Sounding Rocket CDR
Team Aether

Presentation Outline

Team Organization

Names	Roles
Adam	Software Developer
Zach	Rocket Designer
Sarah	Team Captain
Jacob	Mechanical subsystem
Tyson	Payload Electronics
Josh	System Overview
Emily	Testing
Gabriel	Ground Station
Ryan	System Overview
Kyle	Introduction

Acronyms

- PDR: Preliminary Design Review
- CDR: Critical Design Review
- CONOPS: Concept of Operations
- CP: Center of Pressure
- CG: Center of Gravity
- MDRA- Maryland-Delaware Rocketry Association
- TWR – Thrust to Weight Ratio
- OD- outside diameter
- IN- Inside diameter
- SH- Spillhole diameter

System Overview

Mission Summary

- Our mission is to launch a sounding rocket, keeping the rocket's maximum altitude between 1200 and 2000 feet, waiting 5 seconds from launch before taking pictures at a rate of no more than once per second. The rocket must stop taking pictures when it lands.
- Include any external objectives
- Send pictures from rocket to ground computer.

System Requirement Summary

Payload Requirements, we must have:

- A camera with a minimum resolution of 640x480 pixels, in color, no video
- An image capture rate of no more than once per second
- Images stored in the payload for download after recovery
- Telemetry transmitted five times per second, including a timestamp with sufficient resolution, current altitude, speed, acceleration, spin rate, and image number.
- A telemetry packet with a packet count that is incremented for each packet

System Concept of Operations

- Overview of operations of the system from launch to landing to Payload operations.

Insert and connect starter to battery and button/switch → Move to a safe distance an press button/switch after countdown → Rocket waits five seconds from launch

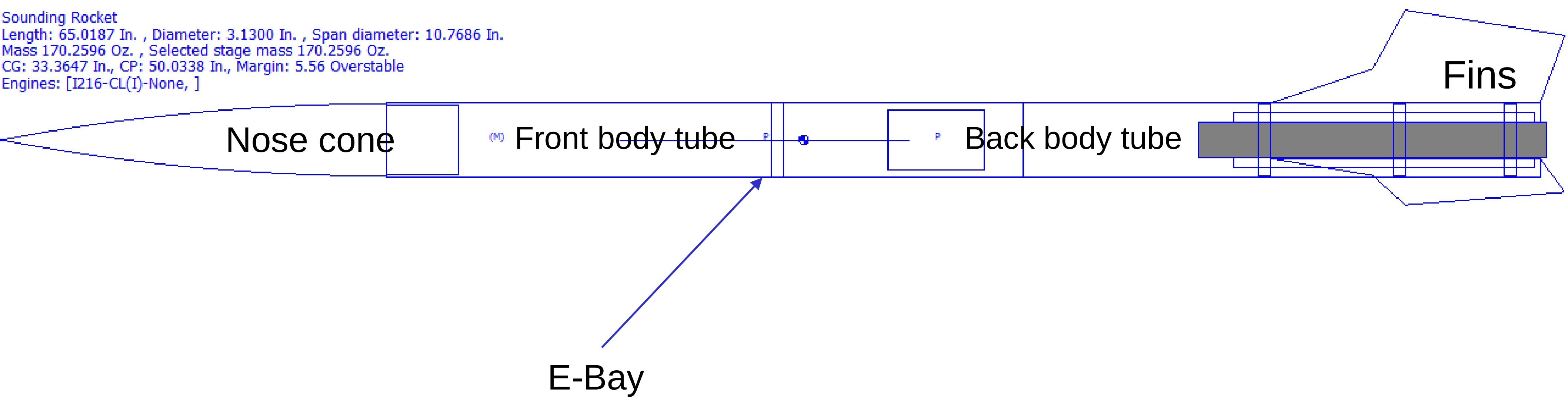
→ Rocket reaches apogee an begins its descent → Rocket takes no more than 1 picture per second while updating ground computer 5 times per second

→ Ejection charges go off, separating the rocket , and the drogue parachute deploys → Main parachute deploys, rocket descends safely to the ground → Recovery team walks to retrieve the two halves of the rocket

→ Rocket is retrieved and data is downloaded from electronics bay

Physical Layout

- Diagram of rocket showing major components
  - The rocket will be 65 inches long, and 3 inch diameter body tube.
  - The payload will be located in the nose cone, and the main parachute will be located in the front body tube. The drogue chute will be in the back body tube.



Rocket Design

Changes Since PDR

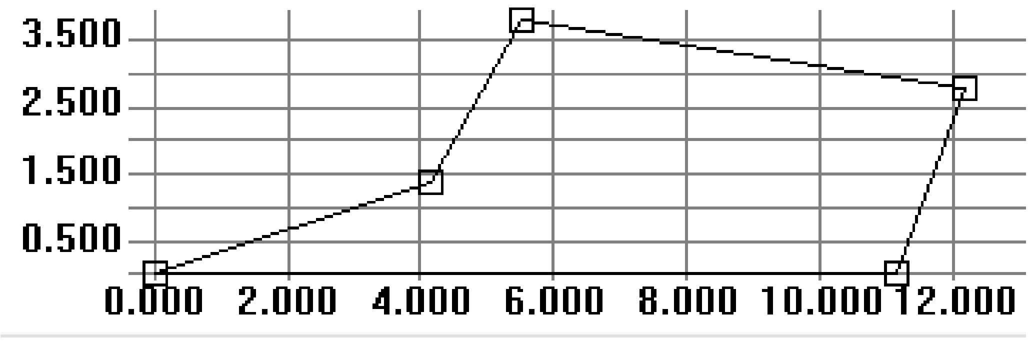
- The ¼ inch plywood fins were replaced by a student designed slip-on ultem 3D printed fin can. The fins still have the same shape, but the mass is less.

- We have used 3D printed fin cans like this on high powered rockets for the past 4 years, and are very confident that it will perform correctly.

Overview of Rocket

- Describe overall rocket design
  - Designed using Rocksim
  - Nose cone in the front of the rocket, connected to the front body tube, which is connected to the electronics bay. The back body tube is attached to the electronics bay, and the motor tube is mounted in the back body tube. Finns are mounted on the back body tube.
  - Rocket weight of 133 ounces
  - Payload weight of 16 ounces
  - Cesaroni I216
  - Airframe diameter of 3”
  - 3 fin design
  - Rocket length of 65 inches
  - CP-50.03 inches from nose cone and CG-33.36 inches from nose cone, which is 16.67 inches apart

Fin Dimensions



Rocket Materials

- Airframe Material - 1/16 inch Fiberglass Tubing
- Fin Material - Ultem
- Nosecone material – Fiberglass
- Adhesives Used - Rocket-Poxy, 5-Minute Epoxy, and JB Weld. They were all used for centering ring and fin attachment
- Rail Guides – Linear Rail Lugs
- Active Motor Retention using Aeropack Motor Retainer

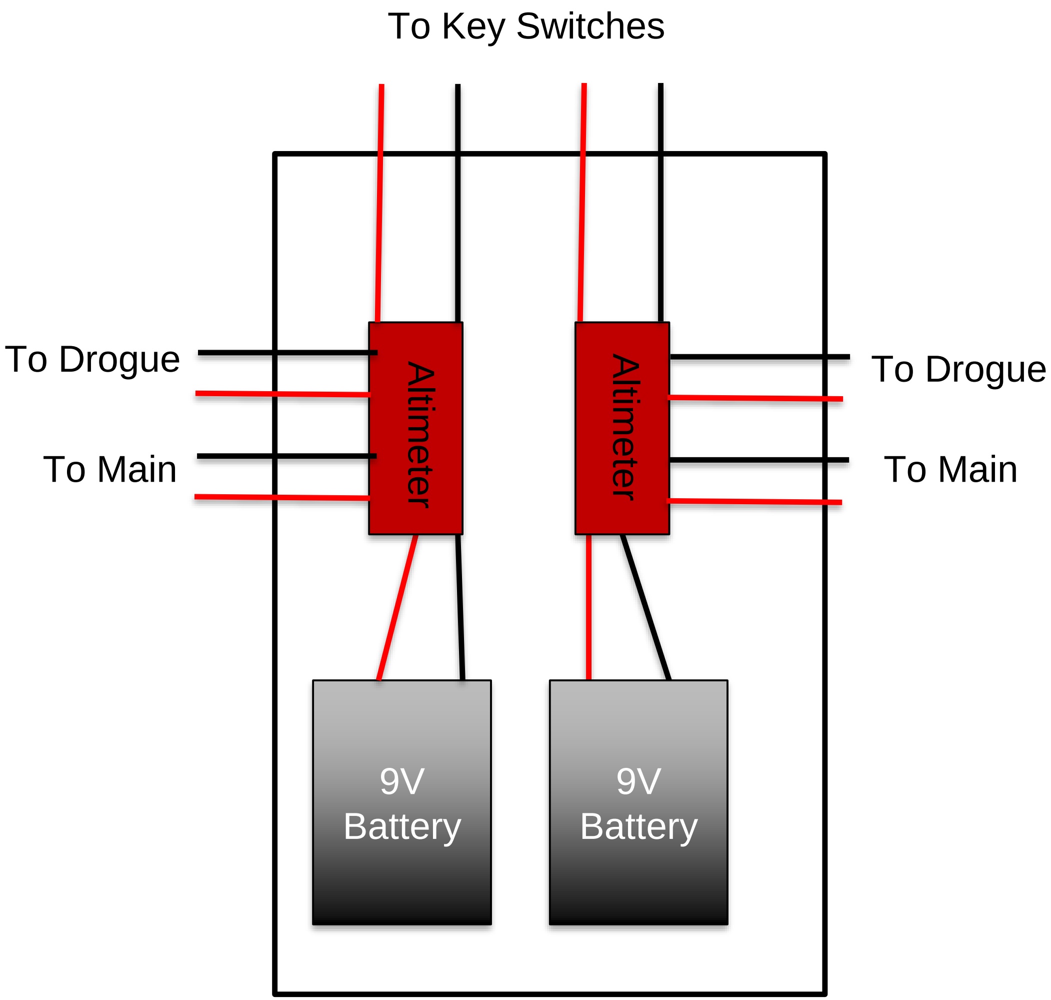
Rocket Recovery System

- Drogue-24 inch Elliptical parachute
- Main- 72 inch Iris Ultra parachute
- Descent Rate Under main- 15.4 ft/s
- Descent Rate Under drogue- 40.2 ft/s
- Harnesses
  - 3/16 inch tubular Kevlar. 15 feet long for front and 15 feet for back half
  - Swivel to hold parachute using quick links. (880 lbs. max)
  - Quick links attached to parachutes are attached to the swivel on the shock cord which are secured to eyebolts on the rocket using quick links
  - Parachutes are protected by Nomex heat shields, and Nomex sleeves are put on the shock cord for protection

Rocket Recovery System Deployment Method

- Altimeter used will be a Perfectflite Stratologger CF. Ejection charges will be at apogee and 600 ft above the ground
  - When loading, an 18 year old student holds electronics bay, while the NAR mentor loads and seals the black powder ejection wells.
  - To arm the recovery system, while on the pad, key switches are turned arming the altimeter. Key switches are removed and stored with the recovery team.
  - Key switches are turned arming the recovery system before the igniter is inserted to ensure safety in the case of an accidental launch.
- 1.9 g of 4F grain size black powder . Through extensive black powder ejection tests, we were able to determine a safe, working amount.

Wiring diagram of altimeter



Rocket Motor Selection

- Primary motor selection- Cesaroni I350
- Backup motor selection- Cesaroni I540
- Primary TWR = 7.42:1
- Secondary TWR = 10.6:1 (Added 300g of mass. Motor originally chosen to account for potential payload mass being higher)
- Expected Altitude
  - I-350: 1955 ft
  - I-540: 1993 ft

Primary Motor Simulations

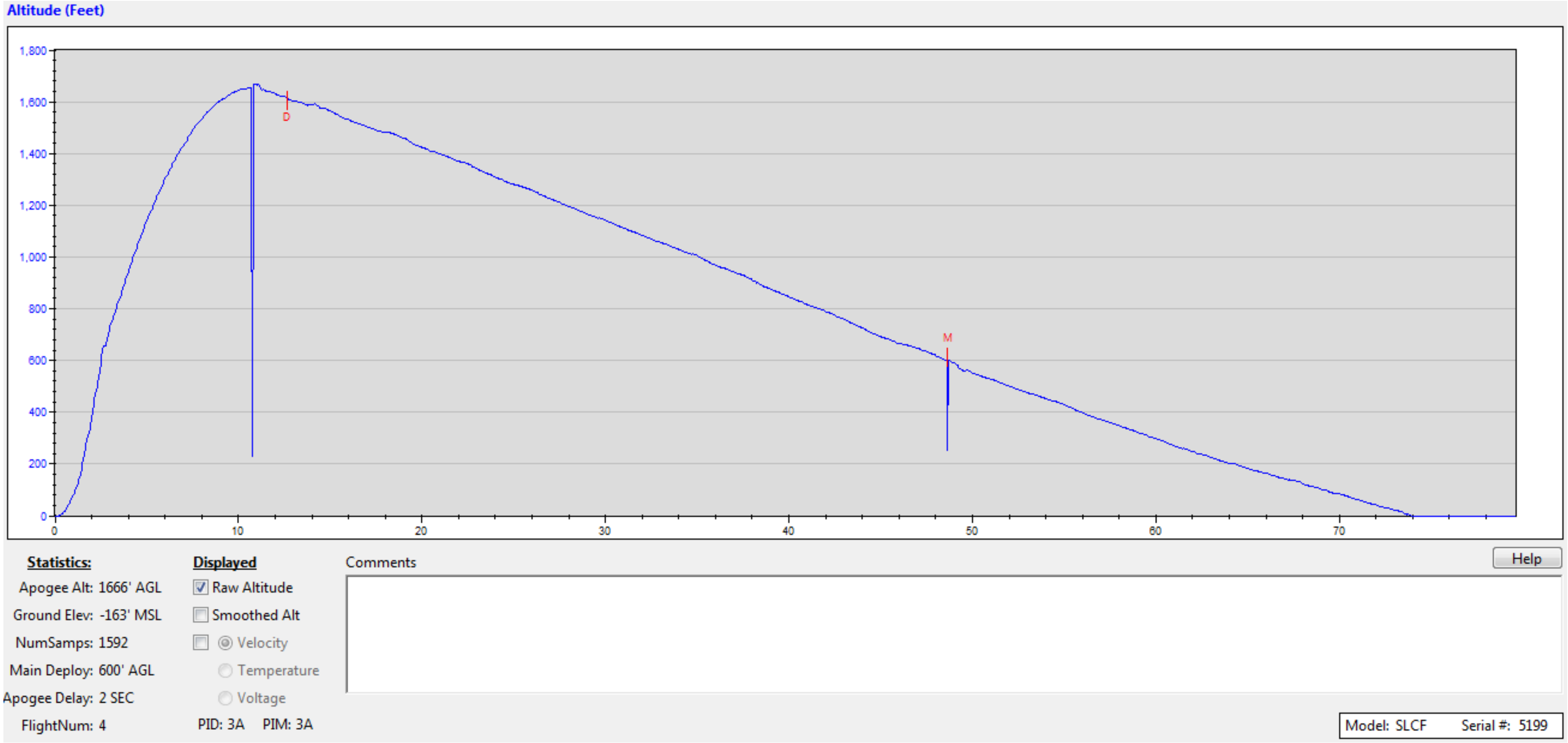
Engines loaded	Max. altitude Feet	Max. velocity Feet / Sec	Max. acceleration Feet/sec/sec	Time to apogee	Velocity at deploym Feet / Sec	Altitude at deploym Feet
[I350SS-None]	1955.34	356.84	644.90	11.45	3.58	1955.34

Secondary Motor Simulations

Engines loaded	Max. altitude Feet	Max. velocity Feet / Sec	Max. acceleration Feet/sec/sec	Time to apogee	Velocity at deploym Feet / Sec	Altitude at deploym Feet
[I540WT-None]	1993.58	371.66	644.96	11.30	5.05	1993.58

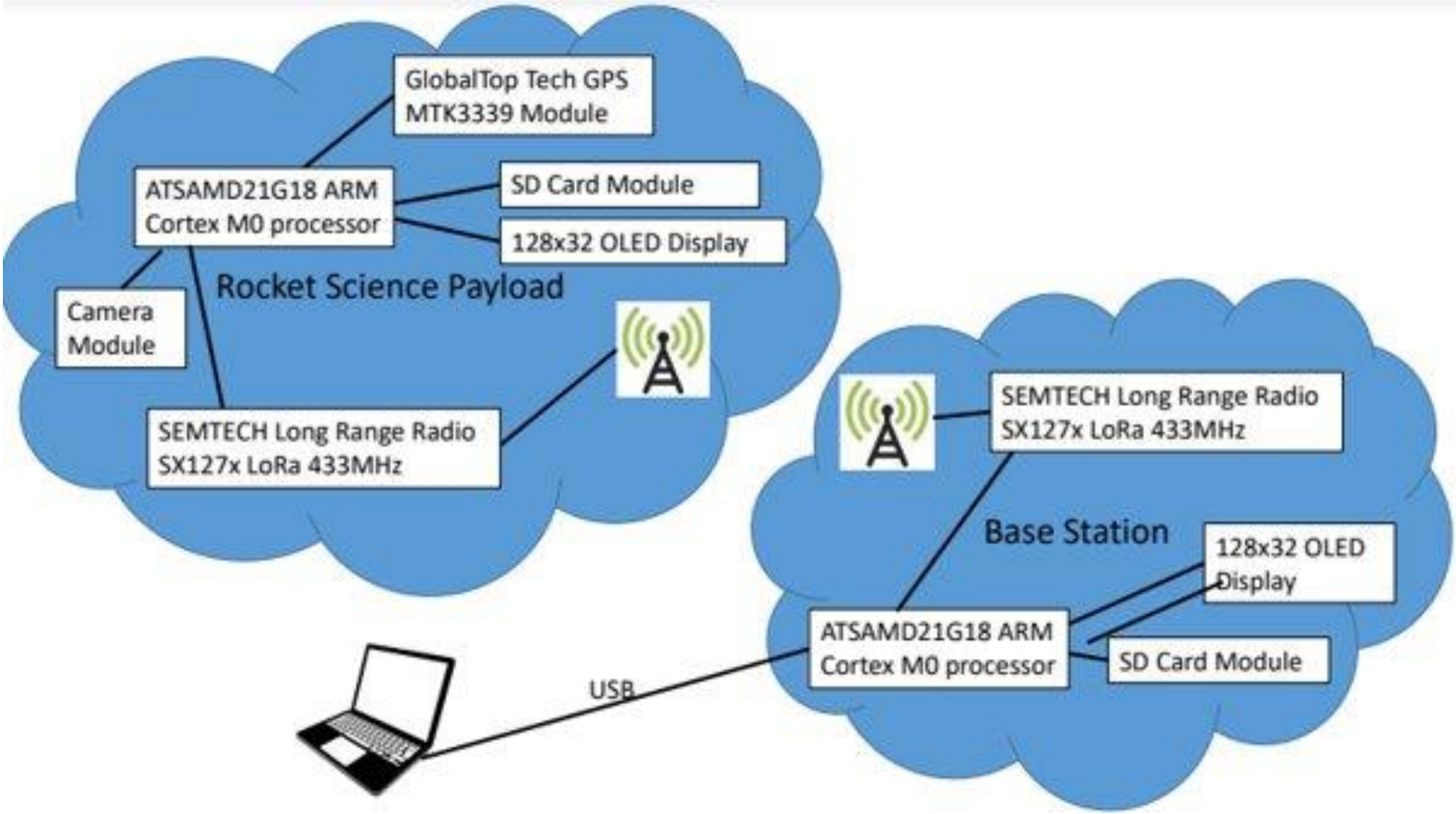
Test Flights

- The rocket was flown with a simulated payload mass in it on December 17th successfully.

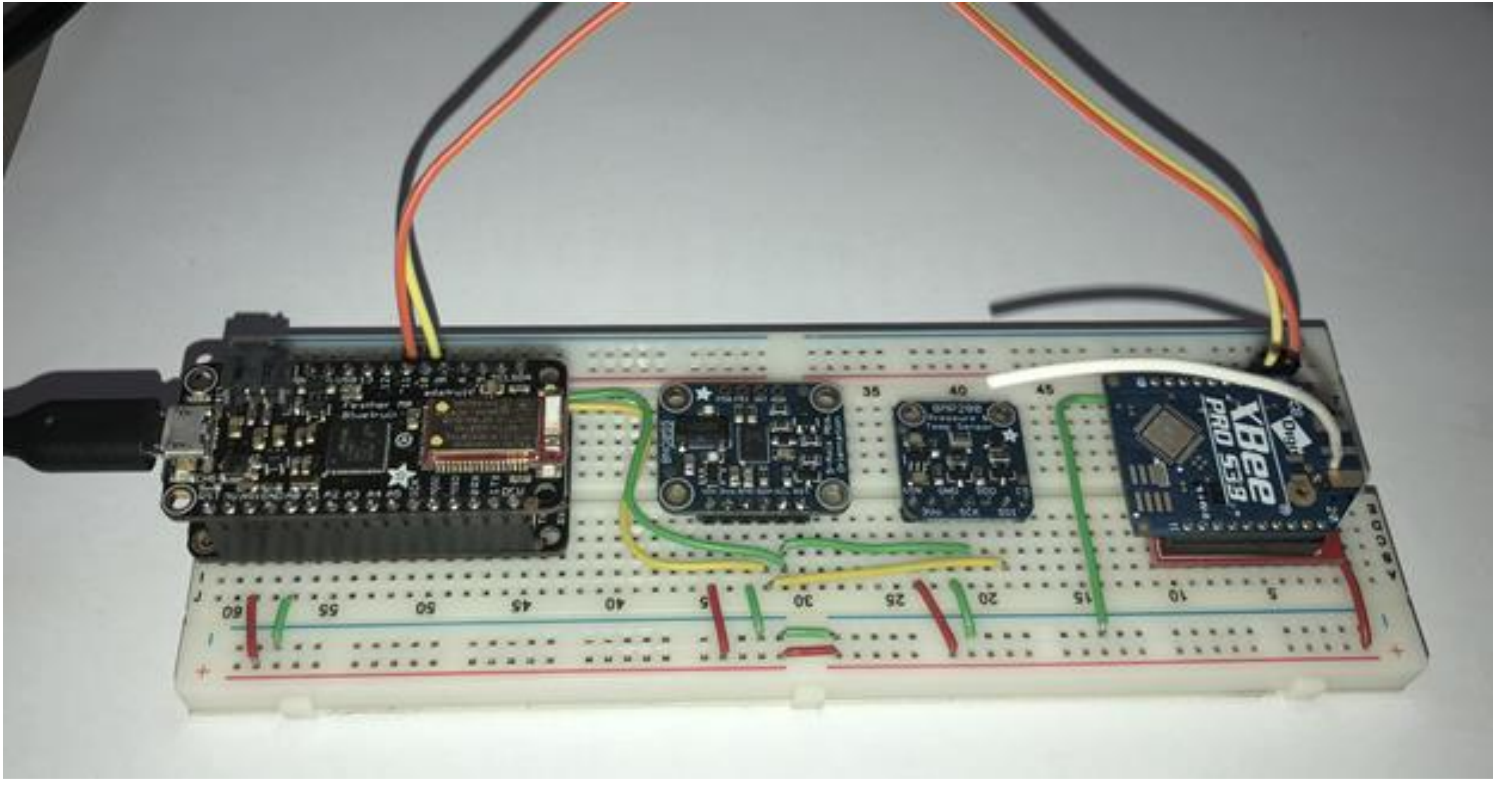


Payload Design

Payload Design Overview



Picture of Payload



Base Station Hardware

1. Adafruit Feather M0 Adalogger
2. SparkFun XBee-Pro 900 XSC S3B Wire
3. SparkFun Breakout Board for XBee Module
4. Adafruit Half-Size Breadboard
5. Adafruit Jumper Wire
6. USB Cable

Rocket Payload components

1. Adafruit Feather M0 Bluefruit LE
2. Adafruit Ultimate GPS FeatherWing
3. Adafruit BME280 I2C or SPI Temperature Humidity Pressure Sensor
4. Adafruit 9-DOF Absolute Orientation IMU Fusion Breakout - BNO055
5. SparkFun XBee-Pro 900 XSC S3B Wire
6. SparkFun Breakout Board for XBee Module
7. SparkFun Full-Size Breadboard
8. Adafruit Lithium Ion Cylindrical Battery - 3.7v 2200mAh
9. Adafruit Mini Spy Camera with Trigger for Photo or Video
10. SD card for images

Mechanical Subsystem

Mechanical Layout

- Mechanical Layout of the payload
  - All parts will be located in the nose cone.
  - The camera module will be located with located in the nose cone by cutting a hole and covering the hole with a thin price of plexiglass to prevent damage

Mechanical Subsystem

Major Mechanical Parts:

Item	Weight (g)	Mass Margin (g)	Length (mm)	Width (mm)	Height (mm)	Voltage
CPU/Radio	9	1	50	23	10	3.3
GPS	13	1	50	23	10	3.3
SD	9	1	50	23	7	3.3
OLED	7	1	50	23	5	3.3
Shield	13	1	50	45	10	-
Camera	2	0.25	28	20	8	5
Power boos	5	0.5	27	22	7	3.3 to 5
IMU	3	0.5	37	23	5	3.3
wire	10	1				
	71	±7.25				

Payload Electronics

Payload Electronics

- Electronic block diagram showing all major components
  - Processors ARM Cortex M0 (32bit)
  - Memories: 256K FLASH, 32K RAM, 4GB SD
  - Sensors: GPS, Camera, 10DOF IMU
  - Drivers for mechanisms and actuators

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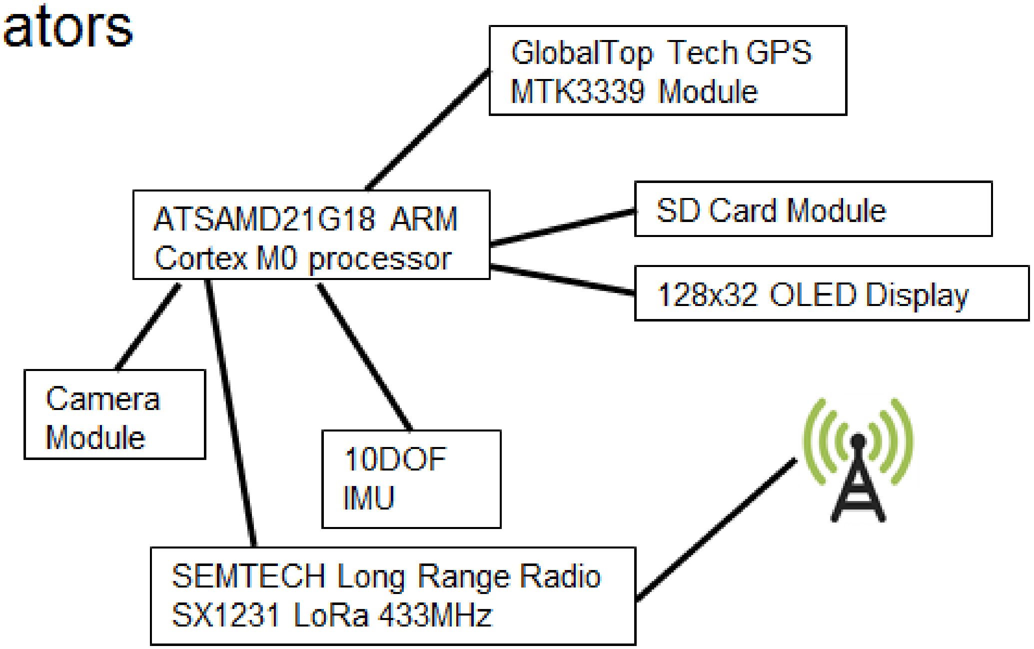
Power boost	5	27	22	7	3.3 to 5
IMU	3	37	23	5	3.3
wire	10				
	71				



Processor and Memory

- ARM Cortex M0
  - 40nm process; 56 Native instructions; 32bit; 256kb storage; 32kb RAM
  - Up to 66µW/MHz @ 1.8v, 25C
  - Up to 2.33MHz
  - Interfaces:
    - UART for GPS, XBee Radios, and Computer
    - SPI for BNO055 and BME280
    - OneWire for Camera
    - I2C for SD card

Payload Sensors

- Camera
  - 640x480 resolution
  - 110mA during operation, 80mA at idle
  - Connected via OneWire
- BNO055
  - Measures absolute orientation on 3 axis, angular velocity, magnetic field strength, linear acceleration, gravity, and temperature
- BME280
  - Measures temperature, humidity, and barometric pressure

Payload Radio

- XBee Radio
  - XBee ADF7023
  - 902-928 MHz Frequency band
  - Connected via UART

Payload Radio Antenna

- Wire Antenna
  - Dipole antenna and High-gain antenna
  - To be mounted in the electronics bay

Payload Power

- 3.3v Li-ION
  - Custom battery

Payload Power Distribution

- Electrical Power System Design
  - Adafruit Feather M0

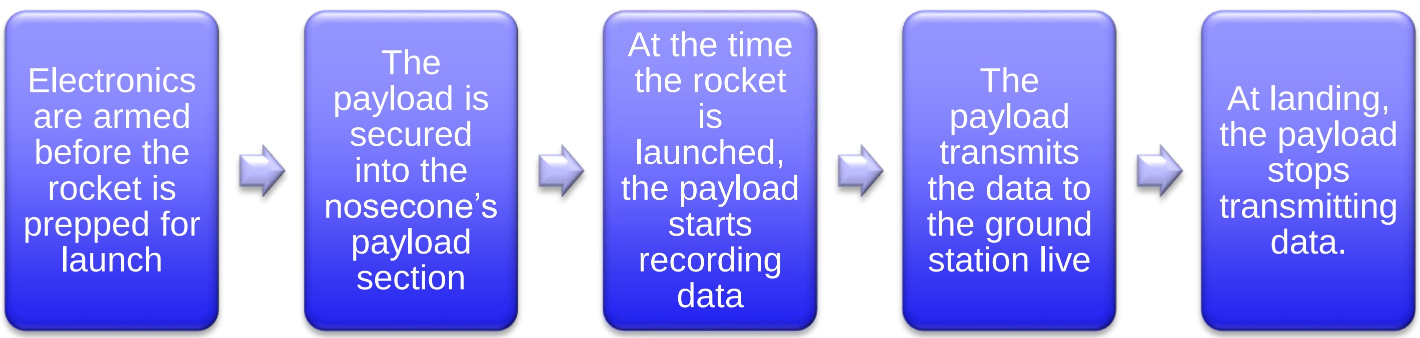
Additional Sensors

- GPS
  - MTK3339 Chipset
  - Mounting method
  - 20mA current draw
  - Connected with UART

Software

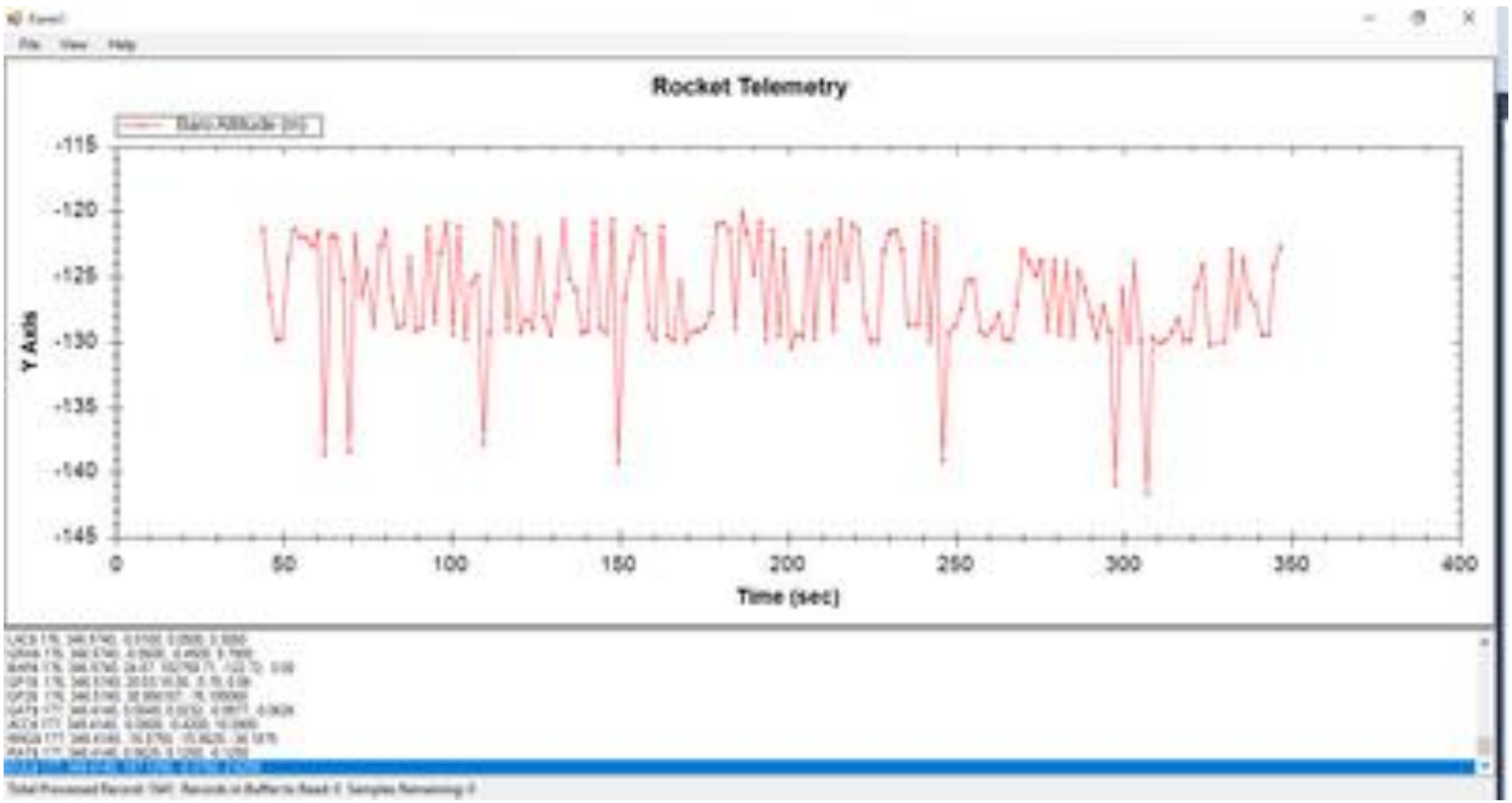
Payload Software Design

- Software Flow Chart



Telemetry

- This is a test of using the rocket's telemetry transmitting software



Software Development Plan

- Describe plan for software development
- Include
  - No commercial software is used, but the software is being posted as an open source
  - The software has been being developed over the last few months, and is still being tweaked, but has been tested and been approved.
  - The data was successfully transmitted to the ground station, and was able to plot telemetry on a telemetry vs. time graph.

Payload Integration

- The payload will be located inside an enclosed tube in the nose cone. There will be a small hole for the camera, which will get larger on the outside in order for the camera to have a wider range of view. It will be mounted in a 3D printed board/case.

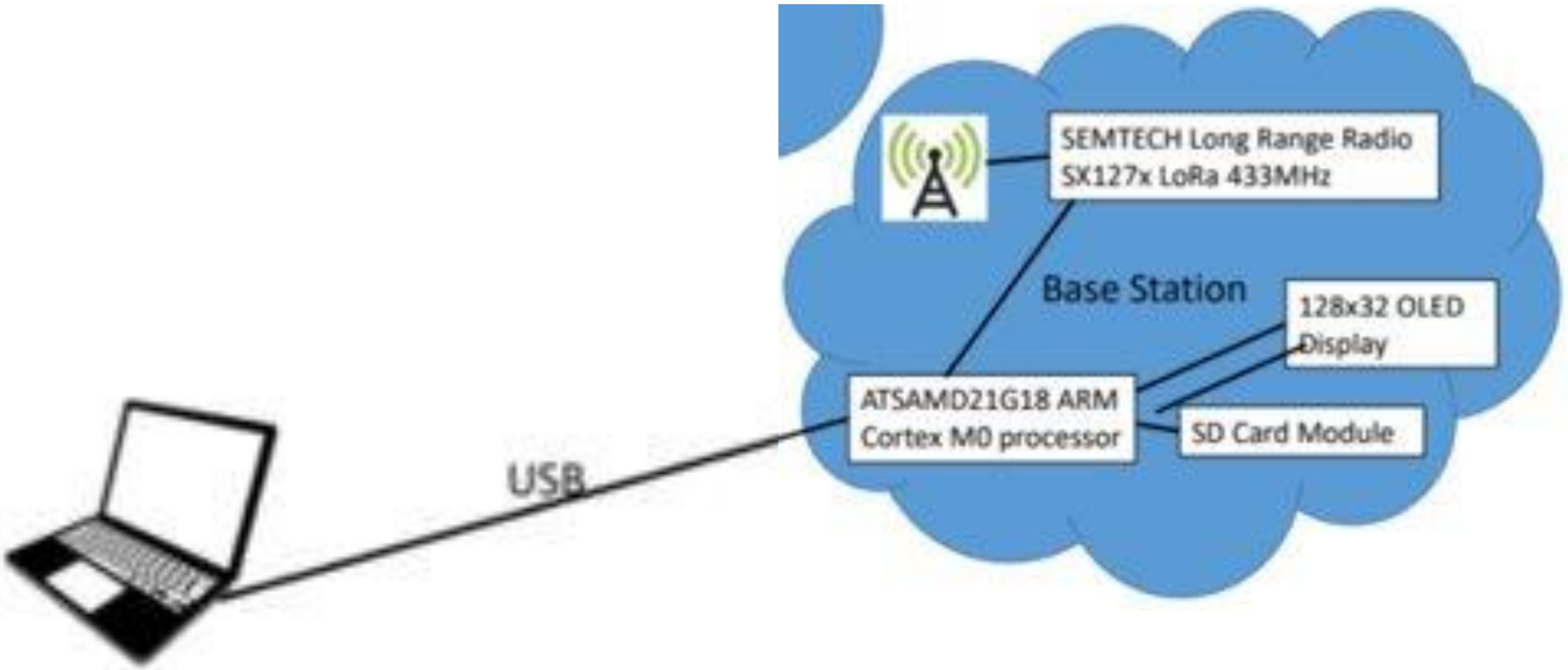
- There is a bulkhead on both sides of this inner tube, and all-threads connecting them, along with washers and locknuts.

Payload Integration (cont.)

Ground Station

Ground Station Design

- Block diagram of ground station



Ground Station Antenna

- We are using XBee pro (Digi) antenna
- Up to 2000 ft (610 m) Indoor/Urban Range
- Up to 9 mi (14 km) LOS w/ Dipole Antenna
- Up to 28 mi (45 km) LOS w/ High-Gain Antenna
- Up to 24 dBm (250 mW) Tx Power (Software Selectable

Ground Station Software

- The ground station software was written by using C# and .Net4.6. The software will be published as an open source under the MIT license.

- Open Source Zed Graph software is used to plot the data.

- The firmware for both the ground station and rocket payload are written in C++ using the Arduino IDE. The software will also be published as open source under the MIT license.

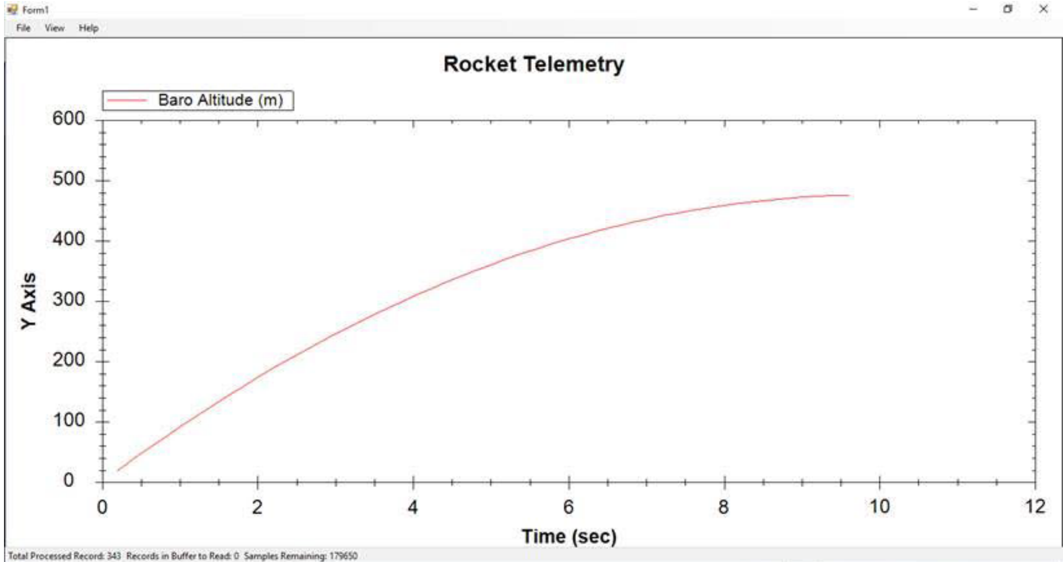
Ground Station Portability

- A cord will connect the receiver to a laptop.
- We will have a battery in the laptop and a fully charged backup battery.

Testing

Payload Testing

- Two xbee radios have been purchased and tested using simulated data (see plot below)
- Testing has shown a total of 27 channels of data sent from the simulated rocket to the base station. The base station system is multi threaded so that data from the radio can be processed at the same time as the plots are updated.
- Flight tests with the payload have been delayed by weather, but a test is planned on February 17



Rocket Testing

- Rocket was launched successfully on November 18th, 2017
  - Parachute deployed successfully
  - Payload deployment testing
  - Flight test
- Rocket was launched on the 16 and 17 of December
- One successful launch on the 16, parachute deployed and shock cord held
- On the 17, the motor chuffed twice, once causing it to land back on the launch pad, and one causing it to fall about 20 feet. The motor casing was pushed into the rocket and then fins broke off. The whole lower half of the rocket had to be rebuilt.

Flight Operations

- Describe procedures during launch day
  - Rocket is assembled by team members and then checked to see if it is properly placed together
  - Payload is prepared and assembled by team and rechecked
  - Payload is placed into nose cone
  - Team members load rocket onto launch rail. The igniter is placed into motor and connected to the system which a person cam launch
  - - Recovery electronics arming process is done on the launch pad. Keys are removed from electronics bay.

    - Payload is turned on five seconds after launch.

Program Schedule

- Meetings take place every Tuesday from 2:30 to 4:00 as well as any additional days we may needed.
- Component and service schedule
  - **Majority of components were already owned by the team, with the exceptions of:**
  - Kevlar shock cords ordered November 28, arrived December 11
  - Perfect flight altimeters ordered October 2nd, arrived October 9th
  - 2 Finn cans printed by TE connectivity from student created design on December 19 (made of ULTEM) arrived December 30

Program Budget

- Show budget for all parts of the program
  - The majority of the components were already owned by the team. Kevlar shock cord (x4)- $84.00 perfect Flight Altimeter (x10)- $470.00
  - Each team member has a food budget of $26. We have 11 members and two chaperones. This will be a total of $338 dollars.
  - We hired to two vans to travel with. Each van is $89 per day. On each van, we receive 50 free miles. After that it is $.25 per miles.

Summary

The Team Aether sounding rocket is designed to take photographs from five seconds after launch up to altitudes reaching but not exceeding 2,000 feet. After several successful tests, the rocket has been trouble shot and primed for competition. The subsystems are in the final stages of development and we feel confident in our pending full system tests.