ASEN 4028 Senior Projects - Spring 2019

Test Readiness Review

Auto-Tracking RF Ground Unit for S-Band

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ENGINEERING EXCELLENCE FUND

Advisor: Professor Dennis Akos

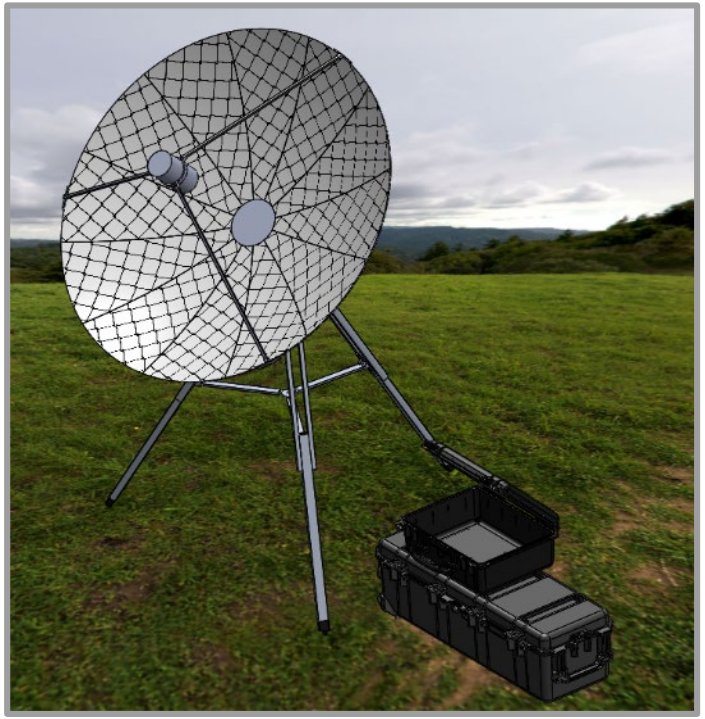
Customer: Raytheon

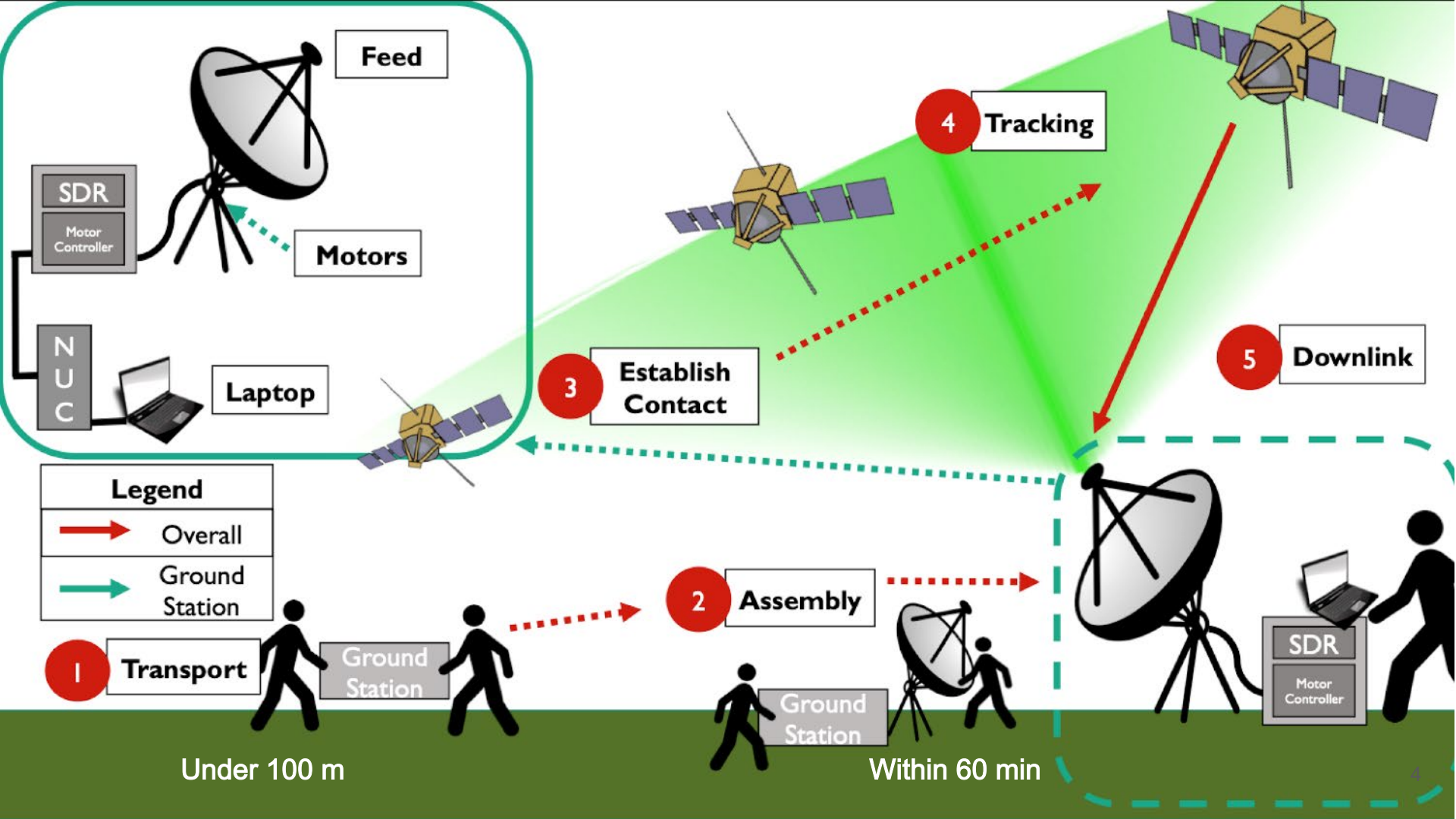
Project Overview

Project Purpose & Objectives

Mission Statement: The ARGUS ground station is designed to be able to track a LEO satellite and receive a telemetry downlink using a platform that is both portable and more affordable than current S-Band ground stations.

- Commercial-off-the-shelf (COTS) where possible
- Interface with user laptop
- Portable: 46.3 kg (102 lbs), able to be carried a distance of 100 meters by two people



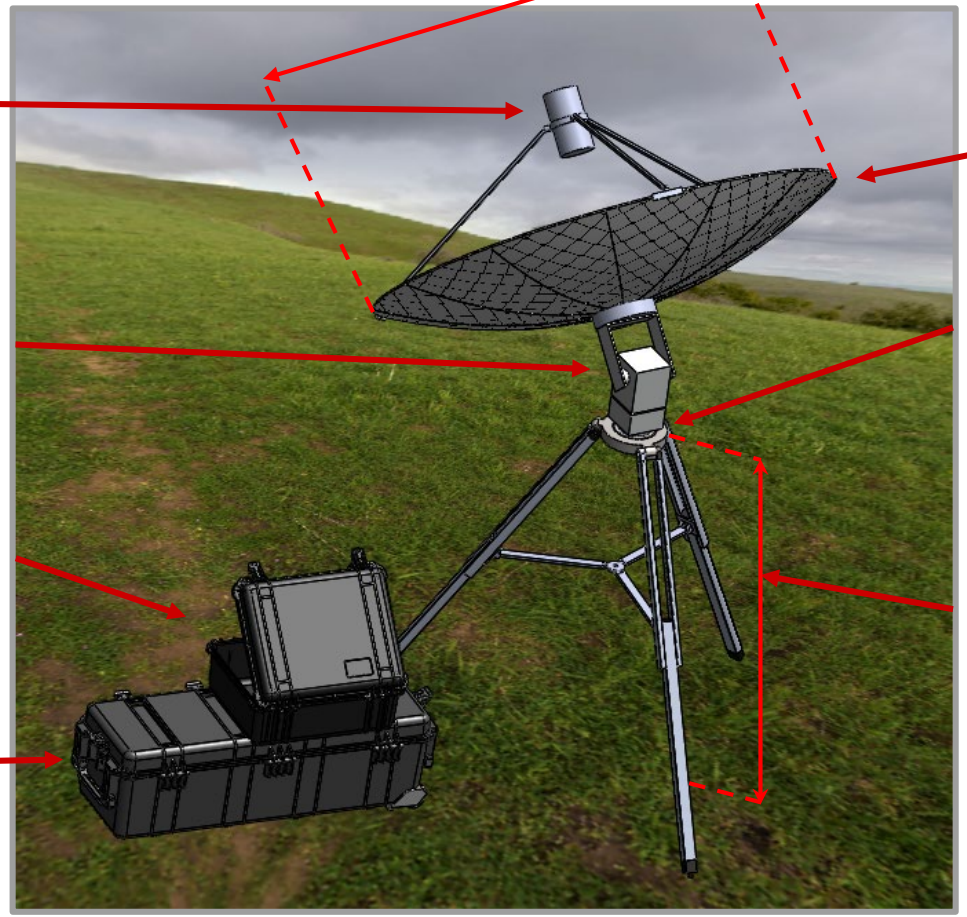

Feed
SDR
Motor Controller
Motors
NUC
Laptop
4 Tracking
3 Establish Contact
5 Downlink
Legend
Overall
Ground Station
1 Transport
Ground Station
2 Assembly
Ground Station
SDR
Motor Controller
Under 100 m
Within 60 min

Levels of Success

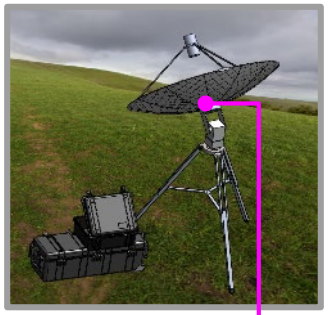
	Mechanical	Software	Electronics
Level 1	- Transportable in back of truck - Assembled < 6 hours **- Track LEO satellites at 5°/sec** - Communicate with LEO satellite at 10+° elevation above horizon	**- Take TLE data and for az/el pointing commands** **- Data packets demodulated using QPSK** - BER ⩽ 10^{-5}	**- Provide power to all sub - systems** **- System used with monitor, keyboard, and mouse**
Level 2	- Transportable by unpowered rolling vehicle - Assembled < 2 hours	- Able to predict LEO satellite locations to less than 2.75° deg accuracy - Reconfigurable for other frequency bands	**- System used with personal laptop interfaced using secure shell over a Cat-5 ethernet cable** - Reconfigurable for other frequency bands
Level 3	- Two people carry 100 meters - Assembled < 1 hour	- BER ⩽ 10^{-9}	

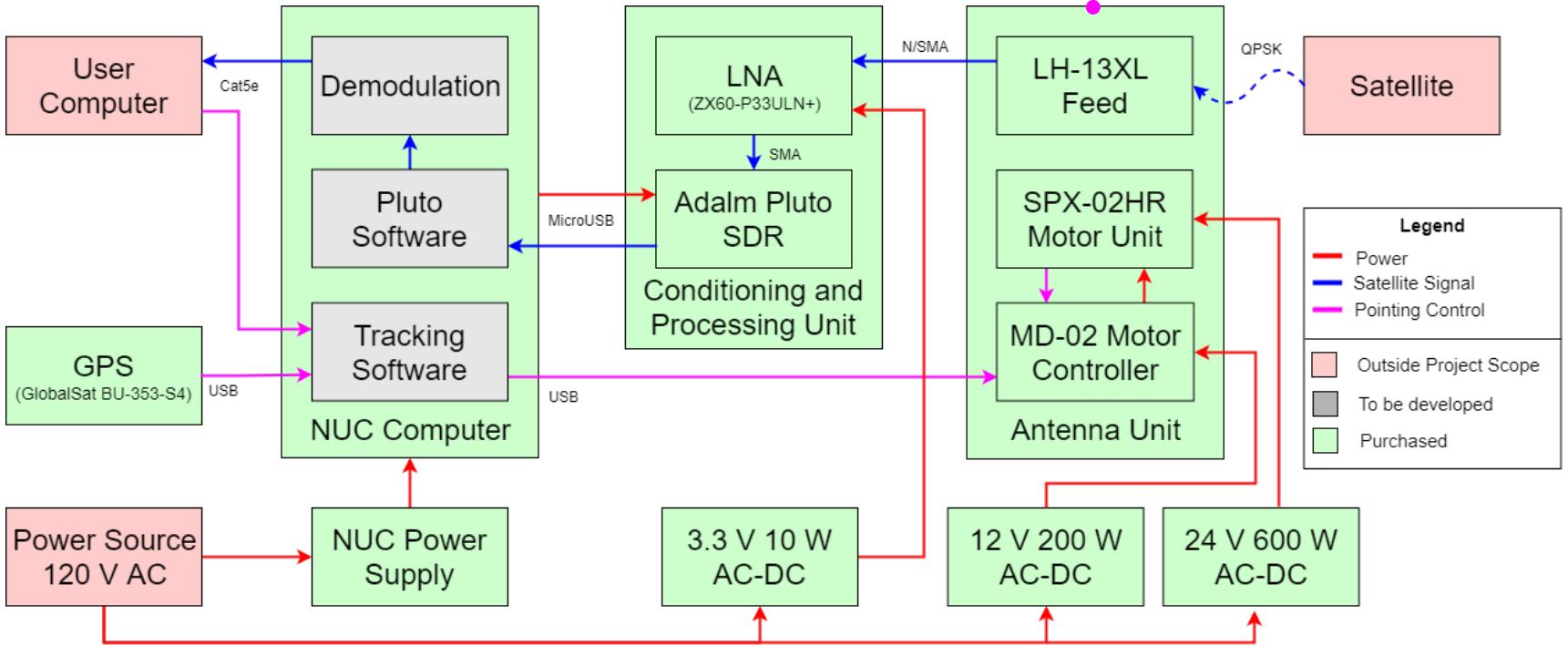
Bold: Complete and verified

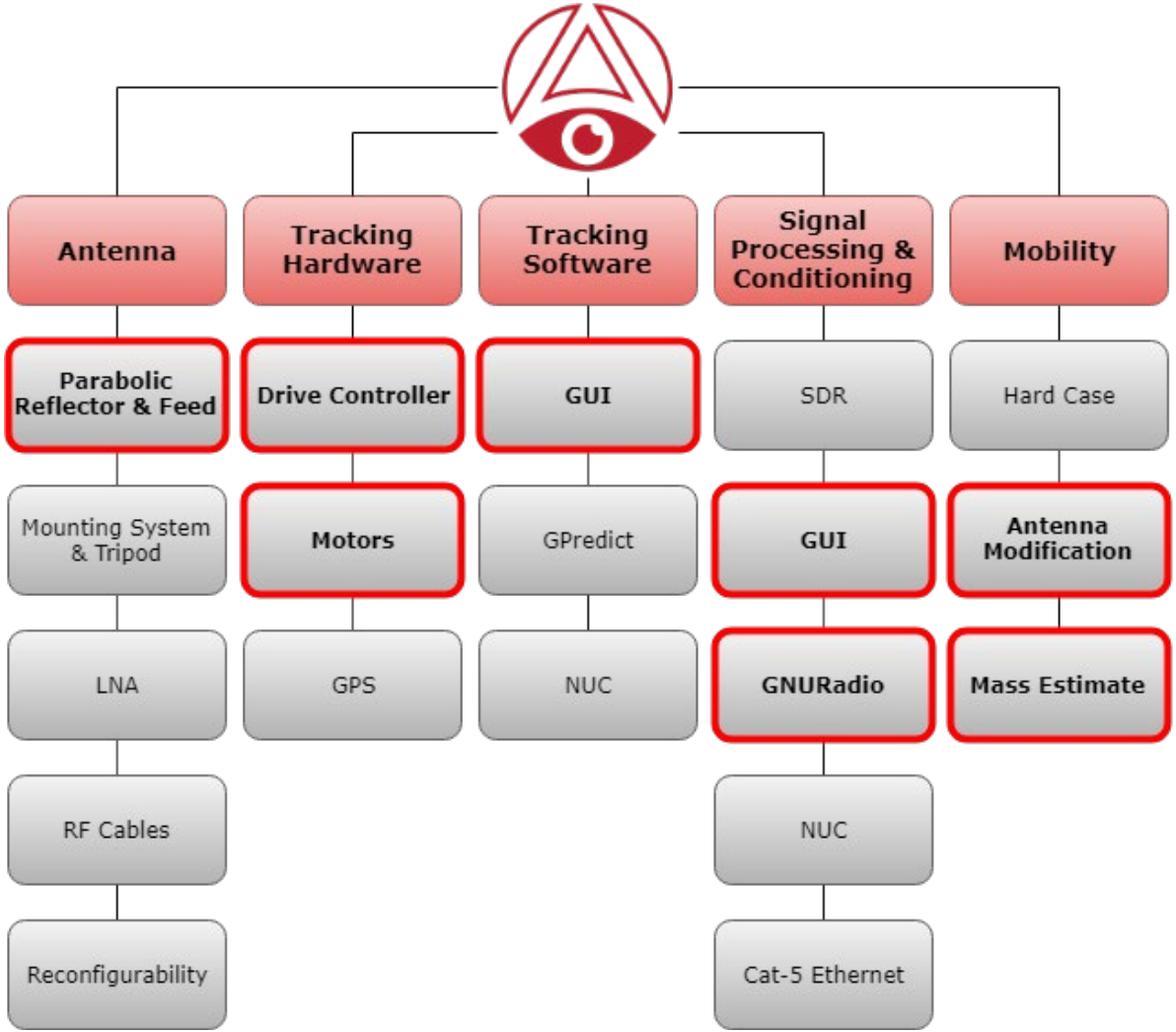
Baseline Design



Functional Block Diagram

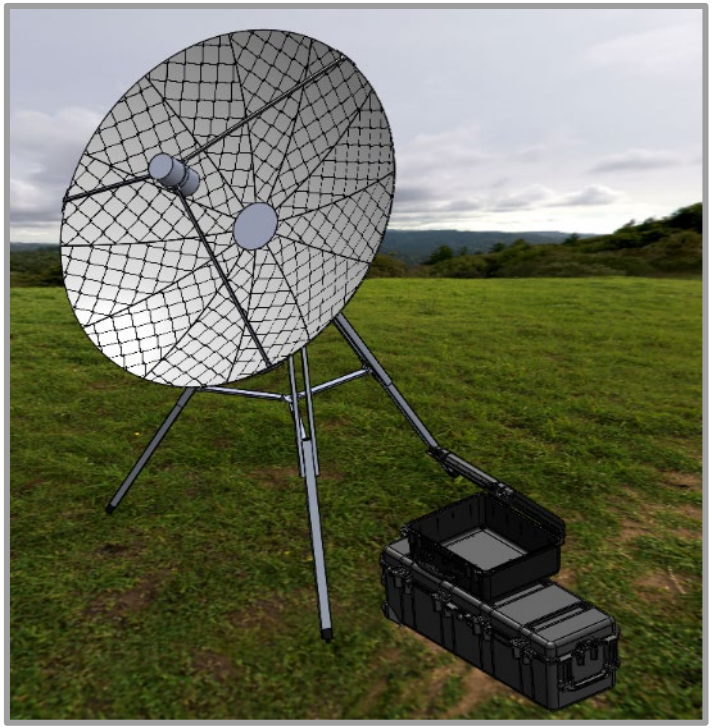





Antenna
Tracking Hardware
Tracking Software
Signal Processing & Conditioning
Mobility
Parabolic Reflector & Feed
Drive Controller
GUI
SDR
Hard Case
Mounting System & Tripod
Motors
GPredict
GUI
Antenna Modification
LNA
GPS
NUC
GNURadio
Mass Estimate
RF Cables
NUC
Reconfigurability
Cat-5 Ethernet
Critical Elements

Updates from MSR

- Electrical relay on motor controller shorted during component testing
  - Replaced relay, motor tested 2/22, full range of motion functionality
  - Demo-dish testing and pointing accuracy testing is now delayed
- All software component tests are complete
- Modified dish being worked on
  - Adapter plates made (2/15)
  - Tabs cut (2/22)



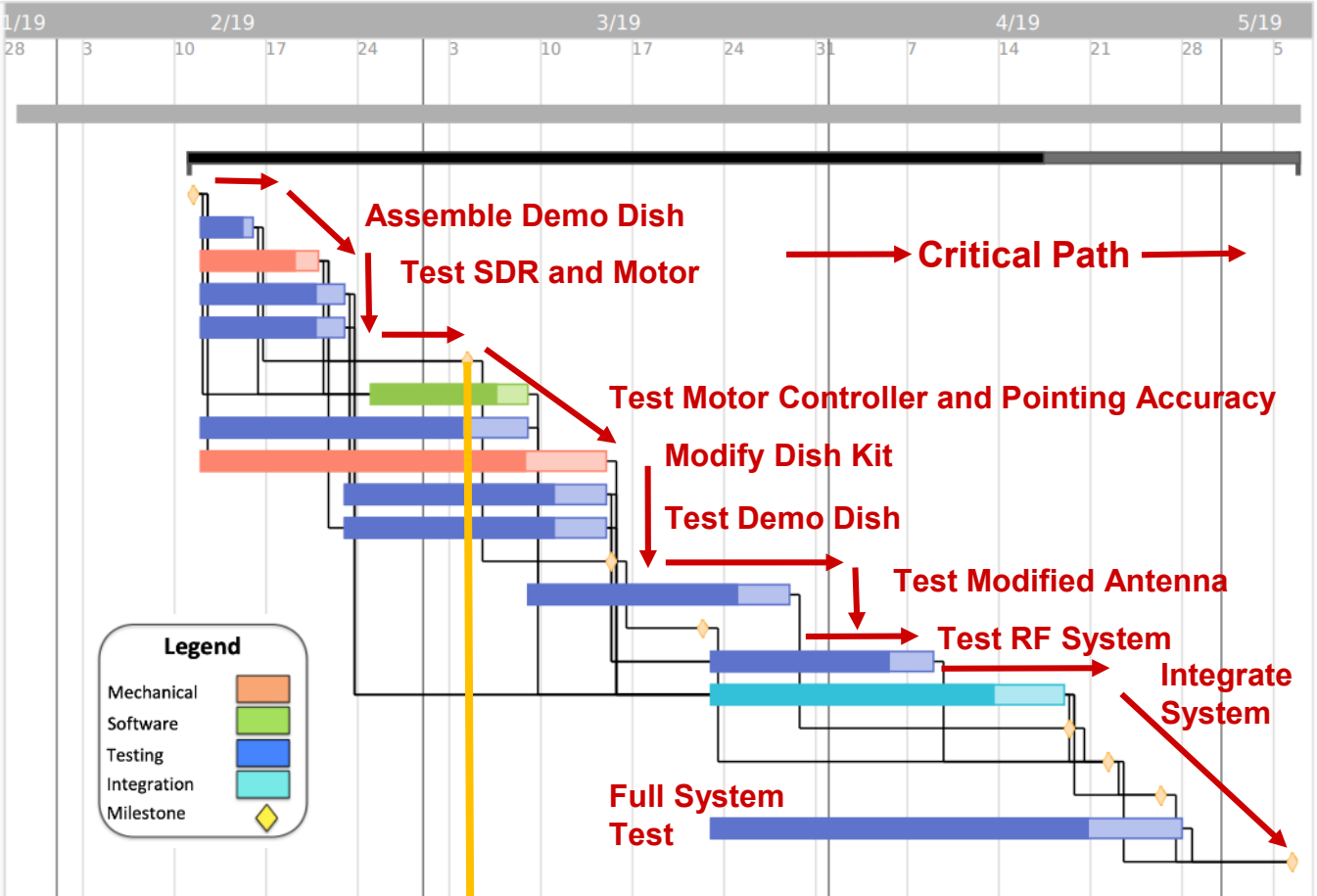
Project Schedule

Schedule

ARGUS

Spring Semester

- MSR
- Test RF Component Losses
- Assemble Full Demo Dish
- Test SDR
- Motor Testing
- TRR
- Calibrate Tracking Software
- Motor-Controller Testing
- Modify Dish Kit
- Test Pointing Accuracy
- Test Demo Dish
- AIAA Paper Due
- Test Modified Antenna
- Last Machining Day
- Test Full RF System
- Fully Integrate System
- AES Industry Symposium
- SFR
- College Expo
- Test Full System
- Final Report Due



Test Readiness

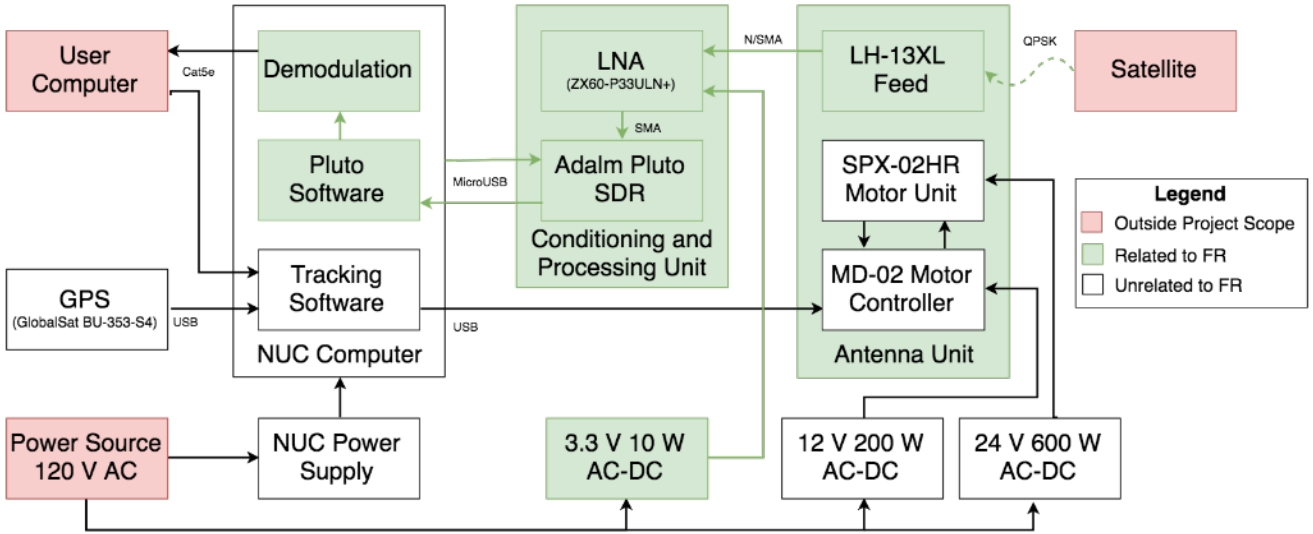
Functional Requirement 1

FR 1.0	The ground station shall be capable of receiving signals from a Low Earth Orbit satellite between 2.2 - 2.3 GHz, in Quadrature Phase Shift Keying (QPSK) modulation with a Bit Error Rate (BER) of 10^{-5}, a bit rate of 2 Mbit/s, and a G/T of 3 dB/K.

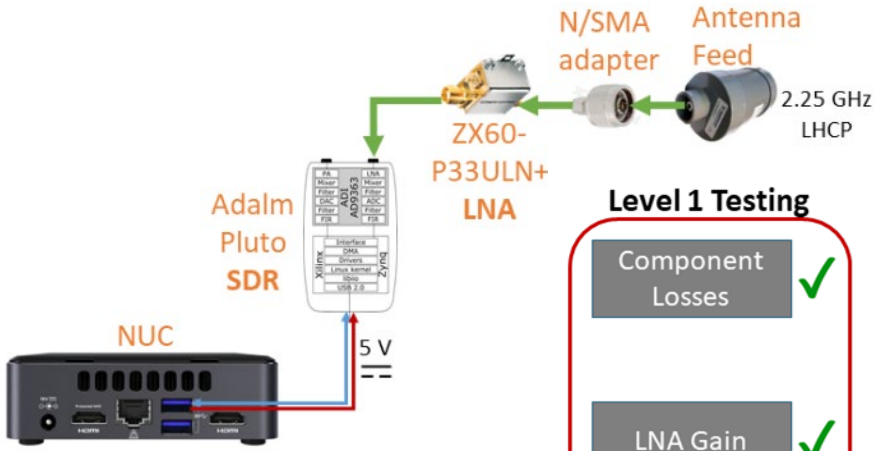
RF Path Verification

Related Components:

- Antenna dish
- Feed
- Low noise amplifier and power converter
- N-SMA adapter
- SMA cables and passthrough
- Signal processing software
- MicroUSB cables
- Adalm Pluto SDRs



RF Path Verification



Level 1 Testing

- Component Losses ✓
- LNA Gain ✓
- SDR -> Dipole ✓
- BER ✓
- NUC Demodulation ✓

Level 2 Testing

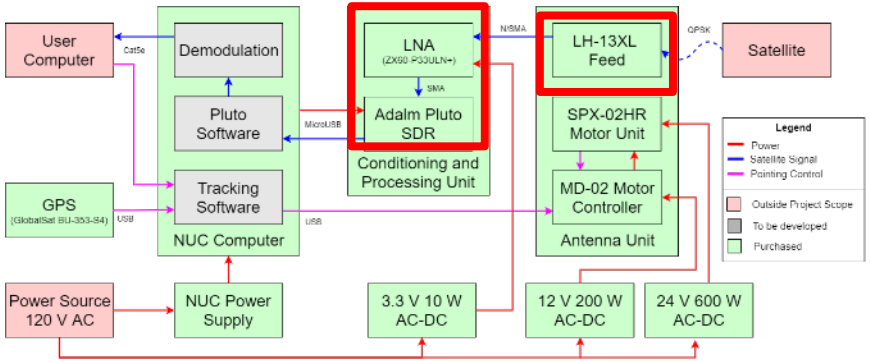
- Feed Rx Test ✓
- Demo Dish Gain 3/14
- Modified Dish Gain 3/22

Level 3 Testing

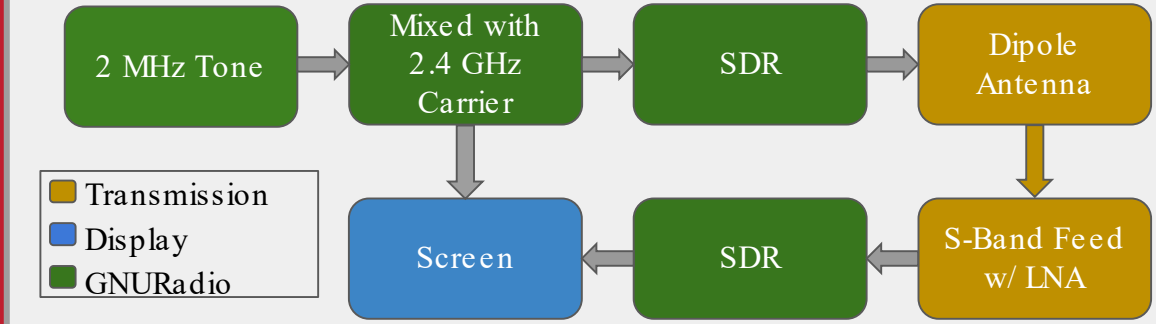
- Full RF System Test 4/5

Level 2 - Feed Rx Test with LNA and SDR ✓ Complete

Objective	● Ensure feed picks up at target frequency ● Show LNA can amplify signal
Location	● Discovery Learning Center

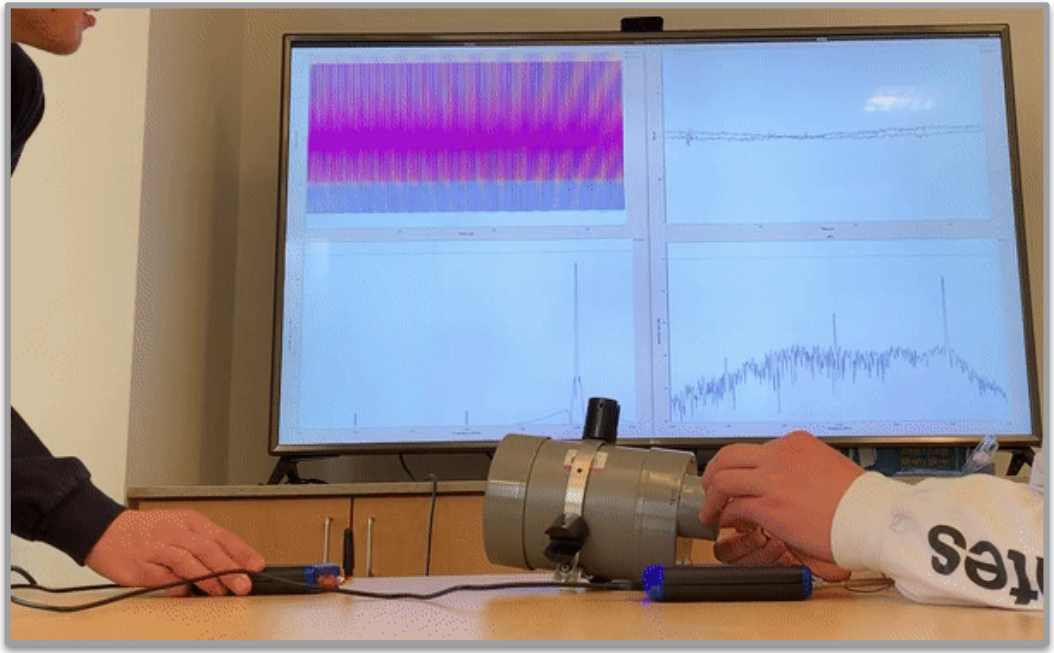


Test Design



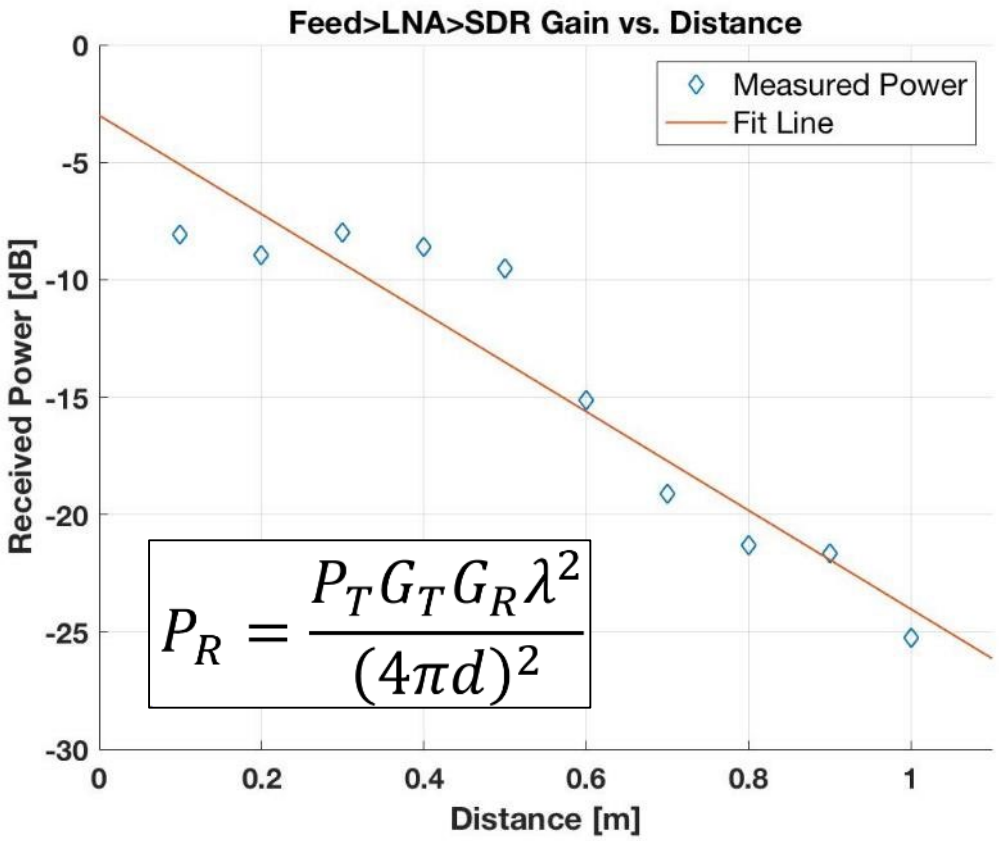
Level 2 - Feed Rx Test with LNA and SDR ✓ Complete

Safety	● No concerns
Project Risk Mitigation	• Shows that feed can pick up target frequency • LNA capable of amplifying target frequency • SDR can process target frequency



Requirement	DR 1.1: The ground station shall receive between 2.2 GHz and 2.3 GHz

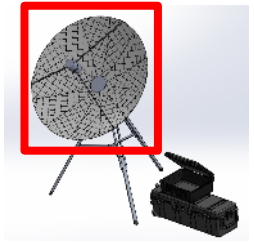
Feed Rx Test with LNA and SDR Results

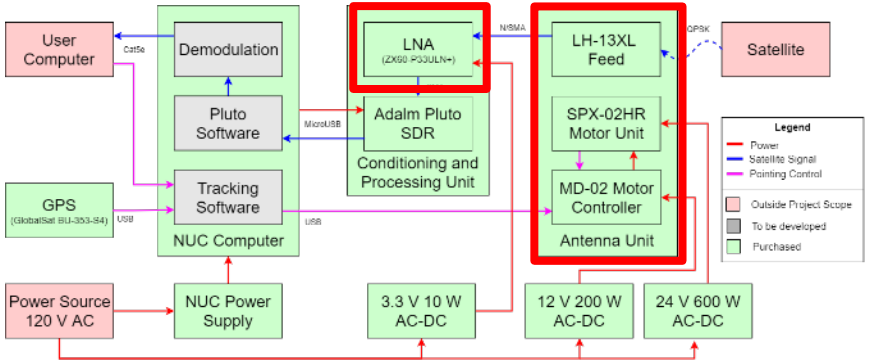


Expectation	● Power loss with increased range, exact loss rate nearly impossible to model
Results	● Gain decreases at a rate of -23.12 dB/meter with test design ● Noise floor of -64.90 dB
Verification	● SDR capable of processing 2.4 GHz signal ● NUC can perform FFT on 2.4 GHz signal

Level 2- Demo and Modified Dish Gain- **March 14 & 22**

Objective	● Ensure dish will have enough gain to validate link budget ● Analyze gain change between demo and modified dish
Location	● Business Field
Test Design	● Use SDR to transmit tone at 2.4 GHz ● Analyze power level received by feed alone and demo dish with feed on network analyzer ● Repeat test conditions with modified dish

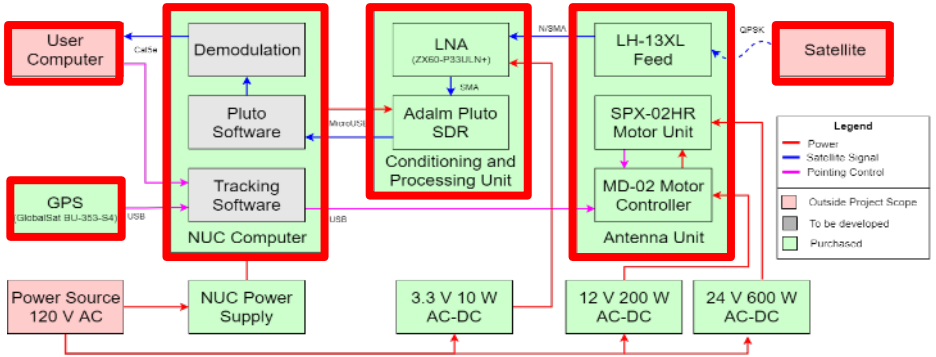




Requirement	Expected	Verification	Project Risk Mitigation
DR 1.5: The ground station antenna shall have a gain of at least 24.3 dBi.	27 dB gain from antenna	Network analyzer power levels	Reduces risk of not having enough gain to receive signal

Level 3 - Full RF Subsystem Test **April 2**

Objective	● Ensure full RF system can receive a signal with a high enough gain
Location	● Engineering Center Roof
Test Design	● Point dish at known satellite location ● Attempt to receive signal from satellite

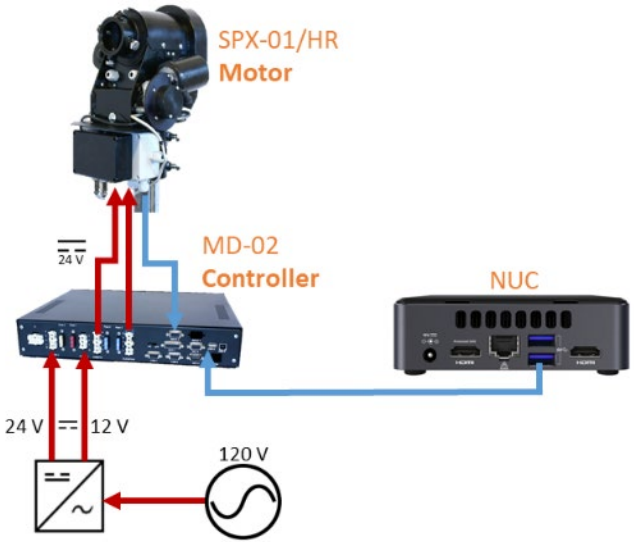


Requirement	Expected	Verification	Project Risk Mitigation
FR 1	Signal received	Receive, demodulate, and save incoming data	Reduces risk of not being able to receive a signal

Functional Requirement 2

FR 2.0	The ground station shall mechanically steer a dish/antenna system to follow a LEO satellite between 200 km to 600 km between 10° elevation and 170° elevation.

Tracking Verification



Level 1 Testing

- Power Converter Output ✓
- Controller Power ✓
- Motor Power ✓
- GPS Functionality ✓

Level 2 Testing

- Computer Motor Control ✓
- Motor Slew Rate ✓
- Motor Range of Motion ✓
- Encoder Accuracy ✓
- Sun Calibration 3/08

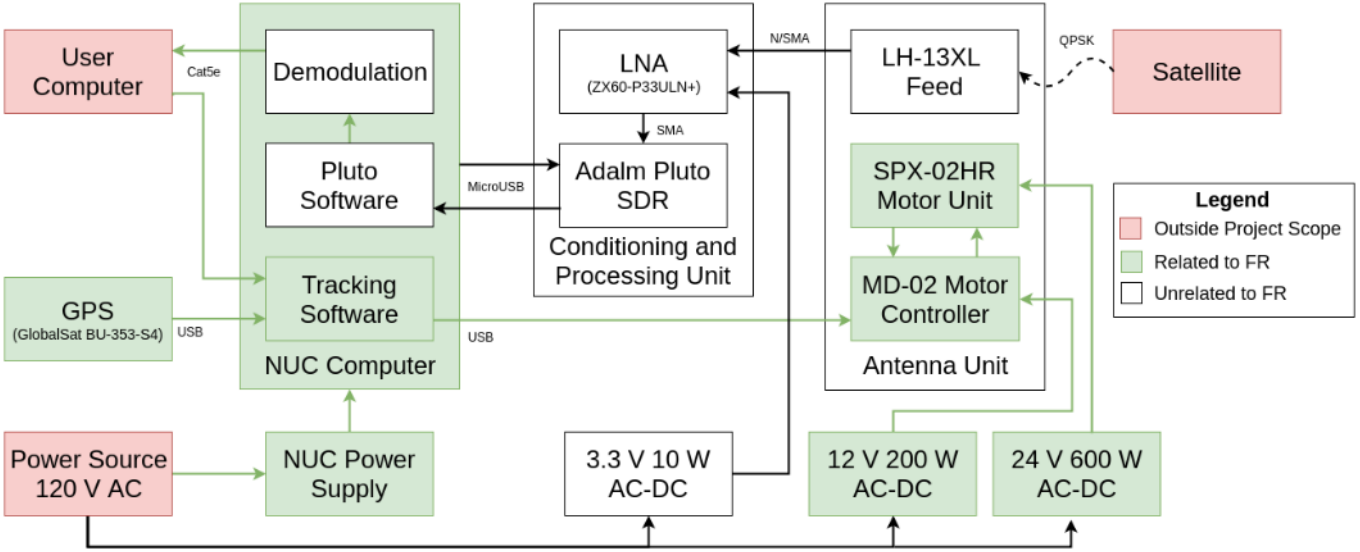
Level 3 Testing

- Track Satellite Over Complete Pass 4/14

Tracking Verification

Related Components:

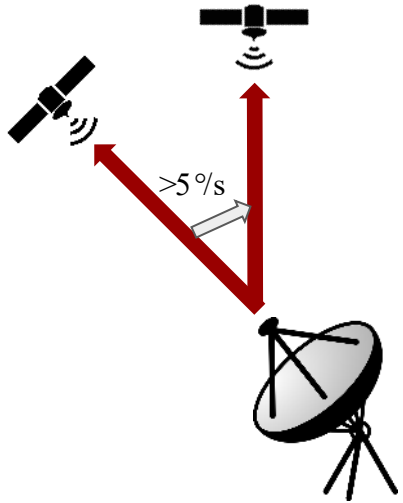
- GPS
- Motors + controller
- Power converters
- NUC computer and power supply
- Cat-5 ethernet cable
- GUI
- Tracking software
- Motor control software
- USB type B cable



Level 2 - Motor Slew Rate Test Design

✓ Complete

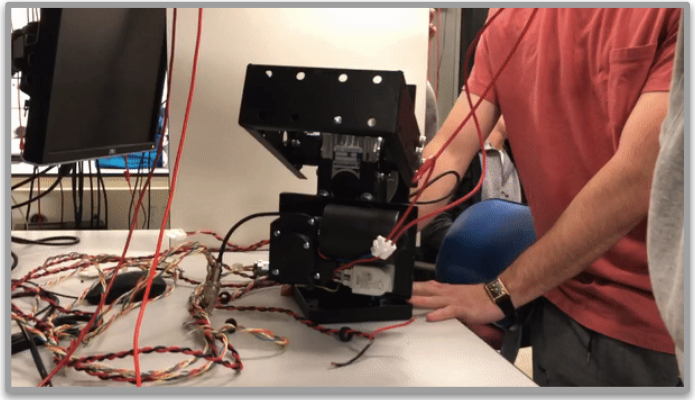
Objective	Ensure motor can move at 5°/s
Location	Senior Projects Room
Test Design	• Give motor a command to rotate 180° • Verify that it rotates in less than 36 seconds • Run 3 trials in each direction

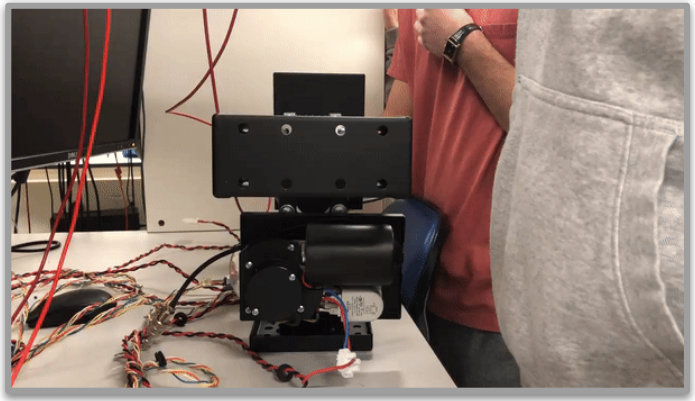


Inputs	Requirement	Expected	Verification	Project Risk Mitigation	Safety
Angle Command	DR 2.3: The antenna motor shall be able to move the antenna at a slew rate of 5°/s	Slew rate: 7.2°/s	Slew time less than 36 seconds	Motor can slew at speed required for tracking LEO satellite	High voltage & current

Level 2 - Motor Slew Rate Test Results

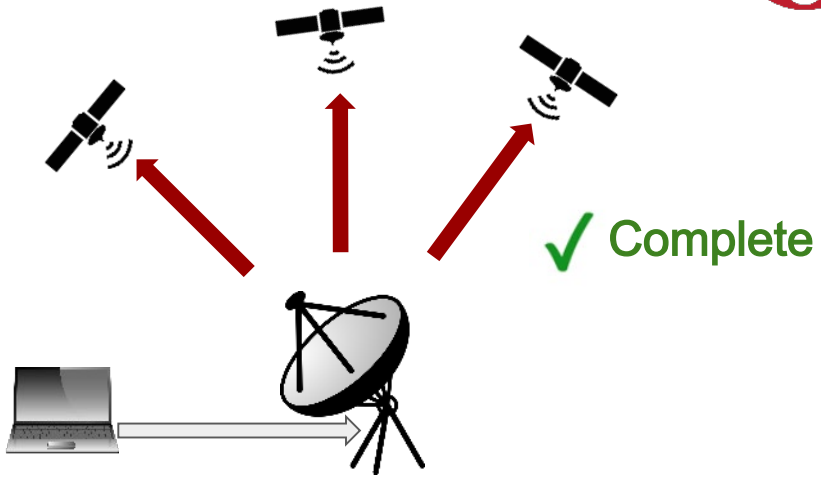
Direction	Average Slew Time (3 Trials)	Average Slew Rate
Expected per Spec Sheet	25 sec	7.2 degrees/sec
Azimuth: 0° to 180°	30.76 sec	5.852 degrees/sec
Azimuth: 180° to 0°	30.29 sec	5.942 degrees/sec
Elevation: 0° to 180°	30.21 sec	5.958 degrees/sec
Elevation: 180° to 0°	29.99 sec	6.002 degrees/sec





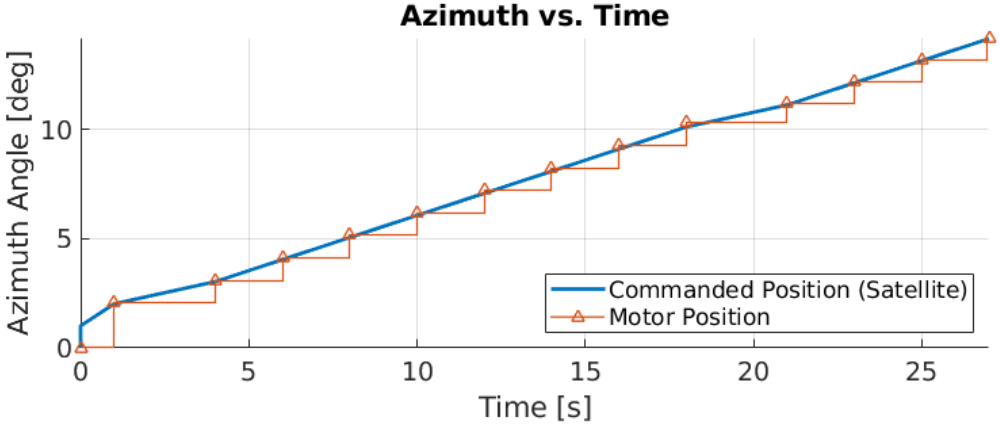
Level 2 - Motor Control Software System Test Design

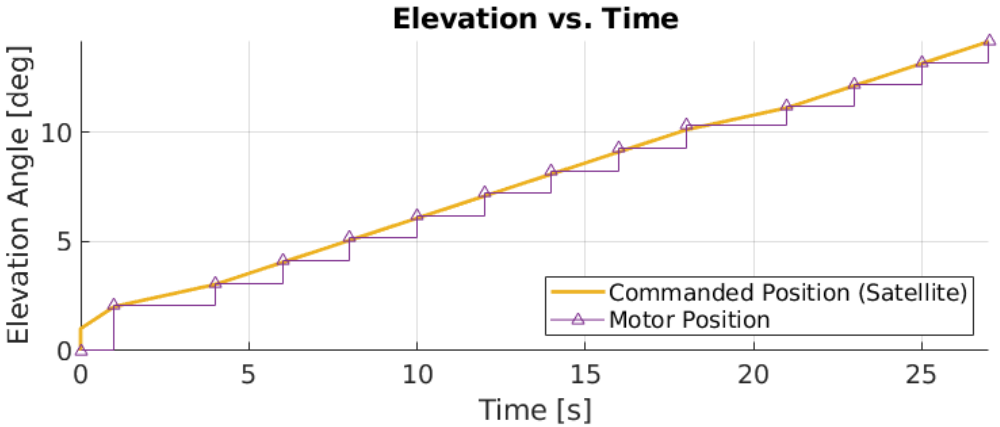
Objective	Ensure GUI can control motor to follow a satellite through a pass
Location	Trudy's Lab
Test Design	• Create a set of simulated passes • Ensure motor control software can control motor to follow passes

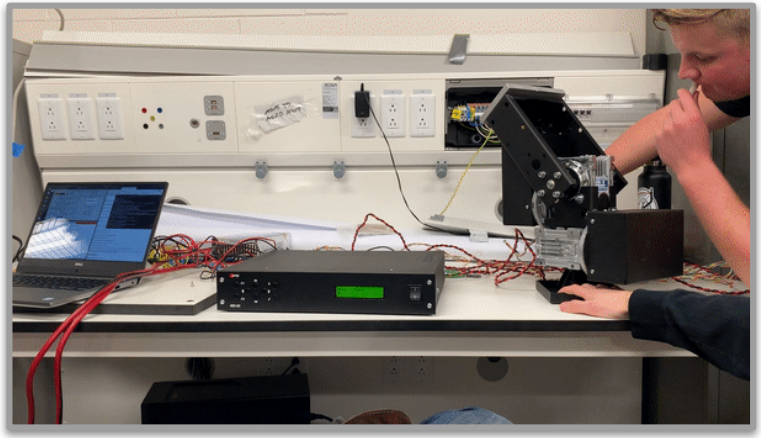


Inputs	Requirement	Expected	Verification	Project Risk Mitigation
Simulated passes	FR 2	Motor will follow all simulated passes accurately	Ensure motor can follow all simulated passes	Ensures that motor can track LEO satellite accurately

Level 2 - Motor Control Software System Test Results

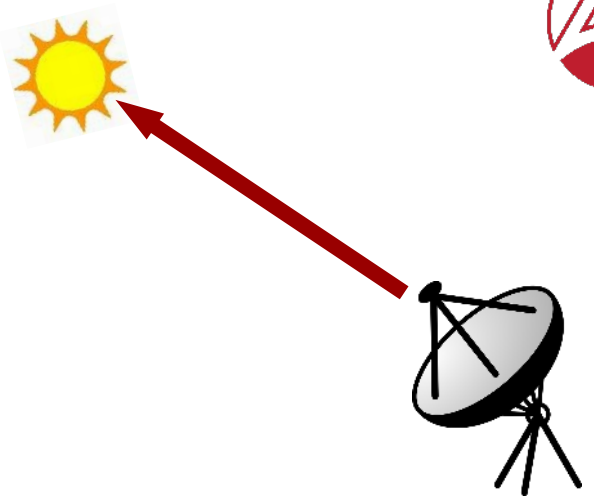






Results	Maximum discrepancy between satellite path and motor pointing is **2.86 degrees.** This remains within expected antenna beamwidth.

Level 2- Sun Calibration - **March 8**

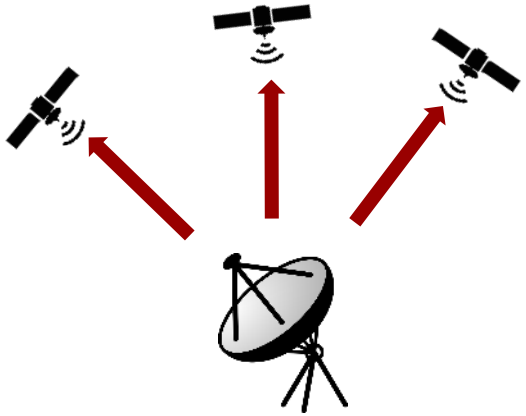


Objective	Ensure system can see the sun in the power spectrum
Location	Engineering Center Roof
Test Design	• Point dish at sun • Ensure power can be seen in frequency spectrum and location can be fine tuned using power spike

Inputs	Requirement	Expected	Verification	Project Risk Mitigation	Safety
Sun location	DR 2.2: The pointing control accuracy must be within 4.5° to maintain downlink capabilities throughout the entire pass.	Sun shows up in frequency spectrum	Ensure sun can be seen in frequency spectrum and be able to find maximum power	Ensures that motor can be calibrated to reduce pointing error	High voltage & current

Level 3 - Full Tracking Subsystem Test - **April 14**

Objective	Ensure ground station can follow satellite over a pass
Location	Engineering Center Roof
Test Design	• Assemble NUC, motor, motor controller, dish, and tripod • Use user laptop to control ground station over a satellite pass



Inputs	Requirement	Expected	Verification	Project Risk Mitigation	Safety
Satellite TLE file from SWAS and SWIFT	FR 2	Signal to noise ratio around 17.21	Signal received from tracked satellite	Ensures that entire tracking subsystem functions as desired	High voltage & current

Functional Requirement 4

FR 4.0	ARGUS shall weigh less than 46.3 kg (102 lbs) and be capable of being carried a distance of 100 meters by two people.

Mobility Verification

Level 1 Testing

Component Weight Measurement ✓

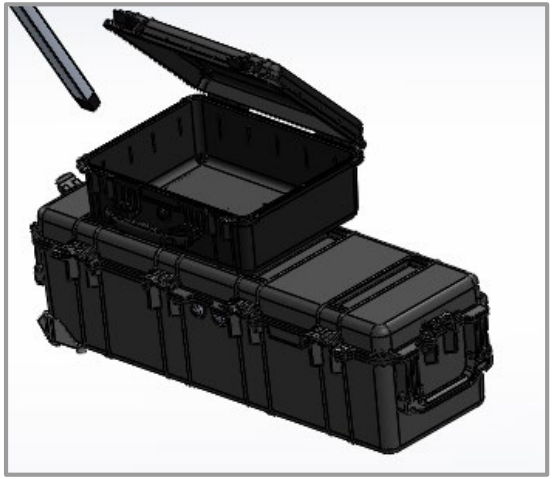
Level 2 Testing

Integrated Case Weight Measurement 3/29

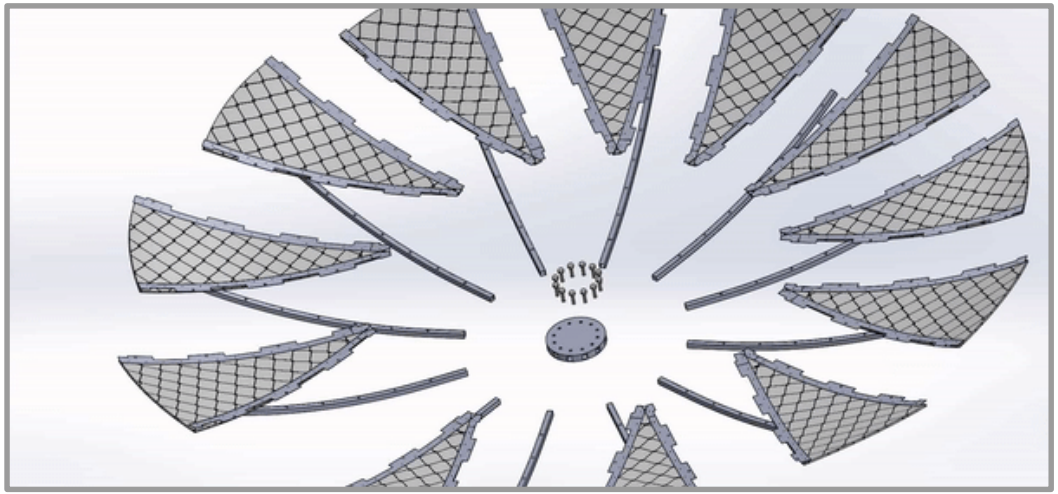
Section Assembly Test 3/31

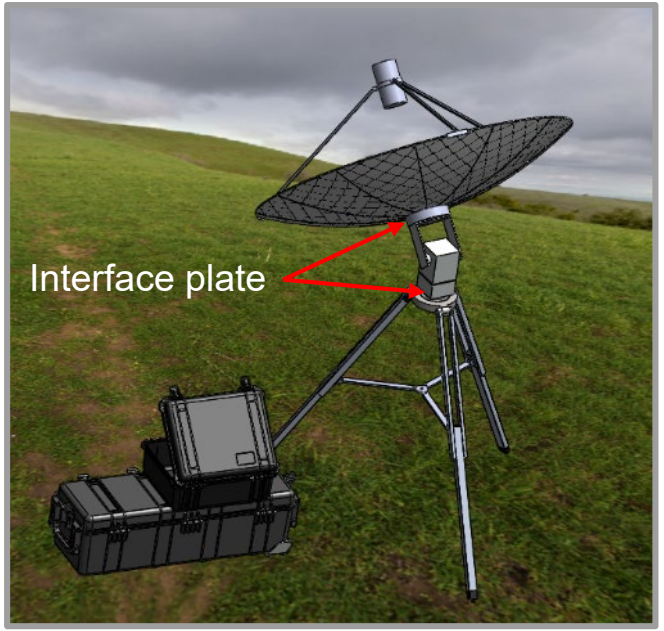
Level 3 Testing

Full Carry/Assembly Test 4/14



Assembly Explanation





Level 1- Component Weights

✓ Complete

Objective	● Verify component weight compared to spec sheets ● Estimate final system total weight
Location	● Senior Projects Room
Test Design	● Weigh components on scale

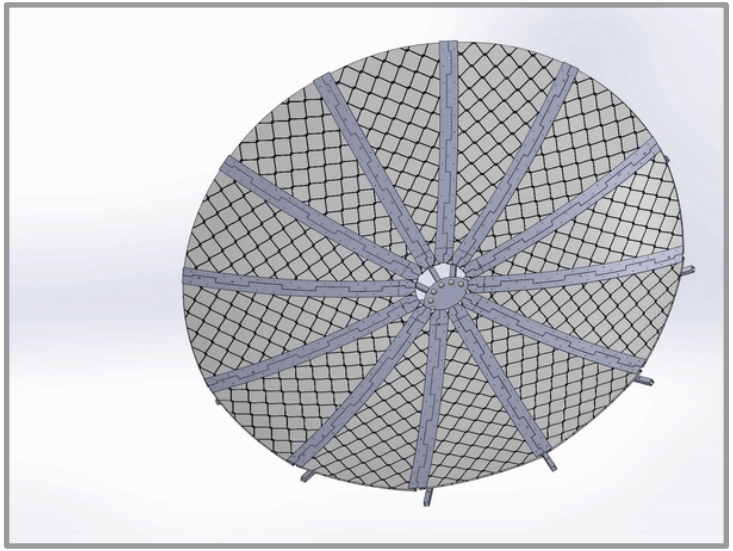
Component	Weight [kg]		
Dish original hardware	2.63	Feed	0.57
Dish modifications	4.22	Tripod	5.82
Electronics	5.02	Cases	T.B.D
Motor	13.51	Power	2.83

Requirement	Expected	Verification	Project Risk Mitigation
DR 4.1: The ground station shall weigh less than 46.3 kg.	Entire system weight less than 46.3 kg	Weighed components on scale	Ensure system can be carried into the field

Current Total	34.59 kg
Maximum	46.3 kg

Level 2 - Dish Section Assembly- **March 22**

Objective	● Verify assembly time ● Determine amount of tools and components needed
Location	● Senior Projects Room
Test Design	● Replicate in field assembly

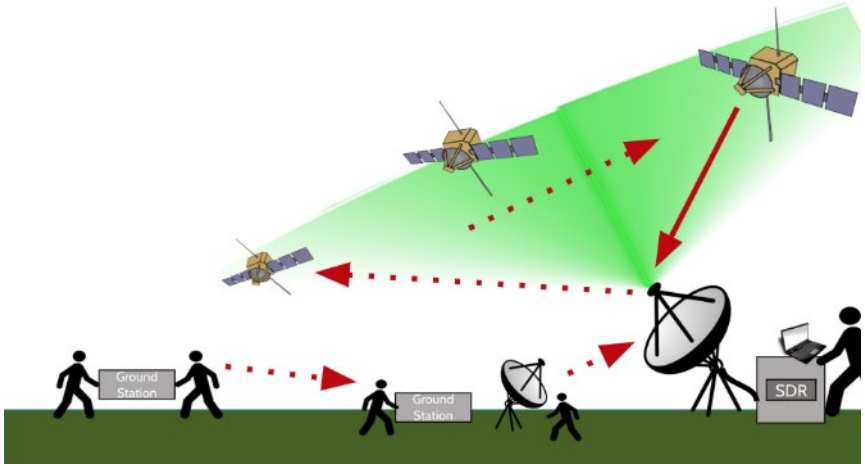


Requirement	Expected	Verification	Project Risk Mitigation	Safety
DR 4.2: ARGUS shall be able to be assembled by 2 operators in less than 60 minutes.	Assembly time is less than 60 minutes with <2 tools	Timed two person assembly test	Ensures dish can be assembled in required amount of time	Cuts or injuries assembling dish

Full System Test

Full System Test- April 14

Objective	Verify entire ground station functions as desired
Location	Business Field
Test Design	• Transport and set up ground station • Track satellite across entire pass • Receive signal from satellite

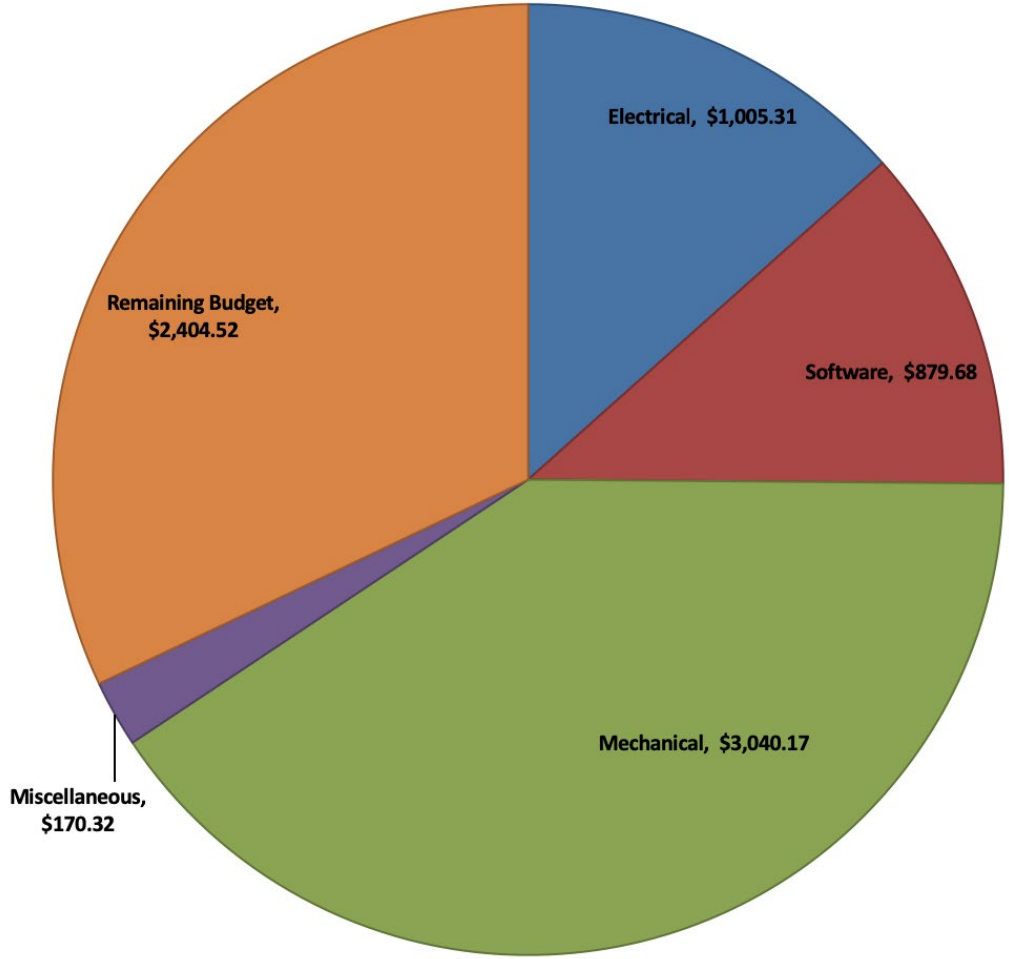


Data Needed	Requirement	Expected	Verification	Project Risk Mitigation	Safety
Satellite TLE file, transmit frequency, and data rate	All FR's	System functions correctly	Ensure signal is received	Ensures complete ground station functions as desired	Injuries carrying system, high voltage & current

Budget

Budget Spent

Subsystem	Cost $
Electrical	1005.31
Software	879.68
Mechanical	3040.17
Miscellaneous	170.32
Money Spent	**5095.48**
EEF Grant	+2500
Remaining Budget	**2404.52**
Total	**7500.00**



ENGINEERING EXCELLENCE FUND

Forward Looking

Procurement		
Item	Status	Date Needed by
Travel Cases	Not Purchased	3/22/19
Capacitor	Not Purchased	3/22/19

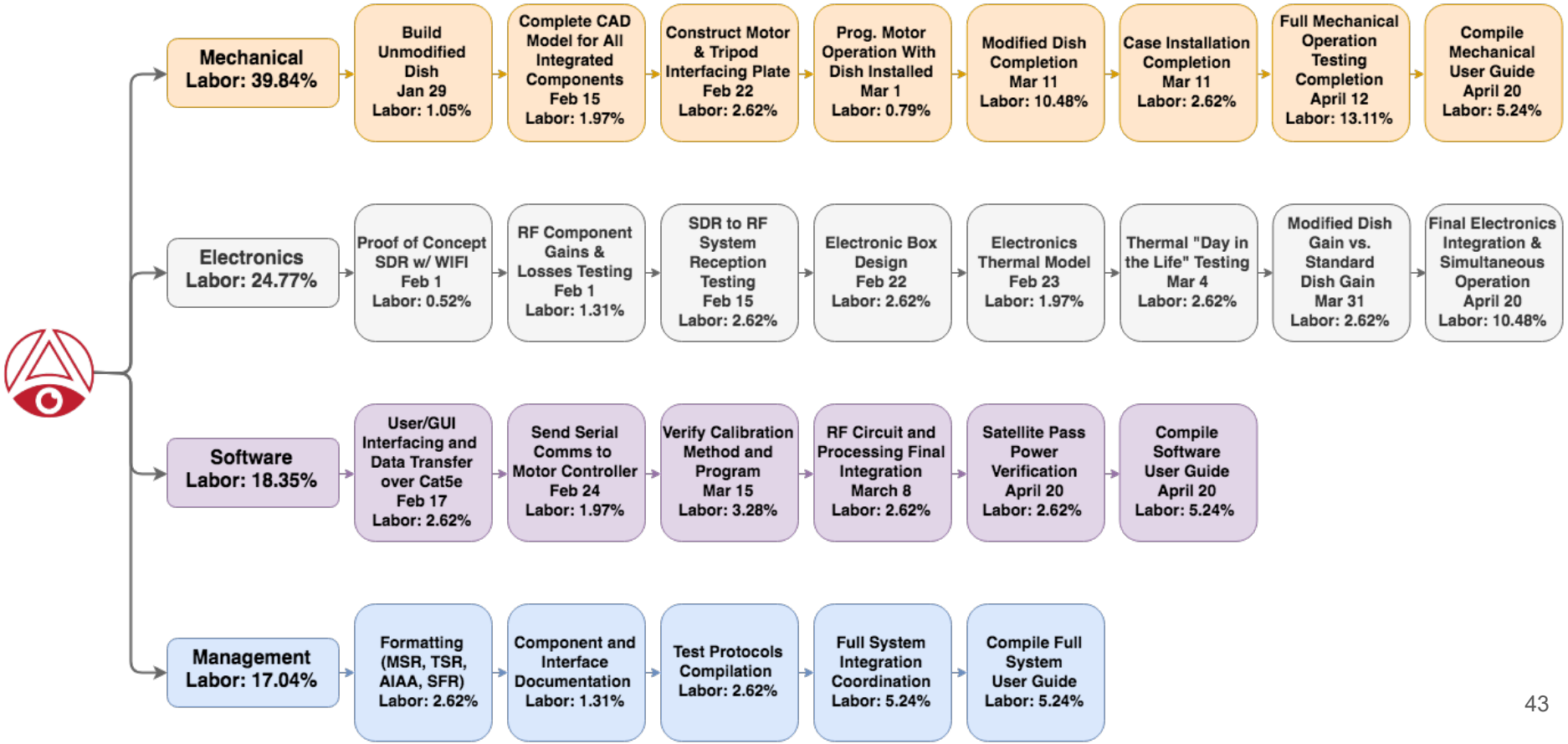
32.06% margin left in budget

Questions?

Backup Slides

Management

Task Breakdown Structure



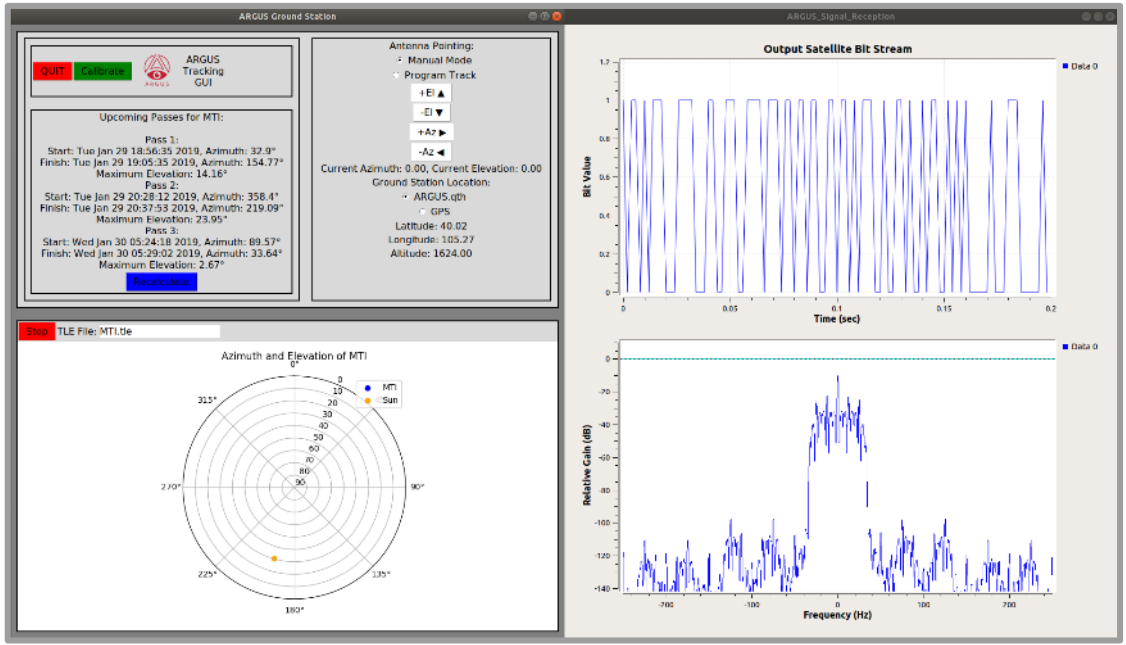
ARGUS

Tracking Hardware Subsystem

FR 2.0	The ground station shall mechanically steer a dish/antenna system to follow a LEO satellite between 200 km to 600 km between 10° elevation and 170° elevation.

Software - Overview

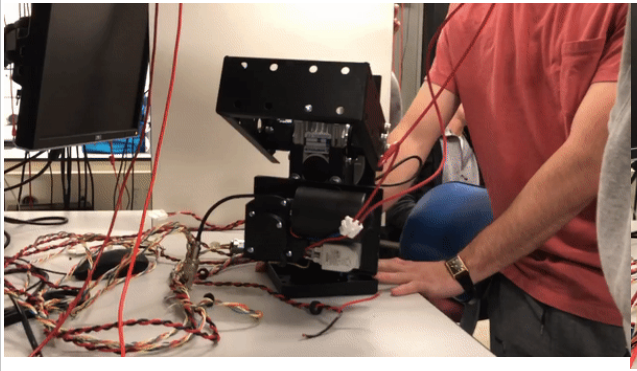
- Overview:
  - Tracks and displays future passes and current location of specified satellite
  - Control antenna pointing position
  - Receive signal, display, and save bit stream to file
- Inputs:
  - Lat/Lon/Alt from GPS or QTH file
  - TLE text file
  - Signal Frequency & Bandwidth
  - Adalm Pluto Signal
- Outputs:
  - Binary text file of demodulated signal
  - Tracking GUI & Signal Processing GUI

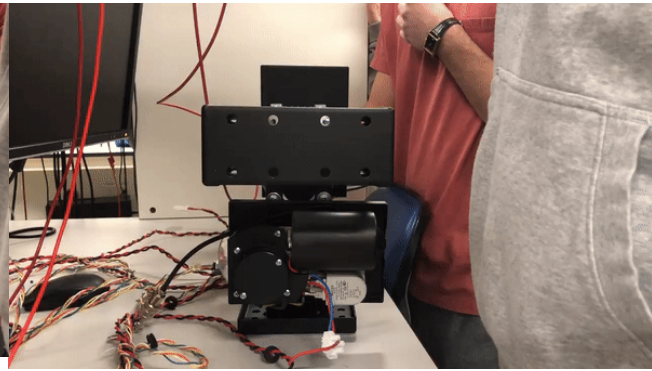


Level 1- Motor Functionality and Power

✓ Complete

Objective	• Ensure motor and motor controller are working together correctly
Location	• Trudy's lab
Test Design	• Test all four directions and full range of motion





Result: Motor works as expected & desired

Data Needed	Requirement	Expected	Verification	Risk
None	DR 2.1, 2.4	Motor moves to all positions and in all directions	Ensure motor can move in every direction and over full range of motion	• High voltage/current • Reduces risk By:

Level 2- Motor Control Software Unit Testing

✓ Complete

Objective	• Ensure all software functions as desired
Location	• Engineering Center Roof
Test Design	• Create a set of unit tests for each part of software • Run unit tests with motor controller, motor, and GPS connected to NUC

```
----------------------
Ran 20 tests in 45.909s

OK
```

Result: All tests pass.

Data Needed	Requirement	Expected	Verification	Risk
None	FR 2	All Tests Pass	All Tests Pass	• Hard to Unit test GUI's • Reduces Risk By:

Level 1 GPS Functionality Test

Objective	• Ensure GPS Data is accurate • GPS is used to determine satellite position • Determine measurement time needed for accurate data
Location	• DLC Roof
Test Design	• Record GPS data and compare to Google Maps data • Compare accuracy of different measurement lengths

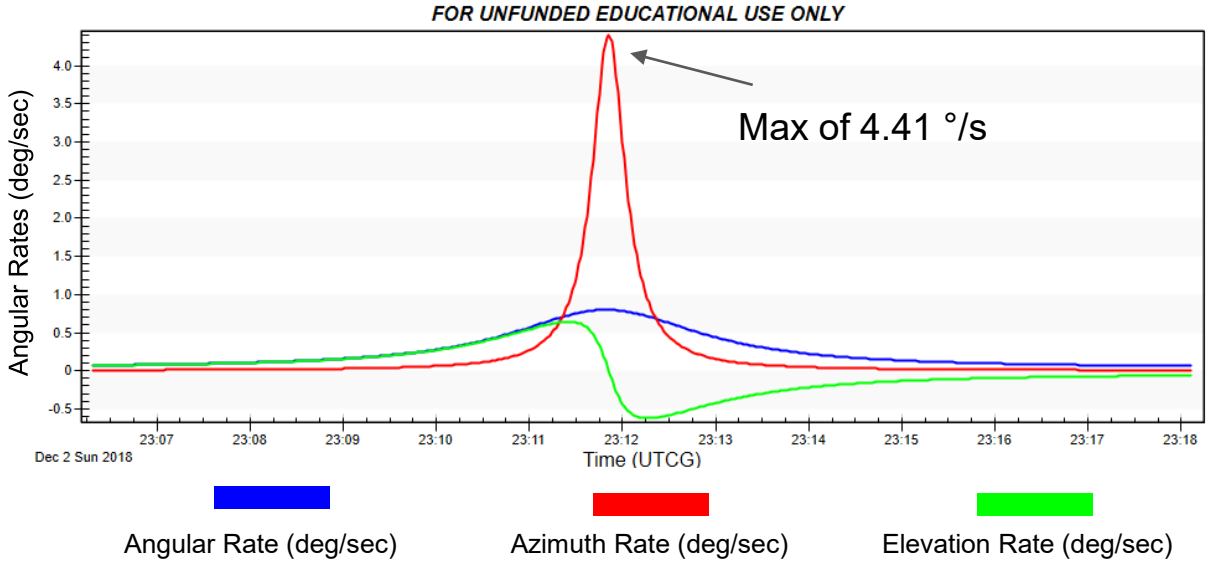
Result: GPS is accurate to less than 10 meters.

Data Needed	Requirement	Expected	Verification	Risk
Google Maps Data GPS Data	DR 2.2	Accurate to ±3 meters	Data matches Google Maps	Multipath

STK: Tracking Rate Verification

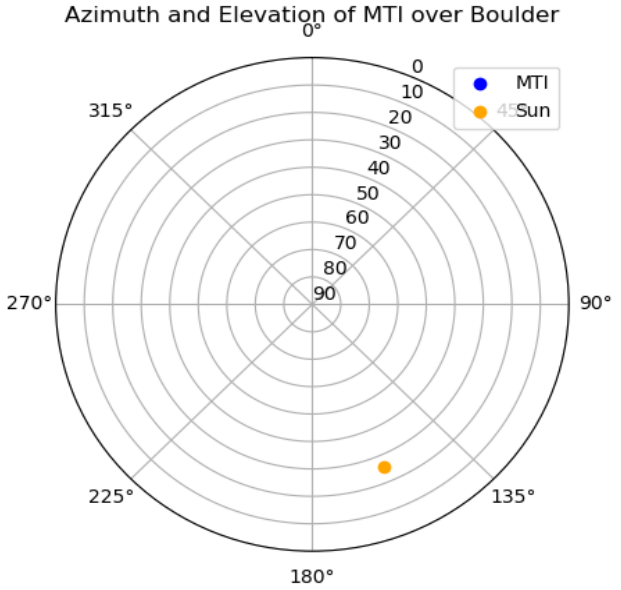
DR 2.3	The antenna motor shall be able to move the antenna at a slew rate of **5.0 °/s**

- Worst case pass
  - Elliptical orbit
  - Pass directly overhead
  - Retrograde
- Max Rate: 4.41 °/s



Azimuth and Elevation Calibration

DR 2.2	The pointing control accuracy must be within **3.25°** to maintain downlink capabilities throughout the entire pass.



- Manual Control Frame - Dither around Sun, find strongest signal strength
- Calibration Frame - Set current pointing angles to predicted Sun location

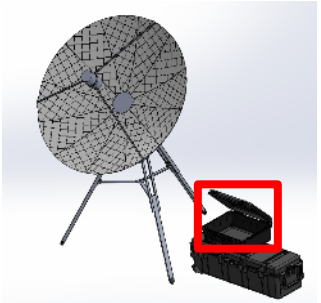
Ground Station Latitude/Longitude (GPS) → ARGUS GUI → Sun Azimuth and Elevation → Point in Predicted Location and Dither

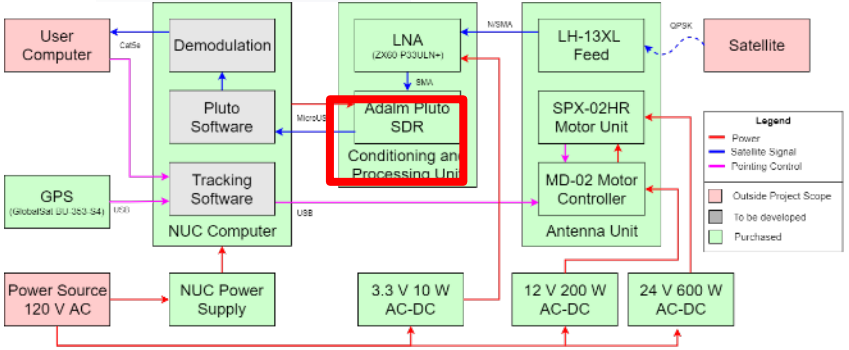
Signal Conditioning & Processing

FR 1.0	The ground station shall be capable of receiving signals from a Low Earth Orbit satellite between 2.2 - 2.3 GHz, in Quadrature Phase Shift Keying (QPSK) modulation with a Bit Error Rate (BER) of 10^{-5}, a bit rate of 2 Mbit/s, and a G/T of 3 dB/K.

Level 1- SDR & Free Space Loss Verification

Objective	• Ensure SDR's are working correctly
Location	• Discovery Learning Center
Test Design	• Transmit tone at 2MHz with 2.4GHz carrier frequency through Adalm Pluto with dipole antenna • Receive tone through second Adalm Pluto with dipole antenna



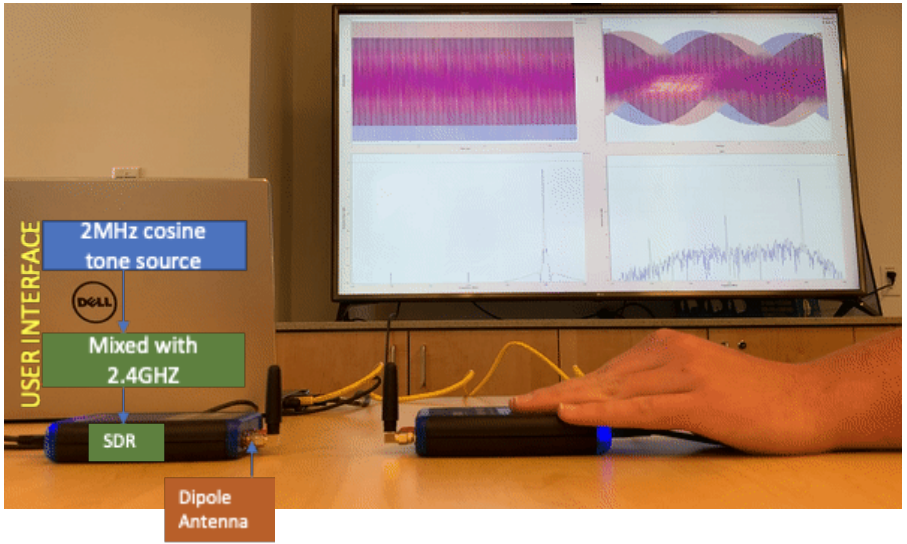


Input Needed	Requirement	Expected	Verification
None	DR 1.10	Receive 2MHz tone from transmitting Pluto	Power level drop with increased range

Level 1- SDR & Free Space Loss Verification

✓ Complete

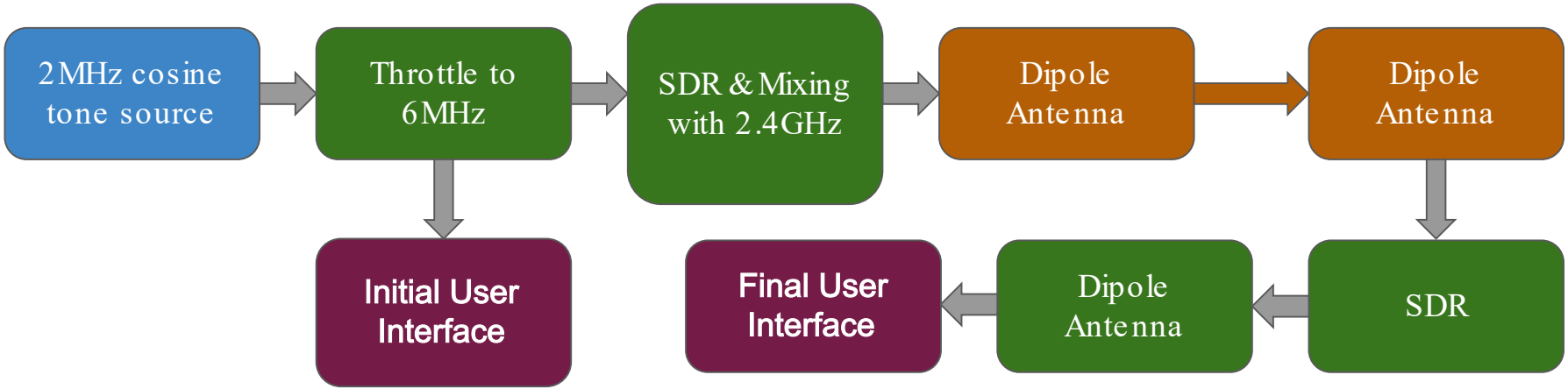
Objective	• Ensure SDRs can interact with RF signals
Location	• Discovery Learning Center
Test Design	• Transmit tone at 2MHz with 2.4GHz carrier frequency through Adalm Pluto dipole antenna • Receive tone through other Adalm Pluto dipole antenna



Result: Power level drops as expected.

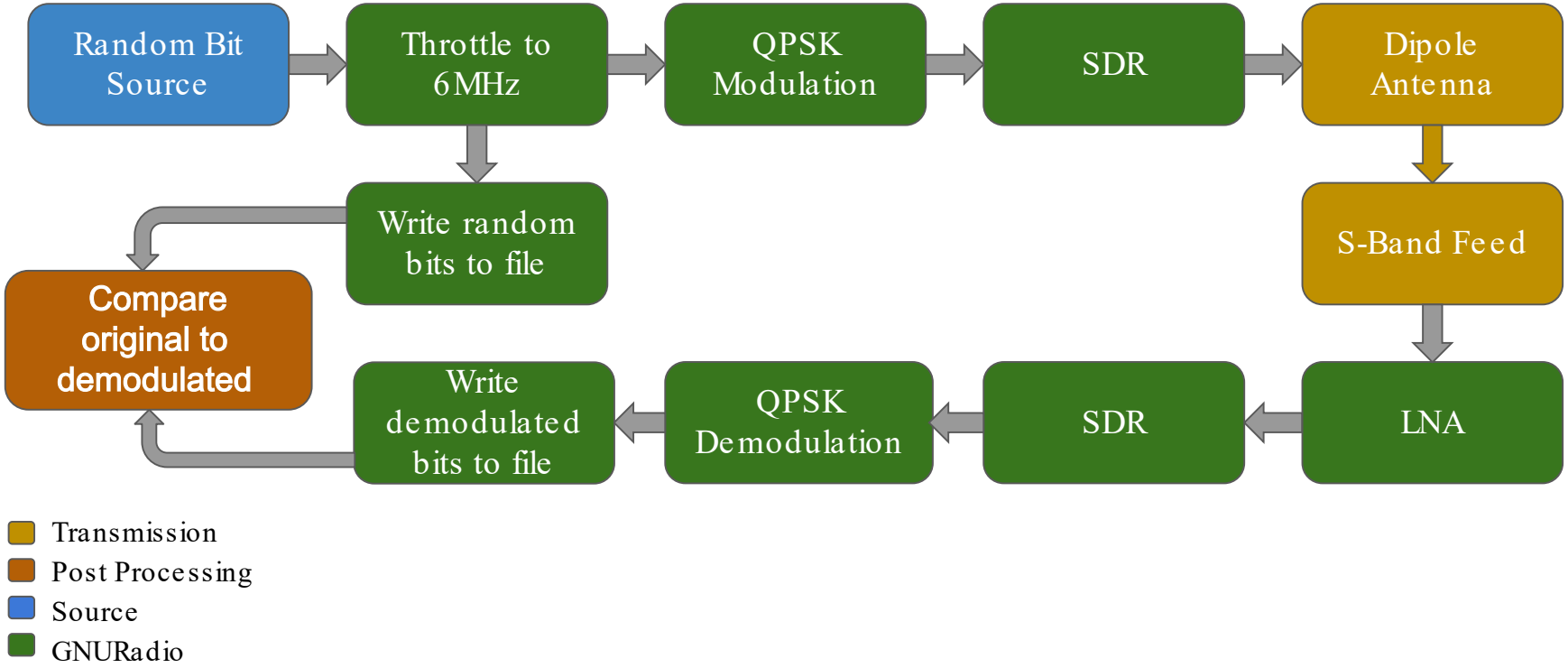
Data Needed	Requirement	Expected	Verification
None	DR 1.10	Receive 2MHz tone from transmitting pluto	Power level drop with increased range

SDR & Free Space Loss Test Design



- Transmission
- Source
- GNURadio
- User Interface

Feed Rx Test Design



Level 1- Bit Error Rate Verification

✓ Complete

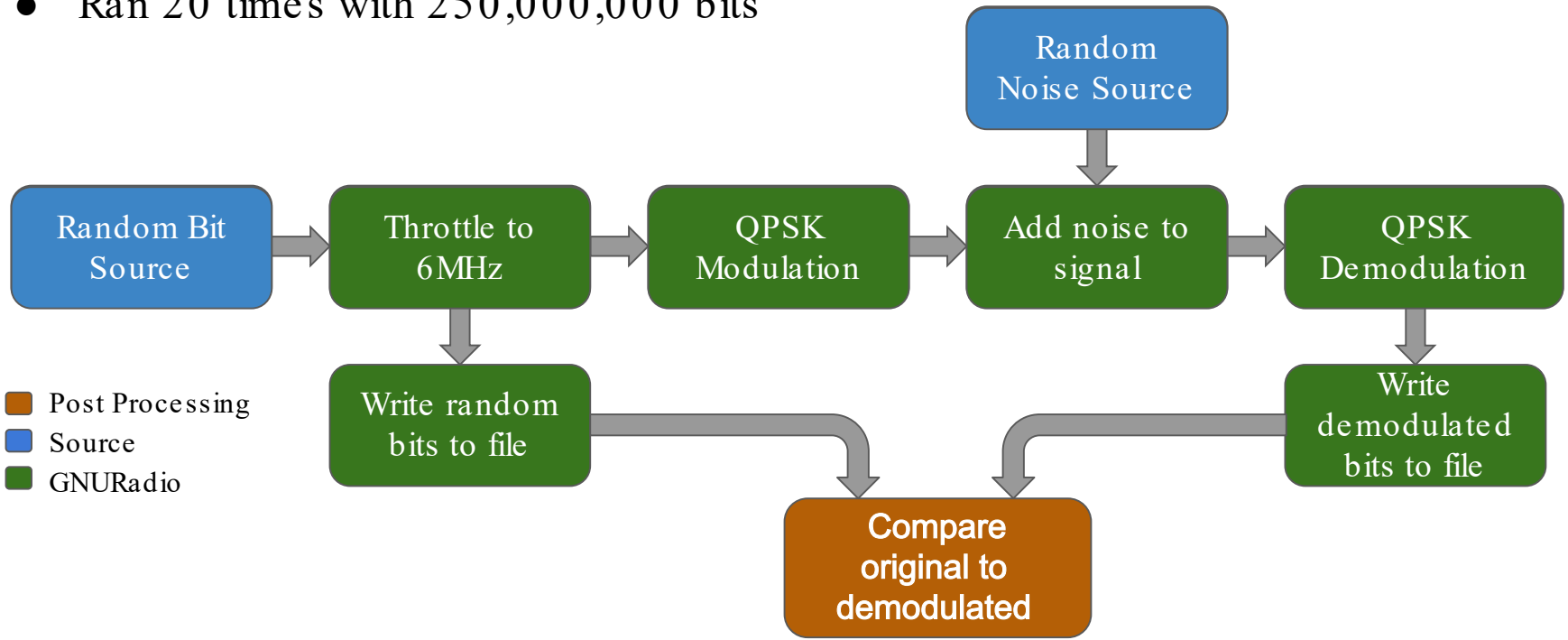
Objective	● Ensure system will be able to receive accurate data from a satellite ● Ensure software is receiving data and modulate the data
Location	● Senior projects room
Test Design	● Create random $5 \cdot 10^9$ bits ● Modulate, add noise, demodulate ● Compare to original signal

- Total System SNR: **17.21**
  - From ASEN 3300 link budget
- **Result**: Sample BER=0
  - With 99% confidence our BER meets requirement at current system SNR

Data Needed	Requirement	Expected	Verification	Risk
System SNR Bit Error Rate	DR 1.2	BER=~10^{-9}	BER<10^{-9}	● Theoretical system SNR ● Reduces Risk By: Modulation Functionality and Receive capability

BER Test Design

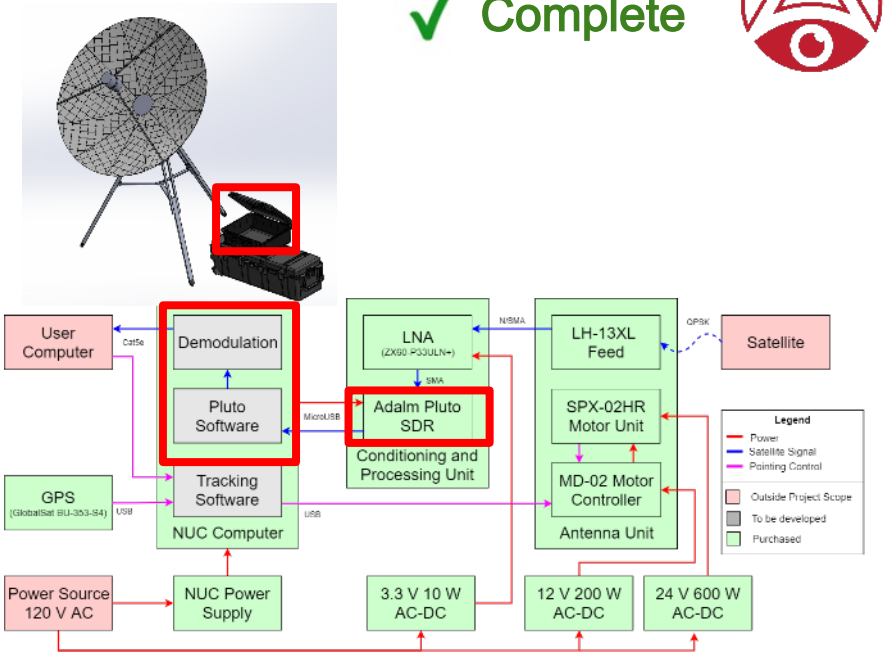
- Ran 20 times with 250,000,000 bits



Level 1- NUC Processing Speed Test

✓ Complete

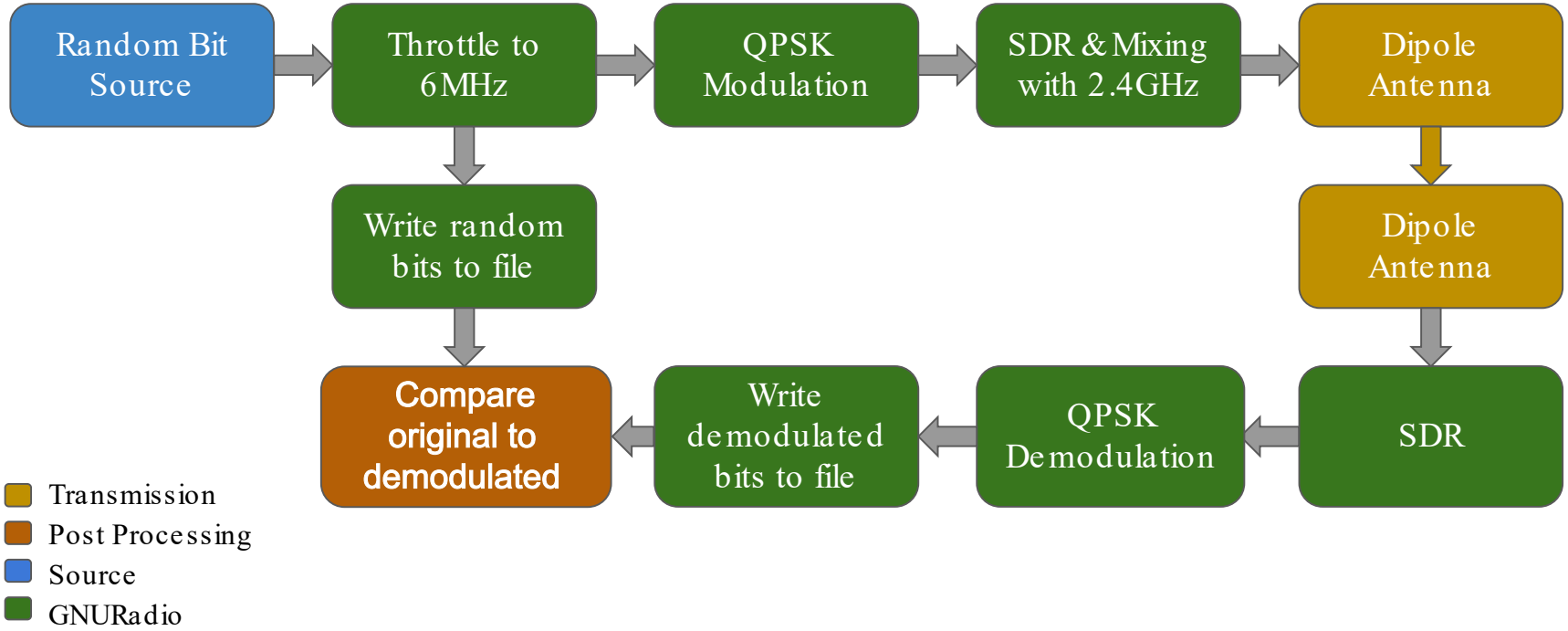
Objective	• Ensure NUC can handle 6MHz sampling frequency
Location	• Clark conference room
Test Design	• Modulate 20Mbits, transmit at 6MHz sampling frequency with 2.5GHz carrier frequency through Adalm Pluto Dipole Antenna • Receive and demodulate through other Adalm Pluto Antenna and NUC • Ensure that 20Mbits were sent and received in 10 seconds, and are identical



Result: NUC handled signal well & demodulated correctly.

Data Needed	Requirement	Expected	Verification	Risk
None	DR 1.4, 1.10	NUC can handle sampling frequency	Ensure bits are all present	• Wifi interference • Modulation

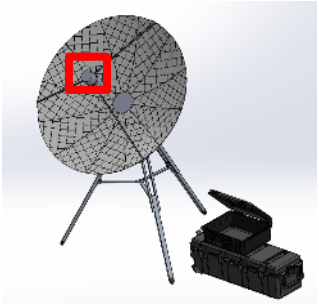
NUC Processing Speed Test Design

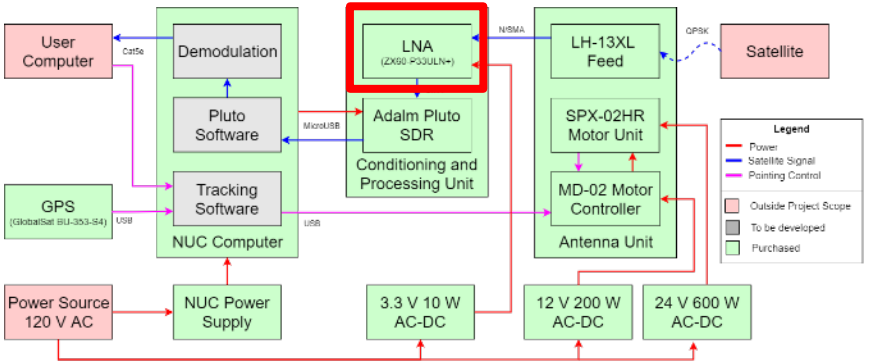


Level 1- Low Noise Amplifier Component Test

☐ Complete

Objective	Determine LNA gain at target frequency
Location	Akos' Office
Equipment	Spectrum analyzer, 3.3V source, N-SMA adapters, attenuator
Test Design	LNA is powered, passed a signal via network analyzer, Rx gain measured



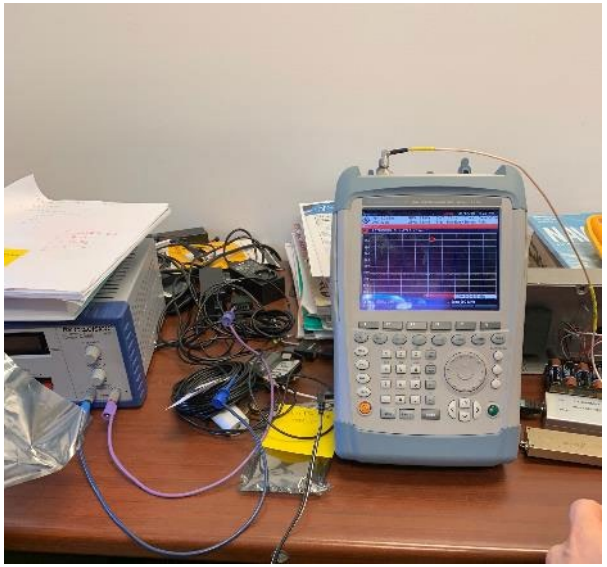


Data Needed	Requirement	Expected	Verification	Risk
LNA Gain	DR 1.9	10.7 dB gain at 2.3 GHz (Spec. sheet)	~10 dB gain increase on Rx when LNA is powered	ESD

Level 1- Low Noise Amplifier Component Test

☐ Complete

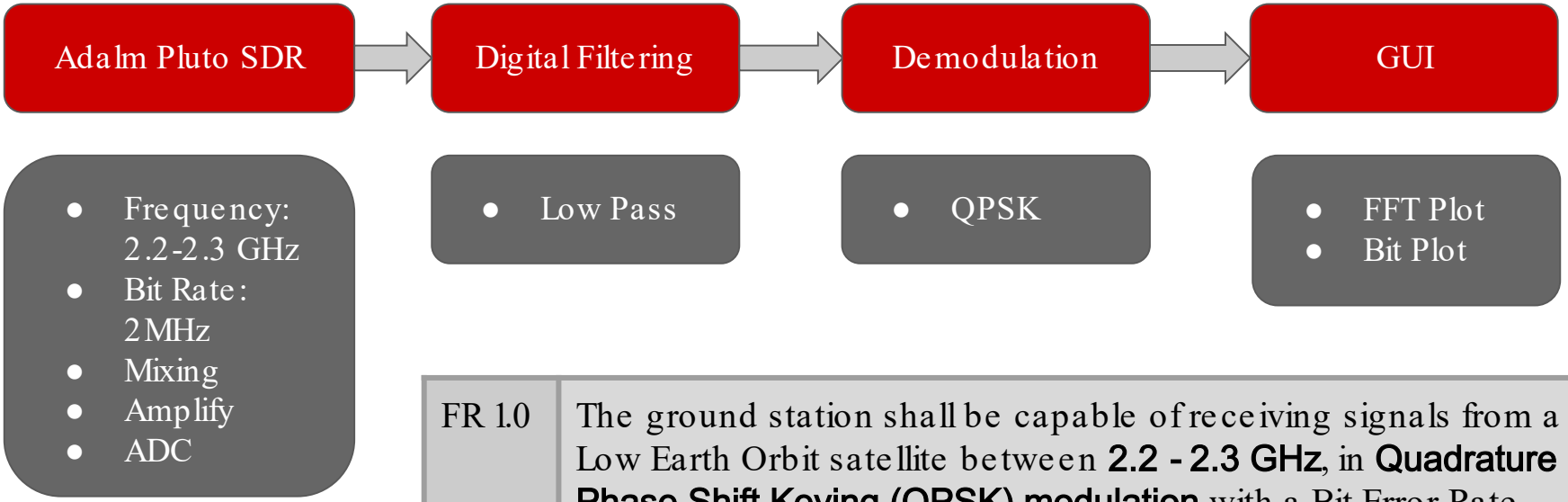
Objective	Determine LNA gain at target frequency
Location	Akos' Office
Equipment	Spectrum analyzer, 3.3V source, N-SMA adapters, attenuator
Test Design	LNA is powered, passed a signal via network analyzer, Rx gain measured



Result: 10 dB increase matches specifications.

Data Needed	Requirement	Expected	Verification	Risk
LNA Gain	DR 1.9	10.7 dB gain at 2.3 GHz (Spec. sheet)	~10 dB gain increase on Rx when LNA is powered	ESD

GNURadio Software Diagram



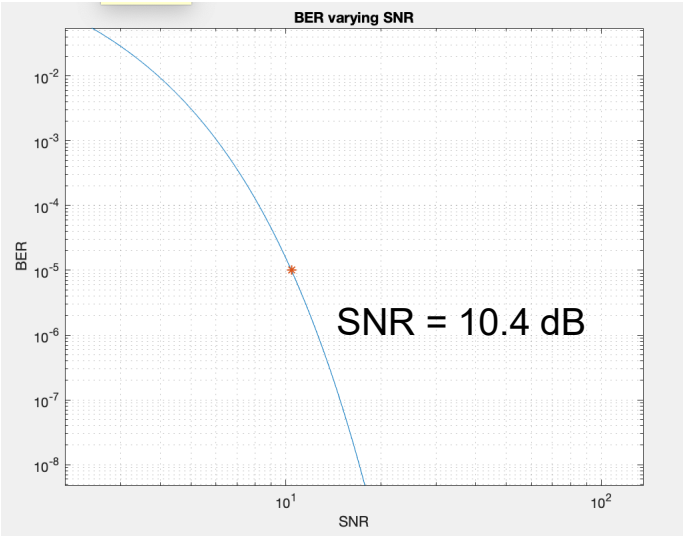
FR 1.0	The ground station shall be capable of receiving signals from a Low Earth Orbit satellite between **2.2 - 2.3 GHz**, in **Quadrature Phase Shift Keying (QPSK) modulation** with a Bit Error Rate (BER) of 10^{-5}, **a bit rate of 2 Mbit/s** , and a G/T of 3 dB/K.

Bit Error Rate

FR 1.0	The ground station shall be capable of receiving signals from a Low Earth Orbit satellite between 2.2 - 2.3 GHz, in Quadrature Phase Shift Keying (QPSK) modulation with **a Bit Error Rate (BER) of 10^{-5}**, a bit rate of 2 Mbit/s, and a G/T of 3 dB/K.

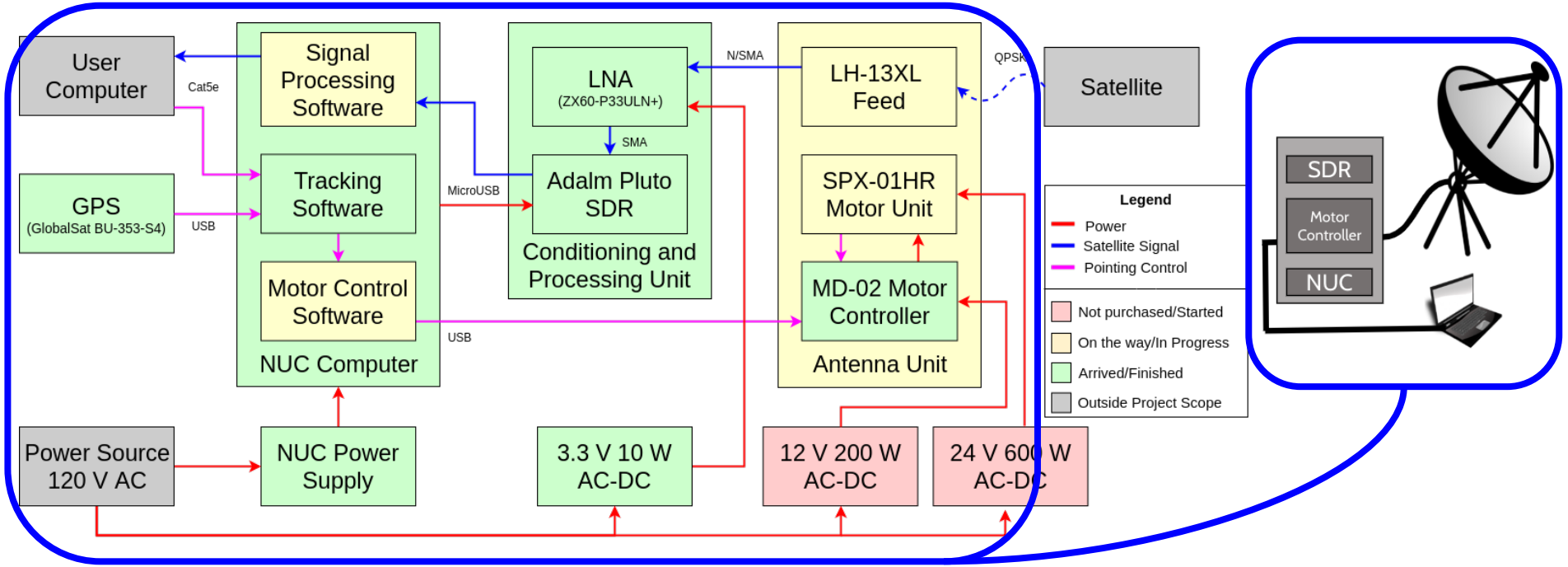
BER is governed by the system Signal to Noise Ratio (SNR)

- Must have SNR $\geq$ 10.4dB to achieve BER of 10^{-5}
- Current system SNR $\cong$ 17.21dB
  - BER $\cong$ 8.9e-9
  - Determined using ASEN 3300 link budget and typical transmit values



✔☐Meets Requirement

Critical Manufacturing Area: Electrical



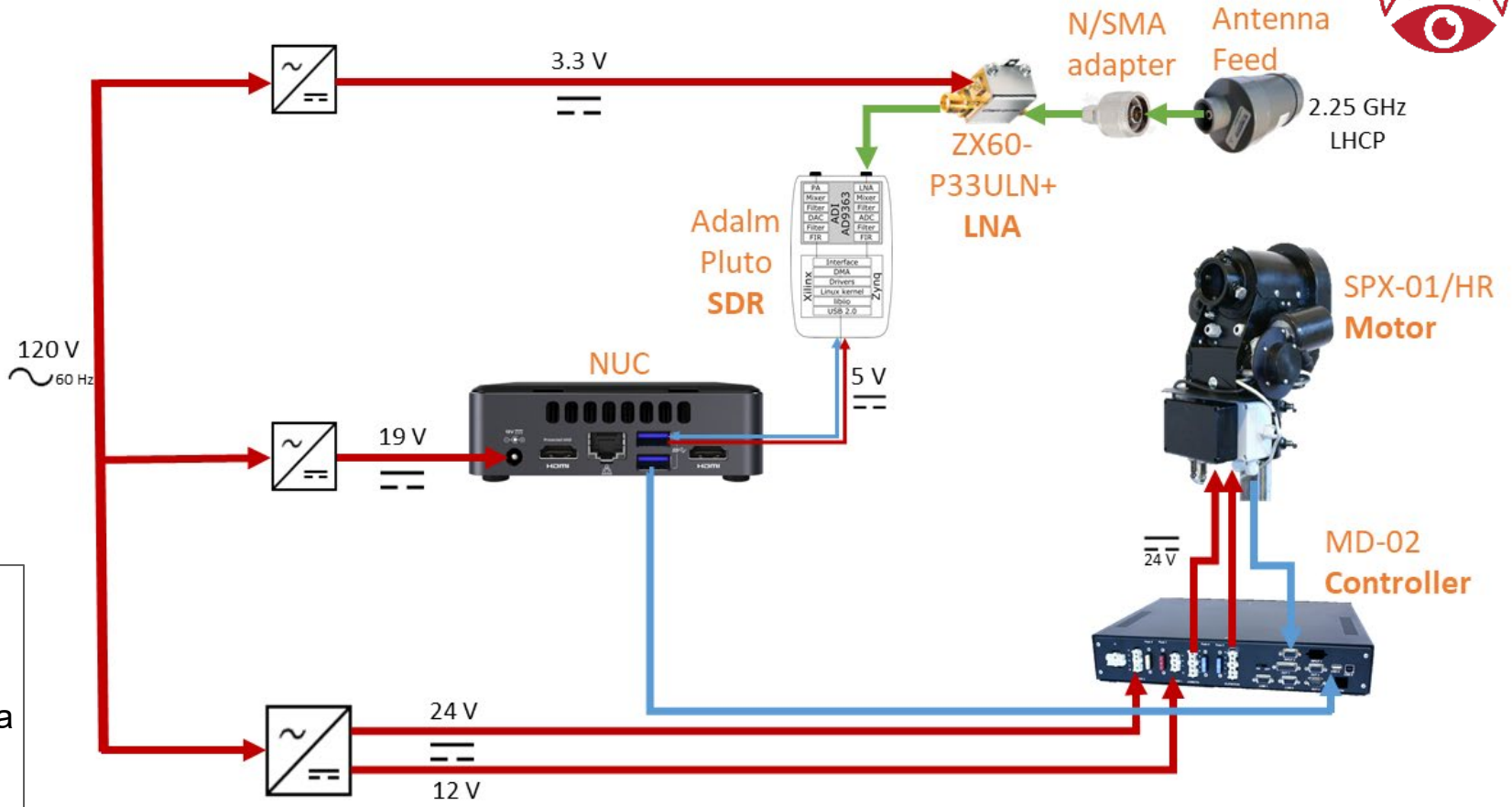
Electrical - Components

Manufacturing
Wiring Assembly
Radio Frequency Path Design
Power Supply

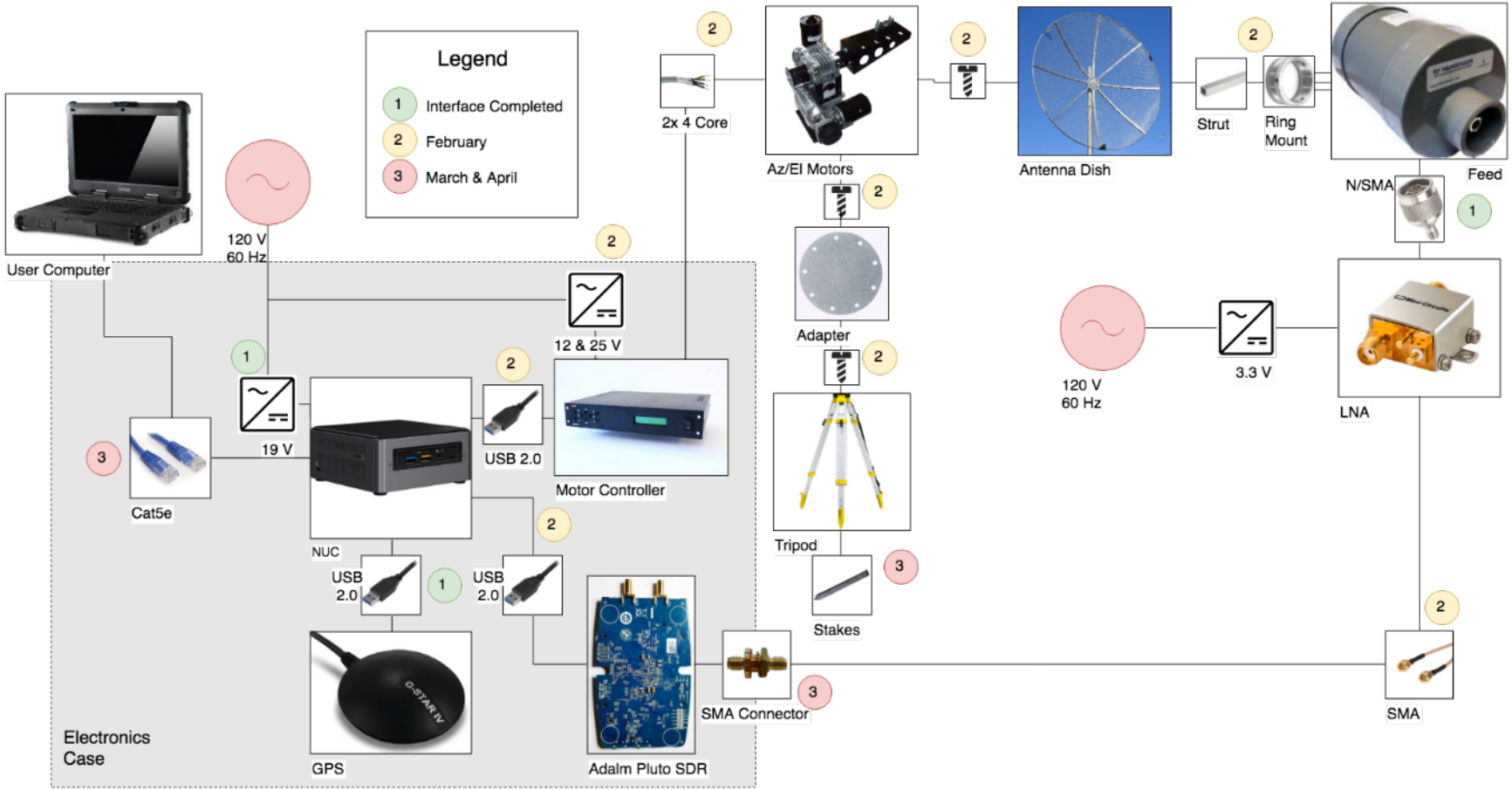
Critical Element

Purchased
Cables ✓
LNA ✓
Motor Controller ✓
NUC ✓
GPS ✓
SDR ✓
Power Converters
Feeds

Electrical - Overview



System Integration Plan



Functional Requirement 3

FR3.0	The ground station shall be **reconfigurable** to be used for **different RF bands.**

Reconfigurability Testing - April 14

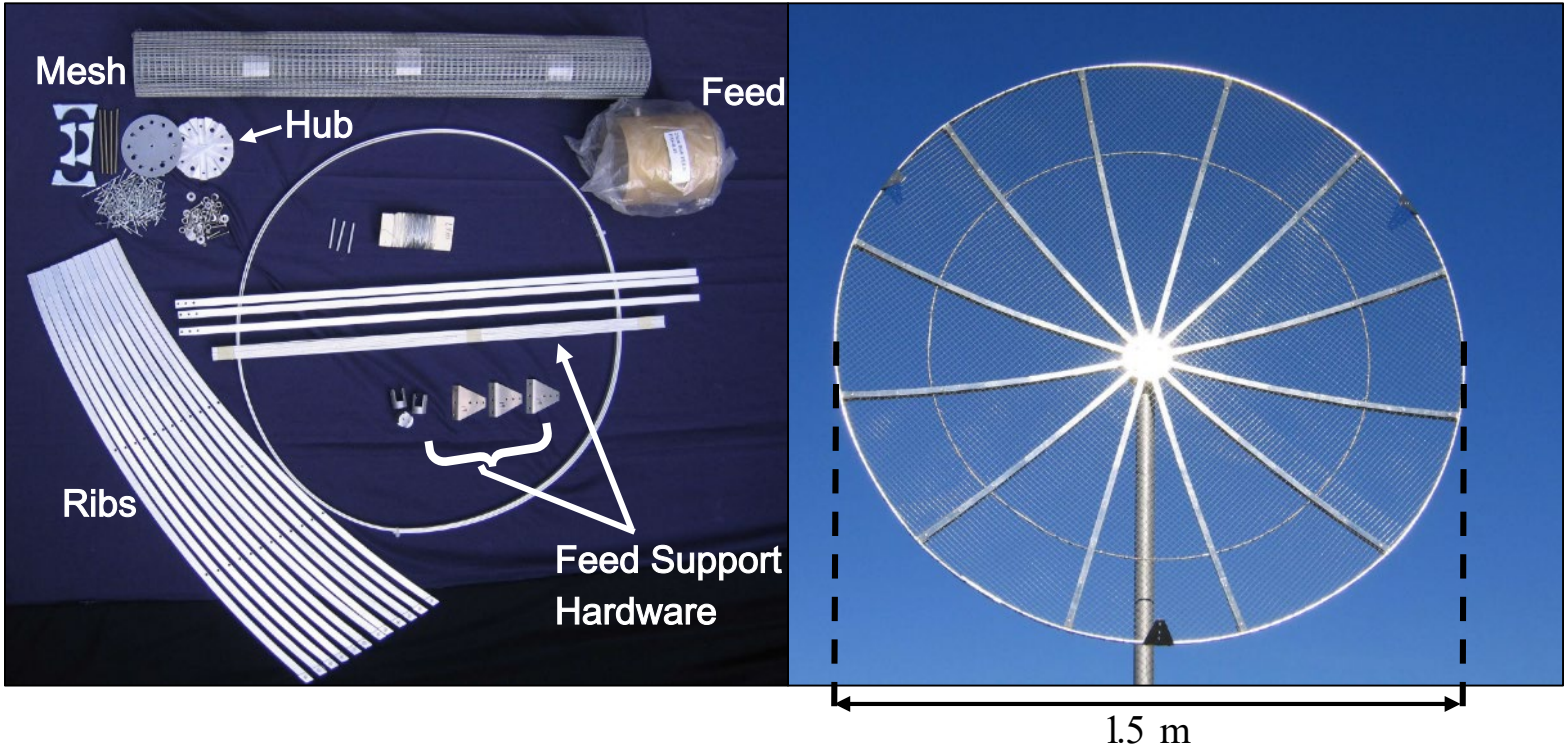
Objective	• Ensure ground station can be reconfigured for other frequency bands
Location	• Senior Projects Room
Test Design	• Take out all components needed for reconfigurability • Feed, SDR, LNA

Requirement	Expected	Verification	Risk
FR 3	Components can be removed easily and quickly	All can be removed within 30 minutes	Ring mount does not fit all feeds. Adjusting size and measuring medigates this

Antenna Subsystem

FR 1.0	The ground station shall be capable of receiving signals from a Low Earth Orbit satellite between 2.2 - 2.3 GHz, in Quadrature Phase Shift Keying (QPSK) modulation with a Bit Error Rate (BER) of 10^{-5}, a bit rate of 2 Mbit/s, and a G/T of 3 dB/K.
FR 4.0	ARGUS shall weigh less than 46.3 kg (102 lbs) and be capable of being carried a distance of 100 meters by two people.

RF Ham Design Reflector



- Meets specified 27 dB at 2.3 GHz requirement; however, fails to meet mobility requirement

Modification of Reflector

Current RFHam dish:

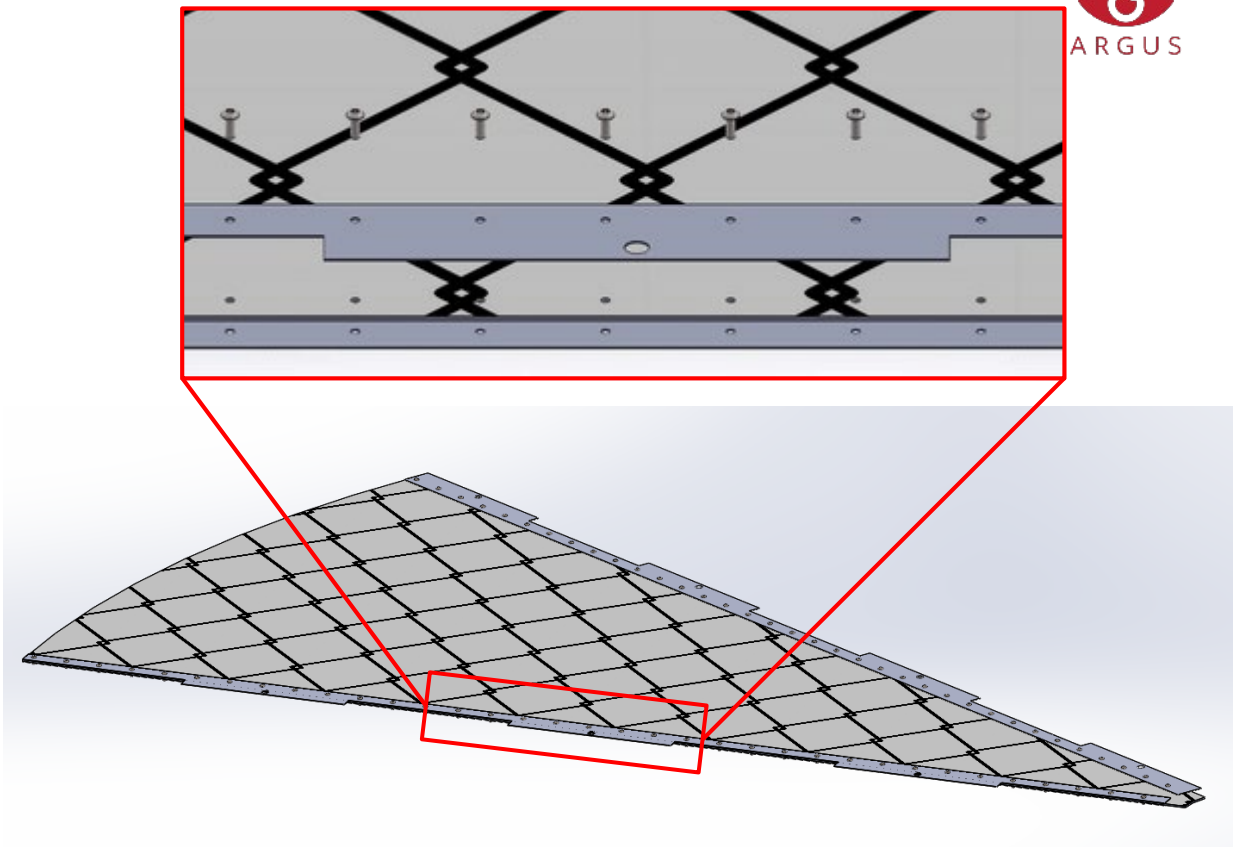
- Assembly time 6+ hours
- Single continuous mesh
- Multiple tools

Modifications:

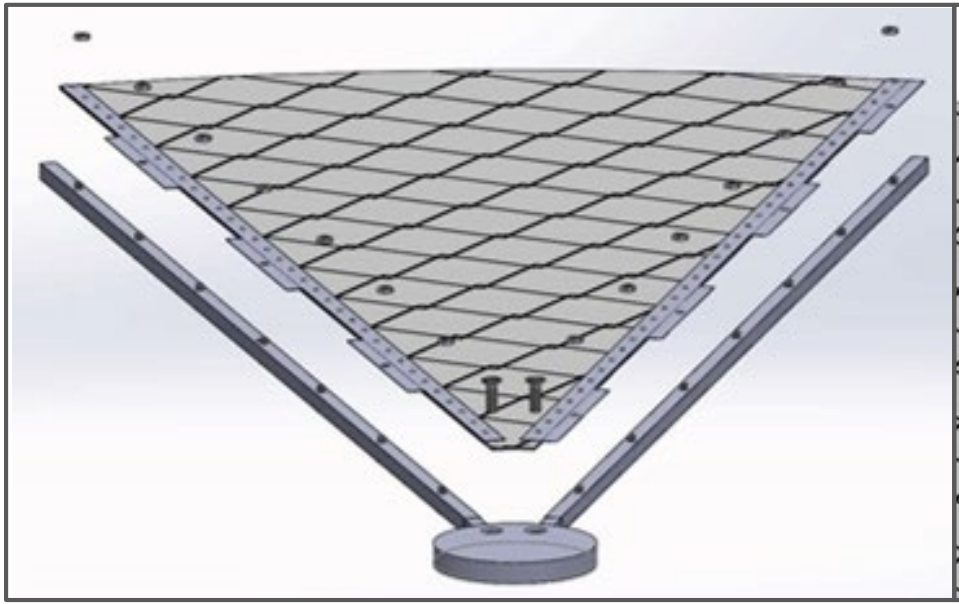
- Assembly time less than 1 hour
- Split into 12 connectable pieces
- Fewer than 4 tools

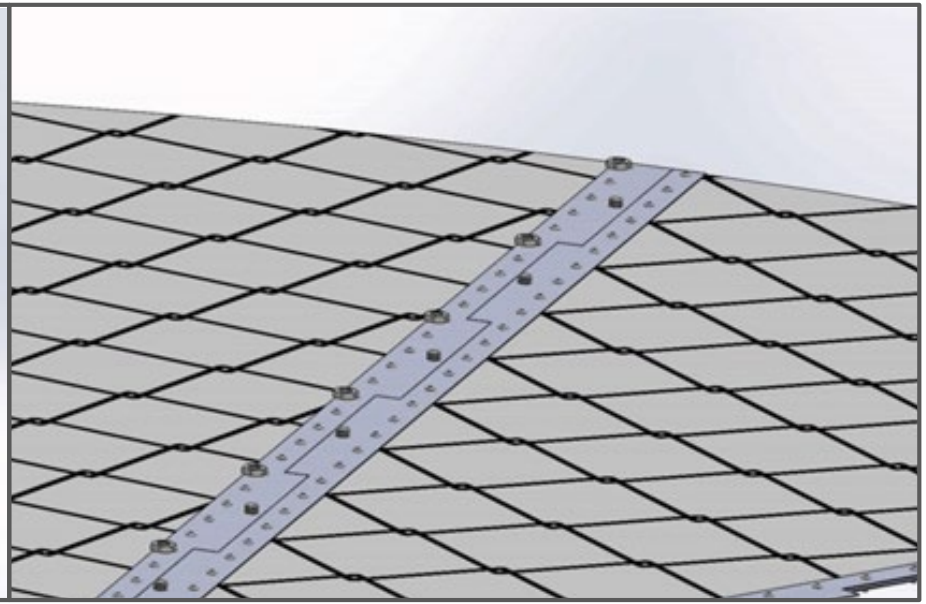
Modularity:

- 22 gauge aluminum sheet attaches to ribs
- Petals attach to central hub



Modification of Reflector





✔☐Meets mobility requirements (FR.4)

Antenna Gain Calculation

Pasternack SMA Male to N Male Adapter

- $L_1 = 0.07\ dB$

ZX60-P33ULN+ MiniCircuits LNA

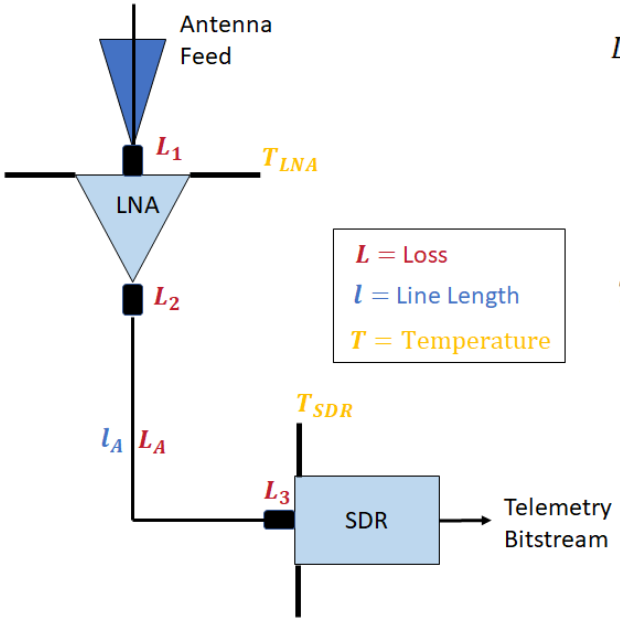
- $T_{LNA} = 44\ K$
- $G_{LNA} = 11.3\ dB$

Pasternack SMA to SMA Cable

- $l_A = 2\ m, 0.7\ \frac{dB}{m} \Longrightarrow L_A = 1.4\ dB$
- $L_2 = L_3 = 0.45\ dB$

Adalm-Pluto SDR

- $T_{SDR} = 288.6\ K$



L = Loss
l = Line Length
T = Temperature

$$L_{tl} = L_1 + L_2 + L_3$$

$$a = 10^{-L_{tl}/10}$$

$$T_S = aT_a + (1-a)T_0 + T_{LNA} + \frac{T_{SDR}}{G_{LNA}/L_A}$$

$$\Rightarrow T_s = 140K$$

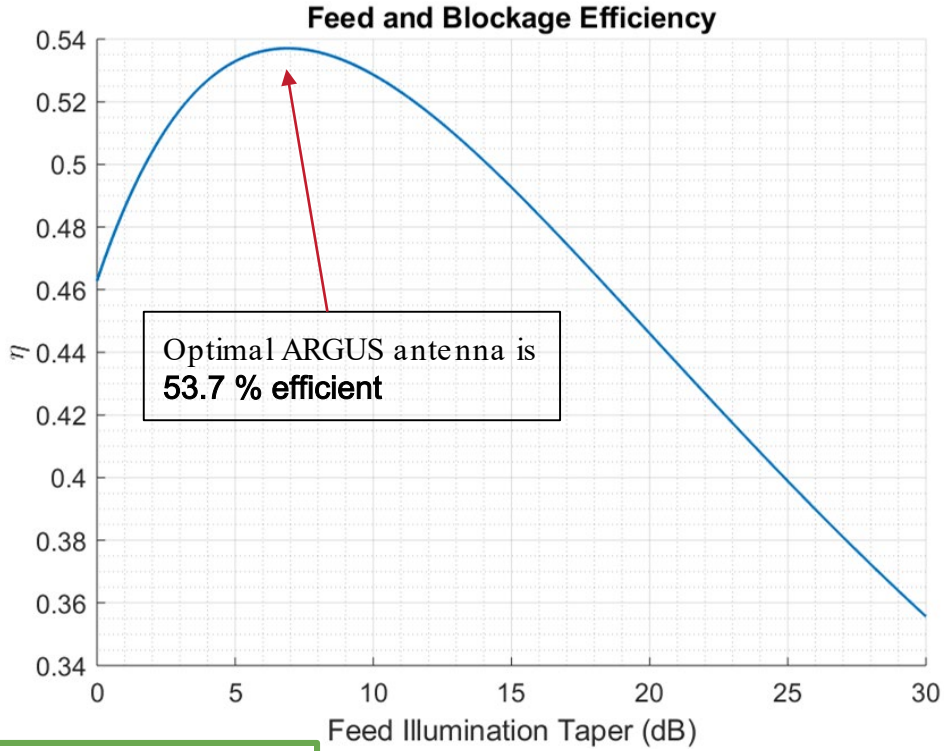
Requirement: $\frac{G}{T_s} = 3\frac{dB}{K}$ → $G_{required} = 26.2\ dBi$

Estimated Efficiency

$$\eta = \eta_{feed}\eta_{bl}$$

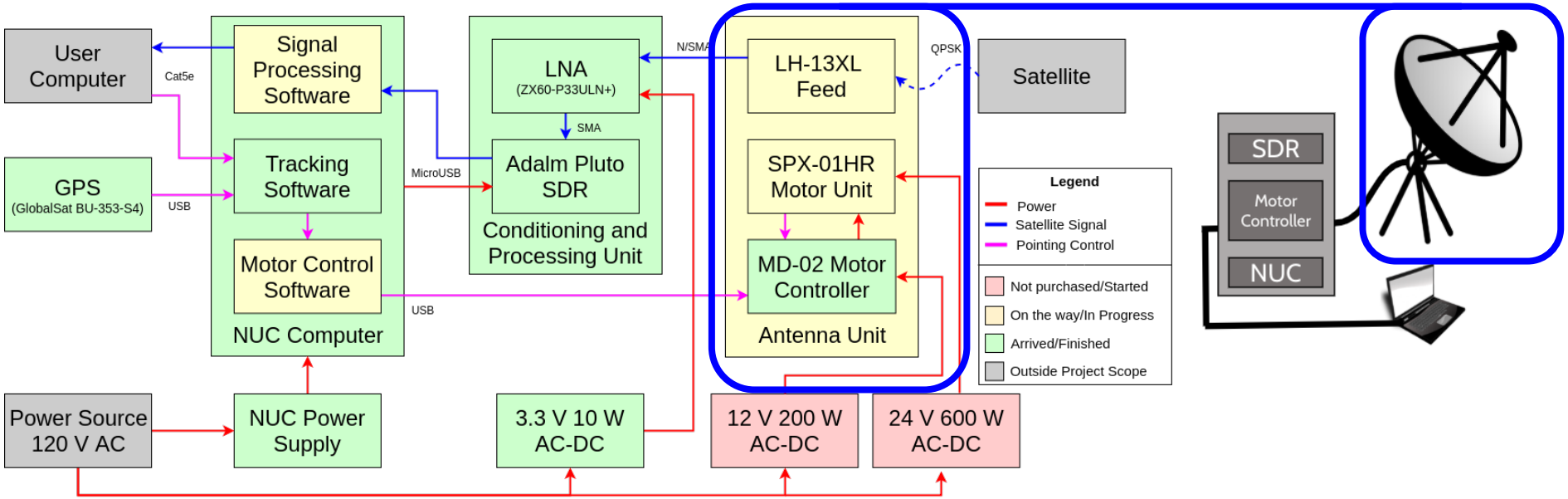
$$G_{parabolic} = \eta\left(\frac{\pi D}{\lambda}\right)^2$$

Gain at **53.7%** efficiency	28.08 dBi
Gain at **35%** efficiency	26.22 dBi
Required gain	26.2 dBi



✔☐Meets bandwidth and gain requirements (FR.1)

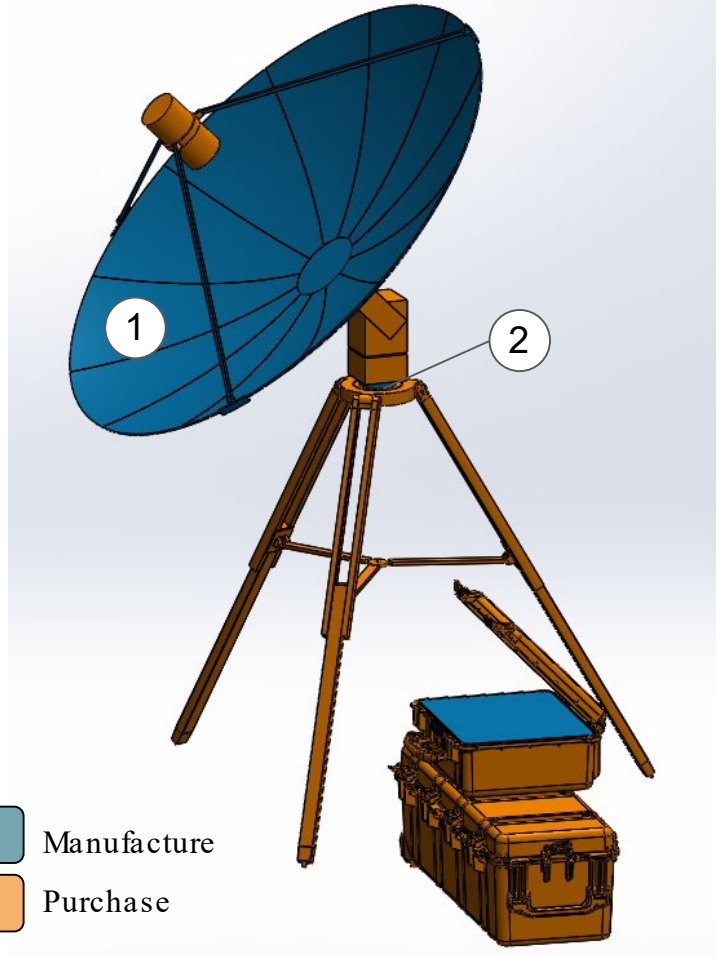
Critical Manufacturing Area: Mechanical



Mechanical - Components

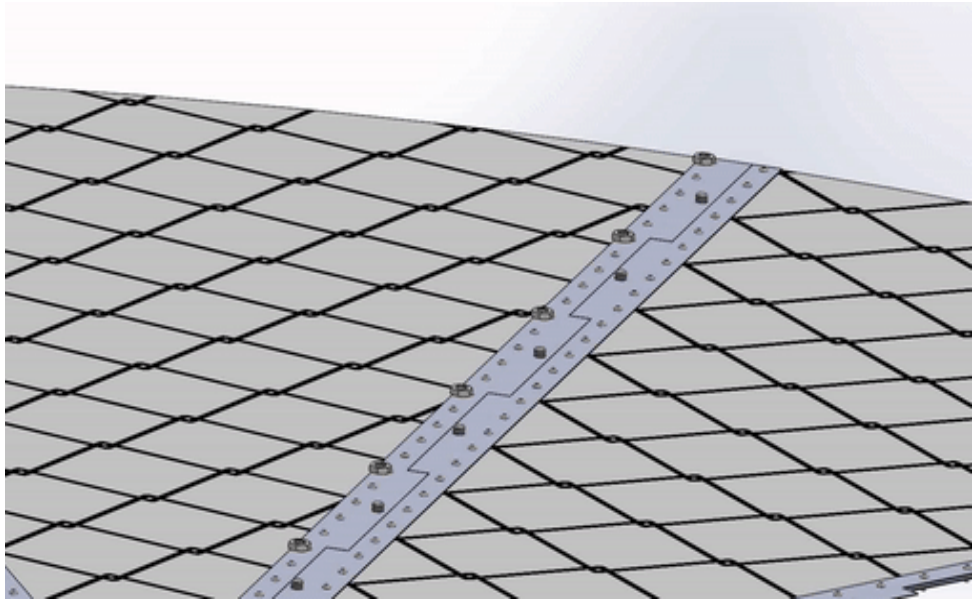
	Manufacture	Purchase
1	Demo Dish	Dish Kits ✓
	Dish Modification	Modification Materials ✓
	LNA Shield	Motor System ✓
	Tripod Feet	Tripod ✓
	Case Modification	Hardware Case
2	Motor System Mount	Electronics Case

Critical Element



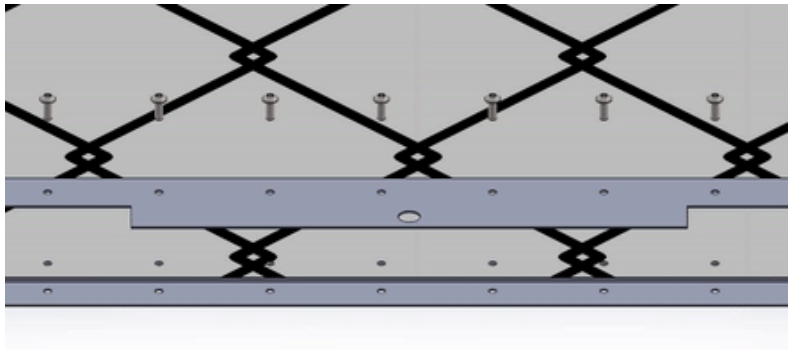
Mechanical - Modified Dish

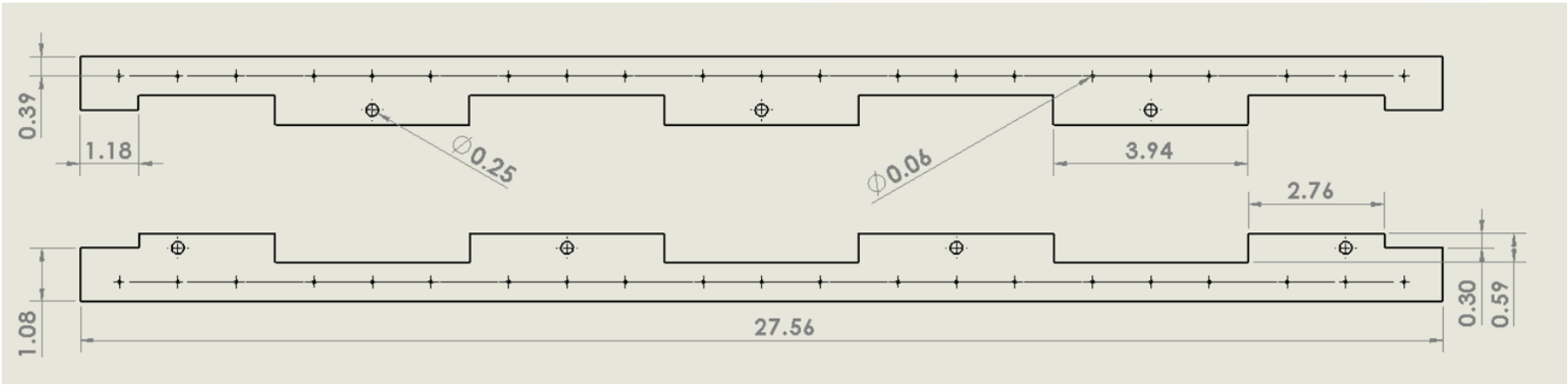
- Slow shipping of dish kit caused later start time
  - Work on off-days and weekends to offset slow start
- All additional components and tools purchased and prepared
- Challenges:
  - Splitting up outer ring for panels
  - Buckling of the mesh



Mechanical - Modified Dish

- Still need to machine aluminum tabs
  - Can be done in stacks in CNC machine
  - Files are prepared
  - Doing test print
- Modification to center hub





Mechanical - Tripod and Motor System Mount

- Changed selected tripod from CDR to accommodate uneven ground
- Need to create adapter plate to connect tripod to motors
  - Tripod and motor have not arrived
- Current plan:
  - Surveying tripod
  - Create adapter plate

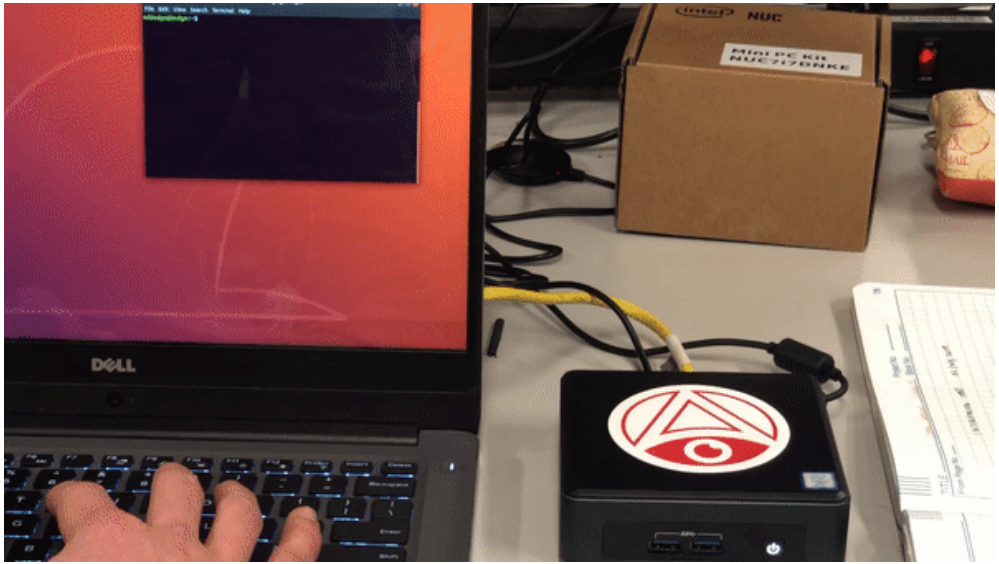
Functional Requirement 5

FR 5.0	The ground station onboard computer shall interface with a laptop using a Cat-5 ethernet cable.

Interfacing Verification

☐ Complete

Objective	• Ensure software has full functionality over secure shell connection
Location	• Senior Projects Room
Test Design	• Complete unit testing of each software piece over secure shell connection



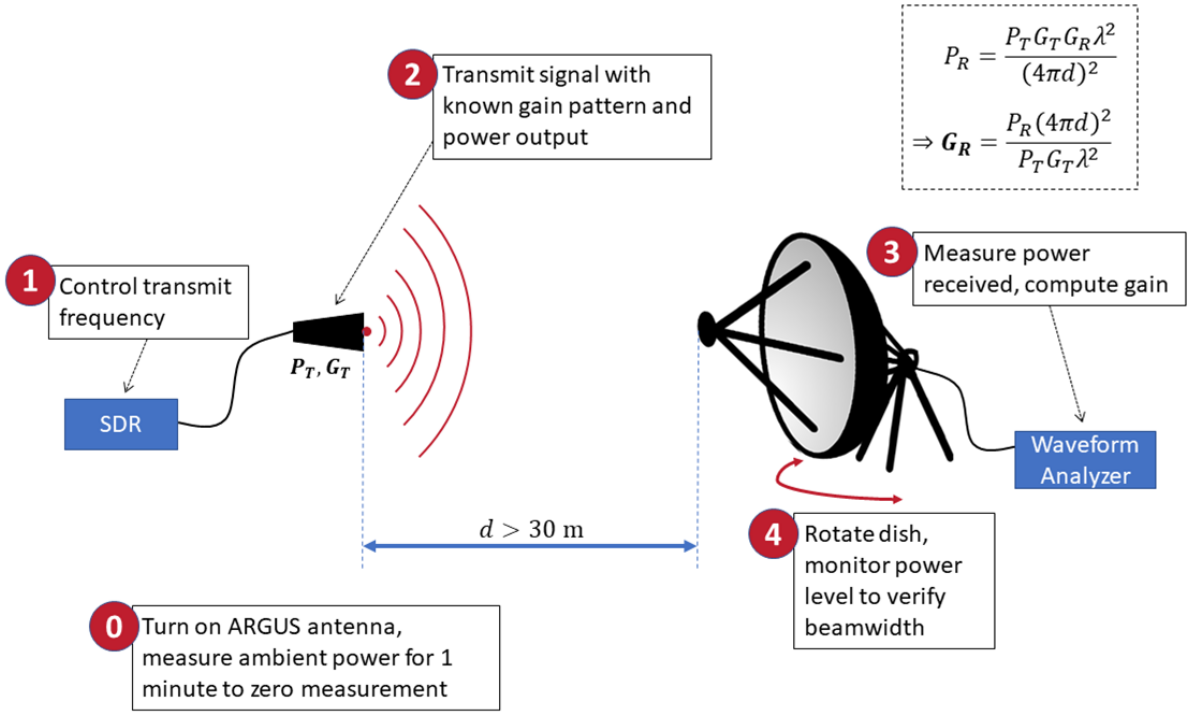
Result: All Tests pass and all pieces work over Cat-5 connection.

Data Needed	Requirement	Expected	Verification	Risk
None	FR 5	All Pass	Ensure all pass	Minimal

ARGUS

Verification and Validation

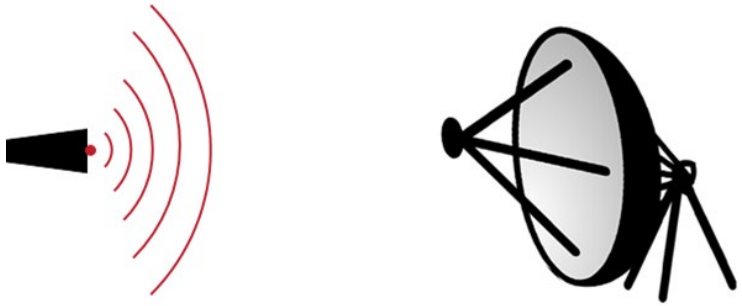
Antenna Gain/Beamwidth Test



Equipment Needed	Procurement
SDR	Purchase
Transmit Antenna	Borrow/Purchase
Waveform Analyzer	Borrow
Measuring wheel	Borrow

Antenna Gain/Beamwidth Test

Objective	• Verify antenna gain • Verify half power beam width (HPBW)
Location	Rural location or RF test range
FR Verified	FR 1: Gain, Beamwidth



Data Needed	Compared To	Expected
Gain	Efficiency model, dish kit specs	29.5dBi at 2.4GHz
Beamwidth	Idealized estimates, dish kit specs	6.5°

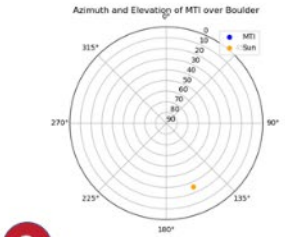
Potential Measurement Issues
• External signal noise • Signal reflection from ground • Incorrect feed placement • Pointing accuracy

Objective	• Test ARGUS portability • Receive signal from satellite
Location	Business Field
FR Verified	All FR

Full System Test

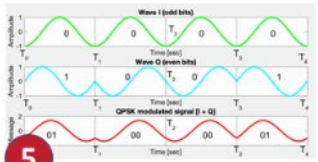
1 Components packed in cases

2 Assemble ARGUS

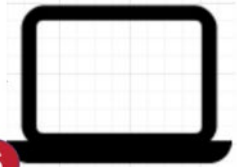


3 Calibrate with Sun Az/El

4 Engage satellite tracking



5 Demodulate Signal



6 Write Bitstream