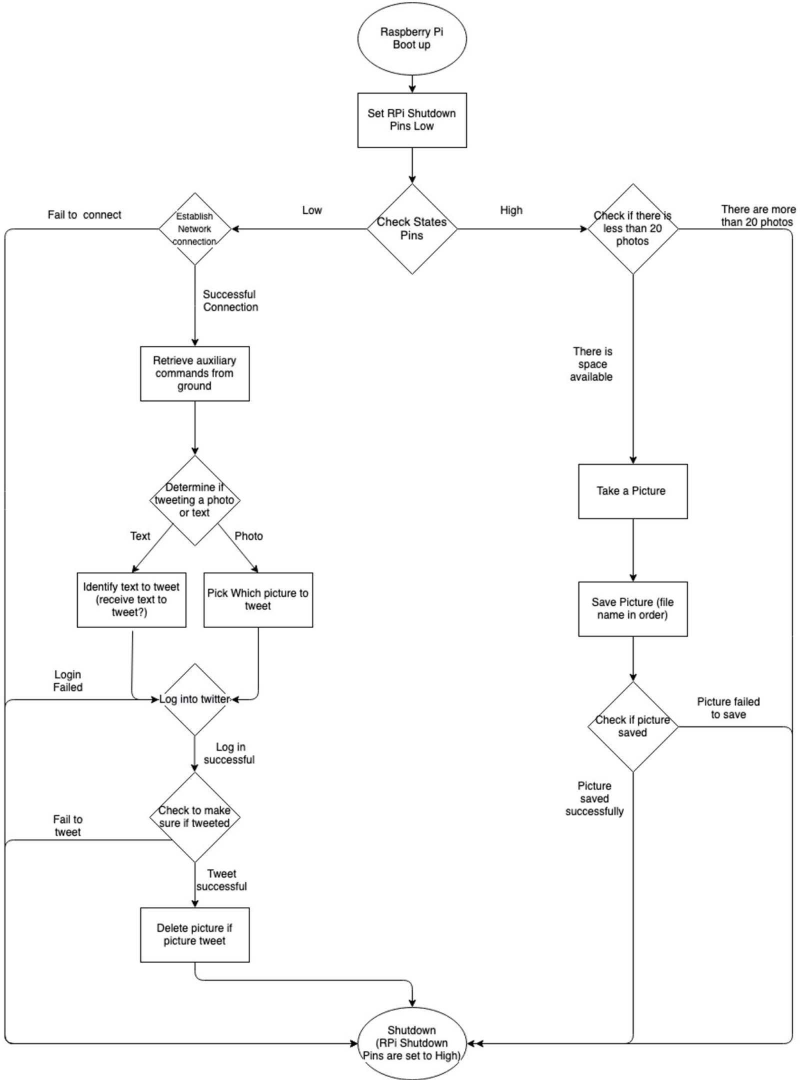
Payload Board - PCB Layout



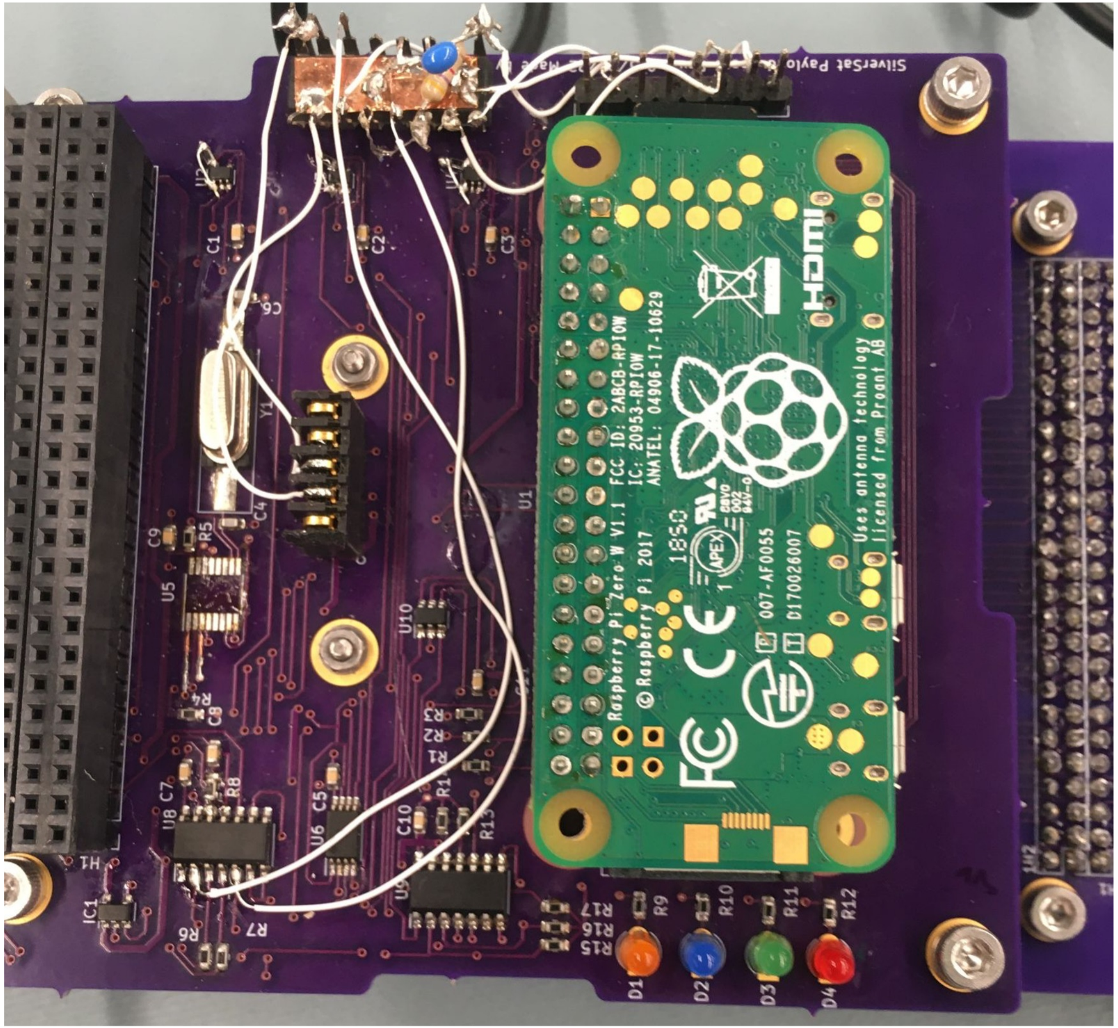
Payload Board - Schematic



Payload Board
- Software Flowchart



Payload Board - Prototype 2



Payload Board - Prototype 2

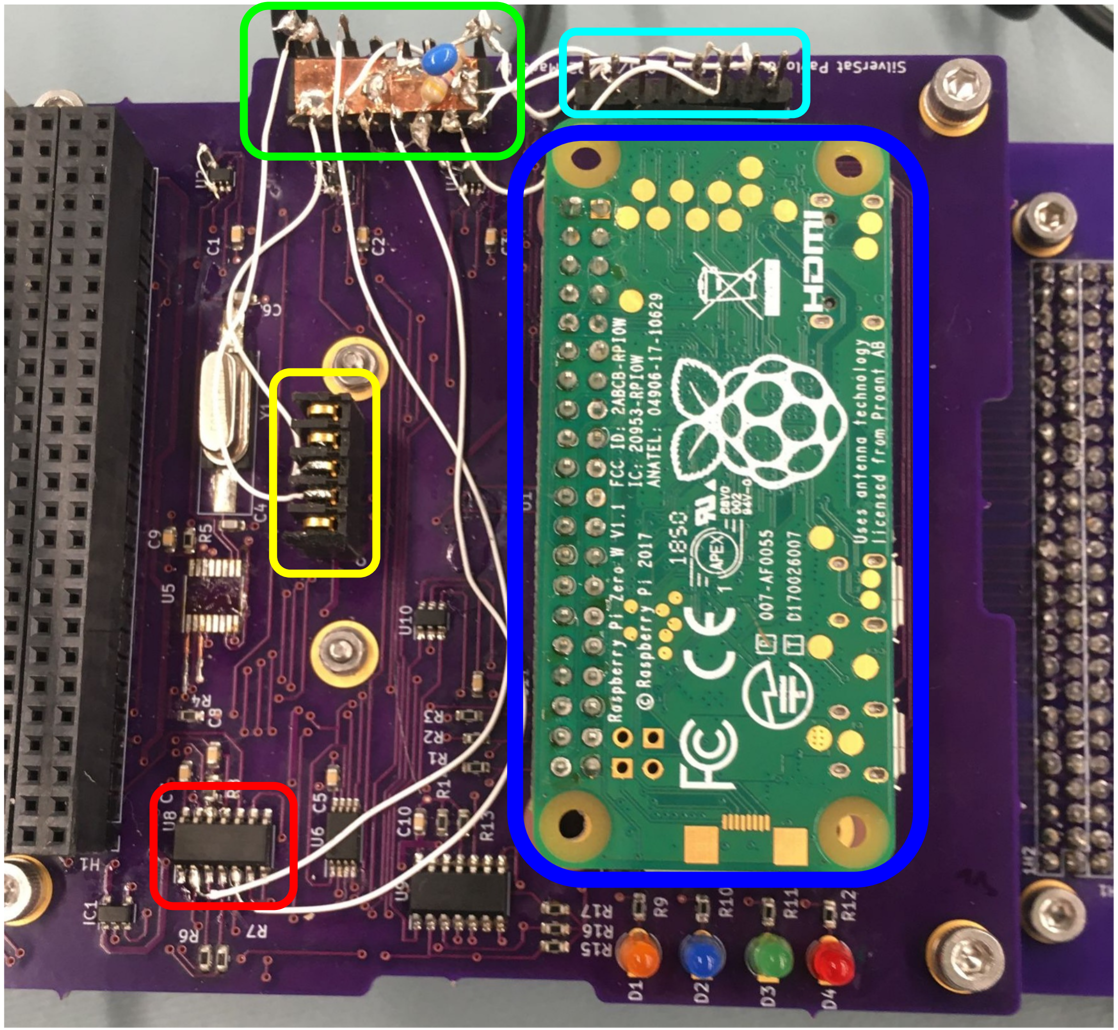
Serial Switch (Dead Bug)

Camera (uCAM-III)

Side Header

Transceiver

Raspberry Pi



Payload Board - Software Infrastructure

- Configuration system in github for Raspberry Pi (Payload/Ground)
  - Simple, reliable, repeatable, named setups for Raspberry Pi

- Swappable Python modules for simple switching of components
  - Camera connection (SPI/Serial); Twitter post (vs alternatives), etc.

- Mini File Server (MiniFS) on Ground for file upload/download to Satellite
  - Auxiliary startup script from Ground, logfiles to Ground

- Twitter alternatives - Reddit or MiniFS
  - MiniFS (on Ground) can be patched, post to multiple sites
  - Consistent interface for Satellite regardless of destination

Payload Board - Prototype 2 Test Results

Payload Board demonstrated its ability to:

- Avionics signaling
  - Correctly powers up when Power On lines high
  - Correctly interprets PHOTO/TWEET on States lines
  - Correctly sets RUNNING/SHUTDOWN on Shutdown lines
- Take a photo
  - Sets Serial switch, syncs with camera, saves photo in filesystem, increments photo counter
- Establish network connection,
  - Sets Serial switch, runs network setup commands, pings the ground, sets the clock, downloads auxiliary startup script, executes code, and sends upload logs to ground
- Tweet
  - Checks for a photo to tweet, text tweet if no photo, if there is a photo tweet deletes photo

Payload Board - Prototype 2 Test Results cont.

- Current Draw
  - Sleep mode: 0 current draw
  - RPi on: 200 to 300mA

- Running Time
  - Bootup: ~50 seconds
  - Take photo: ~90 seconds
  - Tweet: ~5 minutes

- Total Power Usage Estimates
  - Photo: 140 Joules
  - Tweet: 350 Joules

Currently Working On? Going into Flight Model Build…

- Redesign of Payload Board PCB for serial switch

- Low-power Satellite Raspberry Pi configuration
  - Turn off HDMI, WiFI, etc.

- Determine total power consumption for photo and tweet modes
  - Depends on size/complexity of photo

- Easily change tweet text from Ground, and
  - Implement tweet text placeholders for Payload status values

Ground Station

Driving (Derived) Requirements

The Ground Station shall...

- ... transmit and receive Radio signals
- The Ground Station's computer shall host the Satellite's Internet connection
- ... use tracking software to locate the CubeSat
- ... send and receive commands
- ... send and receive data in a data format
- ... receive the Satellite's beacon and status characters
- ... use the location of where we want the CubeSat to be when we take a picture, predict when it will reach it, and send the picture time to the Satellite
- ... receive and filter through public requests for a location of the picture
- A person, either a licensed Amateur Radio Operator or under the supervision of an Amateur Radio Operator, shall be at the control point
- ... consist of the components necessary for proper and sufficient operation, including, but not limited to, those found in the Ground Station block diagram
- ... send a consistent ping up to the CubeSat to start the process of connecting to the CubeSat

SiLVER SAT

Ground Station Software

What does it do?

- ❖ Enables Commands
- ❖ Display Status
- ❖ Rapid Entry of Commands
- ❖ Controls Radio Frequency

Future Tasks

- ❖ Implement and Test Antenna Control

Ground Station Software Establishes Flask Server	Listens and connects with GPredict to get Radio Doppler Frequencies	Provides Interface for Commands
Waits for Input Request/ Submission	On Input, Creates/Sends a Request to Server	Server Converts Data and Sends through Radio
Listens for Response Transmissions	Decodes and Writes Responses on Interface	

Ground Control

Enter Command

Type Command Here...

Transmit

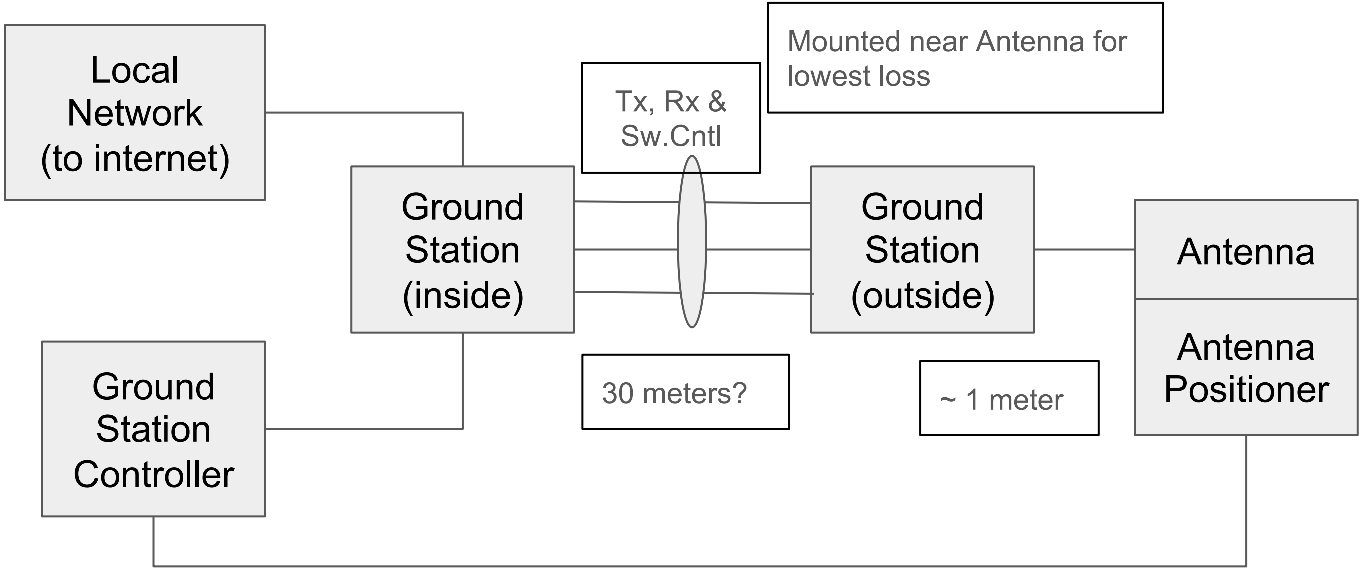
Quick Actions

- No operation
- Send test packet
- Set clock to GMT
- Get clock time
- Payload communications
- Take photo in one minute
- Set beacon interval to one minute
- Set beacon interval to three minutes
- Get telemetry
- Get power
- Transmit call sign
- Refresh data

Received from Satellite

ACK RES SBI

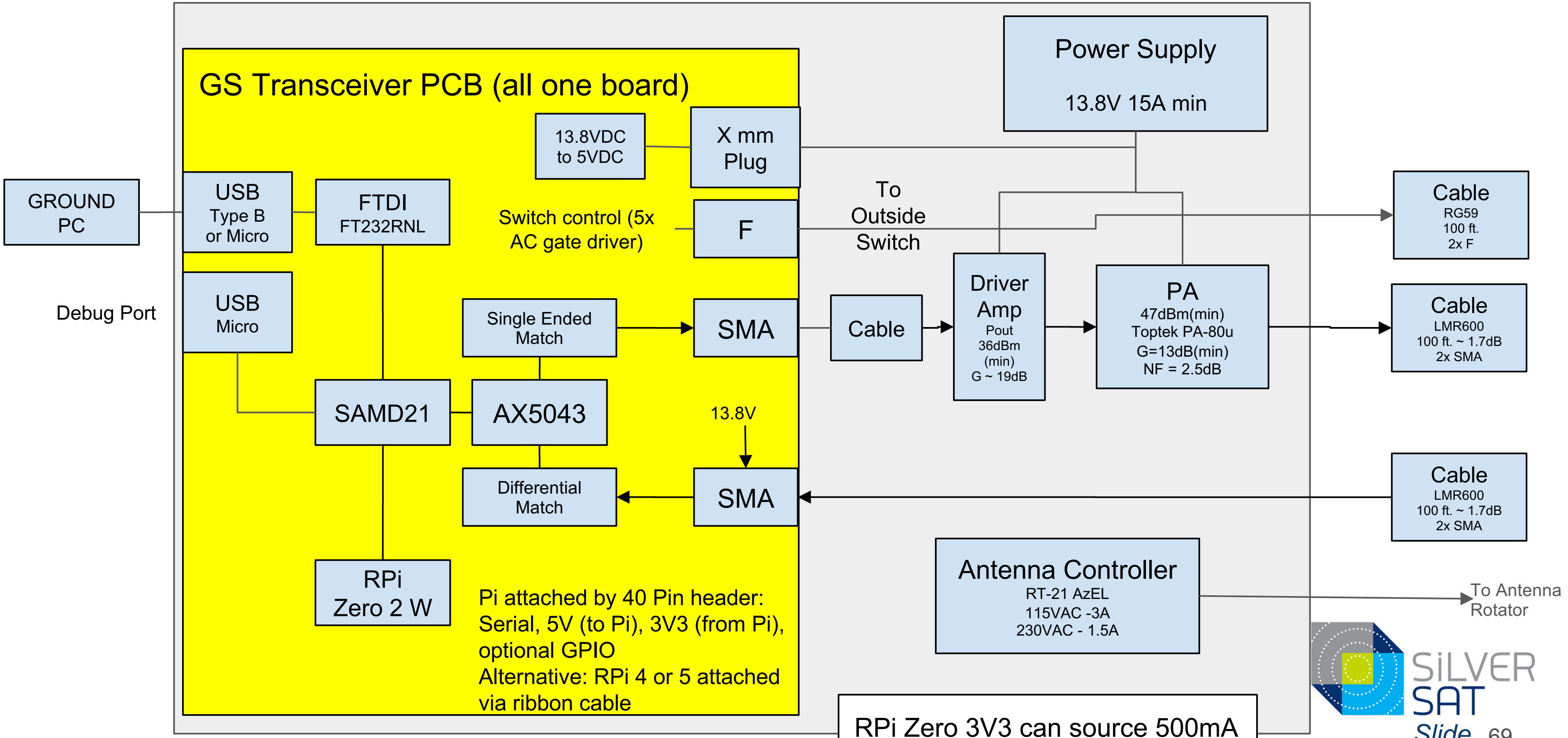
Big Picture



Location: Goddard Amateur Radio Club clubhouse, Glenn Dale, Maryland
HAAT: -15×10^{-1} m* plus tower height

* United States Federal Communications Commission (2016, January 21). Antenna Height Above Average Terrain (HAAT) Calculator, output for 39°00'42.36"N, 76°50'21.33"W. https://transition.fcc.gov/fcc-bin/haat_calculator?dlat=39&mlat=0&slat=... Accessed May 24, 2022 12:00 PM

Ground Station Inside Segment Detail

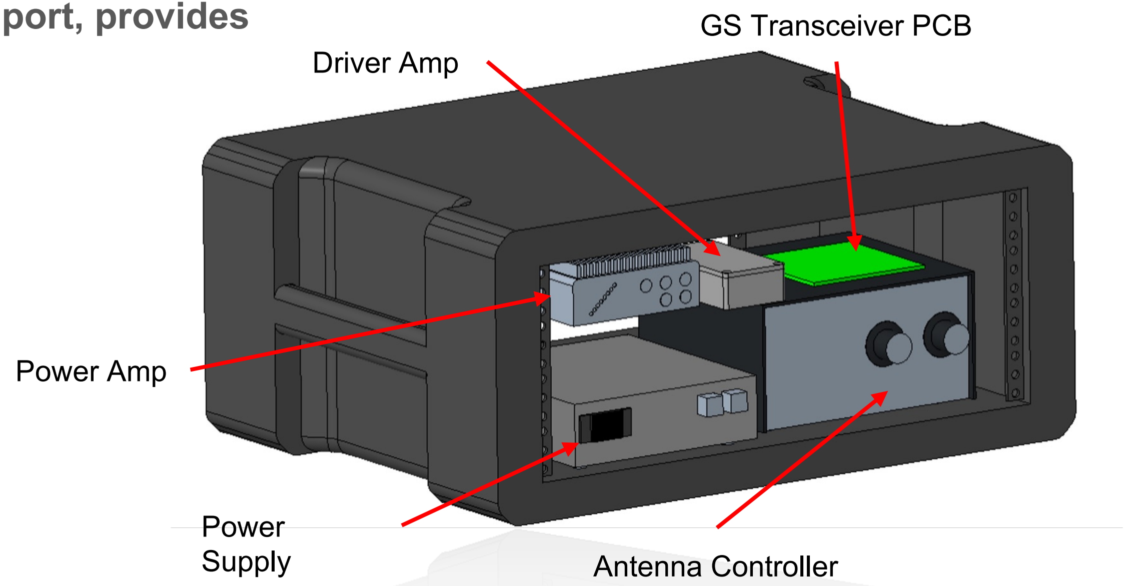


RPi Zero 3V3 can source 500mA

Indoor Ground Station Mechanical Design

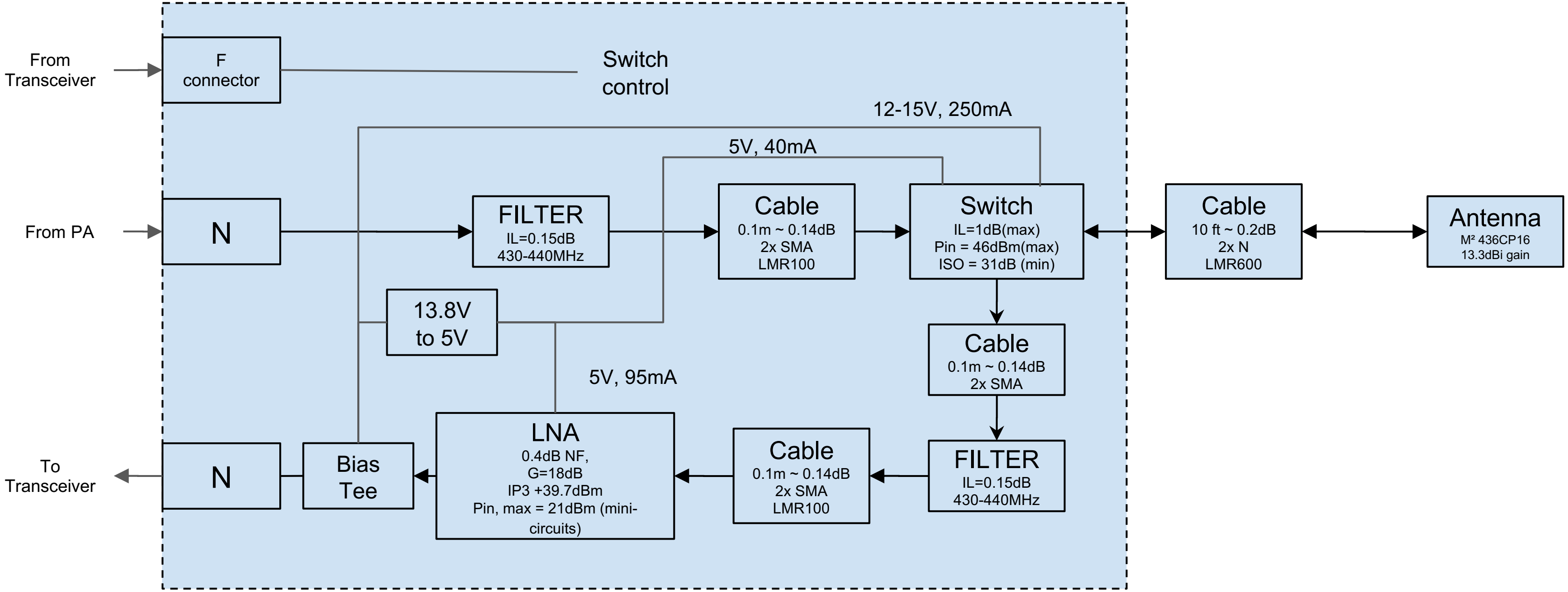
Indoor Box: Compact, easy to transport, provides enough space for circulation

4U, 13" Deep Molded Audio Rack
G-PRO-4U-13
48.26 x 34.29 x 18.29 cm



Indoor Ground Station CAD Model

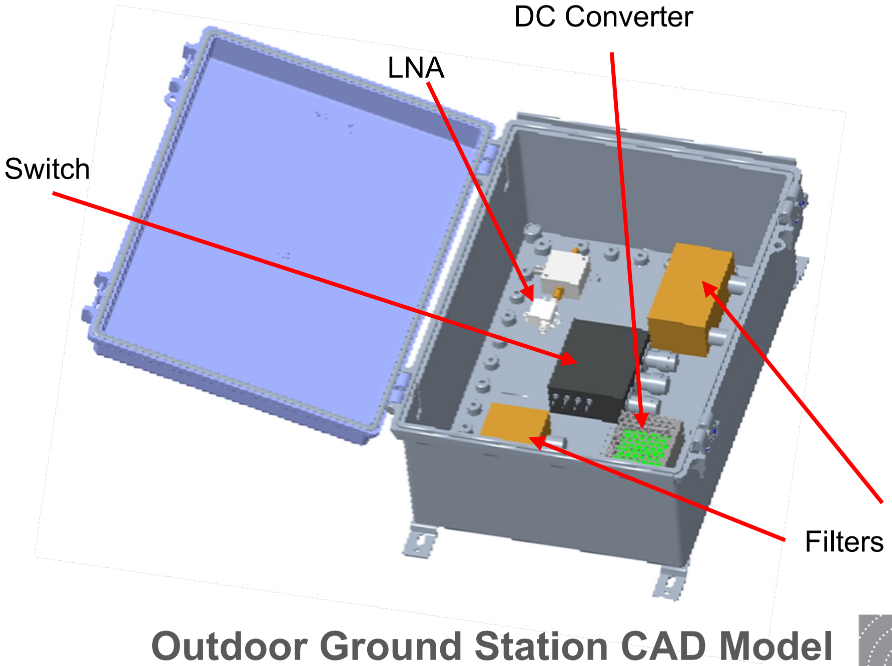
Top-Level Diagram (Outside Segment)



Outdoor Ground Station Mechanical Design

Outdoor Box: Waterproof, components are easily accessible

WH-22-03 Hinged Nema Enclosure
34.9 x 24.9 x 14.9 cm



Outdoor Ground Station CAD Model

Activities Since PDR

- Added more licensed operators: we have 5 Students and 3 Mentors with licenses. Two more Students and 1 Mentor plan to take the exam in February
- Obtained Club Call sign: KC3VVW*
- Submitted AMSAT coordination request

* United States Federal Communications Commission (2023). ULS License: Amateur License - KC3VVW - Silversat. https://wireless2.fcc.gov/UlsApp/UlsSearch/license.jsp?licKey=4748227 Accessed 29 January 2024.

Currently Working On? Going into Flight Model Build…

- Radio Board: Our ground transceiver
- Finalizing the Indoor and Outdoor Ground Station Mechanical Design

Beacon Box

The goal is to have an all-in-one,* easy use portable beacon receiver.

The Beacon Box will be used to receive status updates from the Satellite.

With an max budget of $150 and made out of easily accessible parts, it’s the perfect educational project. It's a great demo tool that is both cheap and portable. Allowing people to hear a Satellite in space put up by Students just like them.

*Antenna has to be added

Requirements:

- External Antenna connect
- CW mode
- Min range of 420-440 MHz
- Output Demodulated audio

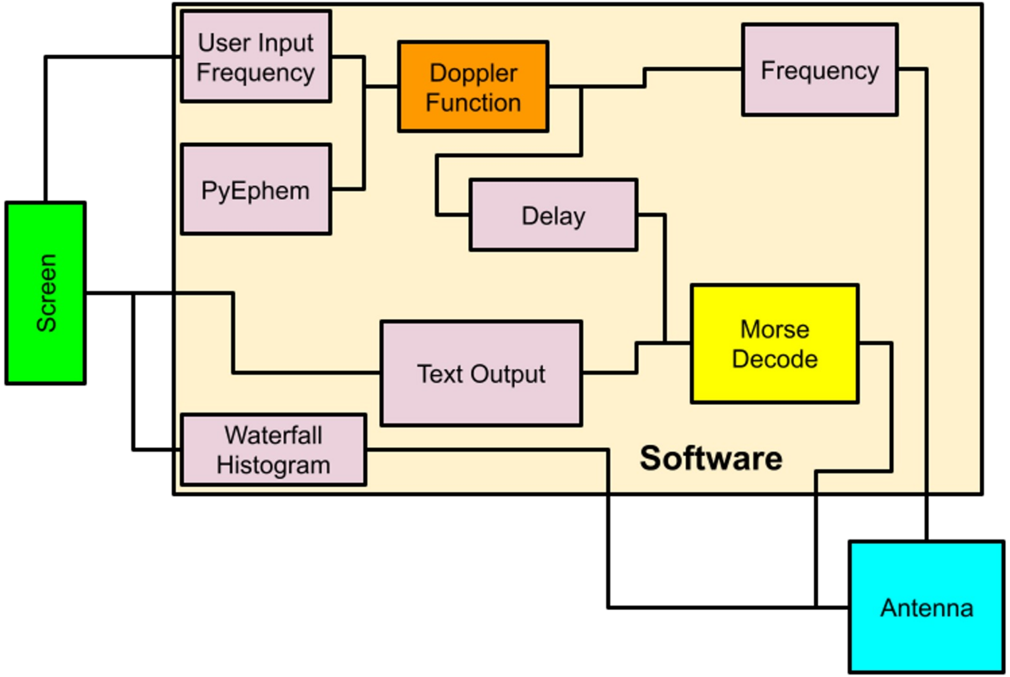
Goals:

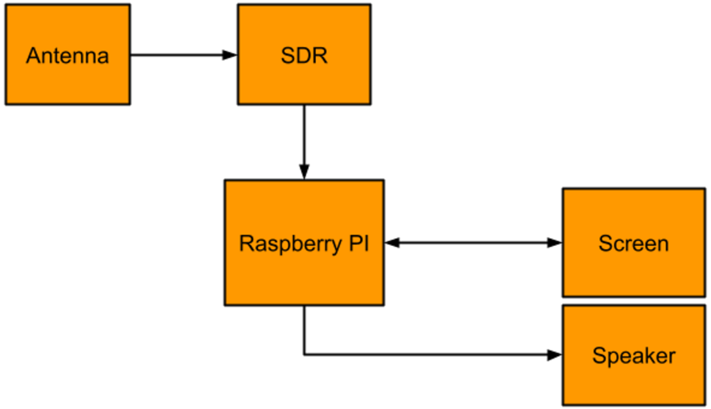
- CW signal to plain text
- Receive frequency over USB or IP (used with gpredict)
- Easily repairable and plug in programmable
- Full documentation
- Portable

SiLVER SAT

Beacon Box

The software will be created in Python using GNU Radio Companion and PyEphem it will be running on an SDR and Raspberry PI.

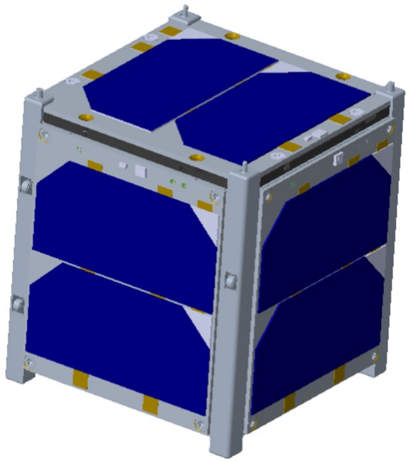




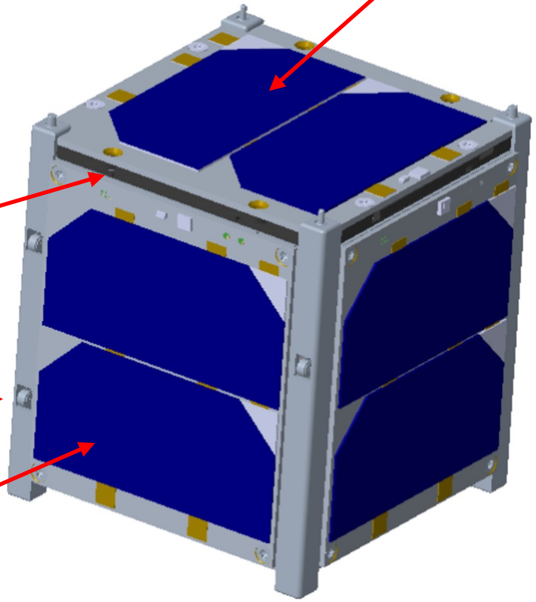
Mechanical

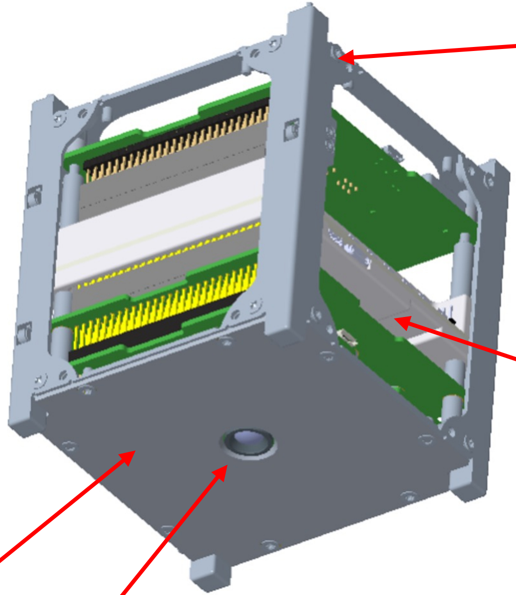
CubeSat Model

- The CubeSat is a 1U design that is 10 cm x 10 cm x 11 cm and 1.33 kg max
- The CubeSat design consists of the following components
  - Frame
  - Board Stack
  - Antenna
  - Solar Cells
- The CubeSat design will meet the mechanical requirements outlined in the following specifications
  - CubeSat Design Specification (CDS Rev 13)
  - Launch Services Program Requirements Document (LSP-REQ-317.01 B)
  - Nanoracks CubeSat Deployer Interface Control Document (NR-NRCSD-S0003)
  - Launch Vehicle Requirements Document (TBD)



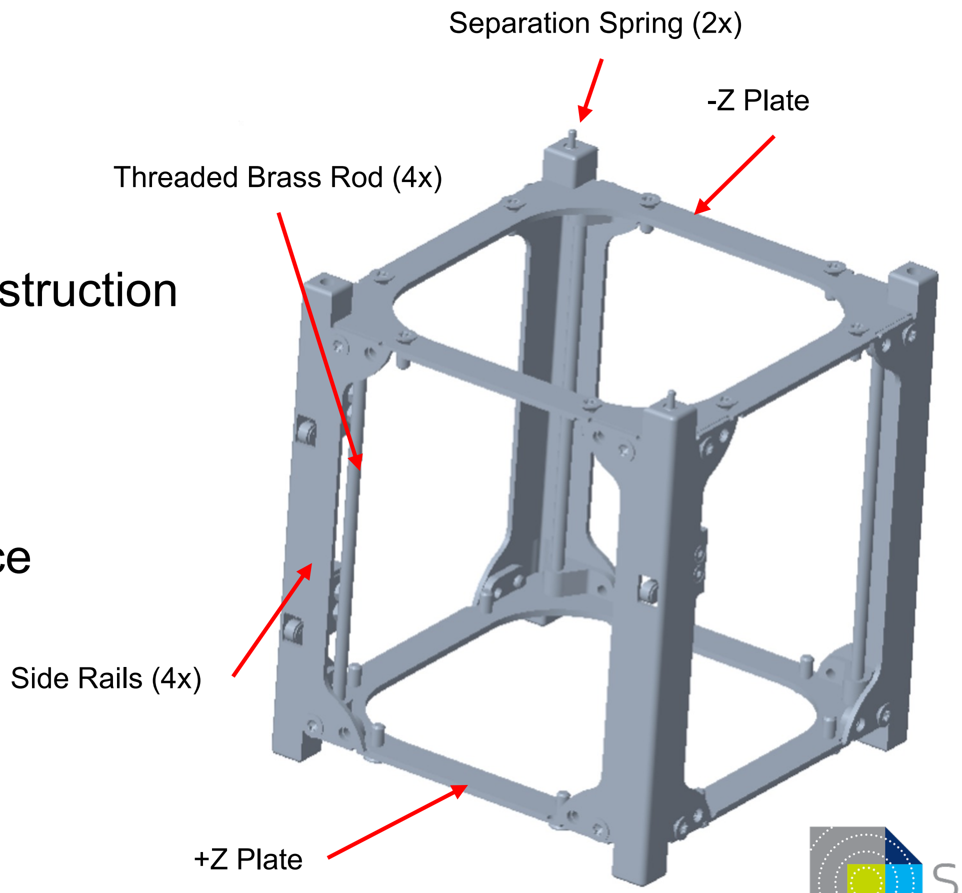
CubeSat Model





CubeSat Frame

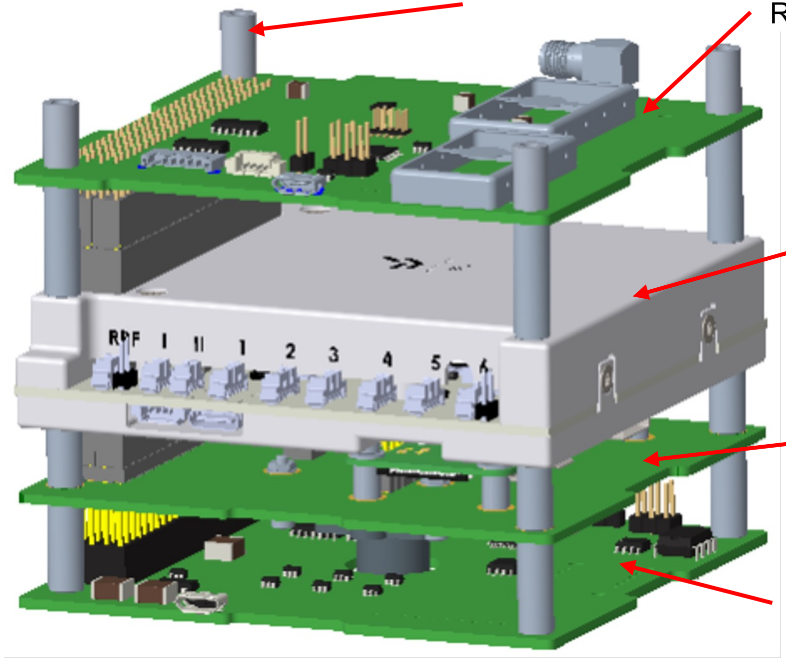
- Purchased from EnduroSat
- Open frame, multi-piece construction design
- Has flight heritage
- Material: Aluminum
- Finish: Hard anodized surface
- Mass: 120g



Board Stack

Aluminum Standoff (16x)

Radio Board



Electrical Power System (EPS1)
(Provides power to the CubeSat)

Payload Board
(Has the camera and Raspberry pi)

Avionics Board
(Board has a hole for the camera)

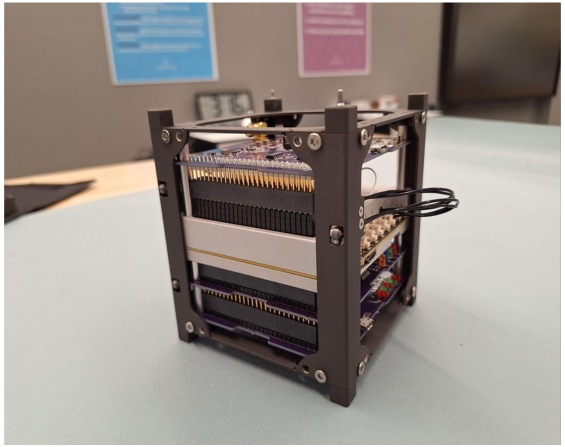
Currently Working On? Going into Flight Model Build…

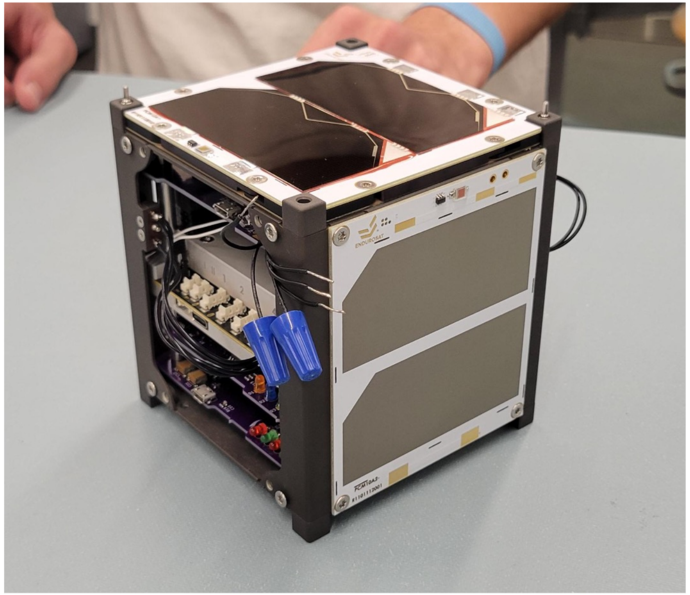
- Setting up the Prototype and fixing problems that may arise
- Finalizing and purchasing the +Z closeout panel

Prototype 2 Results

Prototype 2 Process (Fit Check)

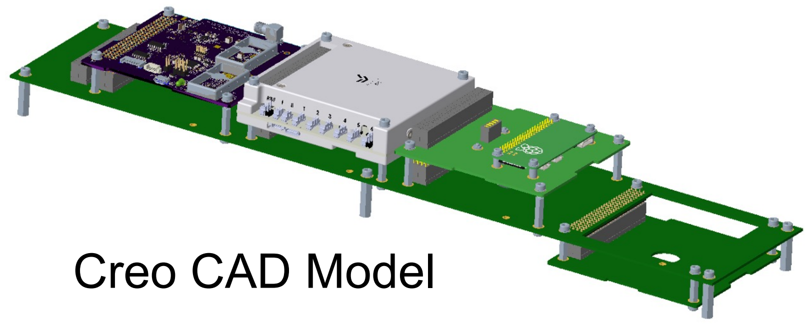
- Assembled the CubeSat to ensure each component could fit and the standoffs were correct



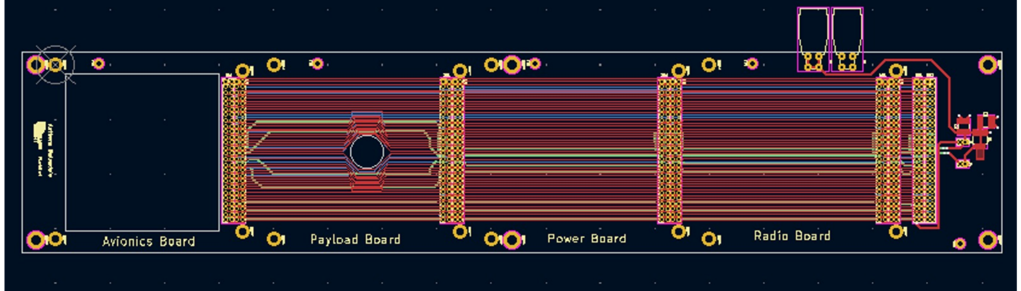


Prototype 2 Process (FlatSat)

- Designed and wired the FlatSat Board in KiCAD and Creo so that other Teams could test



Creo CAD Model

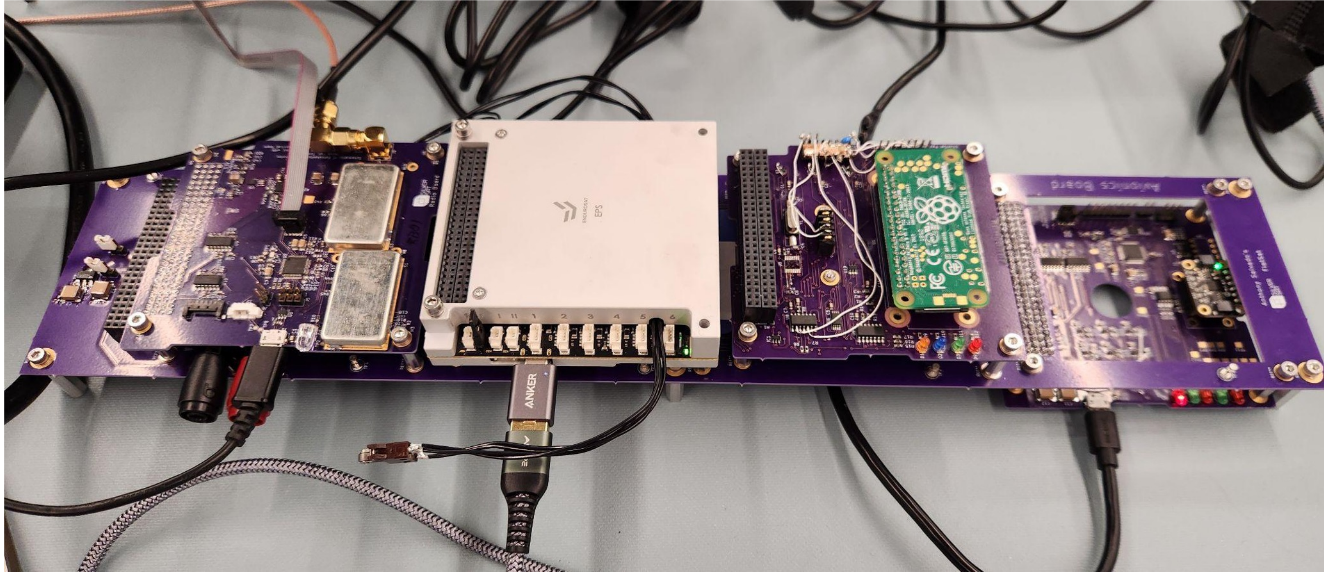


KiCad PCB Layout

What We Learned from Prototype 2

- The release switch for the CubeSat was rubbing against the side of the frame, making it so the switch couldn’t spring back
- The standoffs weren’t right the right size and couldn’t be screwed on, so we switched to non-threaded standoffs

FlatSat Testing



- Long PCB board with connected headers for Radio, Battery, Payload, and Avionics side by side.
- Also prototype Ground Station components with Radio Board, Raspberry Pi, and laptop for sending commands
- Radios connected with a cable
- External Radio for listening to beacon (morse code) and communication between Satellite and ground

FlatSat Testing - Day in the Life

- Day in the Life is the things we will do most days when we are in space
- The big commands the Satellite will do are…
  - Set the Avionics real-time clock (once)
  - Turn on Payload for communication (Tweet)
  - Register a specific time for Payload to take a photo (Payload turns on at the correct time and takes a photo)
  - Turn on Payload for communication (Tweet w/ photo)
- We tested the FlatSat to find out how long it took to tweet text, tweet different sizes of images, and take a picture
- There are four pieces of data sent between the Satellite, the Ground Station, and Twitter; Auxup, Logsdown, Tweetdown, and Tweetup

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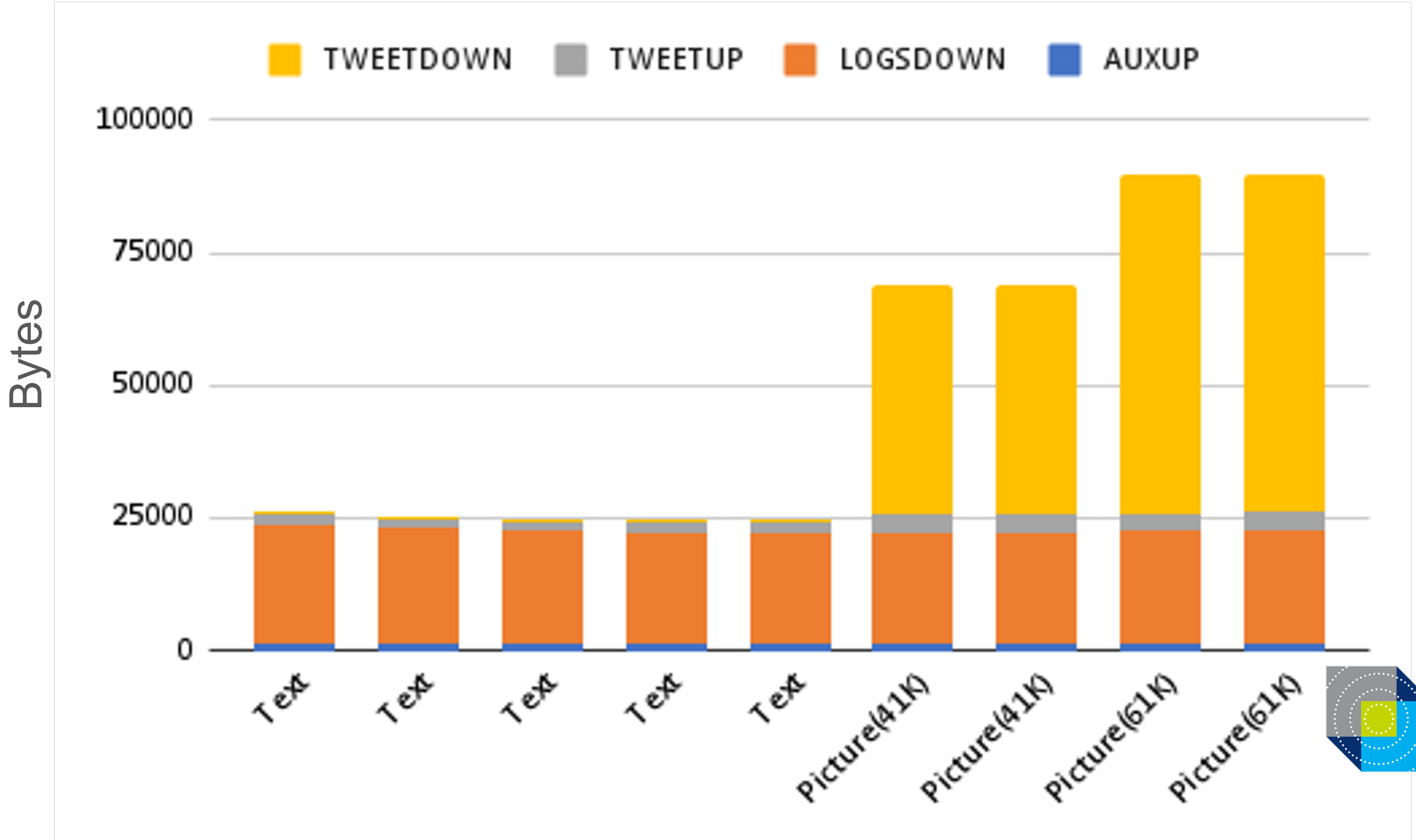
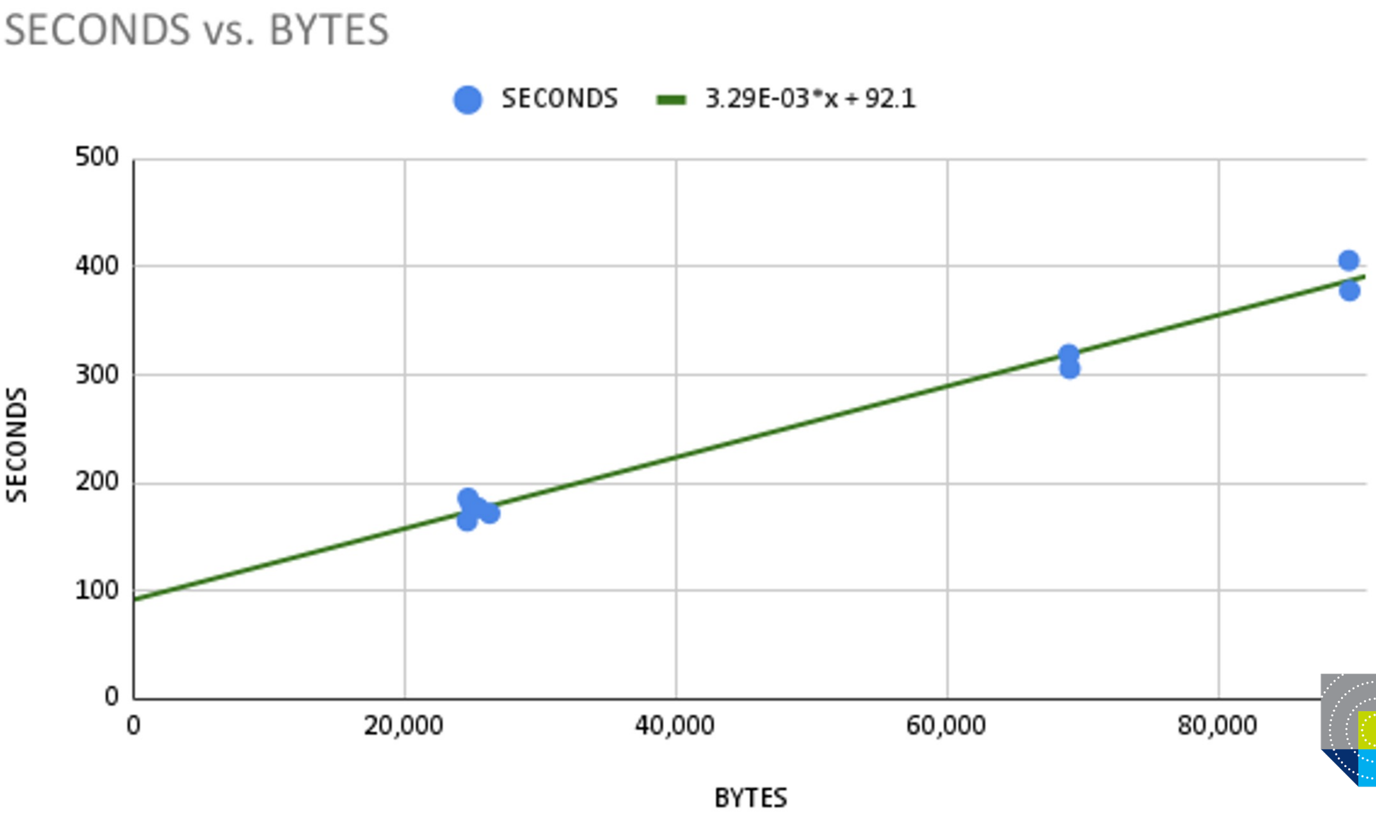
FlatSat - Tweet Amount

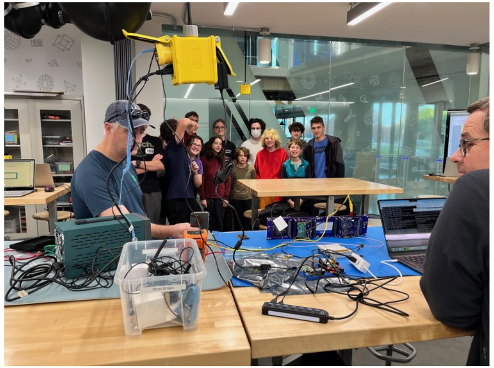


FlatSat - Tweet Times

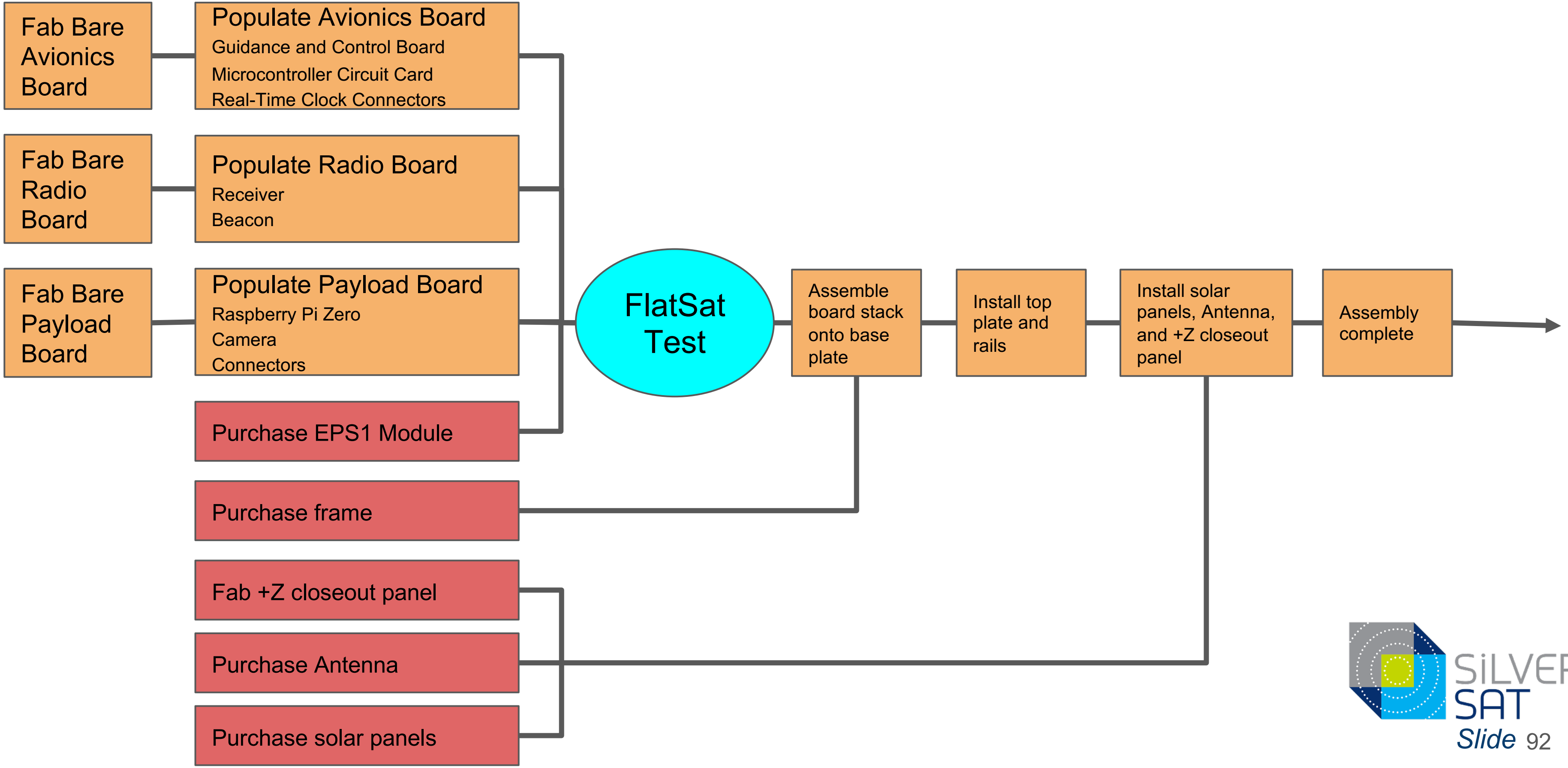


Outline

- Overview & Mission Concept
- Systems Engineering
- Critical Designs (Major Components)
    - Power, Avionics, Radio, Ground, Payload, Mechanical
- Prototype 2 Results
- FM Integration and Test
- Programmatics
- Conclusion/Outbrief

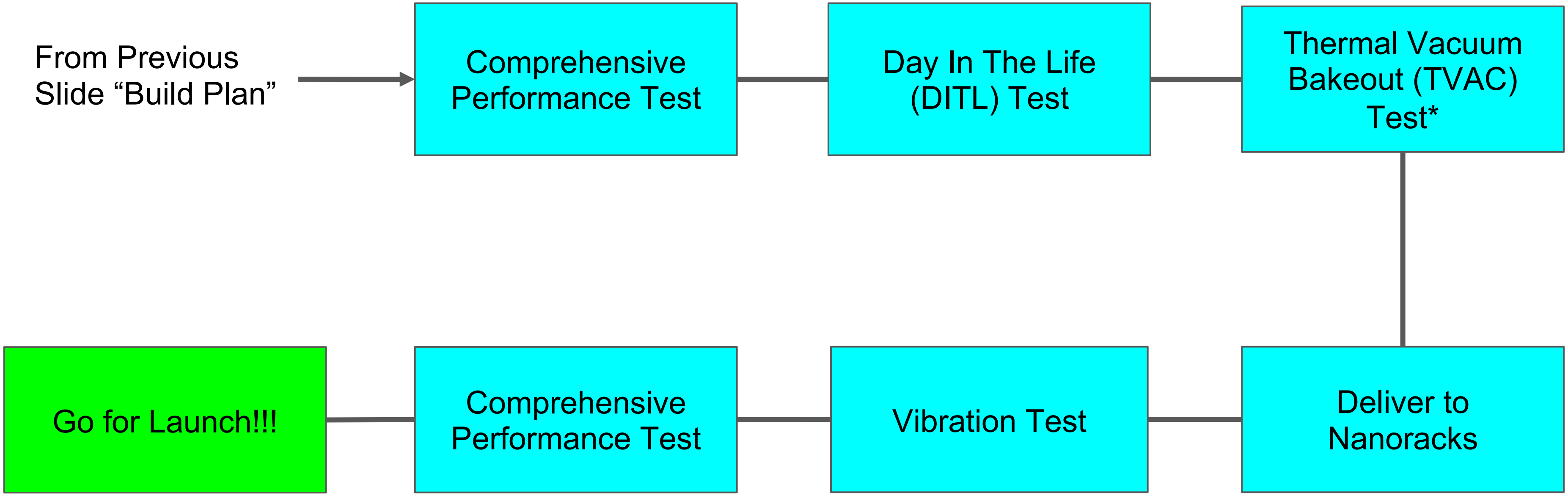


Flight Model Build Plan



SILVER SAT

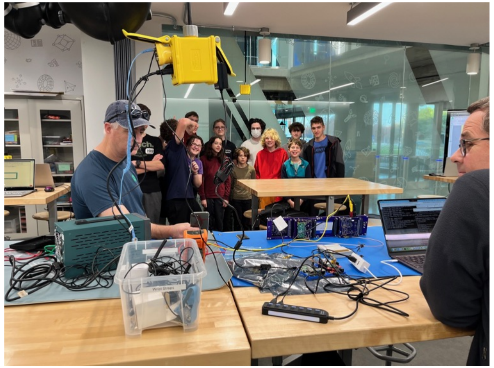
Flight Model Test Plan



*Optional

Outline

- Overview & Mission Concept
- Systems Engineering
- Critical Designs (Major Components)
  - Power, Avionics, Radio, Ground, Payload, Mechanical
- Prototype 2 Results
- FM Integration and Test
- Programmatics
- Conclusion/Outbrief



Risk #	Risk	L	C
1	If critical personnel leave the team, then our critical path will be affected	5	3
2	If the program cannot train new members in a timely fashion, then our critical path will be affected	5	3
10	If Elon Musk changes critical rules that harms our access to Twitter (now X), then our mission success criteria regarding sending tweets may be affected	3	3
11	If mentors are unavailable to assist with major decisions and tasks, then our critical path may be affected	3	3
3	If we cannot acquire facilities for building and securing flight hardware, then our delivery may be delayed	2	4
16	If the flight EPS repair delays the flight build, then the delivery to Nanoracks may be delayed	2	4
17	If we need to add a secondary Radio path to command off our primary transmitter, then our delivery may be delayed.	2	4
7	If data takes too long to send, then we will not complete a tweet in a pass	2	3
5	If certified amateur Radio members are not available at the Ground Station, then links may not be established	1	4
15	If SilverSat doesn't meet criteria for amatuer Radio frequency coordination, then our schedule will be delayed.	2	2
6	If temperature exceeds parts limits, then critical functions may fail	1	3
12	If proper equipment/facilities cannot be secured for flight I&T testing, then the SilverSat CubeSat may fail Nanoracks testing or in Operations	1	3
8	If we experience long delays in acquiring parts because of the supply chain shortages, then our delivery may be delayed	1	1
4	CLOSED: If an expensive component breaks before launch requiring us to replace it, then our delivery may be delayed	1	4
9	CLOSED: If we cannot meet in person more often, then our critical path will be affected	1	3
13	CLOSED, COMBINED WITH 12: If proper equipment/facilities cannot be secured for flight I&T testing, then the SilverSat CubeSat may fail in Operations	1	3
14	CLOSED: If we cannot find a new place to meet, then our critical path will be affected.	1	3

Risk Matrix

Consequence (C)						
	5					
	4	5	3,16, 17			
	3	6,12	7	10,11		1,2
	2		15			
	1	8				
		1	2	3	4	5
		Likelihood (L)				

SilverSat Schedule (1 of 4)

		Task Name	% Complete	Duration	Start	Finish	Predecessors	Successors	Total Slack
1		**SilverSat Major Milestones**	**17%**	**446 days**	**Sat 7/1/23**	**Thu 12/19/24**			**0 days**
2		Prepare for SilverSat CDR	63%	6 wks	Sat 1/6/24	Fri 2/9/24	67	3	0 wks
3		Hold SilverSat Critical Design Review	0%	1 day	Sat 2/10/24	Sat 2/10/24	2	4,45,16,75FS-1 wk,80FS	0 days
4		Work SilverSat CDR Action Items	0%	6 wks	Mon 2/12/24	Sat 3/16/24	3	76,81,87	0 wks
5		Prepare for SilverSat Test Readiness Review (TRR)	0%	3 wks	Sat 7/13/24	Tue 7/30/24	91,96SS,14,15,16	6	0 wks
6		Hold SilverSat Test Readiness Review	0%	1 day	Wed 7/31/24	Wed 7/31/24	5,55	97,7	0 days
7		Work SilverSat TRR Action Items	0%	2 wks	Thu 8/1/24	Mon 8/12/24	6	98	0 wks
8		Prepare for Pre-Ship Review (PSR)	0%	3 wks	Thu 10/10/24	Sat 10/26/24	102SS	9	5 wks
9		Hold SilverSat Pre-Ship Review	0%	1 day	Tue 11/26/24	Tue 11/26/24	103,8	11,104,10	0 days
10		Work SilverSat PSR Action Items	0%	2 wks	Wed 11/27/24	Sat 12/7/24	9	104	0 wks
11		SilverSat Delivery	0%	2 days	Wed 12/18/24	Thu 12/19/24	105,13,17,18,9		0 days
12		**SilverSat - Nanoracks Deliverables**	**99%**	**385 days**	**Sat 7/1/23**	**Wed 10/9/24**			**59 days**
13	✓	Battery Test Report	100%	1 day	Sat 7/1/23	Sat 7/1/23		11	0 days
14		Safety Data Template	0%	0 days	Sat 2/10/24	Sat 2/10/24		5	132 days
15		Bill of Materials	0%	0 days	Sat 2/10/24	Sat 2/10/24		5	132 days
16		ODAR Inputs	0%	0 days	Sat 2/10/24	Sat 2/10/24	3	5	131 days
17		Vibration Test Report	0%	0 days	Fri 8/23/24	Fri 8/23/24	98	11	99 days
18		Investigation Summary Form	0%	0 days	Wed 10/9/24	Wed 10/9/24	101	11	59 days
19		**Prototype #2**	**84%**	**545 days**	**Mon 9/26/22**	**Thu 7/25/24**			**4 days**
20	✓	**Power System**	**100%**	**95 days**	**Mon 9/26/22**	**Mon 1/30/23**			**0 days**
24	✓	**Payload System**	**100%**	**100 days**	**Mon 9/26/22**	**Sat 2/4/23**			**0 days**
28	✓	**Radio System**	**100%**	**220 days**	**Mon 9/26/22**	**Sat 6/24/23**			**0 days**
33	✓	**Avionics System**	**100%**	**130 days**	**Mon 9/26/22**	**Sat 3/11/23**			**0 days**

SilverSat Schedule (2 of 4)

41		**Antenna**	**70%**	**403 days**	**Mon 1/2/23**	**Thu 5/2/24**			**40 days**
42	✓	Select Antenna	100%	2 wks	Mon 1/2/23	Thu 1/12/23		43,48	0 wks
43	✓	Order and Receive Antenna	100%	21 wks	Fri 1/13/23	Mon 5/15/23	42	44FS+80 days	0 wks
44	✓	Test Antenna	100%	10 wks	Thu 8/17/23	Fri 10/13/23	43FS+80 days	45	0 wks
45		Deploy Antenna	0%	10 wks	Mon 2/12/24	Tue 4/9/24	44,3	46	8 wks
46		Antenna Schedule Reserve	0%	4 wks	Wed 4/10/24	Thu 5/2/24	45	93	8 wks
47		**Ground Station**	**56%**	**545 days**	**Mon 9/26/22**	**Thu 7/25/24**			**4 days**
48	✓	Find a Ground Station	100%	7 wks	Sat 4/22/23	Thu 6/1/23	42	50,53	0 wks
49	✓	Design Ground Station	100%	3 wks	Mon 9/26/22	Wed 10/12/22		50	0 wks
50	✓	Order and Receive Ground Station Parts	100%	31 wks	Fri 6/2/23	Fri 12/1/23	48,49	52,53	0 wks
51		Order Ground Station Cables and Enclosures	29%	18 wks	Thu 12/14/23	Thu 4/11/24	52SS+2 wks	54	11.8 wks
52		Build Ground Station	23%	31 wks	Sat 12/2/23	Fri 6/14/24	50	54,51SS+2 wks	0.8 wks
53		Write Code for Ground Station	60%	12 wks	Sat 12/2/23	Sat 2/24/24	48,50	54	19.8 wks
54		Test Ground Station	0%	4 wks	Sat 6/15/24	Mon 7/8/24	52,53,51	55	0.8 wks
55		Ground Station Schedule Reserve	0%	3 wks	Tue 7/9/24	Thu 7/25/24	54	6	0.8 wks
56	✓	**Flat Sat**	**100%**	**225 days**	**Mon 9/26/22**	**Fri 6/30/23**			**0 days**
57	✓	Design Flat Sat	100%	21 wks	Mon 9/26/22	Fri 2/10/23		58	0 wks
58	✓	Order, and Receive Flat Sat	100%	4 wks	Sat 2/11/23	Mon 3/6/23	57	59	0 wks
59	✓	Build Flat Sat	100%	20 wks	Tue 3/7/23	Fri 6/30/23	58	62	0 wks
60	✓	**Integration and Testing**	**100%**	**152 days**	**Mon 6/26/23**	**Fri 1/5/24**			**0 days**
61	✓	Integrate all the boards on the Flat Sat	100%	3 wks	Mon 6/26/23	Wed 7/12/23	23,27,32,40	62	0 wks
62	✓	Test Prototype #2 on the Flat Sat	100%	13 wks	Thu 7/13/23	Tue 9/26/23	59,61	64,63	0 wks
63	✓	Integrate Prototype #2 in CubeSat Frame	100%	10 days	Wed 9/27/23	Sat 10/7/23	62	66	0 days
64	✓	Integrate Board Revisions	100%	40 days	Wed 9/27/23	Sat 11/11/23	62	65	0 days

SilverSat Schedule (3 of 4)

65		Regression Testing of Board Revisions	100%	22 days	Mon 11/13/23	Sat 12/9/23	64	66	0 days
66		Retest Prototype #2	100%	2 wks	Mon 12/11/23	Fri 1/5/24	63,65	67	0 wks
67		Integration and Testing Prototype 2 Schedule Reserve	100%	0 wks	Fri 1/5/24	Fri 1/5/24	66	75,80,85,2	0 wks
68		**Flight Model**	**33%**	**669 days**	**Mon 9/26/22**	**Tue 12/17/24**			**0 days**
69		**Power System**	**100%**	**391 days**	**Mon 9/26/22**	**Mon 1/29/24**			**0 days**
70		Order and Receive Flight EPS	100%	43.8 wks	Mon 9/26/22	Fri 6/23/23		73	0 wks
71		Return Flight EPS to EnduroSat	100%	6 wks	Wed 11/8/23	Thu 12/14/23		72	0 wks
72		Rework and Redeliver Flight EPS (EnduroSat)	100%	5 wks	Fri 12/15/23	Sat 1/27/24	71	73	0 wks
73		Power System FM Schedule Reserve	100%	0 wks	Mon 1/29/24	Mon 1/29/24	70,72	93	0 wks
74		**Payload System**	**0%**	**115 days**	**Tue 2/6/24**	**Tue 6/18/24**			**0 days**
75		Fix any problems found in testing	0%	6 wks	Tue 2/6/24	Mon 3/11/24	67,3FS-1 wk	76	1 wk
76		Build payload flight board	0%	9 wks	Mon 3/18/24	Wed 5/8/24	75,4	77	0 wks
77		Test payload flight board	0%	4 wks	Thu 5/9/24	Fri 5/31/24	76	78	0 wks
78		Payload System FM Schedule Reserve	0%	3 wks	Sat 6/1/24	Tue 6/18/24	77	93	0 wks
79		**Radio System**	**0%**	**115 days**	**Tue 2/6/24**	**Tue 6/18/24**			**0 days**
80		Fix any problems found in testing	0%	6 wks	Tue 2/6/24	Mon 3/11/24	67,3FS-1 wk	81	1 wk
81		Build radio flight board	0%	9 wks	Mon 3/18/24	Wed 5/8/24	80,4	82	0 wks
82		Test radio flight board	0%	4 wks	Thu 5/9/24	Fri 5/31/24	81	83	0 wks
83		Radio System FM Schedule Reserve	0%	3 wks	Sat 6/1/24	Tue 6/18/24	82	93	0 wks
84		**Avionics System**	**0%**	**115 days**	**Tue 2/6/24**	**Tue 6/18/24**			**0 days**
85		Fix any problems found in testing	0%	6 wks	Tue 2/6/24	Mon 3/11/24	67,3FS-1 wk	87,86	0 wks
86		Third release of Avionics board code	0%	10 wks	Tue 3/12/24	Wed 5/8/24	39,85	88	0 wks
87		Build avionics flight board	0%	9 wks	Mon 3/18/24	Wed 5/8/24	85,4	88	0 wks

SilverSat Schedule (4 of 4)

88	Test avionics flight board	0%	4 wks	Thu 5/9/24	Fri 5/31/24	87,86	89,92	0 wks
89	Avionics System FM Schedule Reserve	0%	3 wks	Sat 6/1/24	Tue 6/18/24	88	93	0 wks
90	**Integration and Testing**	**0%**	**176.01 da**	**Sat 5/25/24**	**Tue 12/17/24**			**0 days**
91	Write FM Integration and Test Plan	0%	8 wks	Sat 5/25/24	Thu 7/11/24	93SS-20.01 days	5	0.2 wks
92	Final Release of Avionics Board Code (If necessary)	0%	2 wks	Sat 6/1/24	Wed 6/12/24	88	94	1.2 wks
93	Hold System Integration Readiness Review (Receive FM Boards)	0%	1 day	Wed 6/19/24	Wed 6/19/24	46,73,78,83,89	91SS-20.01 days,94	0 days
94	Integrate FM Board Stack onto Frame	0%	3 wks	Thu 6/20/24	Sat 7/6/24	93,92	95	0 wks
95	Closeout FM Frame Structure	0%	1 wk	Mon 7/8/24	Fri 7/12/24	94	96	0 wks
96	Install FM Solar Panels	0%	1 wk	Sat 7/13/24	Thu 7/18/24	95,21	5SS	0 wks
97	Perform FM Initial Comprehensive Performance Test	0%	2 wks	Thu 8/1/24	Mon 8/12/24	6	98	0 wks
98	Perform FM Vibration Test	0%	2 wks	Tue 8/13/24	Fri 8/23/24	97,7	99,17	0 wks
99	Perform FM TVAC Testing	0%	4 wks	Sat 8/24/24	Mon 9/16/24	98	100	0 wks
100	Perform FM Final Comprehensive Performance Test	0%	2 wks	Tue 9/17/24	Fri 9/27/24	99	101	0 wks
101	Perform FM Day-In-The-Life Test	0%	2 wks	Sat 9/28/24	Wed 10/9/24	100	102,18	0 wks
102	Perform FM Final Document Closeout/Prepare for Pre-Ship Review	0%	4 wks	Thu 10/10/24	Fri 11/1/24	101	103,8SS	0 wks
103	FM SCHEDULE RESERVE	0%	4 wks	Sat 11/2/24	Mon 11/25/24	102	9	0 wks
104	Prepare to Ship FM CubeSat	0%	8 days	Mon 12/9/24	Tue 12/17/24	9,10	105	0 days
105	FM CubeSat Ready for Delivery	0%	0 days	Tue 12/17/24	Tue 12/17/24	104	11	0 days

SilverSat Open Items Update

- Attitude Control - Need to conduct detailed design for passive magnetic stabilization
  - **Open** - Have conducted initial simulations only. Need to analyze further, choose magnetic materials, and incorporate into the design
- Thermal Design - Need to conduct thermal analysis
  - **Open** - No analysis to date
  - Design does not contain anything ‘out of family’ for 1U missions. Expect our thermal profile to be similar.
  - Power budget is sensitive to battery heater cycling
- Antenna
  - **Resolved** - Using the EnduroSat Antenna. Purchased an EM Antenna for conducting one deployment test, and measure RF return loss.
- Spacecraft Telemetry
  - **Resolved -** Implemented RReport command to Avionics

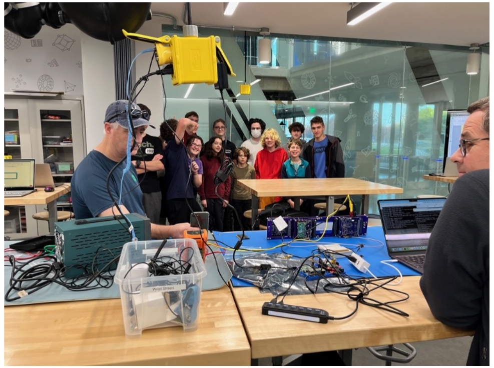
SiLVER SAT

SilverSat Open Items Update

- Flight Model I&T Facilities - Need to secure where we can store flight components, and assemble/test the flight unit
  - **Open**
    - Secured facilities in Columbia for PCB population
    - Evaluating using the APL STEM facilities for flight build
  - Wish to secure facilities for environmental testing, but it is not a requirement for flight
    - Nanoracks will facilitate the vibration testing required for score
- Ground Station Facilities - Need to secure a location for Ground Station
  - **Resolved**
    - Working with Goddard Amateur Radio Club to use their facilities
    - Designed Ground Station equipment to be portable
- Materials - The camera contains ABS plastic
  - **Resolved** - ABS is an acceptable material for Nanoracks

Outline

- Overview & Mission Concept
- Systems Engineering
- Preliminary Designs (Major Components)
    - Power, Avionics, Radio, Ground, Payload, Mechanical
- Prototype 2 Results
- FM Integration and Test
- Programmatics
- Conclusion/Outbrief



Conclusion and Thank You!

- The SilverSat Team is ready for Flight Build and Test
- We would like to thank you, the Reviewers, for your time and your feedback
- We would also like to thank those individuals and organizations that have supported our efforts to date
  - AGI, Inc
  - The Maryland Space Business Roundtable
  - Rockville MakerSpace
  - Steve Morris, Catylator, LLC.
  - Nanoracks
  - NASA CSLI Partners

SilverSat Limited logo designed by Brent Almond, Designer Daddy

SiLVER SAT

Questions?

Review Board Outbrief

How did the CDR go?

Do you have any comments or suggestions for us?

Do you have any action items for us?

Backup Slides

SilverSat Risk Matrix - Likelihood Criteria

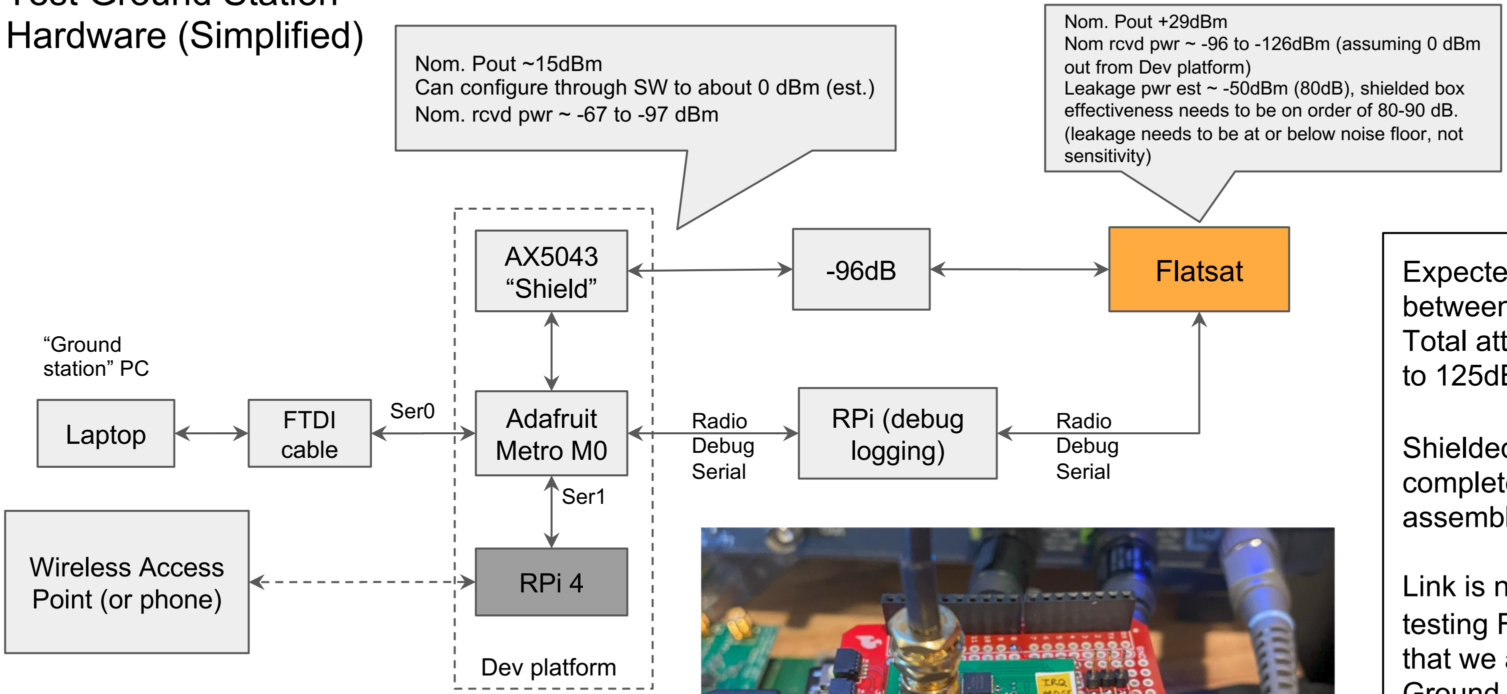
Type || Rank	1	2	3	4	5
Technical - estimated likelihood of not meeting mission requirements (educating)	0-15%	16-25%	26-50%	51-75%	>75%
Cost - estimated likelihood of exceeding available funds	0-5%	6-10%	11-25%	26-50%	>50%
Schedule - estimated likelihood of missing delivery date	0-15%	16-25%	26-50%	51-75%	>75%

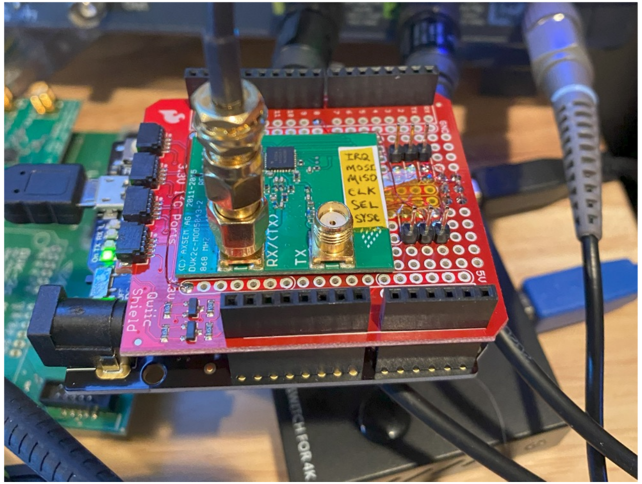
SilverSat Risk Matrix - Consequence Criteria*

Type || Rank	1	2	3	4	5
Technical	No impact to full mission success criteria	Minor impact to full mission success criteria	Moderate impact to full mission success criteria. Minimum mission success criteria are achievable with margin	Major impact to full mission success criteria. Minimum mission success criteria are achievable	Minimum mission success criteria are not achievable
Cost	<2% increase over allocated and negligible impact on reserve	Between 2% and 5% increase over allocated and can handle with reserve	Between 5% and 7% increase over allocated and cannot handle with reserve	Between 7% and 10% increase over allocated and/or exceeds proper reserves	>10% increase over allocated and/or cannot handle with reserve
Schedule	No or negligible slip in schedule	Slip in schedule that does not impact critical path/delivery	Slip in schedule that does impact critical path/delivery, but can be mitigated with schedule reserve	Slip in schedule that does impact critical path/delivery and cannot be mitigated with schedule reserve; slip to delivery = 1-3 months	Slip in schedule that does impact critical path/delivery and cannot be mitigated with schedule reserve; slip to delivery = >3 months

* Criteria are based on GSFC-STD-0002

Test Ground Station Hardware (Simplified)





Expected receiver sensitivity between -110 and -120dBm
Total attenuation required 115 to 125dB.

Shielded enclosure required to complete testing (in fully assembled configuration)

Link is not symmetric; we're testing FlatSat Rx, so its okay that we are not at noise floor of Ground Station Radio

Radio Communication Characteristics

Parameter	Value
Modulation (data mode)	GMSK (h=0.5)
Data encoding	NRZI
Deviation	+/- 2.4 kHz (h=0.5)
Transmit BW	28.8 KHz (main lobe) (19.2kbaud), 14.4 KHz (9600 baud)
Symbol rate (BITRATE) with FEC	19.2kbps
Symbol rate (BITRATE) without FEC	9600 bps
FEC	Uncoded, or Rate 1/2 , k=7 Convolutional
Operating frequency range	400 to 520 MHz
Operating frequency	TBD
Receiver Bandwidth	14400 Hz (9600) 28800 Hz (19200)
Error control	TBD
Radio Serial1 settings	19200, N, 8, 1
Radio Serial0 settings	57600, N, 8, 1

What Way are We Pointing?

5.4.1 Left Hand Circular Polarization

“The Antenna is positioned at the origin of the coordinate system hence the Antenna boresight (θ =0 deg and φ =0 deg) is along the Z axis on the top cover of the Antenna.”

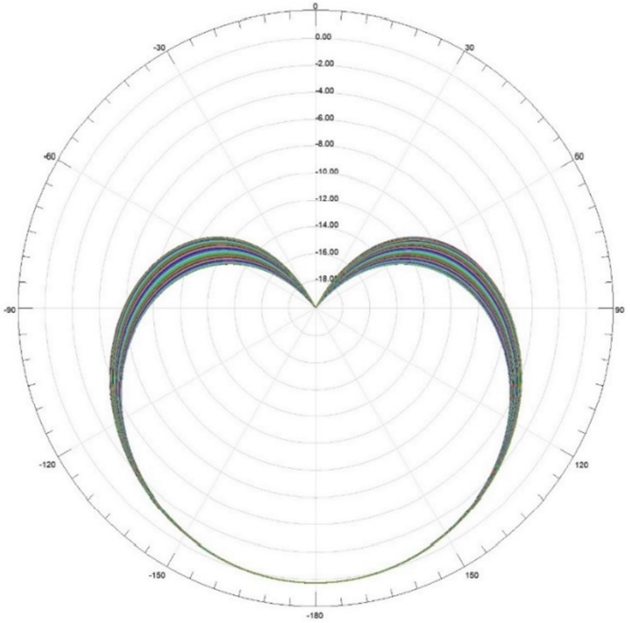
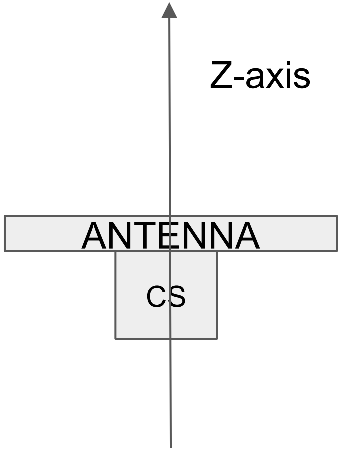


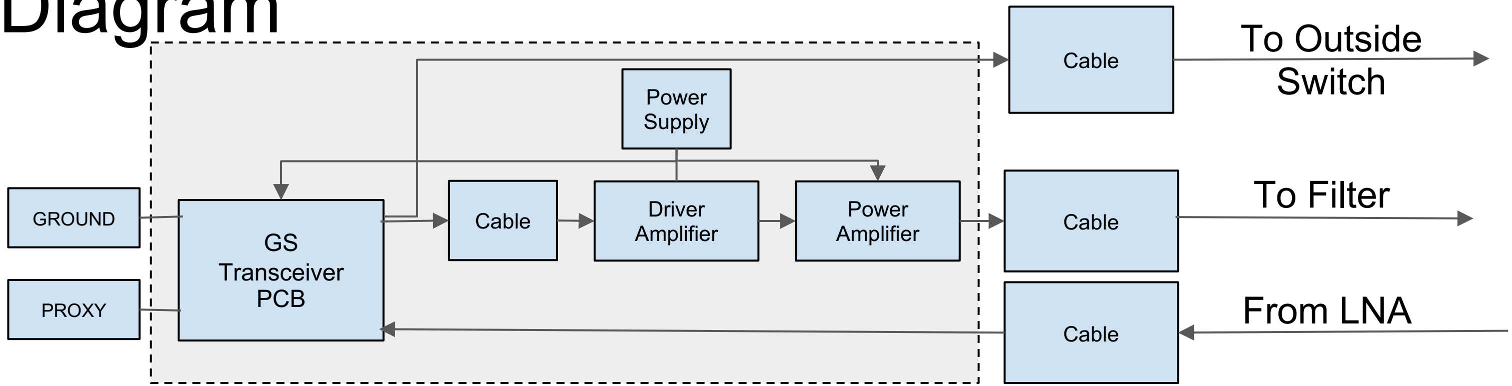
Figure 7: LHCP Radiation Pattern of the Antenna (Free Space)



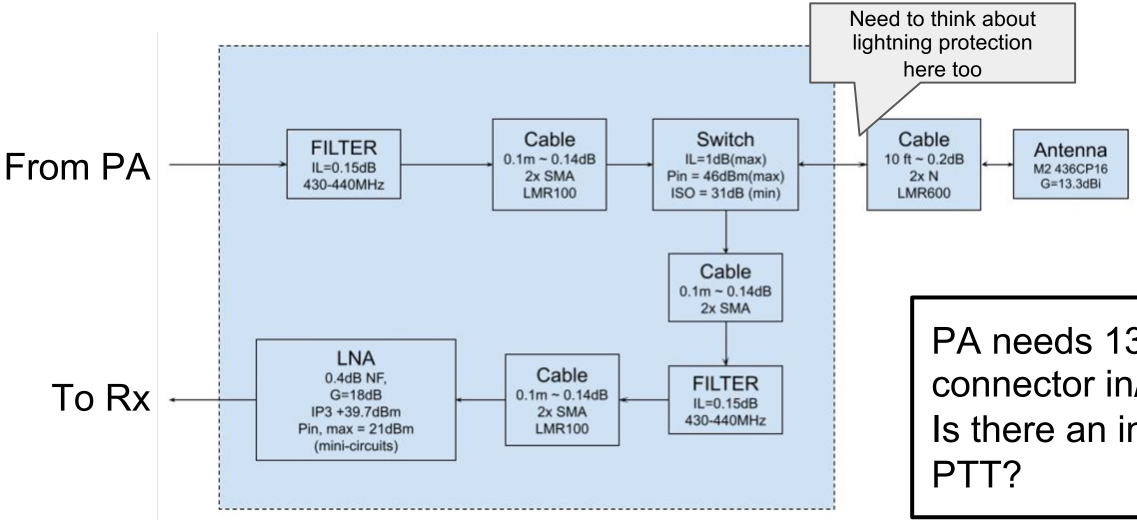
So, if the camera is pointed down, then we’re LHCP

Top-Level Diagram

Inside Segment



Outside Segment



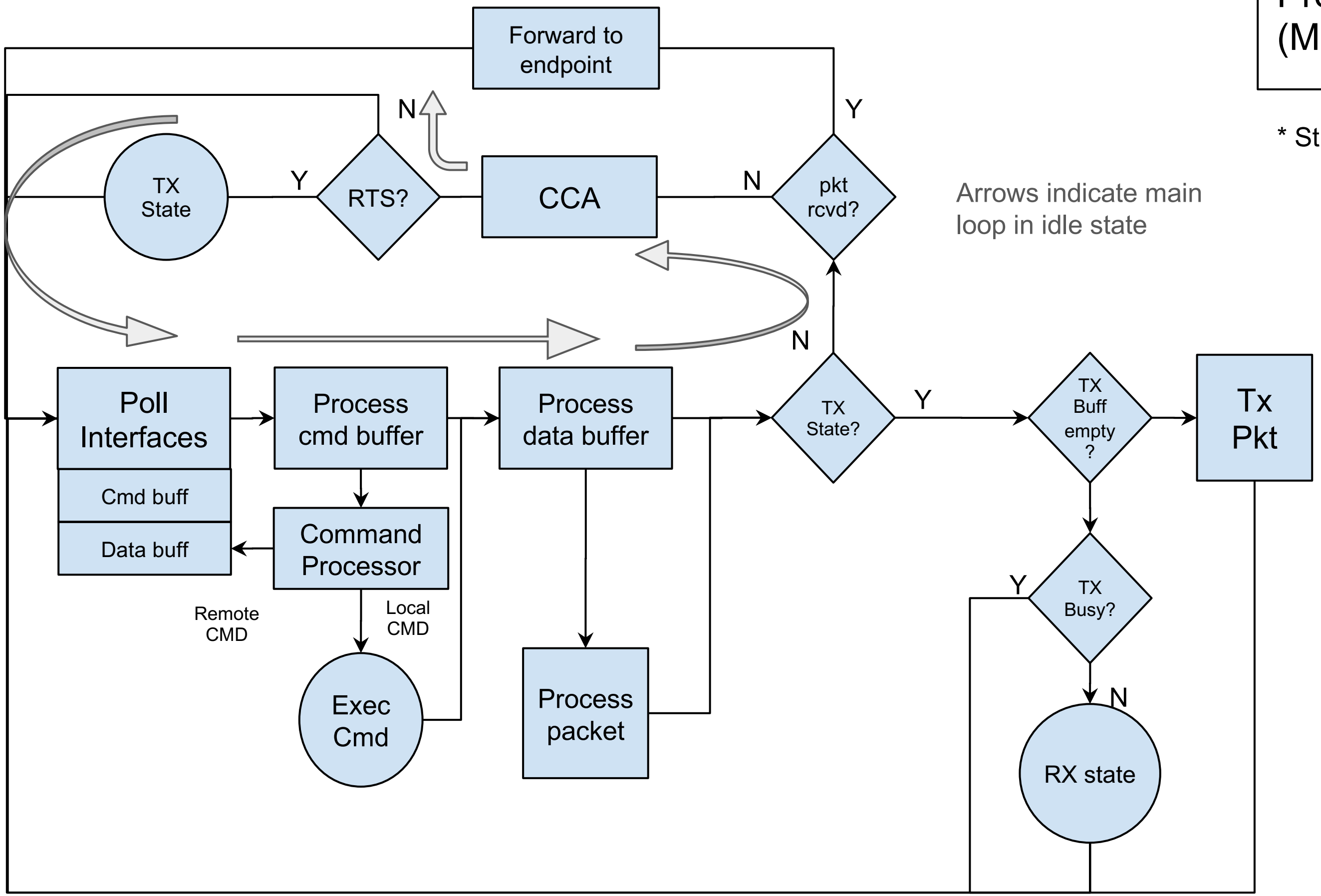
Add lightning arrestors at entry

PA needs 13.8V @ 13A, N-connector in/out.
Is there an interface on PA?
PTT?

SILVER SAT

Prototype Radio Code Main Loop (Mentor Version*)

* Student code used for Morse Code Generation



Important points:

- Single threaded, non-blocking to max extent possible
- Sets up and manages Radio
- Continually polls interfaces (Serial0, Serial1, SPI)
- No flow control. BIG buffers
- Transmit/Receive state must be changed by software
- Performs clear channel assessment, transmits when clear
- Processes cmds, executes if local, forwards if remote
- Fast frequency updates for doppler compensation

Radio Design Decisions

- Payload talks directly to the Radio when tweeting
- No AX.25. Opted for tncattach over kissattach to reduce per packet overhead
- No layer 2 protocol, just TCP. No HW flow control
  - We rely on big buffers and TCP to handle end to end flow and error control
- Test Ground Station is assumed to be a duplicate of the Satellite Radio, without PA (see Ground Station section)
- Doppler compensation only on ground (none on satellite)
- Doppler offsets provided by Ground Station software
  - Radio can re-tune quickly within expected doppler offset range (AX5043 supports FHSS)
  - Ground Station forwards offset to center frequency through local commands to Radio
    - Radio retunes up/down depending on TX/RX state and sign of offset