Comprehensive Testing Procedures for Robust Avionics

Team 21 Project Technical Presentation to the 2019
Spaceport America Cup

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Agenda

Avionics Sub-team

Avionics Systems

Configuration Testing

- Preliminary anechoic chamber tests
- Radiation pattern tests

Integration Testing

- Spectrum Analyzer tests
- Preliminary short-range tests
- Long-range tests

Summary and Impacts

Follow-on work

- SRAD Antenna design

AVIONICS SUB-TEAM

Avionics sub-team

Background

- Lost both SRAD and COTS telemetry and did not recover previous 30K rocket
- Undocumented test setup, procedures, and results

Importance of robust testing

- Testing COTS modules provide a reference for future SRAD designs
- Quantitative measurement of the performance. More than just “it works” or “it doesn’t work”
- Repeatable tests allows possibility of optimization and iterative design

AVIONICS SYSTEMS

Avionics Systems

Requirements

- Telemetry link for full duration of flight, coverage for up to 20 km
- Dual-stage e-match ignition for drogue and main parachute deployment

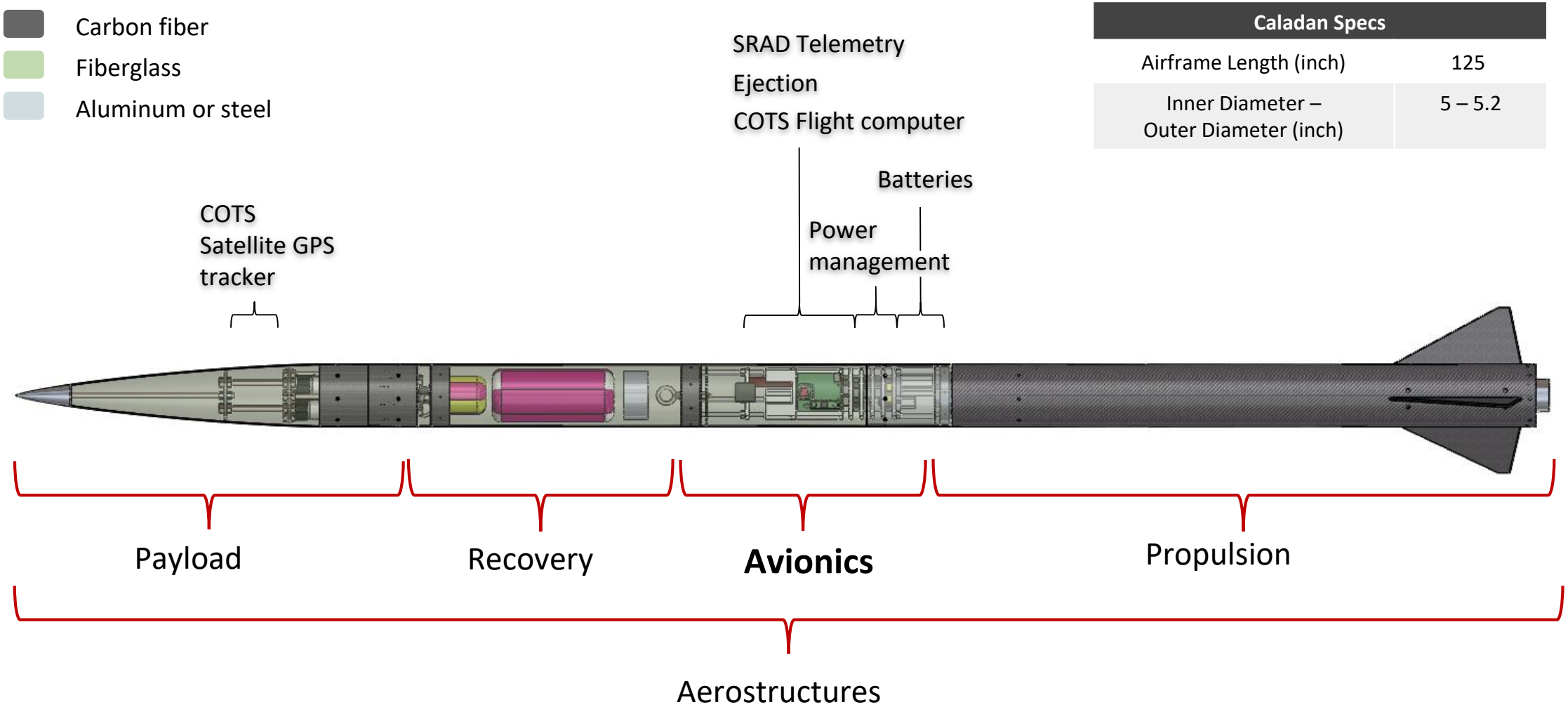
Overview

- SRAD Telemetry
- COTS Telemetry
- Ejection
- Power Management
- Ground-station

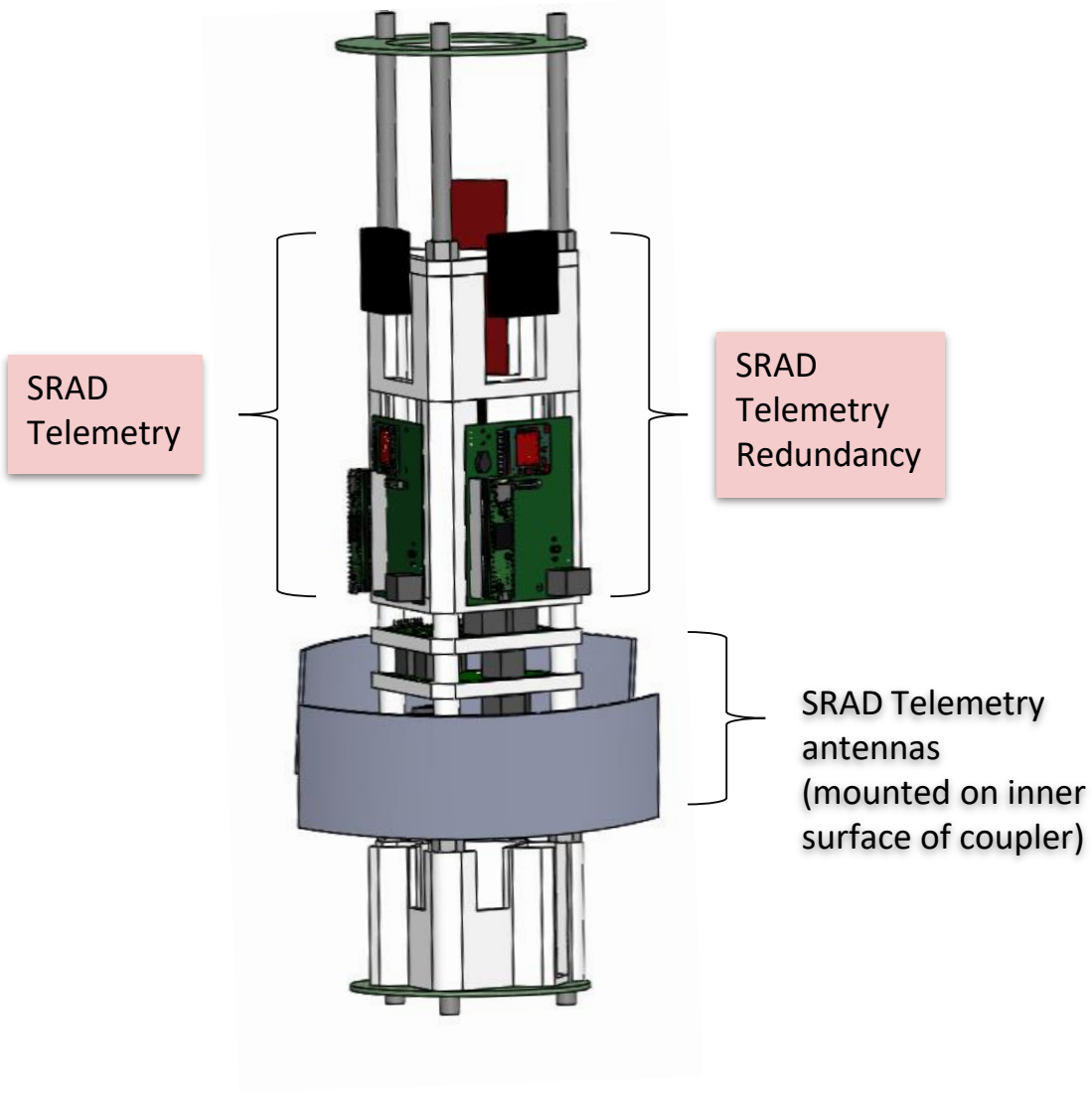
Project Caladan

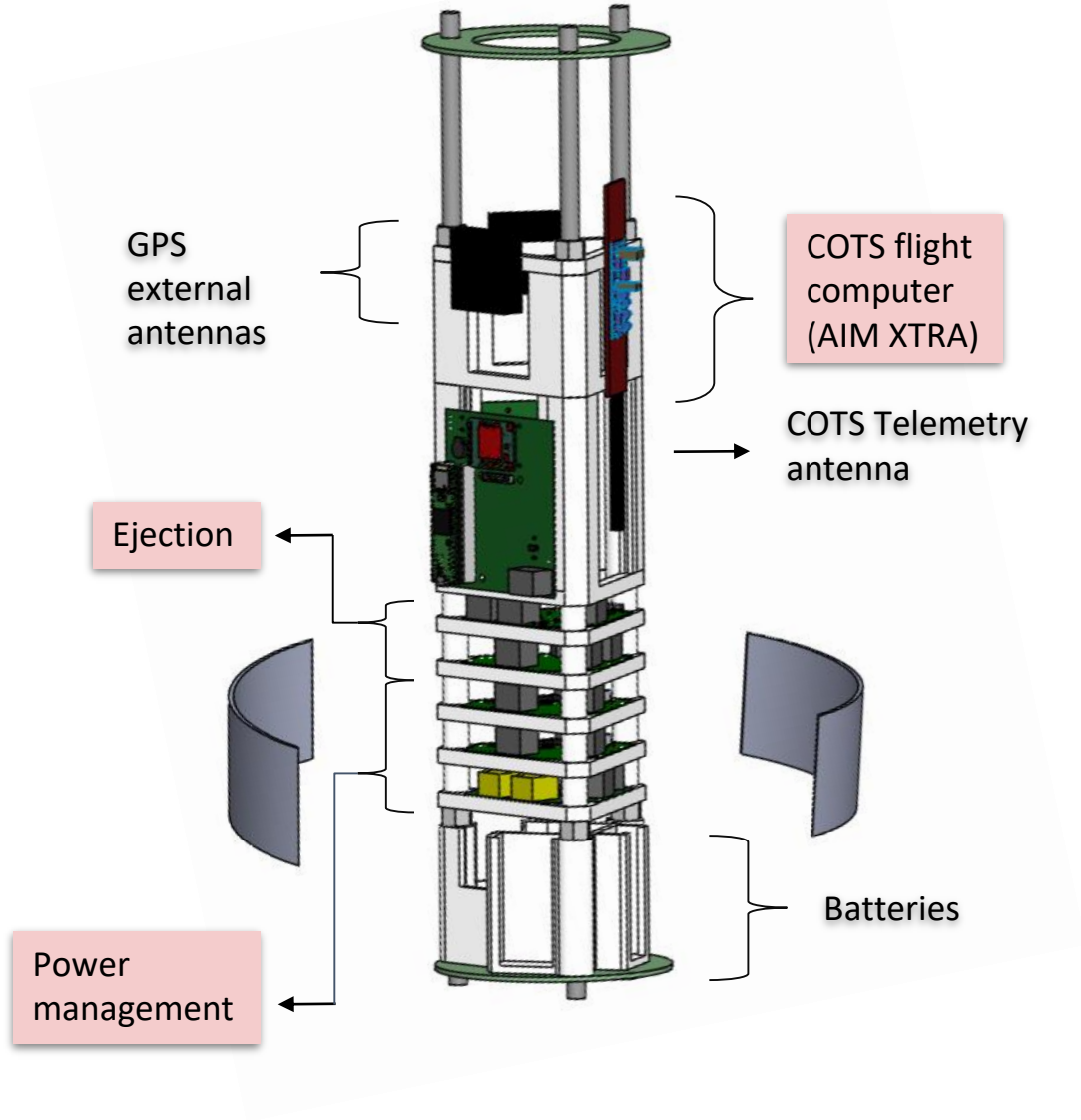
Carbon fiber
Fiberglass
Aluminum or steel

Caladan Specs	
Airframe Length (inch)	125
Inner Diameter – Outer Diameter (inch)	5 – 5.2



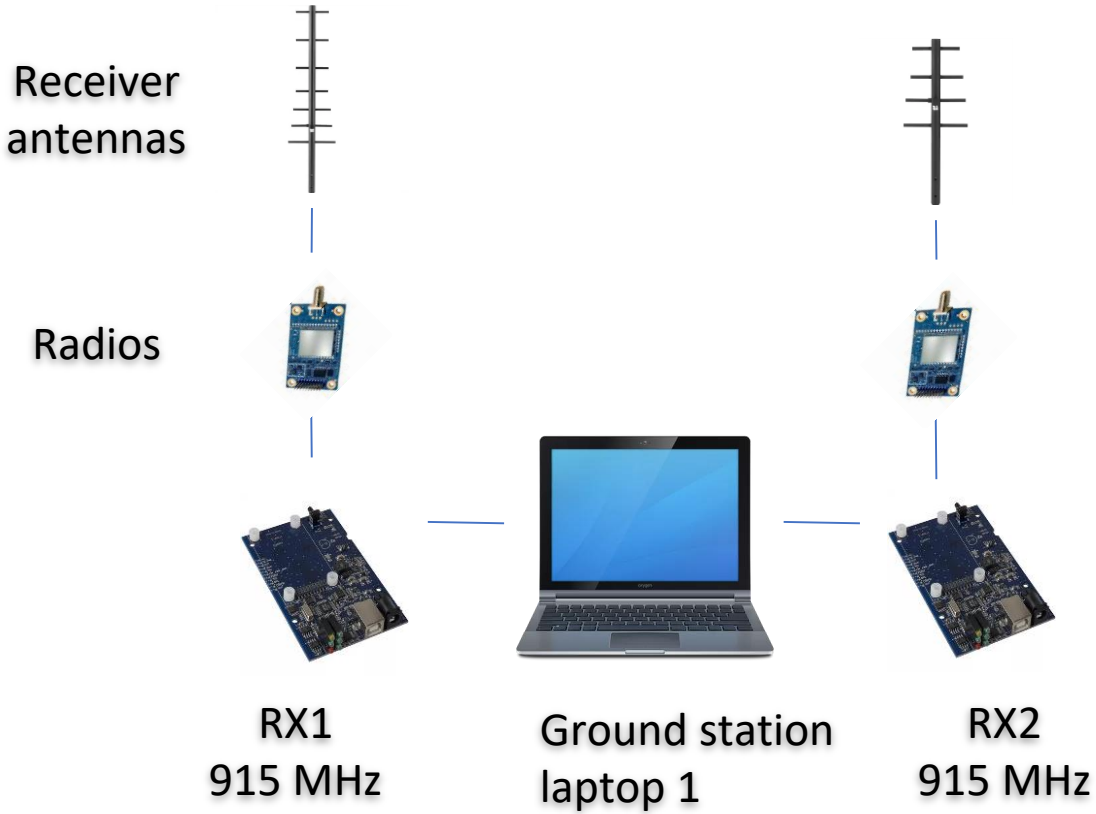
Avionics bay



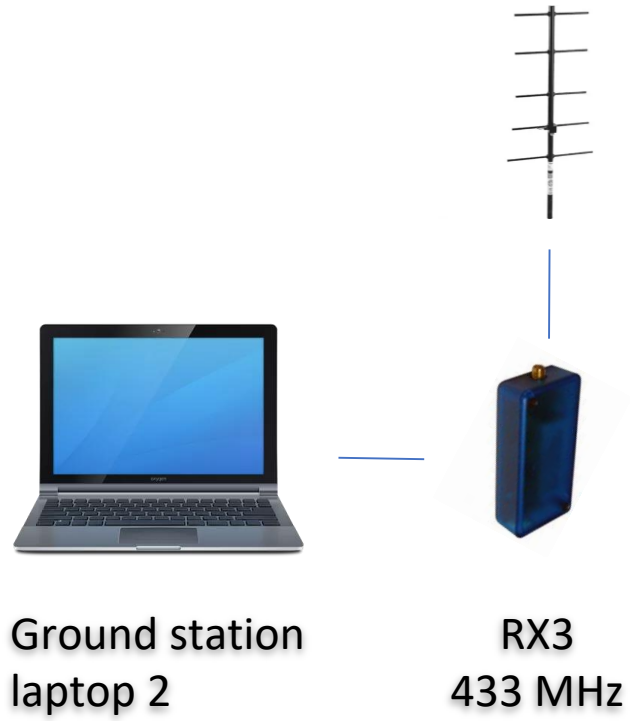


Ground-Station

SRAD Telemetry



COTS Telemetry



CONFIGURATION TESTING

Configuration Testing

Overview

- Drives design decisions to select the optimal configuration of individual subsystems

Preliminary anechoic chamber tests

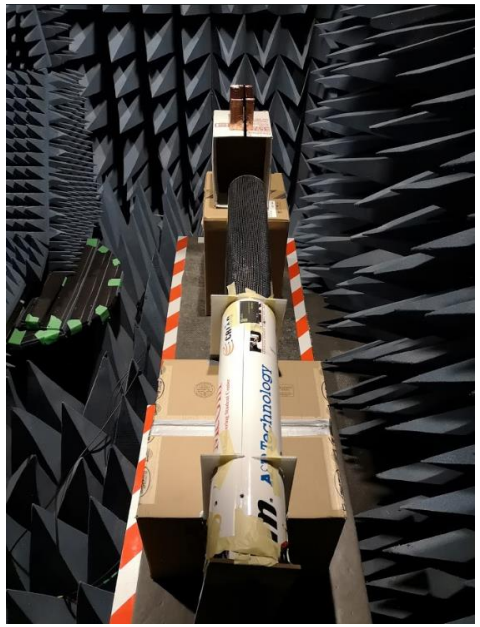
- Easy to setup, fast test results (8 readings in 30 s)
- Implemented to be remote-controlled with automated data recording and post-processing
- Only requires one person to operate test

Configuration Testing

Example configurations

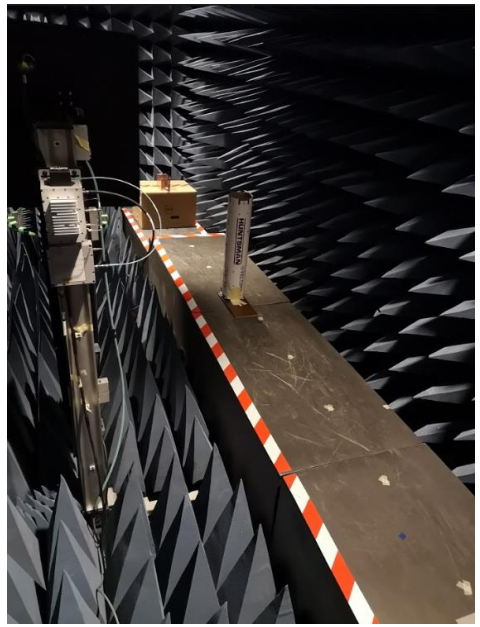
- Simulates link at various flight stages
- Measuring effects of different materials

Apogee (vertical 180°)

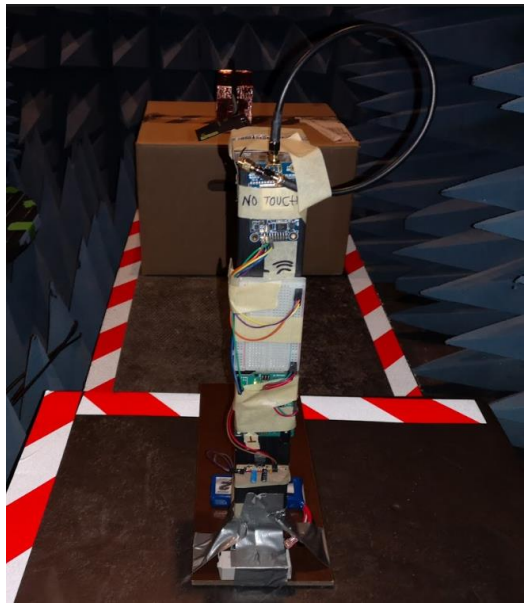


Horizontal position

Launchpad and landing (horizontal 0°)



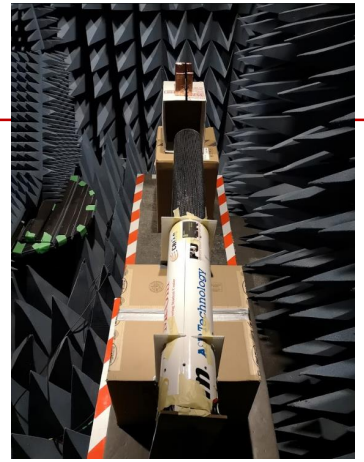
Vertical position



Without fiberglass body tube

Conductive mounting surface

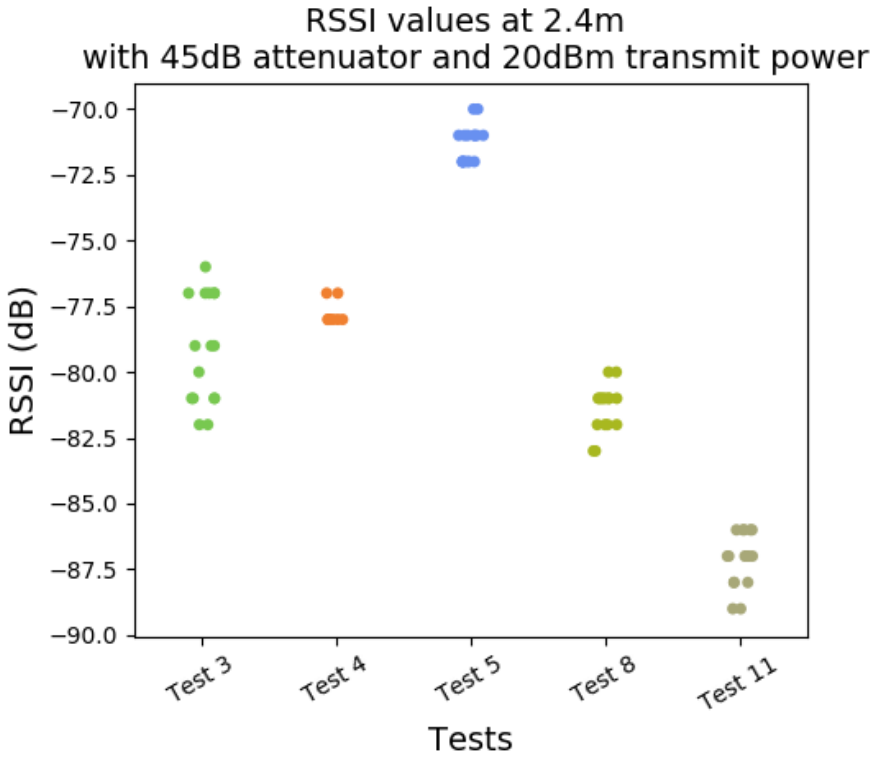
Configuration Testing



Example test results

Test 3: FXP400 patch antenna 5 cm close to the carbon fiber tube
Test 4: FXP400 patch antenna 20 cm away from the carbon fiber tube
Test 5: FXP400 patch antenna 45 cm far away from the carbon fiber tube
Test 8: Test 4 on double layer of fiberglass tubes
Test 11: Test 8 with a 7cm x 15cm copper ground plane behind antenna

- Test 3 vs. 4&5: being close to the carbon fiber tube attenuates the signal
- Test 8 vs. 4: double layer of fiberglass also attenuates the signal
- Test 11: ground plane behind the antenna does not improve its performance



Configuration Testing

Antenna radiation pattern test

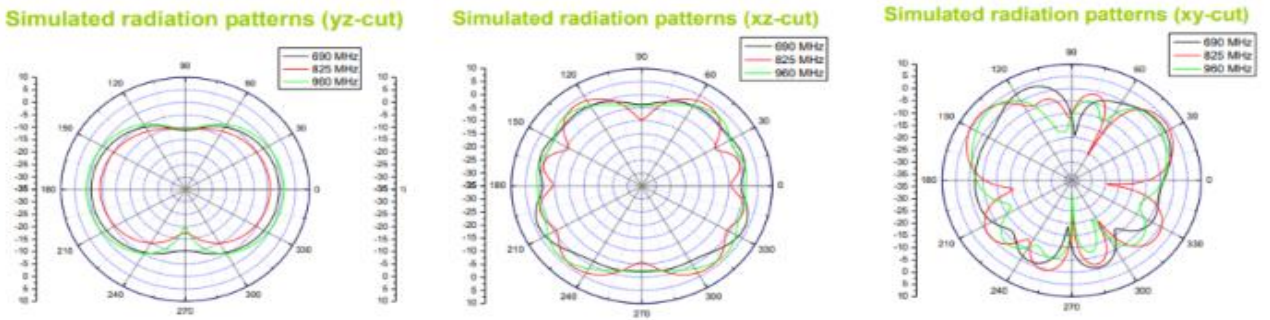
- Used the NSI-MI Technologies Near-Field test equipment in the anechoic chamber
- Detailed and precise measurement of antenna’s radiation pattern
- 30 min each test run, fully automated by test equipment
- Tested with top configurations selected from preliminary tests

Configuration Testing

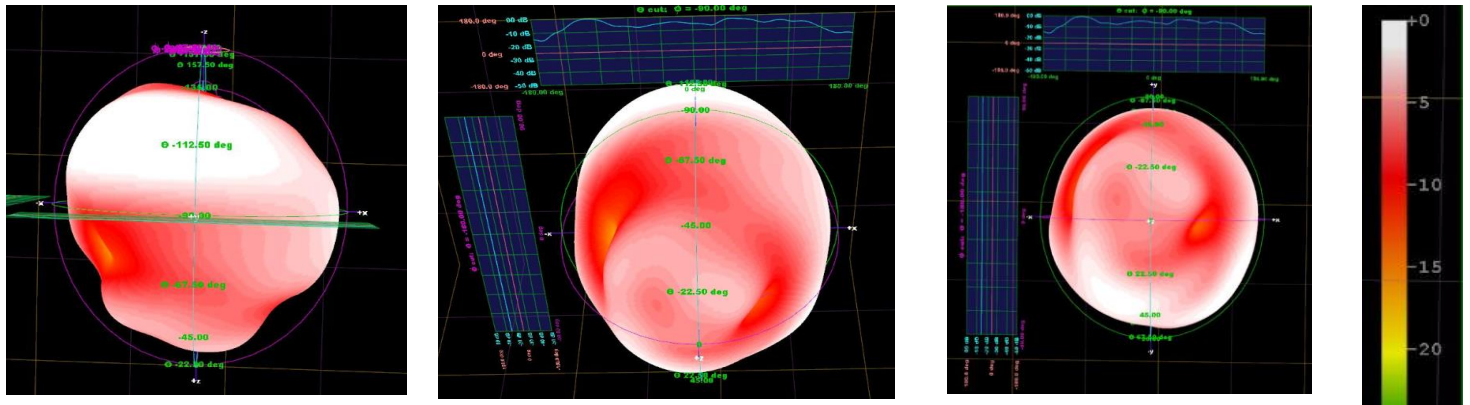
FXP400 facing up on fiberglass tube ending with carbon fiber coupler

- Slight deviations from COTS antenna's datasheet due to surrounding materials and bent shape to match curvature of rocket body tube

Datasheet
(simulated pattern)



Measured pattern



Horizontal link (0°) | Diagonal link (45°) | Vertical link (180°)

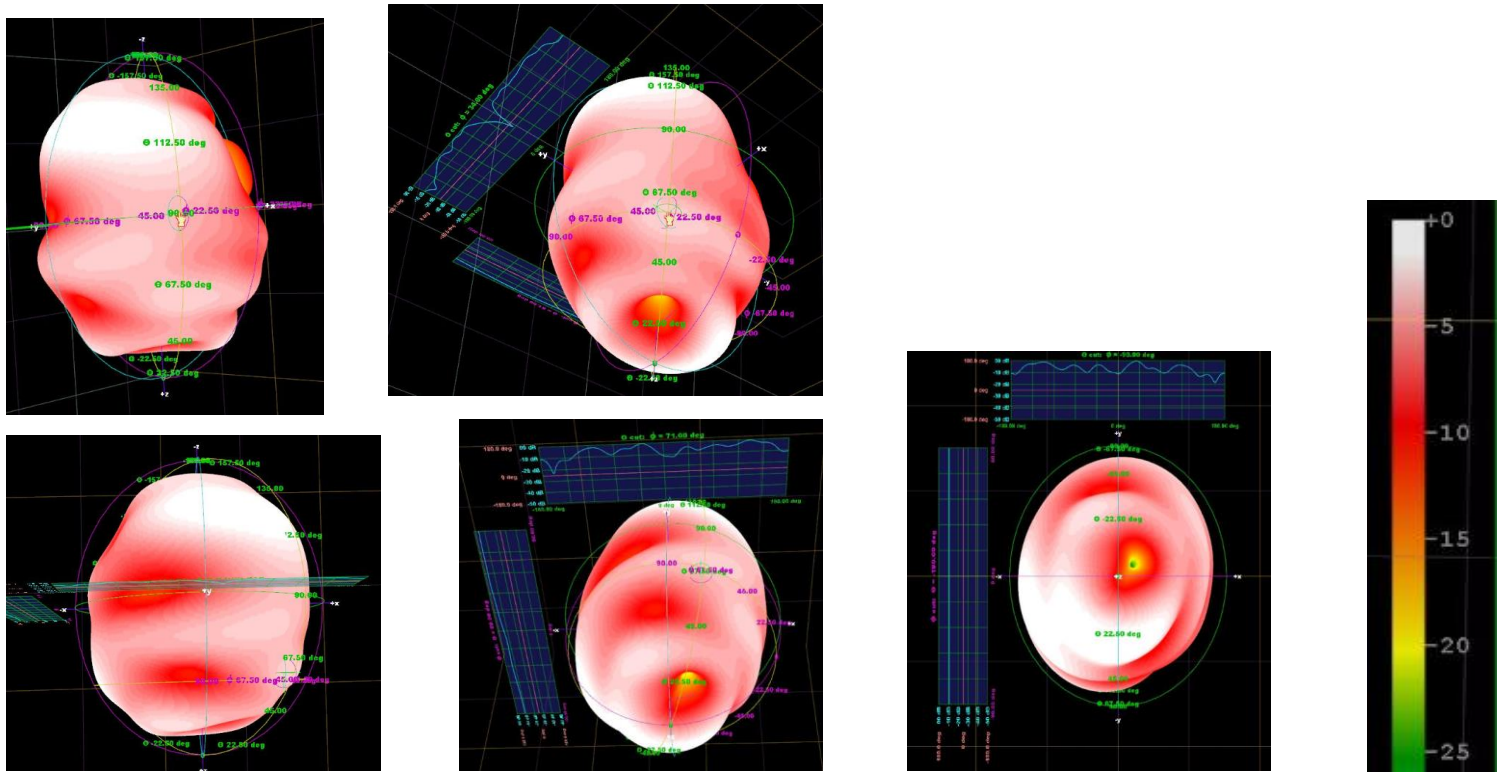
Configuration Testing

FXP400 facing down on fiberglass tube ending with carbon fiber coupler

- Less directional, more probability of maintaining stable link throughout flight

Slightly rotated view (30°)

Straight view (0°)



Horizontal link (0°)

Diagonal link (45°)

Vertical link (180°)

INTEGRATION TESTING

Integration Testing

Overview

- Aims at optimizing for the best performance of the overall system, verifying any effect of interference between individual subsystems
- Simulates in-flight conditions with all subsystems integrated and assembled

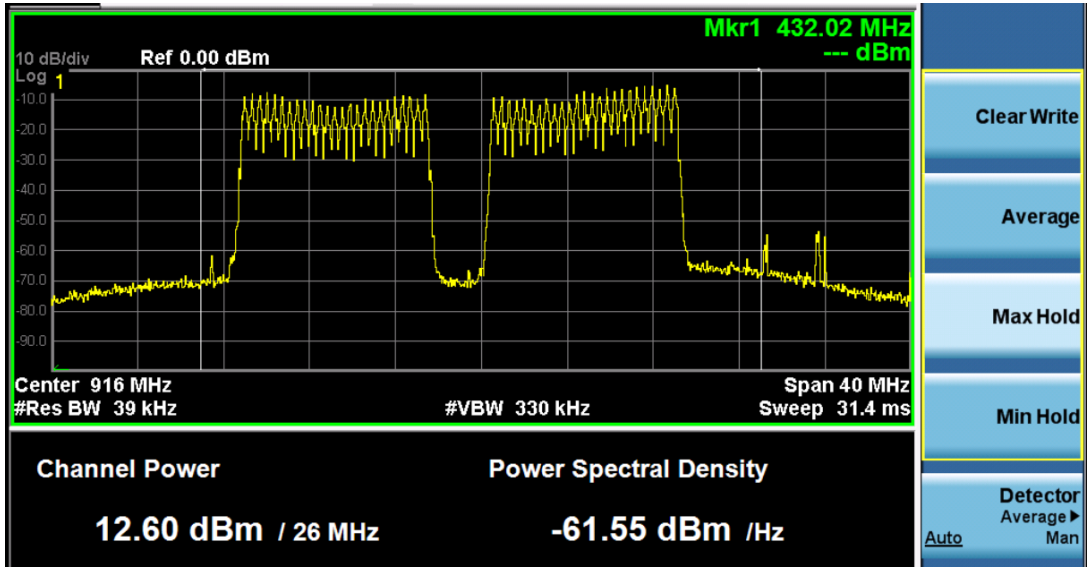
Spectrum analyzer tests

- Displays power level of an input signal over specified frequency range
- Can measure the noise floor level and signal-to-noise ratio
- Can observe interference like intermodulation

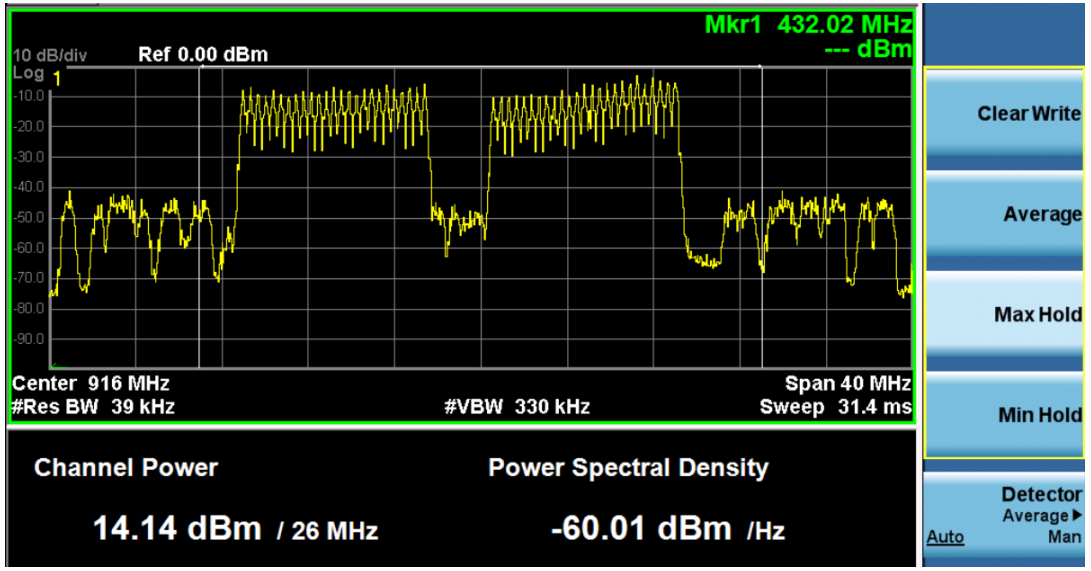
Integration Testing

Example of interference: intermodulation distortion

- Higher noise floor
- Out-of-band frequencies



One pair of transmitter and receiver radios

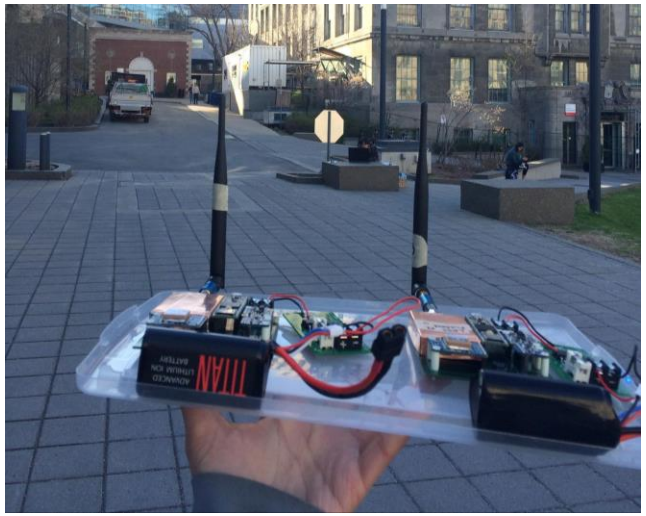


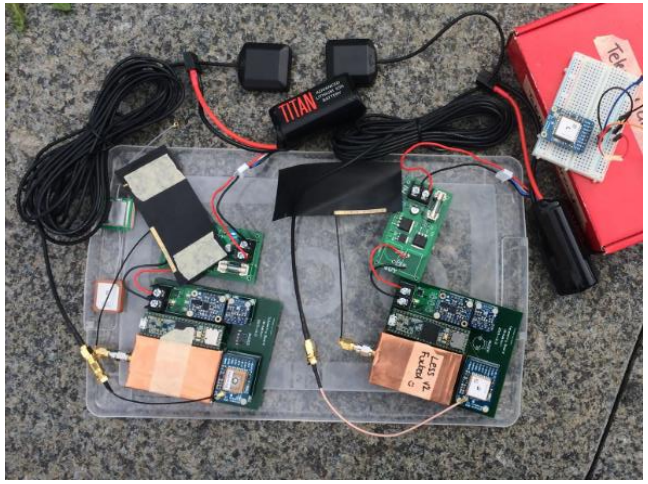
Two pairs of transmitter and receiver radios

Integration Testing

Preliminary short-range tests

- 15 -100 meters distance
- Easy to setup and execute test: can be tested by 1-2 people
- Simulated long-range with added attenuators (40-80 dB)
- Used shielding to minimize leakage from adding too much attenuation





Integration Testing

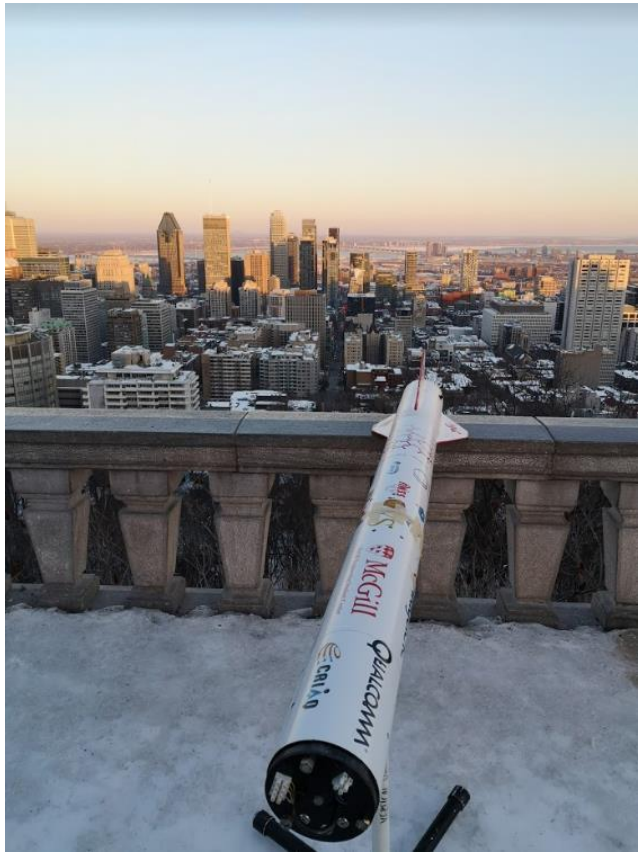
Long-range tests

- 10 and 15 km line-of-sight distance
- Logistically heavy: need minimum 5 people to transport test setup, hold antennas and record data
- Harder to vary test setups and configurations
- Test all telemetry systems with their respective ground-stations
- Measure the Received Signal Strength Indicator (RSSI) and throughput
- Verify the effect of interference caused by individual subsystems
- Spin test to observe the effect of potential spinning of the rocket over its dominant axis

Integration Testing

Transmitter and receiver setup

Transmitter (higher altitude)

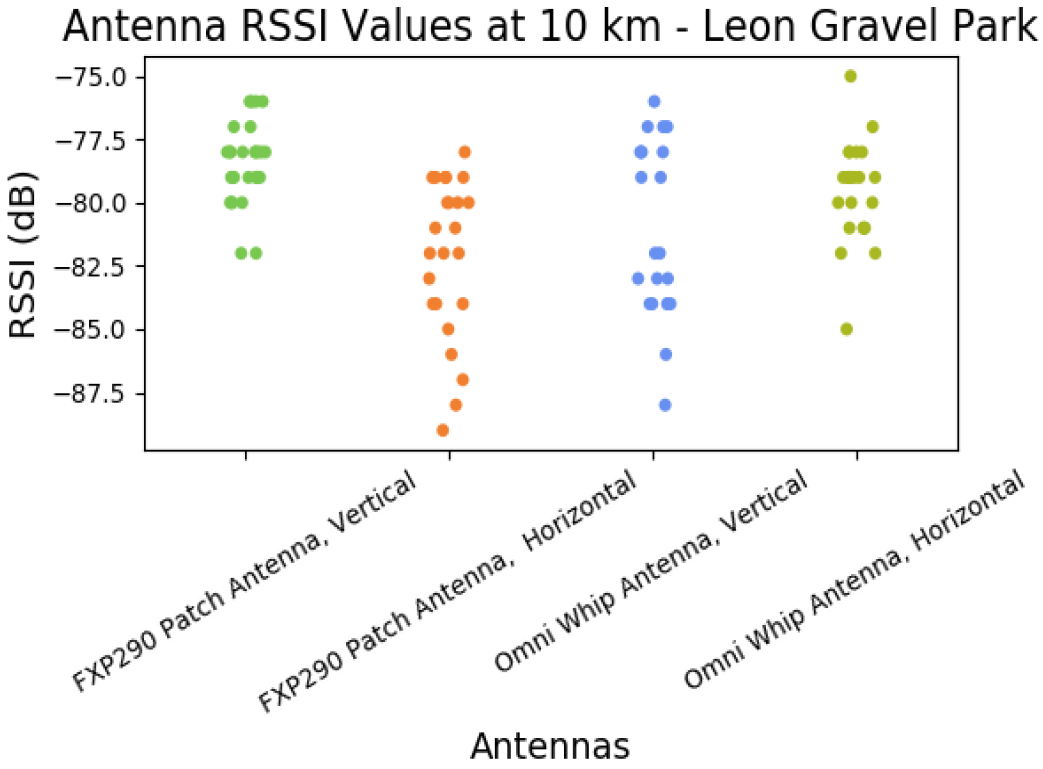


Receiver (ground)

Integration Testing

Example test result

- RSSI is about 2dB lower in the horizontal position
- RSSI did not seem to be affected when powering all radios at the same time, full power



Integration Testing

Spin test

SUMMARY AND IMPACTS

Summary and Impacts

Summary

- Started testing previous design year's modules to serve as reference
- Kept testing iteratively throughout the year to make sure every design decision integrates well with the rest of the systems
- All design decisions were based on extensive test results

Impacts

- Iterative designs instead of re-inventing the wheel
- Quantitative assessment of performance allows deeper understanding of why a system does not behave as expected and how to improve it

Summary and Impacts

Additional tests

- We are still looking for a vibration test facility
- 5k feet test flight on May 18th

FOLLOW-ON WORK:

SRAD ANTENNA DESIGN

Follow-on work

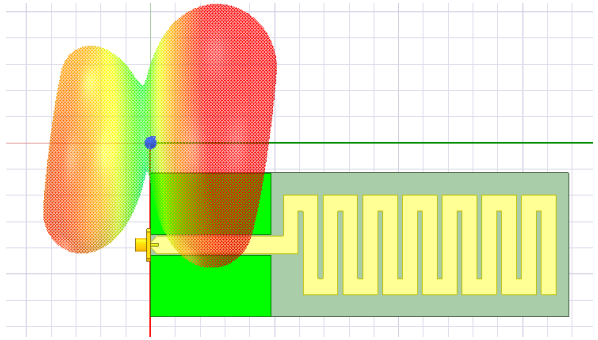
SRAD Antenna design: Meander line patch antennas

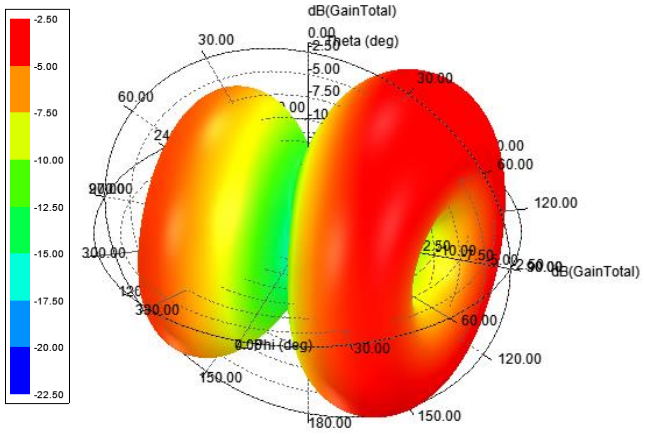
- Preliminary SRAD antenna design
- Simple solution given size and shape constraint but not very performant
- Learned how to use antenna simulation software and introduced to basic antenna design

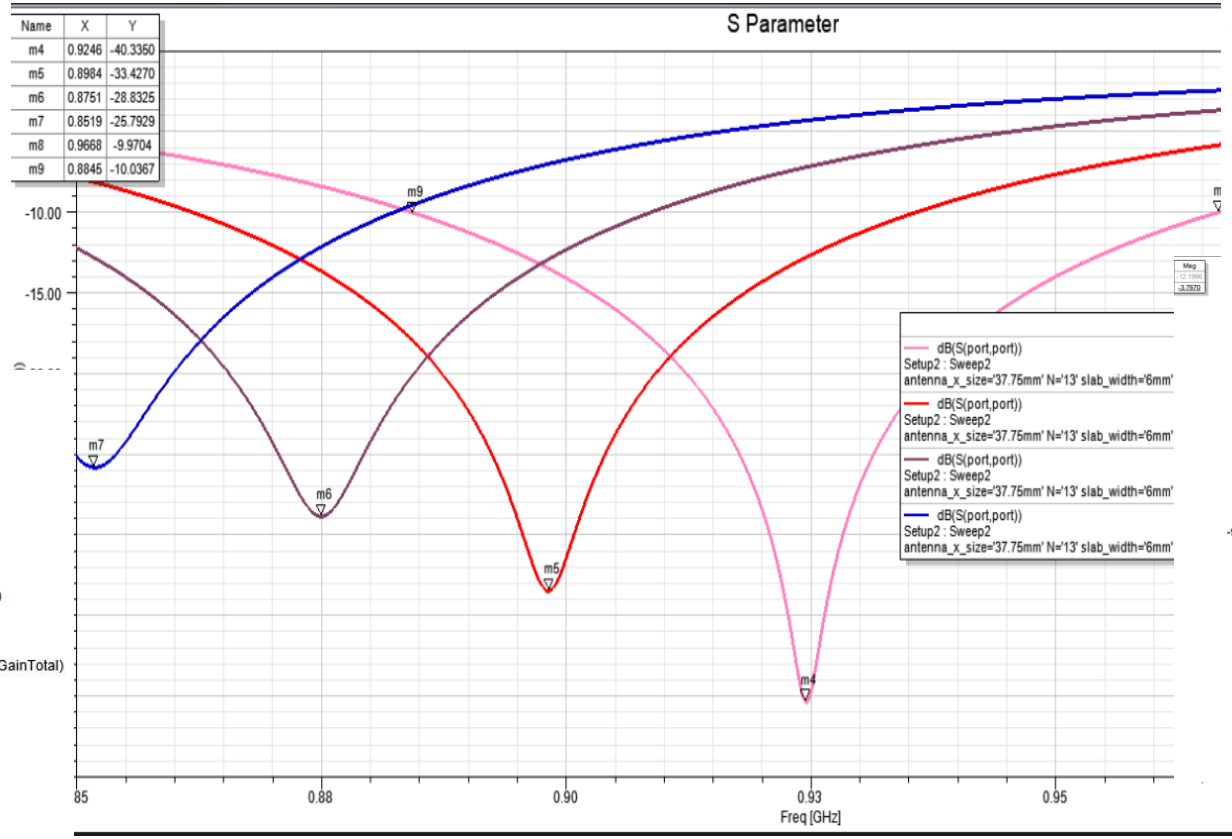
Antennas –Telemetry (R&D)

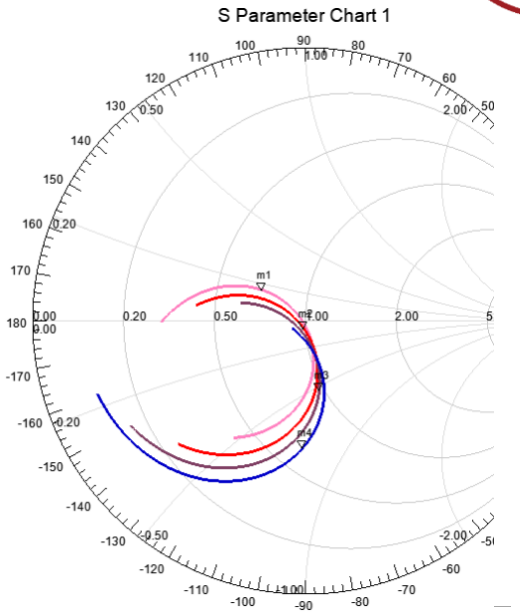
Design C

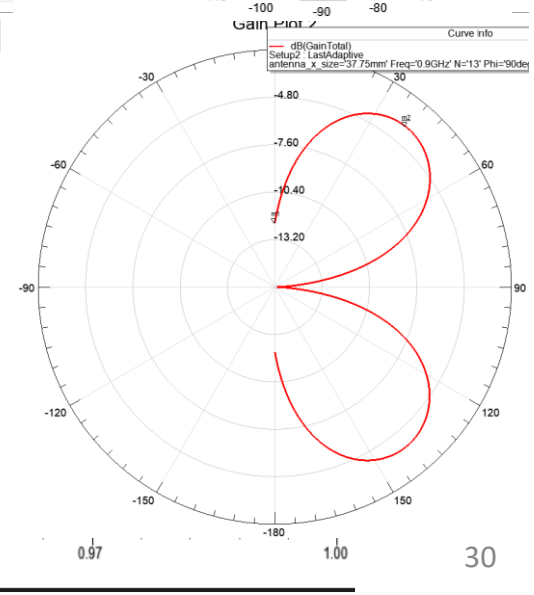
- Simulated with a lumped port
- Really good bandwidth and matching
- Negative gain



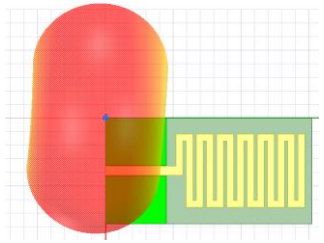








Antennas –Telemetry (R&D)



Design A

Return loss/s11:

- -24.2 dB

Peak gain:

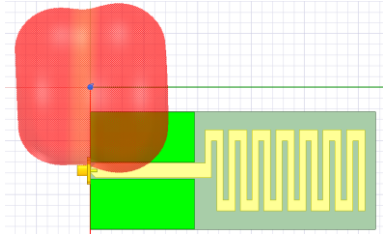
- -3.66 dBi

Bandwidth:

- 30 MHz

Dimensions:

- 78 mm x 152.5 mm x 0.1524 mm



Design B

Return loss/s11:

- -11.6 dB

Peak gain:

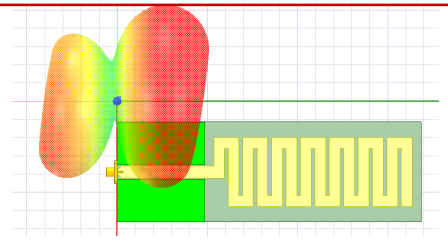
- -5.97 dBi

Bandwidth:

- 25 MHz

Dimensions:

- 54.95mm x 133 mm x 0.1524mm



Design C

Return loss/s11:

- **-40 dB**

Peak gain:

- **-3.37dBi**

Bandwidth:

- **82.3MHz**

Dimensions:

- 54.95mm x 168.5 mm x 0.188mm

Follow-on work

SRAD Antenna design: Beamforming patch antenna array

- Antenna array can steer its radiation beam through phase synchronization at different stages of flight
- Allows for better performance due to higher directivity controlled to beam towards the ground station
- Way more complicated and will require bigger mounting surface


MRT