GoatBusters Planetary Lander CDR

Battle of the Rockets 2017

Presentation Outline

- Team Organization
- System Overview
- Rocket Design
- Lander Design
  - Mechanical Subsystems
  - Lander Electronics
  - Software
- Ground Station
- Testing

Team Organization

Team Leader	Matias F. Campos A.
Ground Station Design	Nathan Siegel, Lead
	Peter Dohn
Lander Design	Zane Weissman, Lead
	Caleb Wagner
	Dan Pelgrift
	Robaire Galliath
Rocket Design	Steven Laudage, Lead
	Steffany Halfrey
	Grace Gerhardt
	Theresa Bender

Acronyms

WPI	**Worcester Polytechnic Institute**
CP	**Center of Pressure**
CG	**Center of Gravity**

System Overview

Mission Summary

Design and fly a high power rocket that will be launched beyond 1,000 feet. The rocket will deploy a robotic planetary lander payload. The rocket system and payload will return to ground safely. The payload will right itself and perform several operations including the transmission of telemetry and pictures back to a ground station.

Lander System Requirement Summary

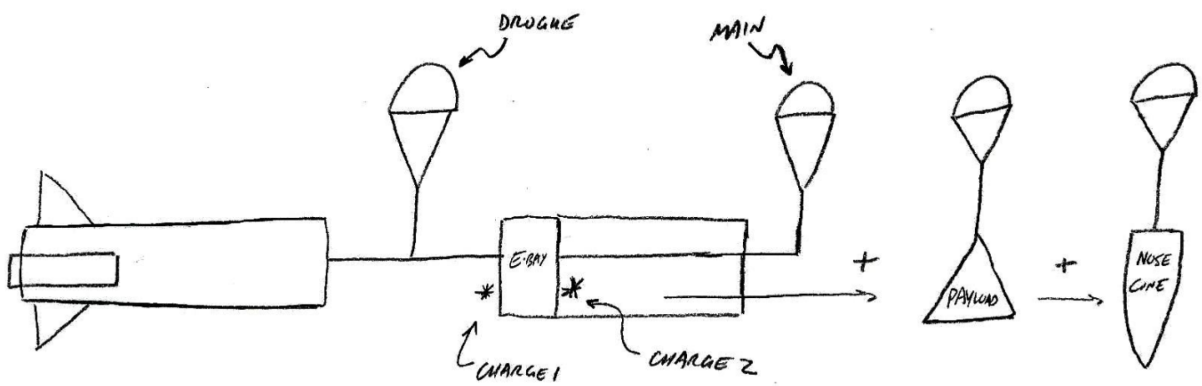
Req #	Requirement
1	Cannot weigh more than one kilogram
2	Must be contained with rocket for launch
3	Must be autonomous
4	Lander cannot be controlled except for camera positioning
5	The lander cannot free fall
6	No pyrotechnics
7	No Lithium Polymer batteries are permitted
8	Must use one XBEE at a frequency of either 900 MHz or 2.4 GHz
9	XBEE cannot broadcast. PAN/NET ID must be set to team number
10	All telemetry must be transmitted by the XBEE
11	Telemetry transmitted no more than once per second

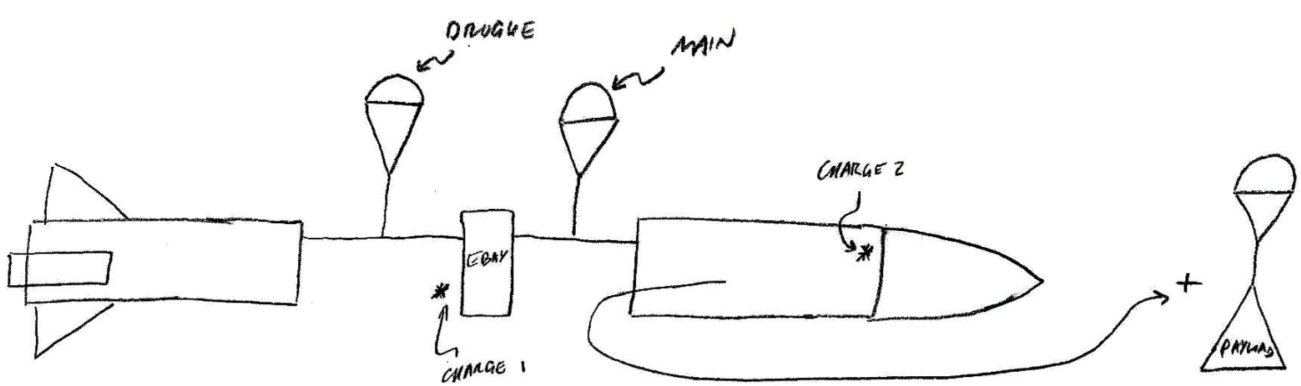
Rocket System Requirement Summary

Req #	Requirement
1	Motor must not exceed 1280 N-s
2	Must reach 1000 ft
3	Must use a motor retainer
4	All common rules must be followed

System Level Trade and Selection: Rocket

Preliminary Rocket Concepts Considered: Four vs. Three parachutes



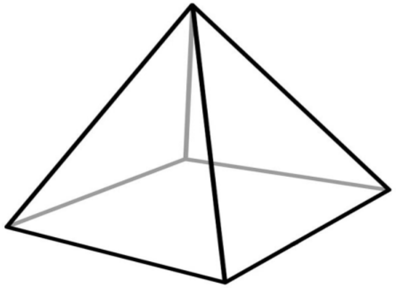


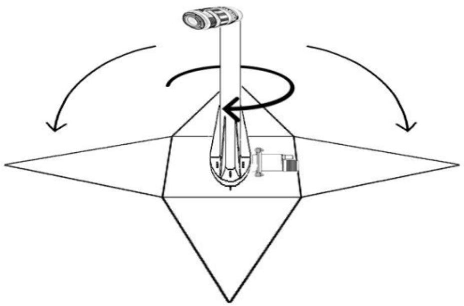
	Pros	Cons
4 Parachute Option	Simple wiring	More materials Larger mass
3 Parachute Option	Fewer separated pieces	Complex, single-use wiring

System Level Trade and Selection: Lander

Preliminary Lander concepts considered:

- Pyramidal Lander e.g. Mars Pathfinder



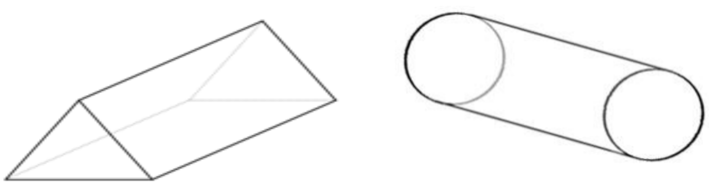


The operation of deploying the lander sides will function to right the lander.

- Pyramidal Lander weighted rounded base

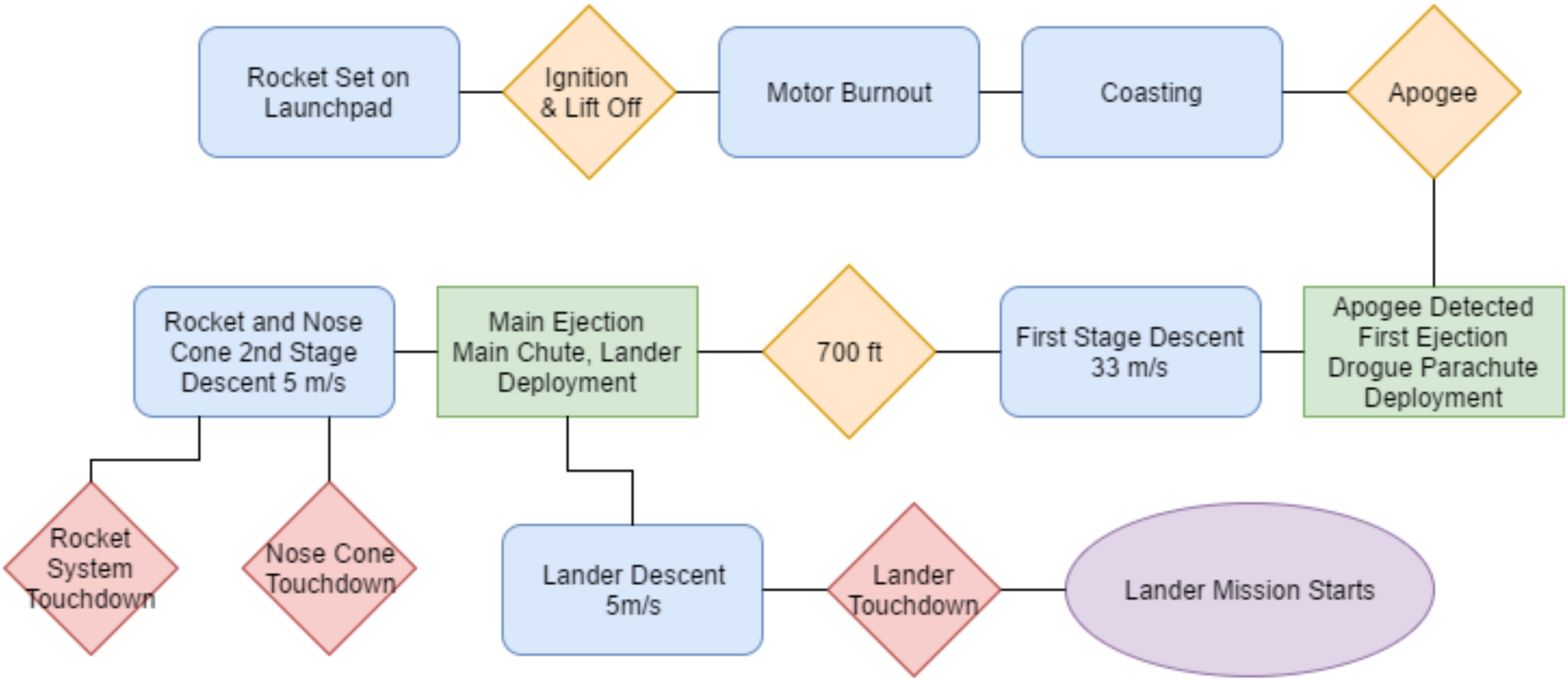
Weighted and rounded base will allow the lander to right itself before side deployment.

- Cylindrical/Triangular Prism Lander

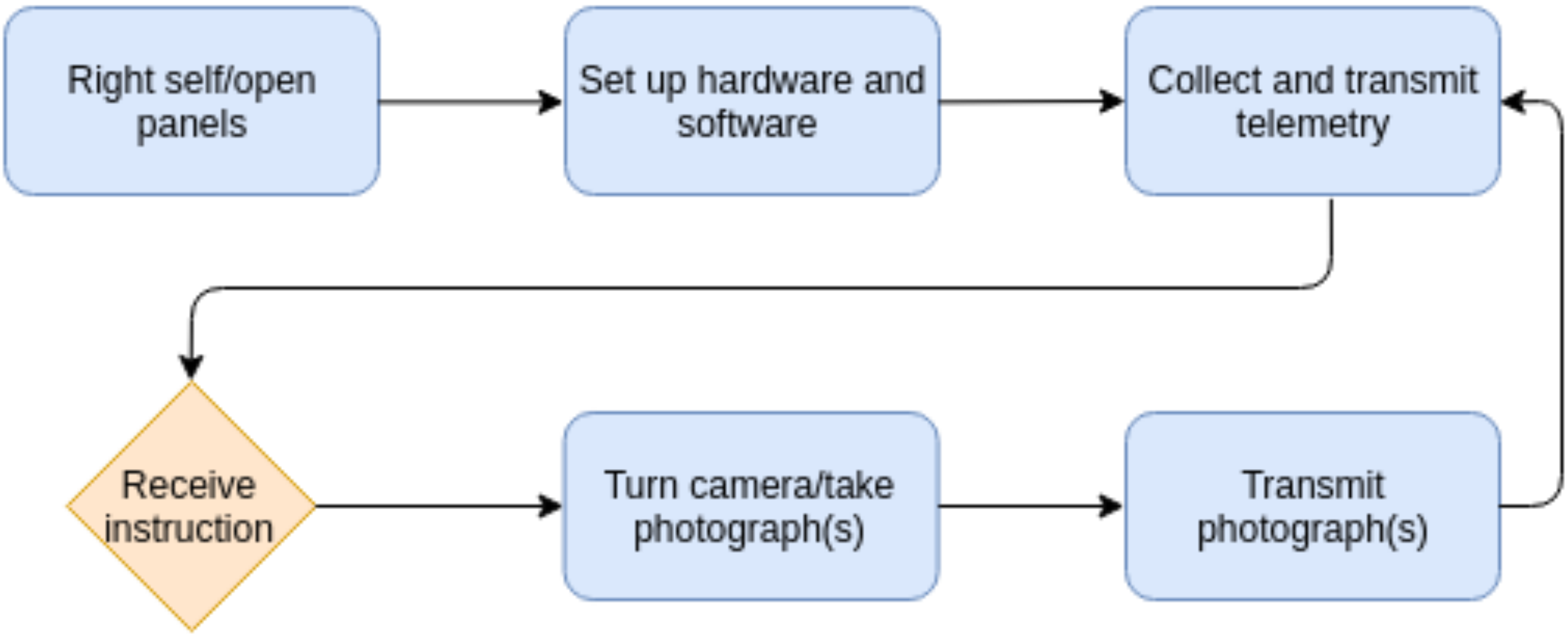


Internal payload free moving within a cylinder so as to always be upright.

Rocket Concept of Operations



Lander Mission Concept of Operations



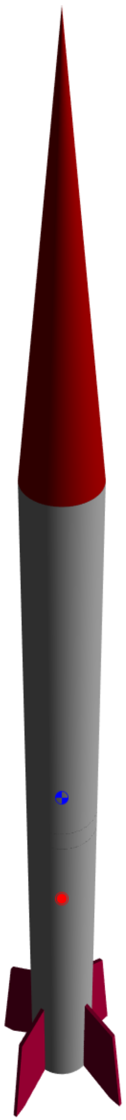
Rocket Design

Changes since PDR

- Drogue parachute size changed from 60” to 54”
- Computer simulations and diagrams updated
- Black Powder charge contencion changed from taped plastic bags to end of latex glove finger cut out.
- Parachute protection changed from Dog Barf to NOMEX Parachute Protectors
  - Budget updated accordingly

Overview of Rocket Design

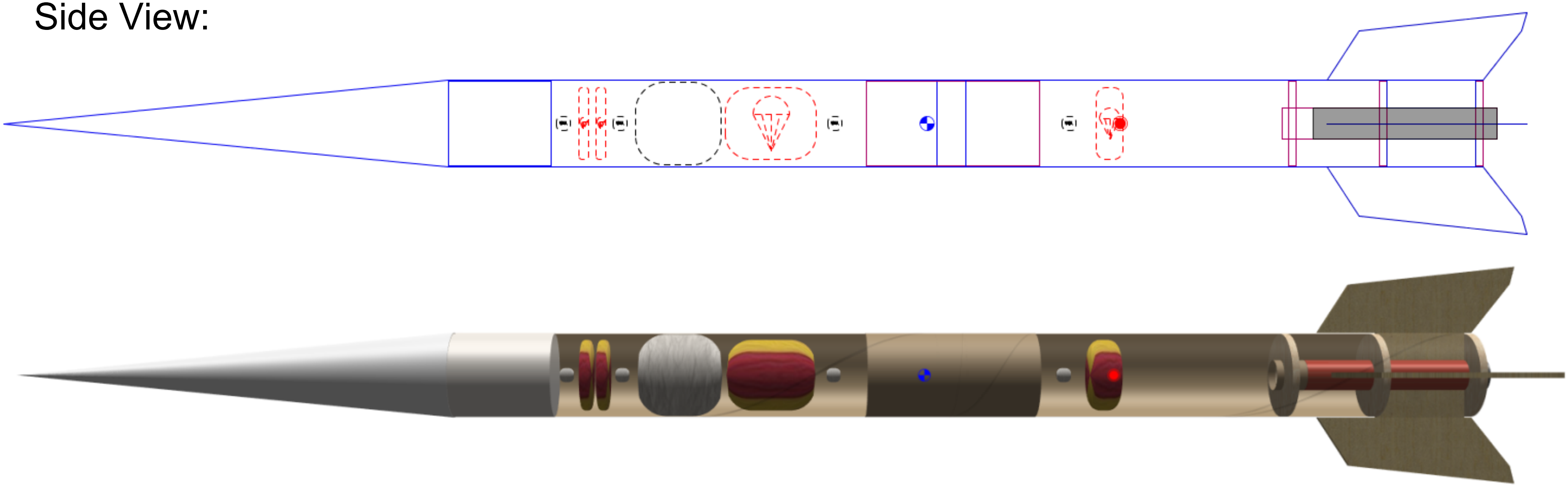
- Rocket weight: 6.47 kg
- Motor: Cesaroni Technology Inc. J760WT
  - Alternate: Cesaroni Technology Inc. J745WW
- Airframe: 6”x 72”, 0.074” wall
- 4 Fins: ~15” long x ~6” radially
- Full Rocket Length: 105.9” (8.8’)
- Nose Cone:
  - Nose Length: 31”
  - Shoulder Length: 7.13”
- Distance between CP and CG: 13.78” (35 cm)



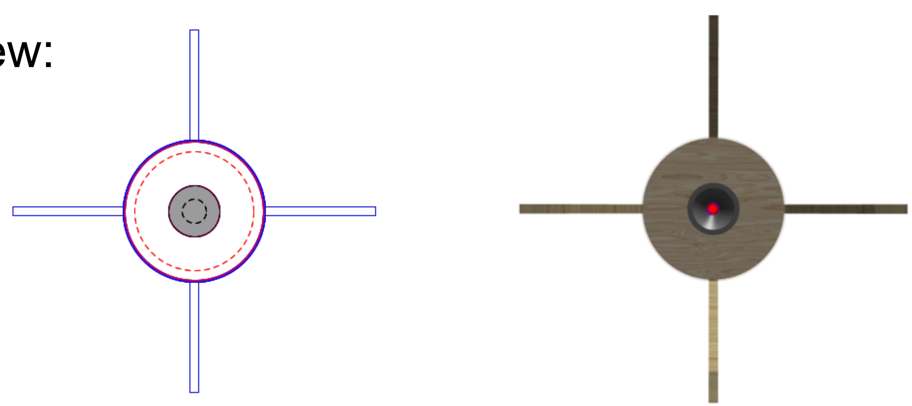
WPI

Overview of Rocket Design

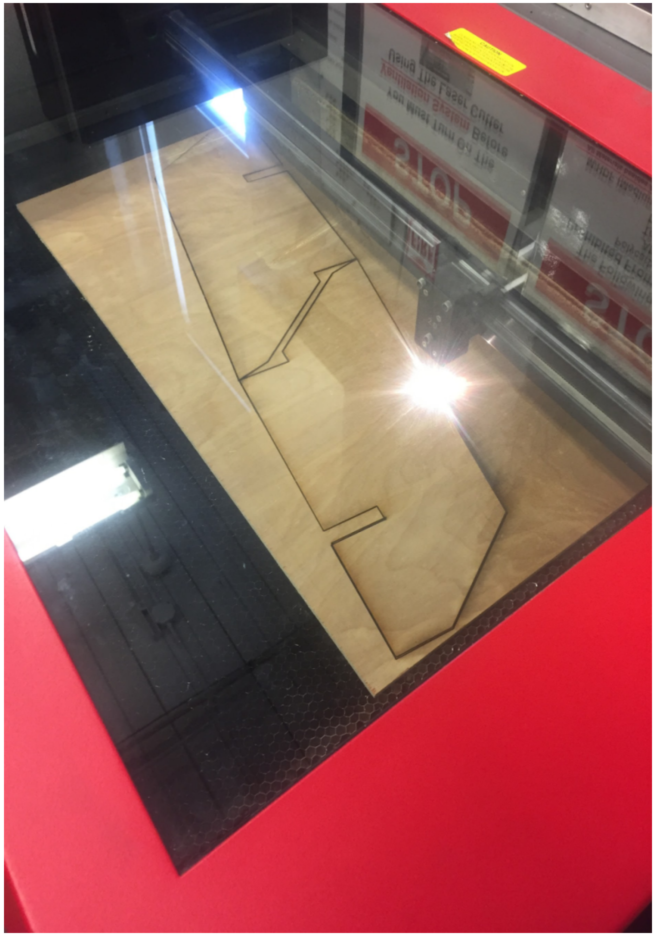
Side View:



Bottom View:



Overview of Rocket Design



Rocket Materials

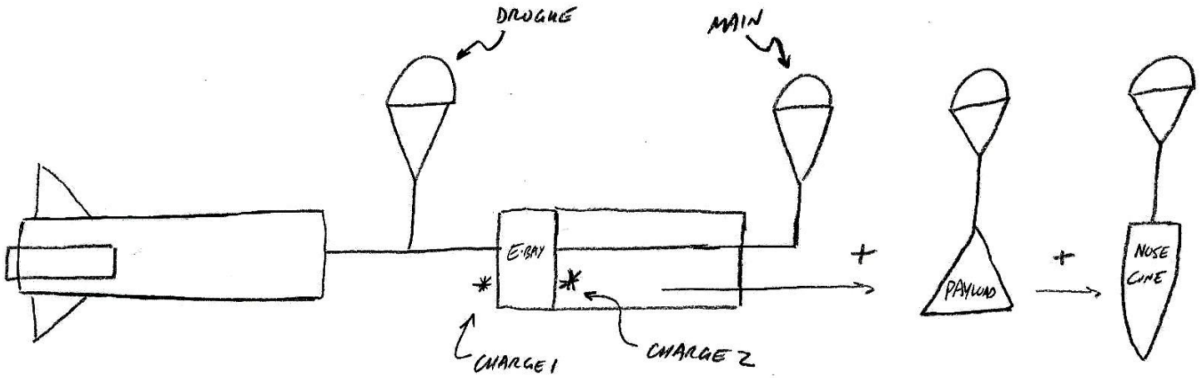
- Airframe Material: Blue Tube, 6” Diameter
- Fin Material: ¼” Plywood
- Centering Ring material: ½” Plywood
- Nose Cone Material: Fiberglass
- Adhesives: Slow Curing Epoxy
  - West Systems 105 Epoxy Resin
  - West Systems 206 Slow Hardener
- Rail Button Type: 1515
- Motor Retention: Hanger Wire, Nut and Clamp Retention

Rocket Recovery System: Parachutes

- Parachute Selection: 4 Parachutes
  - 54” Rocket Body Drogue Parachute, deployed at apogee
  - 72” Rocket Body Main Parachute
  - 36” Payload Parachute
  - 36” Nose Cone Parachute

  (72” main, 36” payload and 36” nose cone parachutes: deployed at 700 ft)

- Descent Rate
  - Rocket Body: 17.45 ft/s ground hit velocity
  - Payload & Nose Cone: 15-20 ft/s ground hit velocity (spherachutes.com)



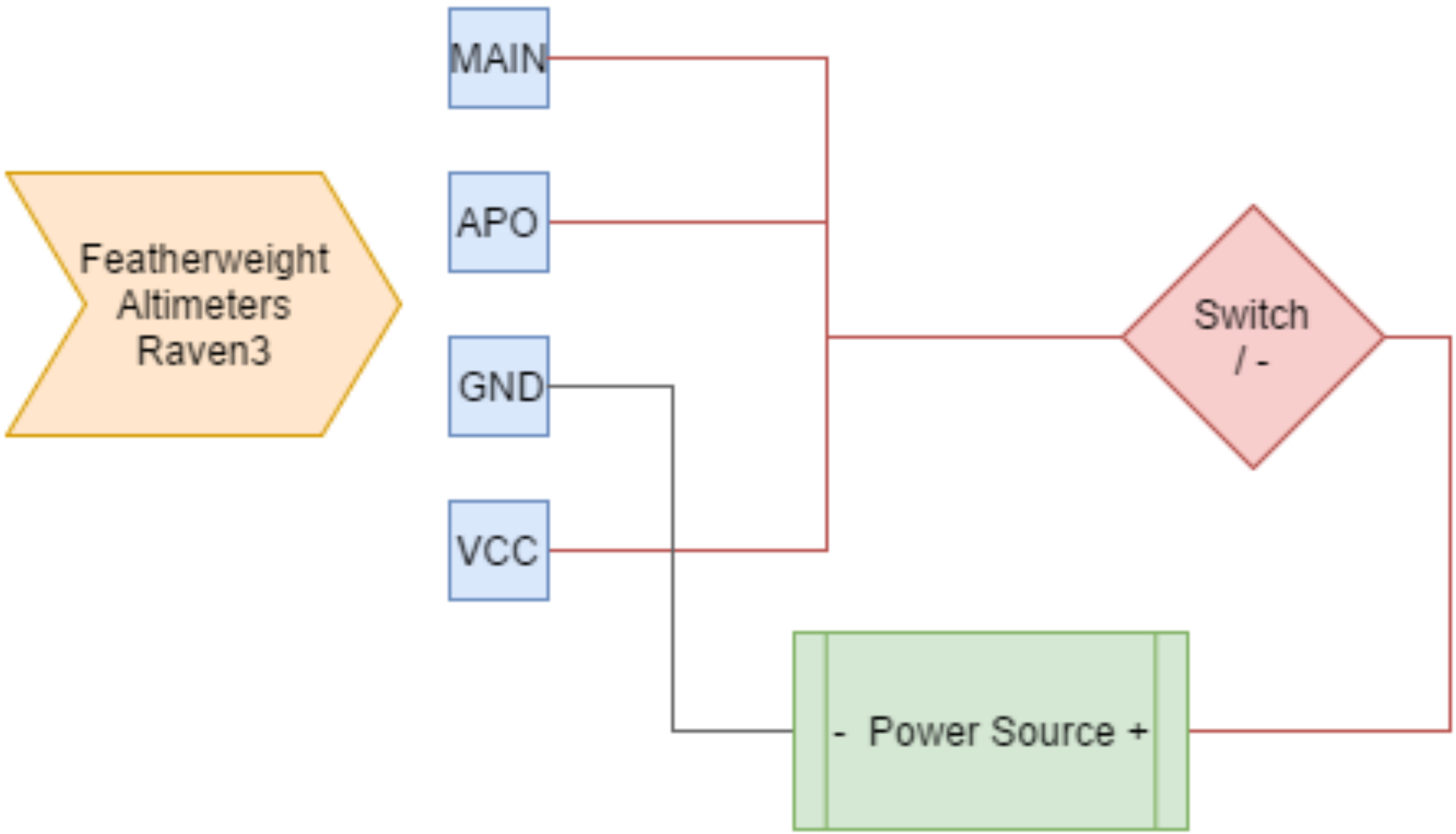
Rocket Recovery System Harness

- Tubular Nylon Shock Cord
  - 2,000 lbf break force
  - Length: 106 in (2.5x rocket length)
- Epoxy reinforced U-bolt connections between shock cord and rocket body
- Parachute Protection: 18” NOMEX Parachute Protectors

Rocket Recovery System Deployment Method

- Altimeter-based electronic deployment
  - Featherweight Altimeters: Raven3 Altimeter
  - Lightweight, fast, 4 high-current outputs
- Barometric Apogee Detection -> first ejection charge -> drogue parachute deployed
- Barometric Detected 700 ft altitude -> second ejection charge -> main rocket body parachute, nose cone, payload deployed
- 2, 4F black powder charges will be used for first and second ejection charges
  - Motor delay used as backup apogee ejection charge
  - Apogee (first) Charge will be 3.11 g of Black Powder
  - Main (second) Charge will be 2.94 g of Black Powder
  - Calculated using *rockethead.net* Black Powder Charge Calculator

Altimeter Wiring Diagram



Charge Installation Process

1. Correct black powder mass measured using a scale on-site.
2. Powder and a low-current igniter enclosed in a finger of a plastic glove.
3. Make sure power is shut down
4. Charges taped into place on the lids of the the electronics bay.
5. Wires stripped and connected to the altimeter MAIN and APO terminal blocks as the last step before the rocket is closed.

Arming Process

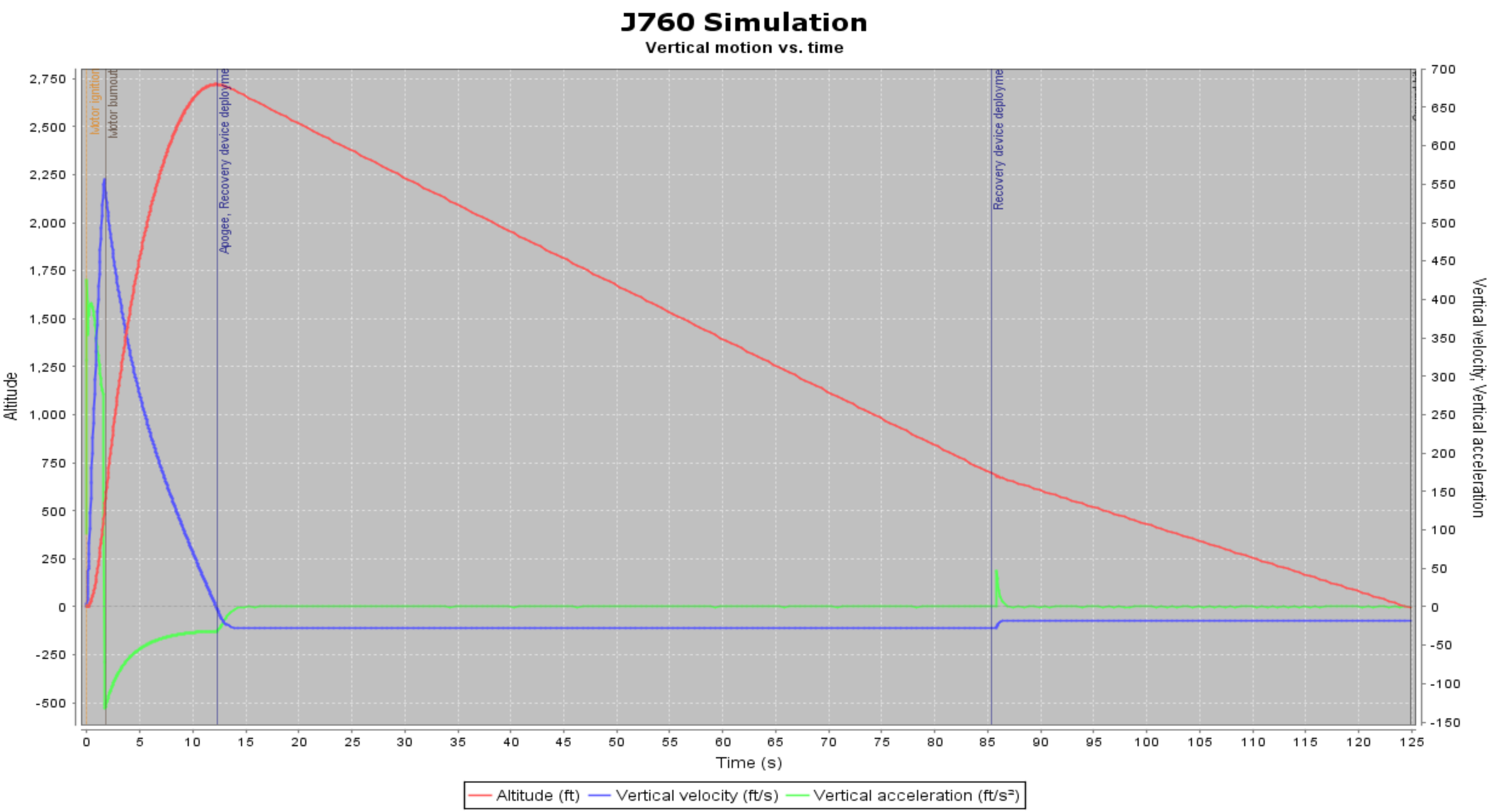
1. Power source constructed to incorporate external screwdriver switch
2. Rocket set up at launch site
3. All clear area, except the person arming rocket
4. Rocket armed using a screwdriver to flip the external switch
    a. *Note*: this will be the first time the rocket is armed since the black powder charges were placed
5. Listen for altimeter beeping to indicate continuity and proper connection of the charges
6. Motor armed with launch pad alligator clips
7. All back up to safe area and wait for launch

Rocket Motor Selection

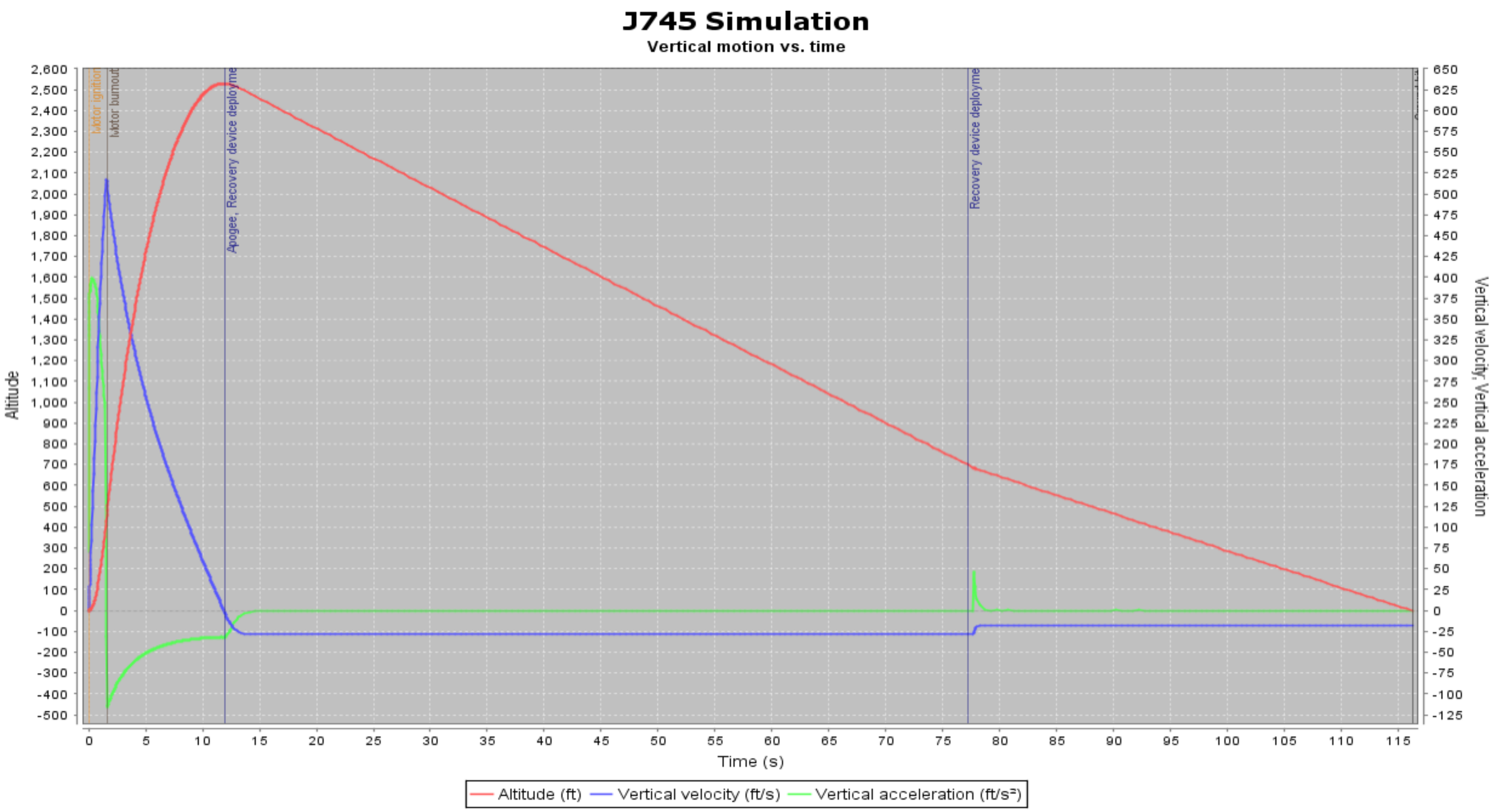
- Motor Selection:
  - Primary Motor: Cesaroni Technology Inc. J760WT
  - Backup Motor: Cesaroni Technology Inc. J745WW
- Thrust-to-Weight Ratios:
  - Primary Motor: T/W = 760 N /(6.473 kg * 9.8 m/s^2) = 11.50
  - Backup Motor: T/W = 745 N /(6.616 kg * 9.8 m/s^2) = 11.49
- Apogee Values:
  - Primary Motor: h = 829 m (~2720 ft)
  - Backup Motor: h = 771 m (~2530 ft)

Name	Configuration	Velocity off rod	Apogee	Velocity at de...	Optimum delay	Max. velocity	Max. acceler...	Time to apogee	Flight time	Ground hit ve...
Simulation	[1266-J760-WT-19...	15 m/s	829 m	8.39 m/s	10.5 s	169 m/s	130 m/s²	12.2 s	125 s	5.32 m/s
Simulation 1	[J745WW-P]	15.5 m/s	771 m	8.51 m/s	10.3 s	158 m/s	121 m/s²	11.9 s	116 s	5.38 m/s

J760 Simulation



J745 Simulation



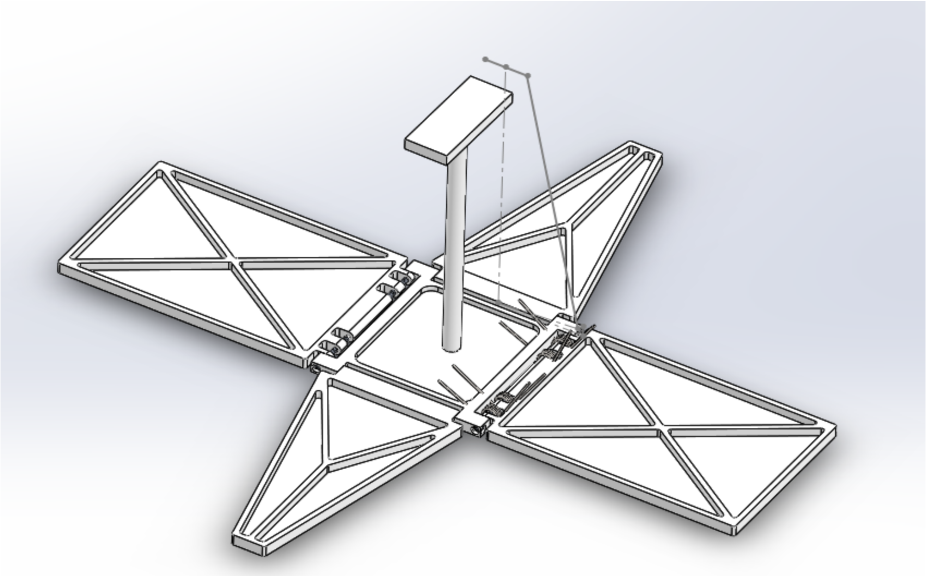
Test Flights

- No test flights have been performed
  - Waiting for rocket construction and improved weather conditions
  - Tentative test flights scheduled for Spring Term.
  - Test flights will include a dummy payload to simulate flight conditions and deployment.
  - Test flights will focus on redundancy systems.
  - Based on test flights, modifications and upgrades will be performed as needed.
  - Final test flight. Day before competition.

Lander Design

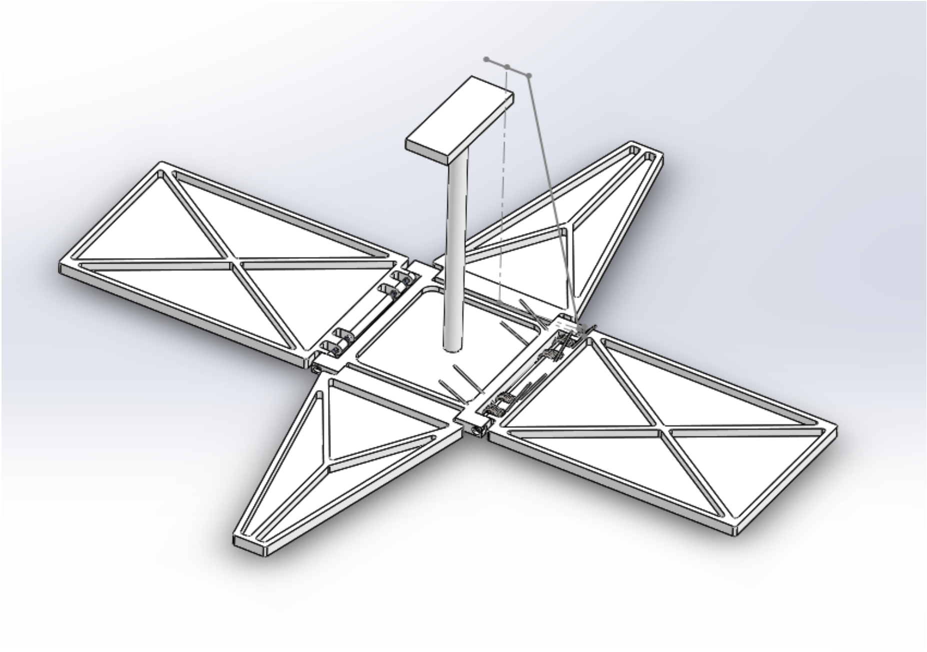
Lander Design Overview

- 4” long × 4” wide × 6” high
- Nylon frame
  - Sturdy and lightweight
- Rotating Inner disk
  - Carries electrical components
  - Rotates to release the side panels and change angle of camera
- Mass of lander
  - 847.6 grams
    - Frame: 590 grams
    - Electronics: 257.6 grams



Changes Since PDR

- The shape of the sides was modified slightly to allow the lander to close more completely

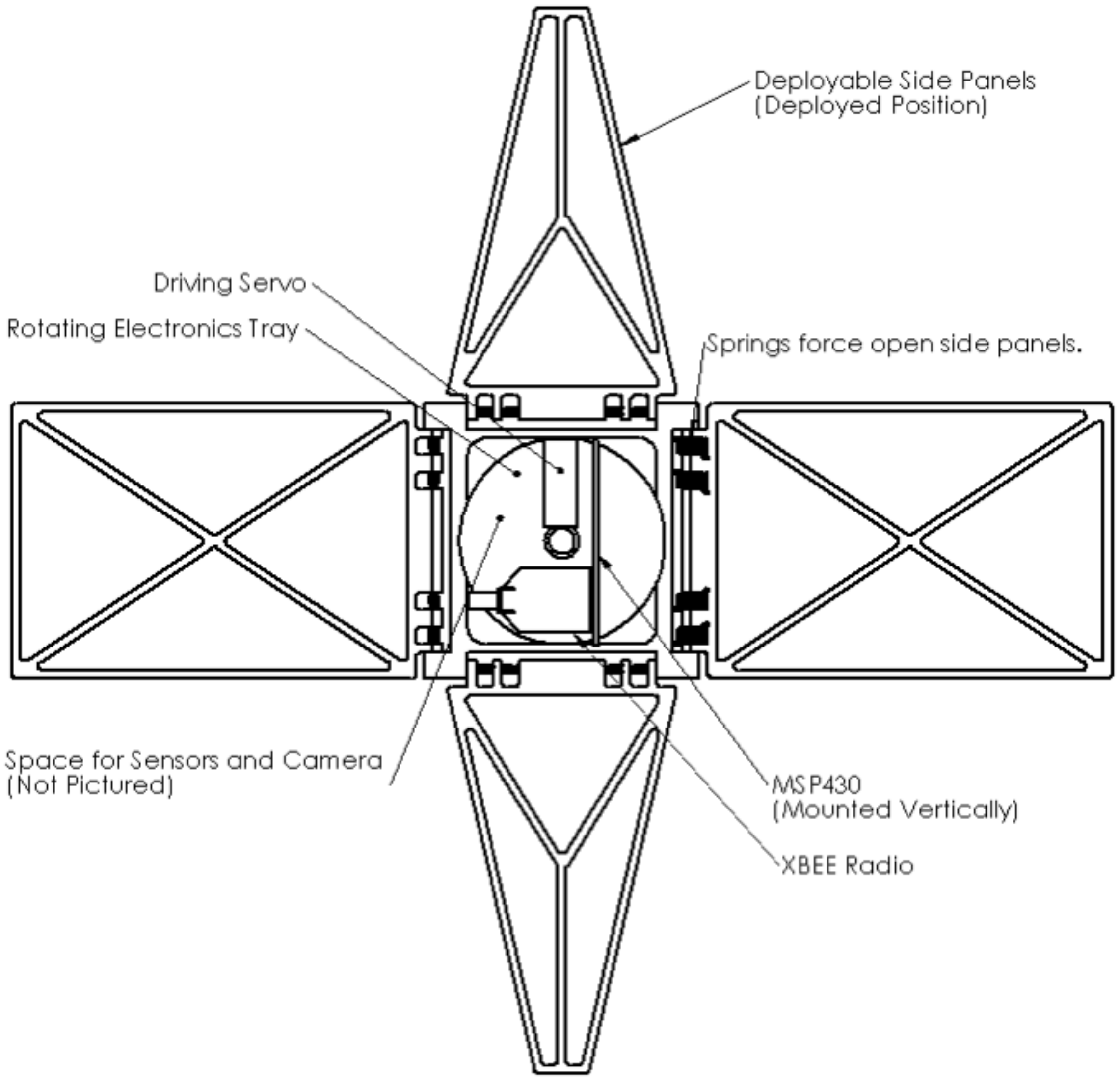


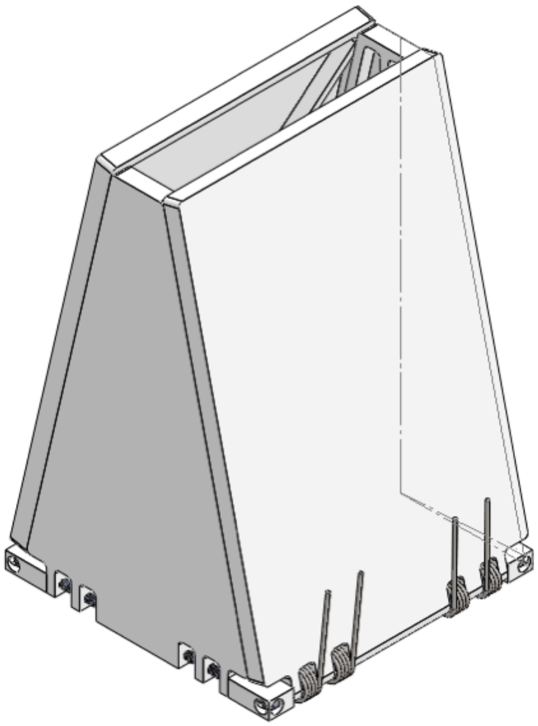
Lander Design: Mechanical Subsystem

Mechanical Layout and Component Selection

- Major Mechanical Parts
  - Continuous Rotation Micro Servo - FS90R Servo used to drive inner disc for camera pointing and side deployment
    - Small
    - Continuous rotation
  - 180° Music Wire Torsion Springs
    - Cheap and readily available alternative to powered deployment
  - Disc-mounted restraining hooks
    - Material not chosen, to be determined during construction based on requirements for strength, weight, and availability

Physical Layout





Lander Uprighting Mechanism

- Method Selected: Rotating Inner Section
  - Lander sides tensioned into a closed position using springs and secured by restraining hooks to a rotating disk, rotating the disk releases the sprung sides
  - The rotating inner section and sprung sides will require less power and serve a dual purpose of also being used to point the camera

- Major components
  - Rotating inner section
  - Restraining hooks
  - Springs to open sides when unhooked
    - Selected based on torque estimates, assuming the entire mass of the lander was concentrated at the center of mass.

Lander Descent Control

- Descent control is achieved by deploying a 36" parachute after lander ejection
    - Descent rate: 15-20 ft/s for a 1 kg lander
    - This value was obtained using the chart provided by spherachutes.com

Elevation at Launch Site

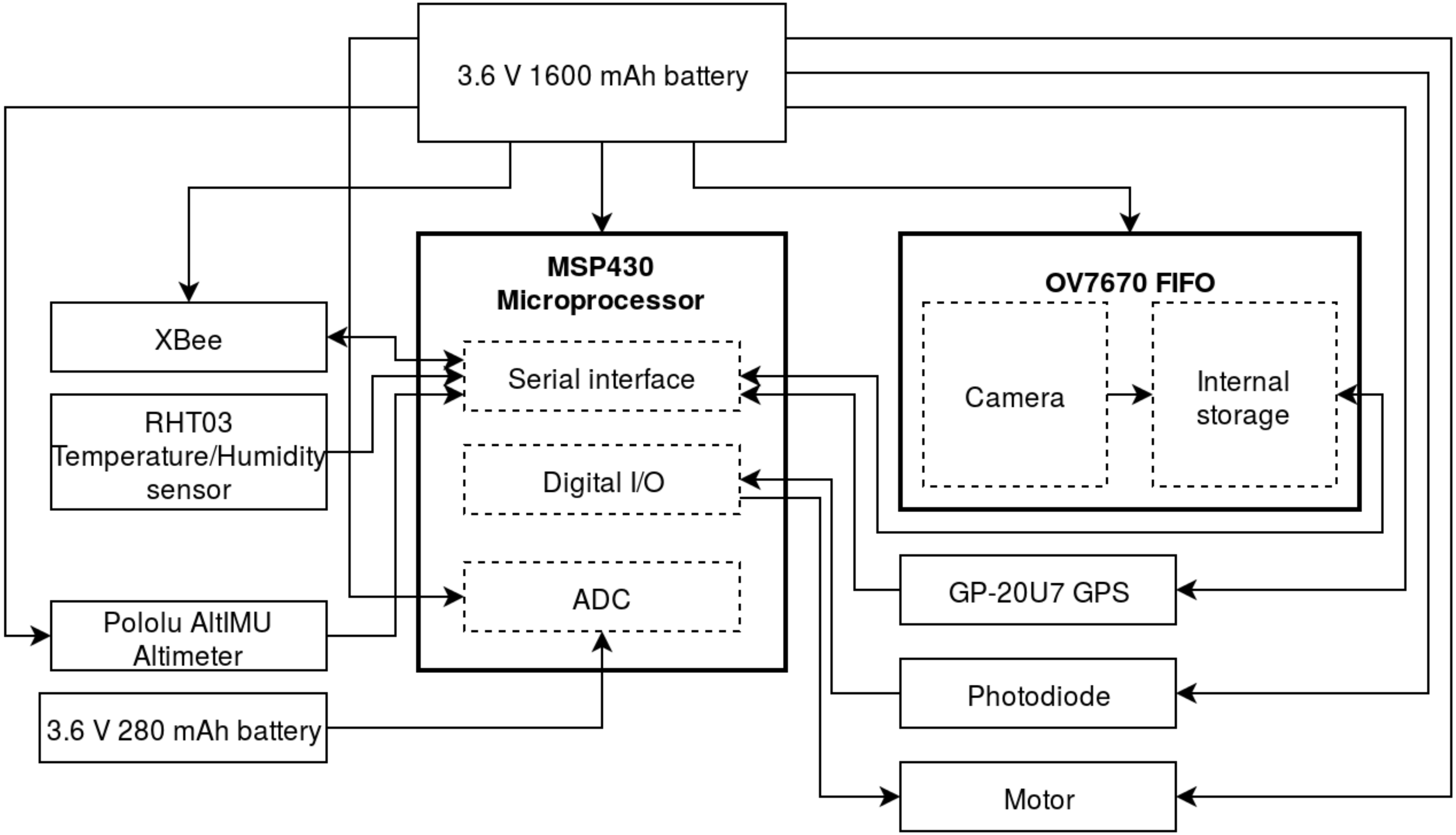
	Sea Level		5,000 Feet		10,000 Feet	
Chute Size	Min. Payload	Max. Payload	Min. Payload	Max. Payload	Min. Payload	Max. Payload
18"	less than 13 oz.		less than 11 oz.		less than 9 oz.	
24"	13 oz.	24 oz.	11 oz.	20 oz.	9 oz.	16 oz.
30"	22 oz.	37 oz.	18 oz.	31 oz.	14 oz.	26 oz.
36"	1.9 lbs.	3.4 lbs.	1.6 lbs.	2.8 lbs.	1.3 lbs.	2.3 lbs.
42"	2.6 lbs.	4.7 lbs.	2.2 lbs.	3.9 lbs.	1.8 lbs.	3.2 lbs.
48"	3.4 lbs.	6 lbs.	2.8 lbs.	5 lbs.	2.3 lbs.	4.1 lbs.
54"	4.3 lbs.	7.65 lbs.	3.6 lbs.	6.4 lbs.	3 lbs.	5.2 lbs.
60"	5.3 lbs.	9.3 lbs.	4.4 lbs.	7.8 lbs.	3.6 lbs.	6.4 lbs.
66"	6.6 lbs.	11.1 lbs.	5.2 lbs.	9.4 lbs.	4.3 lbs.	7.7 lbs.
72"	8 lbs.	13 lbs.	6 lbs.	11 lbs.	5 lbs.	9 lbs.
84"	10 lbs.	18 lbs.	9 lbs.	15 lbs.	7 lbs.	13 lbs.
96"	13 lbs.	24 lbs.	11 lbs.	20 lbs.	9 lbs.	16 lbs.
108"	17 lbs.	30.5 lbs.	14 lbs.	25.5 lbs.	11.5 lbs.	21 lbs.
120"	21 lbs.	37 lbs.	17 lbs.	31 lbs.	14 lbs.	26 lbs.
144"	30 lbs.	54 lbs.	25 lbs.	45 lbs.	21 lbs.	37 lbs.
168"	41 lbs.	73 lbs.	34 lbs.	61 lbs.	28 lbs.	50 lbs.
192"	54 lbs.	96 lbs.	45 lbs.	80 lbs.	37 lbs.	60 lbs.

Lander Mass Budget

Component	Mass (g)	Source
Frame	590	Solidworks Mass Properties
Servo	10	Data Sheet
MSP430	50	Handheld Estimate
Camera	25	Data Sheet
GPS	25	Weight taken as a high estimate based on experience
XBEE	25	Weight taken as a high estimate based on experience
Battery	62	Data Sheet
Secondary battery	40	Weight taken as a high estimate based on experience
Pressure Sensor	0.6	Data Sheet
Temp/Humidity Sensor	25	Weight taken as a high estimate based on experience
Light Sensor	25	Weight taken as a high estimate based on experience
Springs	50	Handheld estimate
Total	**927.6**	
Margin	**73.4**	

Lander Design: Electronics

Lander Electronics



Processor and Memory

- MSP430F5529 Launchpad
  - 16-bit MSP430F5529
  - Up to 25 MHz, 1 MHz default
  - 128KB Flash and 8KB RAM
  - ~150 uA, ~.2-2 uA in low power mode
  - Hardware interrupts - lots of options
  - 12 Bit ADC
  - Hardware support for UART, SCPI, and I2C
  - Debugging over USB 2.0

Lander Sensors

- Sensors Implemented:
  - Pololu LPS331AP Pressure/Altitude Sensor Carrier with Voltage Regulator
  - RHT03 Temperature and Humidity Sensor
  - Adafruit TSL2561 Digital Luminosity/Lux/Light Sensor Breakout
  - GPS Receiver GP-20U7
  - OV7670 FIFO camera
- Reasons for Selection:
  - All sensors are relatively inexpensive and compatible with MSP430F5529 Microprocessor over one of its several native serial interfaces
  - OV7670 has a hardware FIFO or queue - has internal memory buffer
    - MSP430F5529 has only 8KB RAM - not enough to store a 640x480 color image

Lander Radio Trade and Selection

- XBee 2mW Wire-Antenna Series 2 (400 feet range)
  - Successfully tested at ~750 feet with our ground station XBee and antenna
- Operational Data Rate & Frequency
  - 250 kbps at 2.45 GHz
- Will communicate with MSP430 microprocessor over standard serial interface.

Lander Radio Antenna Trade and Selection

- XBee transmitters have built-in antennae
  - The radio model includes a standard omnidirectional antenna mounted on baseplate
  - The antenna has a ~5dBi loss
  - Toroidal pattern, weak spots directly above and below

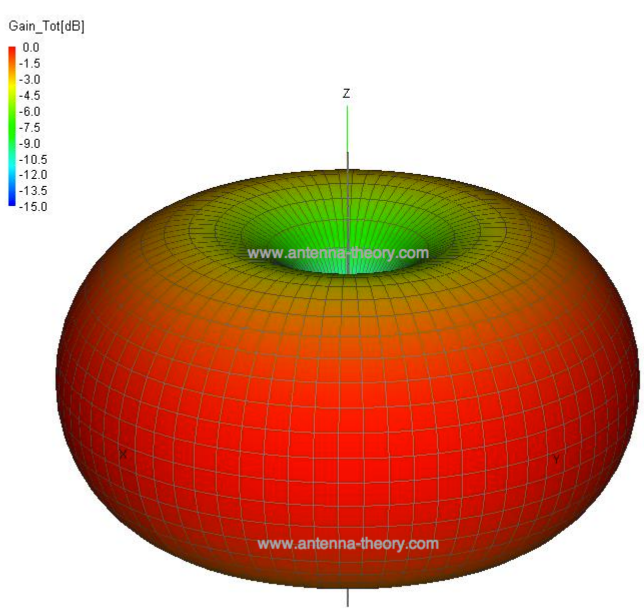


Image from www.antenna-theory.com

Lander Power Trade and Selection

- Power sources considered:
  - Nickel-cadmium vs. nickel-metal hydride
    - Both rechargeable
    - Generally similar prices
- Selection: nickel-metal hydride
  - More capacity, more environmentally friendly, safer, can be recharged without affecting capacity
  - Chose a 3.6V 1600mAh battery pack
    - Reasonable voltage
    - Plenty of capacity
    - Not too heavy (62 grams) or large (2” x 1” x .7”)
  - Will be mounted to the rotating disc along with other components
  - Protection circuits
    - Short circuit

Lander Power Distribution

- Estimated current draw from telemetry transmission

Device	Estimated power draw
MSP430F5529	150 μA
XBee	40 mA active
RHT03 Temperature/humidity sensor	50 μA, 1 mA active
TSL2561 luminosity sensor	15 μA, .5 mA active
LPS331AP	5 μA
GP-20U7	40 mA
Average assuming 20% uptime for peripherals w/ low power modes	**48 mA**

- Assume other current draw is negligible
  - Detecting landing
  - Taking a single panorama
- 30+ hours theoretical operation

Additional Sensors

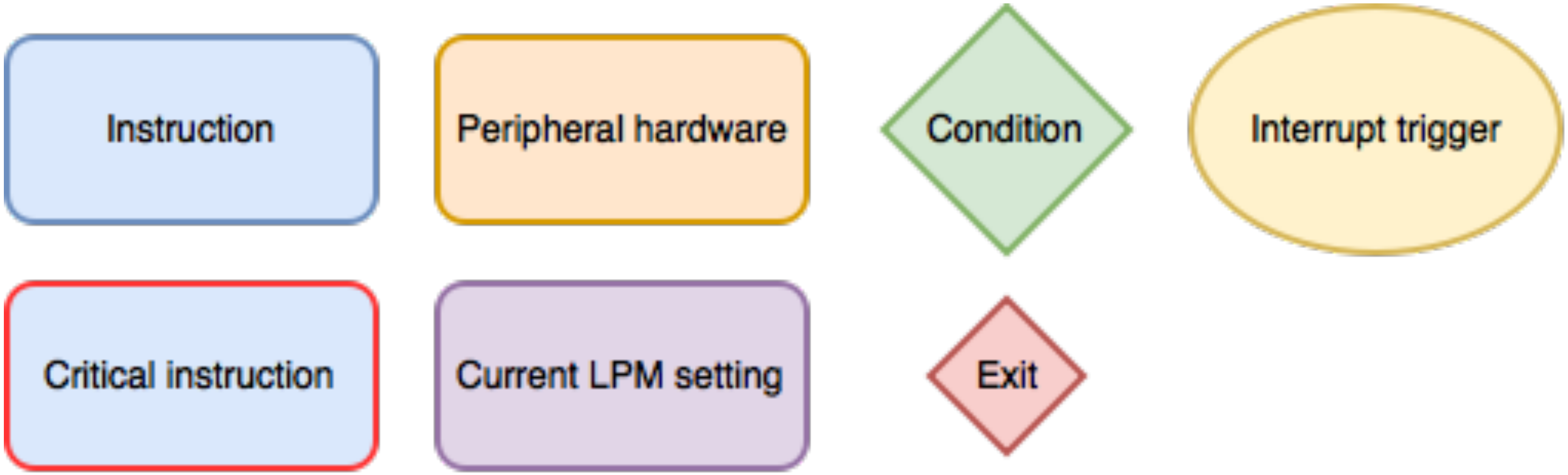
- ov7670 FIFO camera
  - Takes 640x480 photographs
  - Can take images in a compressed YCbCr format that packs two 24-bit images into a single 16 bit image
    - Sacrifices edges of colors
    - Edges in luminance (much more visible) completely preserved
  - Hardware FIFO storage
    - Enables low RAM chip like MSP430 to stream image
    - Very hard to find this feature
- GP-20U7 GPS Receiver
  - Complies with National Marine Electronics Association standard
  - Small, low power, inexpensive, and has built in antenna

Lander Design: Software

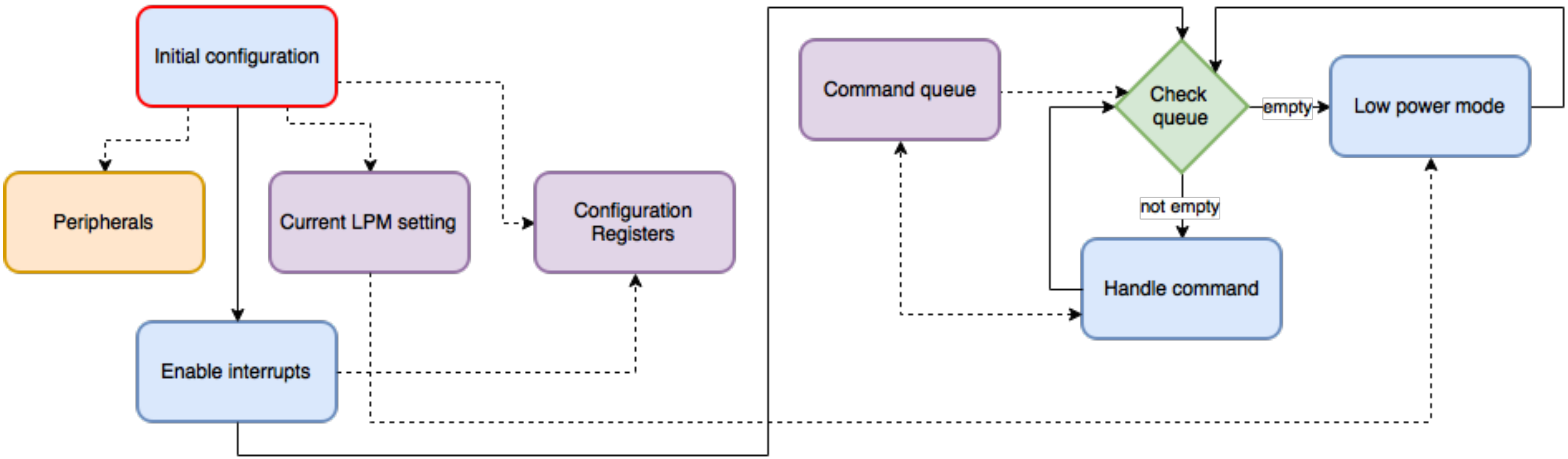
Lander Software Design

- Not using state-based programming: using hardware interrupts and interrupt service routines (ISRs) and a software queue of commands
  - ISRs allow for faster handling of time-critical events
    - Timer-driven events
    - Receiving commands from the ground station
  - Command queue allows for FIFO handling of low priority subroutines
    - Processing and executing commands from the ground station
- Software to be written in C programming language
  - Built in libraries for MSP430 from Code Composer Studio 5.4

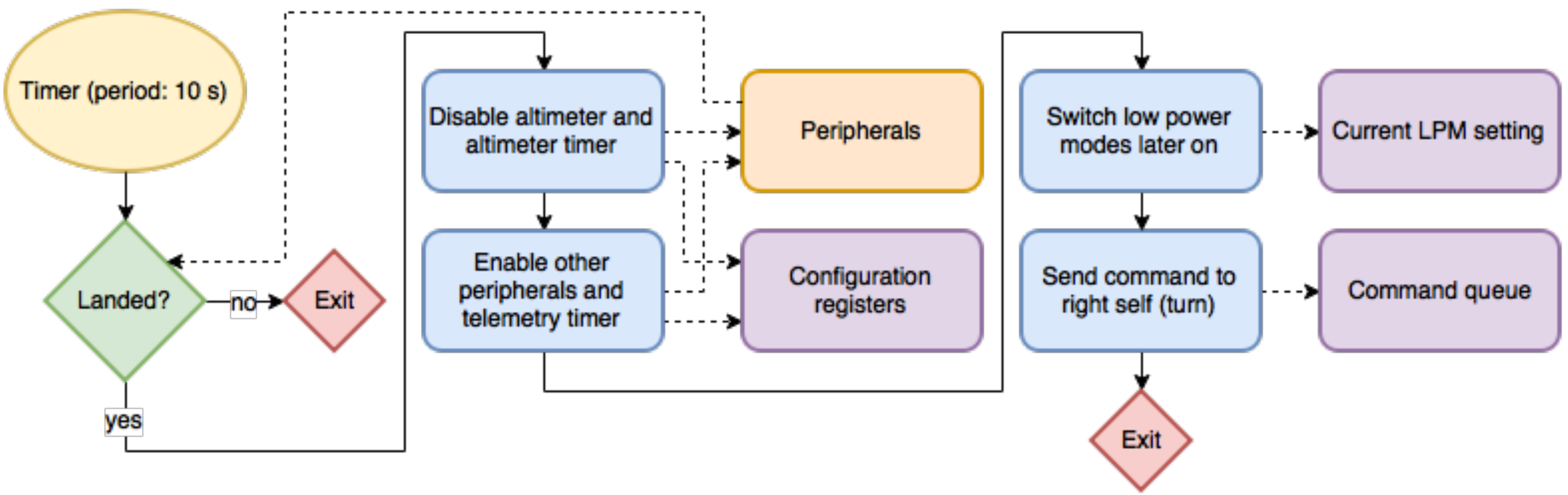
Flowchart Key



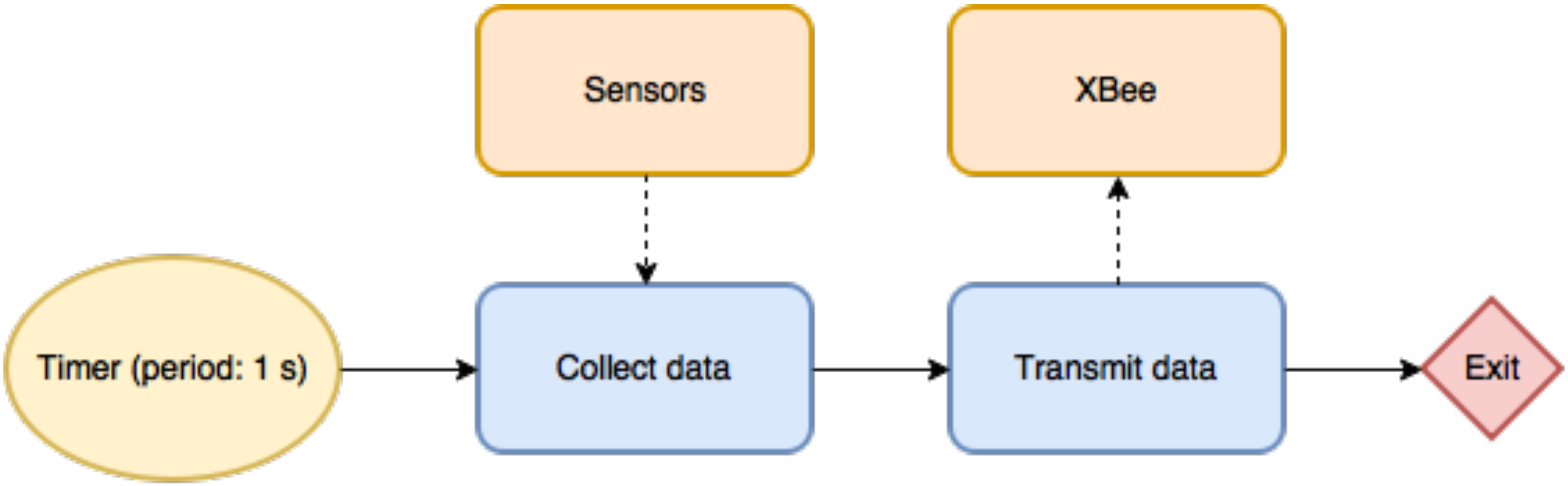
Main Structure



Altimeter ISR



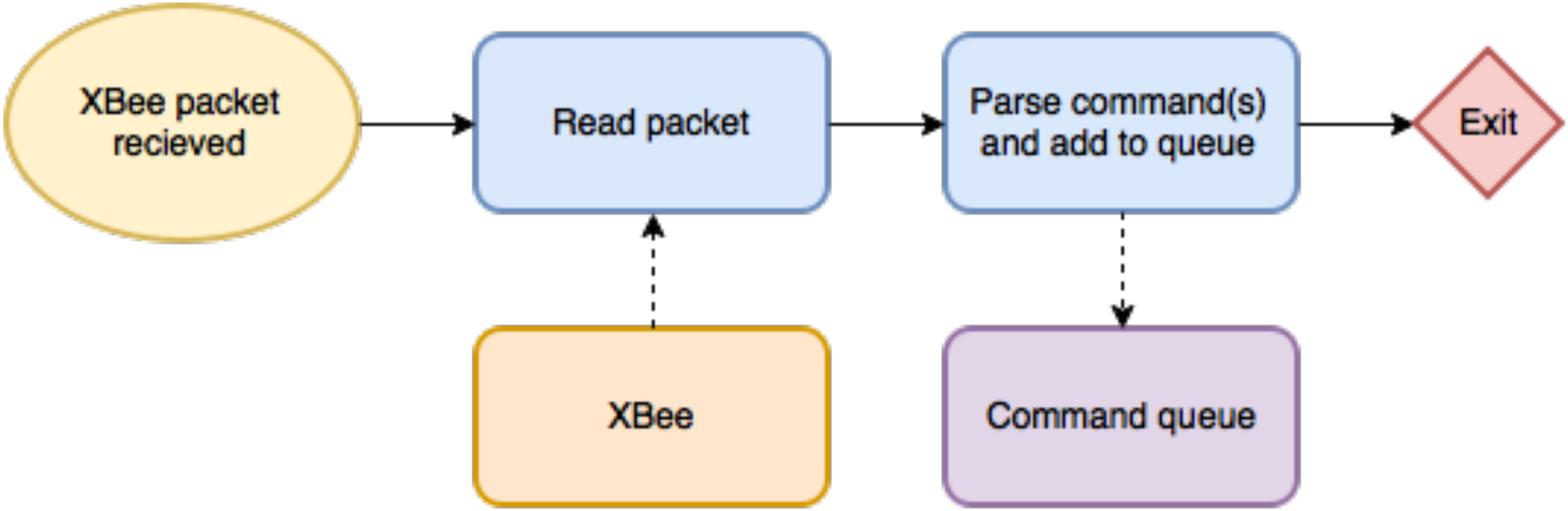
Telemetry ISR



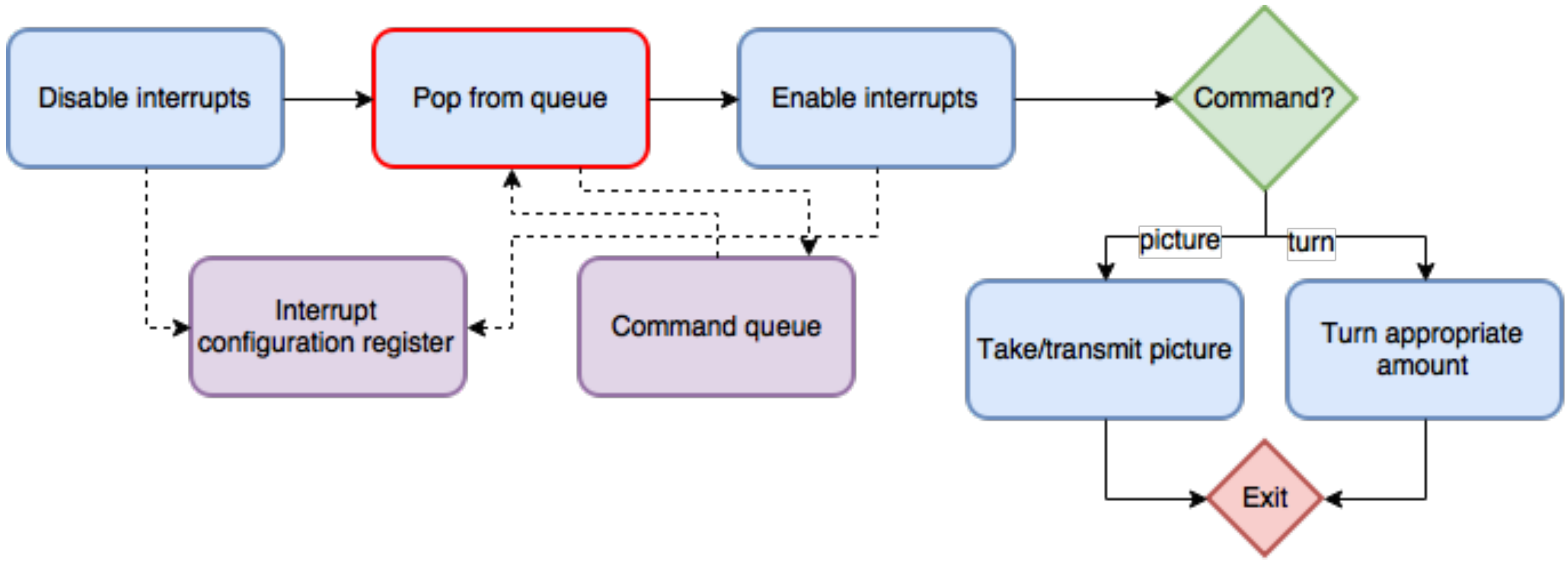
Telemetry format

- Up to 72 characters per frame in transparent mode (easiest mode to use, as far as we can tell)
- Frame will contain 21 or 31 characters depending on speed test results:
  - 1/2 character for packet identification
    - 1 bit identifier, 3 bit padding
  - 1 1/2 characters for battery life
  - 2 character timestamp indicating seconds since landing
  - 3 characters for altitude
  - 2 characters for temperature
  - 2 characters for humidity
  - 8 or 18 characters for GPS depending on encoding

XBee Receive ISR



Handle Commands Subroutine



Picture Subroutine

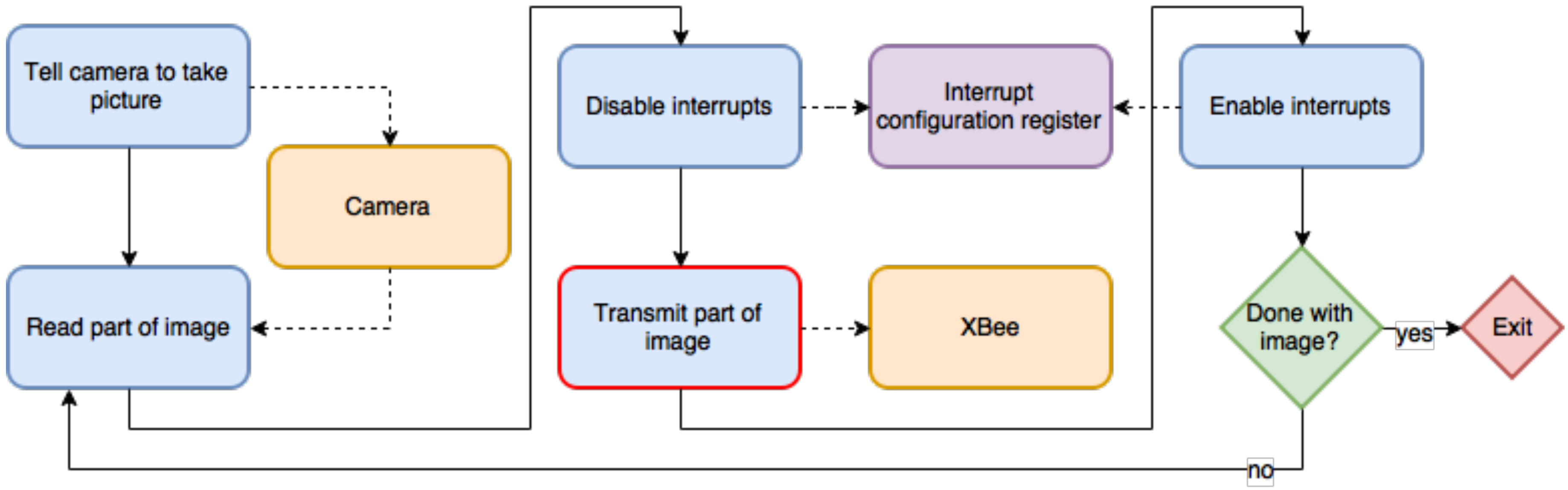
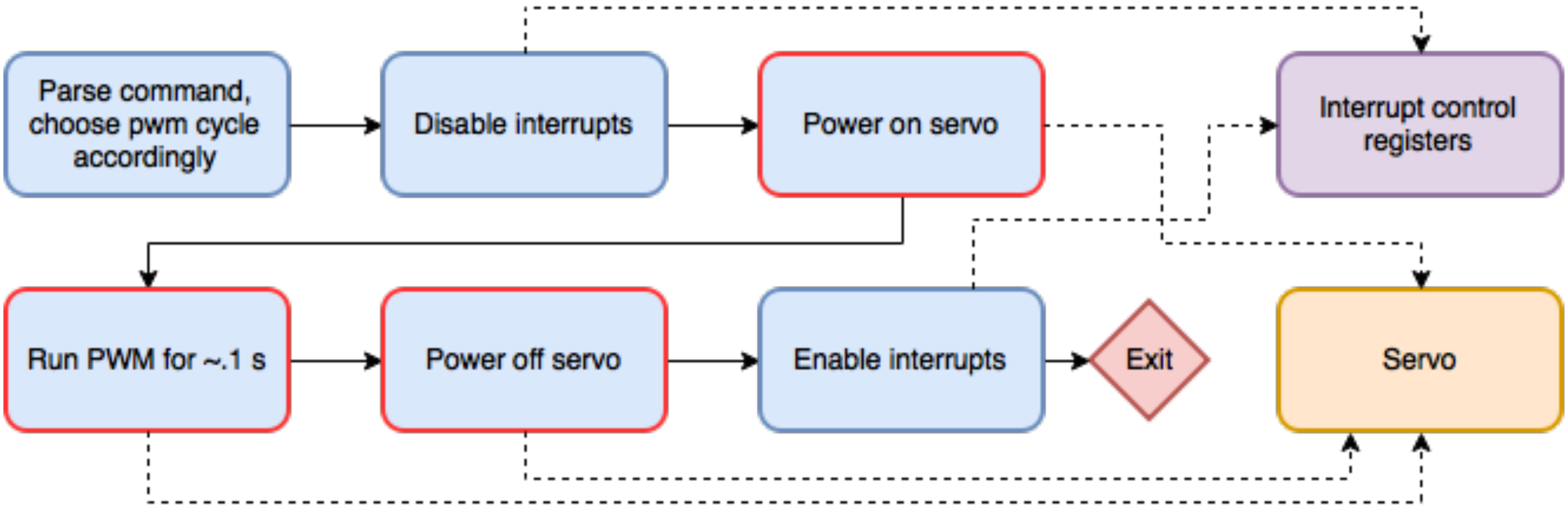


Image transmission format

- Again, up to 72 characters per frame
  - 2 character of packet identification
    - 1 bit identifier, 1 bit padding, 14 bit packet number
  - Up to 70 characters of image data
- Raw image will contain 640x480x2 characters worth of data
  - 8778 packets total

WPI

Turn Subroutine



Software Development Plan

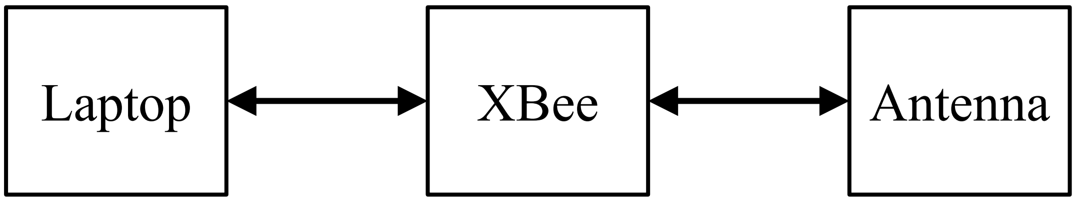
- Software development will be hierarchized by point acquisition capability and reliance on other features
- Code will be written stand alone separate blocks to assure each operation functions individually
- In order of priority:
  - Telemetry transmission
    - Telemetry collection
    - Transmission over XBee
  - Righting of Lander
    - Landing Detection
    - Motor control
  - Taking Pictures
    - Camera control
    - Picture encoding to XBee over multiple packets

Lander Payload Integration

- Lander will be enclosed on custom made mold foam enclosure that will protect the payload from stress sustained during flight.
- Enclosure will fit rocket just right so that deployment is controlled and easy on the payload. Protecting it from the heat and damage that can be produced by the black powder.
- Enclosure will break apart due to drag forces after initial deployment and payload will proceed with parachute descent.

Ground Station

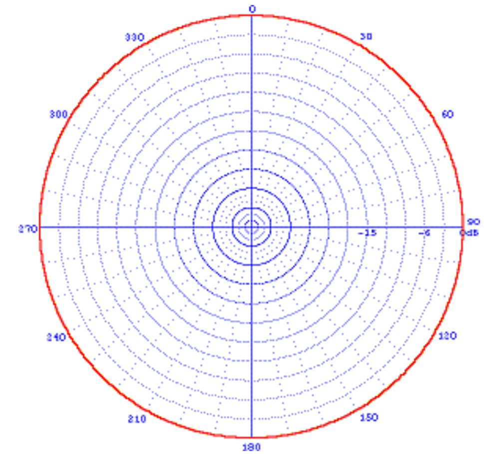
Ground Station Design

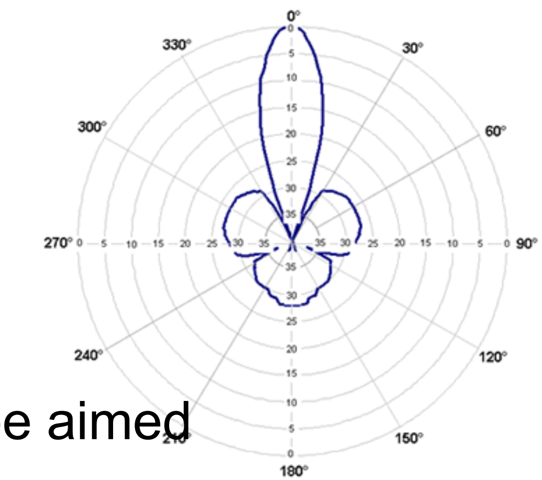


- Laptop connected to XBee via USB
- XBee connected to Antenna via RP-SMA to N-type connector

Ground Station Antenna Trade and Selection

- Antennae considered:
  - Traditional “rubber ducky” antenna
    - ▪Very small
    - ▪Quarter-wave Monopole
    - ▪Nearly Omnidirectional
    - ▪~5dBi Loss
  - Hyperlink Technologies T2400F
    - ▪Hand Held
    - ▪Parabolic Grid Antenna
    - ▪Directional: 9.5° Horizontal, 13° Vertical
    - ▪24dBi Gain
- Final decision: Hyperlink Technologies T2400F
  - Power usage on lander is an issue
    - ▪High gain requires less transmit power
  - Directional antenna still has a wide enough beam to be aimed

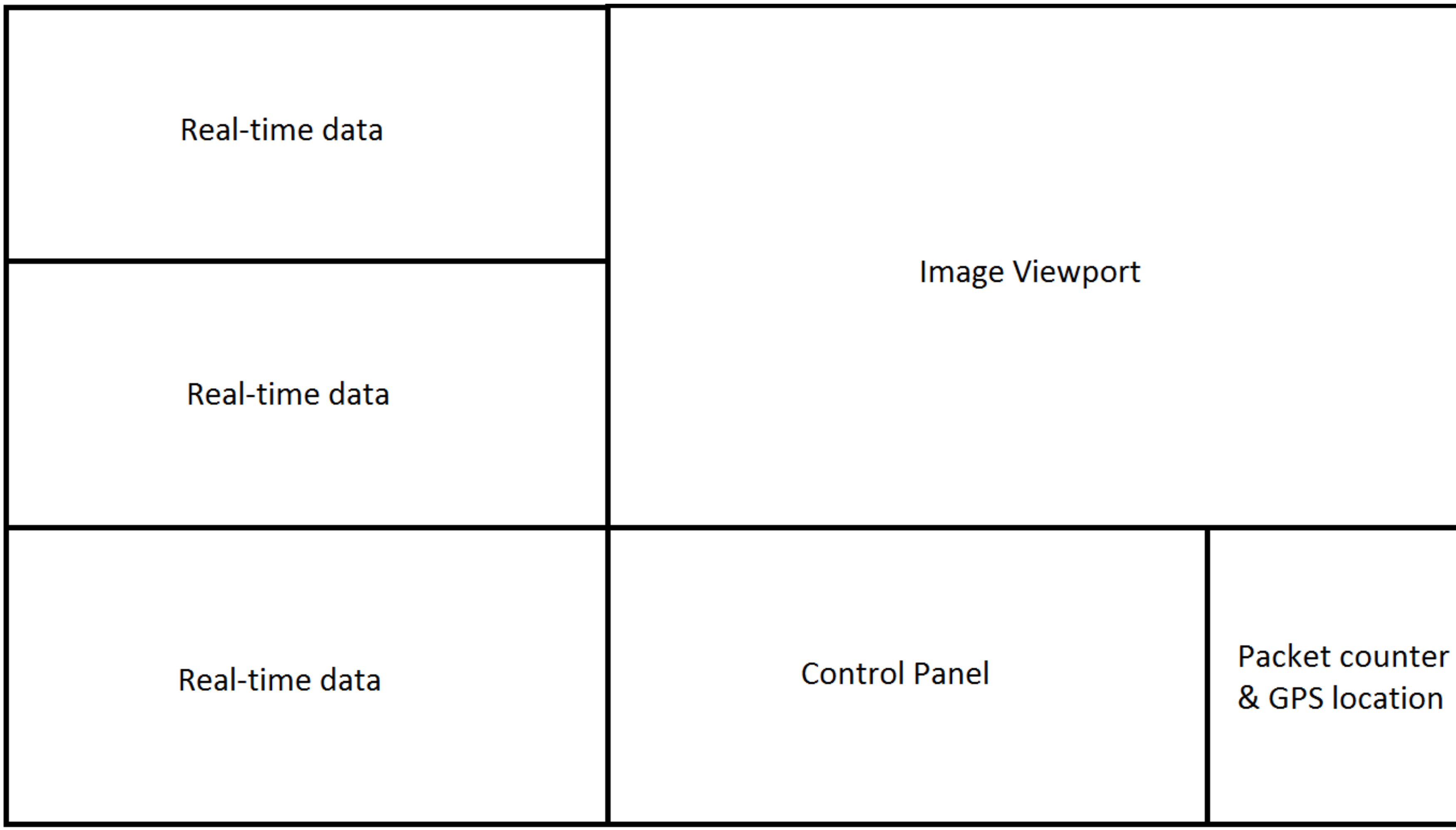




Ground Station Software

- Commercial or open source software packages (Python)
  - –Matplotlib for plotting data in real time
  - –Python-XBee for communication
  - –Pillow for image display
- HAVE GITHUB SET UP

Telemetry Display Prototype



Ground Station Portability

- ThinkPad laptop
  - >2 hours battery life
- Hyperlink Technologies T2400F Antenna
  - Attached to PVC pipe that serves as a handle
  - Handle and mount will be improved if suitable materials can be found for minimal cost
- Wooden folding stand to support laptop

Testing

Ground Station Testing

- Individual Component Testing
  - Receiving antenna
    - Connect to Wi-Fi antenna
  - Laptop
    - Turn on and run for an hour with all software running
  - XBee
    - Receiving from antenna and communication with computer
- Integrated System Testing
  - Use a separate XBee to send simulated packets

Lander Testing

- Drop test
  - –Worst-case landing situation
  - –Self-righting mechanism
  - –Structural Integrity test on lander mockup. No electronics integrated
- XBee transmission - 1000 ft range test
  - –400 ft vs. 1 mile range
  - –Power draw a concern
  - –Telemetry & camera test

Rocket Testing

- Parachute deployment testing
  - Rocket body tube will be loaded with one parachute at a time and clamped horizontally
    - Repeated for each Drogue chute and Main chute
  - Area will be cleared and marked for safety.
  - The powder charges will be fired to ensure that ejection is functioning properly
    - Will help to ensure enough friction fit to avoid problems during flight but still able to be separated
  - Adjust accordingly for shock cord size to avoid problems like zippering of the rocket body

Payload Deployment Testing

- Rocket body tube will be fully loaded with a mock lander
- Rocket will clamped at an angle of -30° to the horizontal
- Area will be cleared and marked for safety
- Ejection charge fired
- Parachute deployment and parachute descent landing
- Adjust accordingly to account for payload mass and optimal parachute size

Flight Operations

- Rocket preparation and transportation
  1. Inspect launch site and rocket
  2. Lander Preparation (Next Slide)
  3. Reload and insert engine.
  4. Place rocket on launch pad
  5. Activate electronics.
  6. Check for charge continuity.
  7. Set igniter
  8. Launch

Lander Preparation

- Lander Preparation
  - Final Setup, all systems integration.
  - All operation last check of proper functionality.
  - Upload Rocket ready software.
  - Attach Lander Parachute to Lander
  - Lander close up and preparation to be enclosed on foam container
  - Add a parachute protection device between foam enclosure and deployment charge.
  - Foam enclosure incorporation onto rocket body payload bay.
  - Proceed with rocket launch procedure, preparation and charge installation.

Program Schedule

GoatBuster's BOR Schedule

**Twice weekly meetings

"A" Meetings Thursdays 6:30-7:30pm

"Z" Meetings Sundays 3:00-5:00pm

* Indicates specific deadlines

ACTIVITY	ACTIVITY START	APPROX. PLAN DURATION	BI-WEEKLY Sept. 4	Sept. 18	Oct. 2	Oct. 16	Oct. 30	Nov. 13	Nov. 27	Dec. 11	Dec. 25	Jan. 8	Jan. 22	Feb. 5	Feb. 19	Mar 5	Mar. 19	Apr 2	Apr 16	Apr 23*
Team Interest Meeting	Sept. 4	1 meeting																		
Rocket Design Workshop	Sept. 15	1 meeting																		
Open Rocket Workshop	Sept. 29	1 meeting																		
Choose Team Name & Discuss Team Goals	Oct. 9	1 week																		
Familarize w/ Competition Guidelines	Oct. 9	2 weeks																		
Research Lander & Ground Station Design	Oct. 9	4 weeks																		
Create Rocket Design	Oct. 16	2-4 weeks																		
Competition Registration Deadline	Oct. 30	N/A					*Oct. 30													
Finalize Lander Design	Oct. 30	2-4 weeks																		
Finalize Rocket Design	Oct. 30	2 weeks																		
Create PDR	Oct. 16	8 weeks																		
Order Rocket & Lander Parts	Nov. 25	4 weeks																		
Lander Testing	Nov. 27	12 weeks																		
Rocker Testing	Nov. 27	12 Weeks																		
PDR Deadline	Dec. 1	N/A							*Dec. 1st											
PDR Review	Dec. 5-9	1 meeting																		
Create CDR	Dec. 15	8 Weeks																		
Lander Building	Dec. 11	20 weeks																		
Rocket Building	Dec. 11	20 weeks																		
Ground Station Assembly	Dec. 11	20 Weeks																		
CDR Deadline	Feb. 1	N/A											*Feb. 1st							
Competition	Apr 22,23	2 days																		

Component and Service Schedule

GoatBuster's BOR Components and Service Schedule

ACTIVITY	ORDER DATE	DATE RECEIVED/ DATE DONE
XBee Pro 63mW RPSMA - Series 2B	Nov. 13	Nov. 20
SparkFun Xbee Explorer USB/ shipping and handling	Nov. 13	Nov. 20
RPSMA MALE - N1 MALE 6FT	Nov. 13	Nov. 20
MSP430F5529LP	Nov. 13	Nov. 21
XBee (400 ft range with built in antenna)	Nov. 13	Nov. 21
ov7670 FIFO	Nov. 13	Nov. 22
Continuous Rotation Micro Servo - FS90R	Nov. 13	Nov. 23
Adafruit TSL2561 Digital Luminosity/Lux/Light Sensor Breakout	Nov. 13	Nov. 25
Rocket Body Tube	Dec. 7	Dec. 17
Rocket Nose Cone	Dec. 8	Dec. 14
Rocket Electronics Bay	Dec. 8	Dec. 14
2 36" Parachutes	Dec. 12	Dec. 15
Assembling/ Building Ground Station Platform	N/A	Jan. 22- Jan. 26
Assembling Electronics Bay	N/A	Jan. 22
Laser Cutting Parts	N/A	Jan. 29- Feb. 1

Key

Red = Part
Gray = Service

Program Budget

Program Budget: Rocket

Part	Cost	Website
Airframe (6"x 0.074 wall x 72")	$105.95	http://www.alwaysreadyrocketry.com/product/1-15-29mm-x-062-wall-x-48-airframe-mmt/
Nose Cone (6" conical fiberglass)	$116.33	https://www.apogeerockets.com/Building_Supplies/Nose_Cones/Fiberglass_Nose_Cones/6in_Fiberglass_Conical_5_1_Nose_Cone?cPath=42_47_61&
E-Bay (Standard Coupler 6" x 0.074 wall x 16")	$27.95	http://www.alwaysreadyrocketry.com/product/1-15-29mm-x-062-wall-x-8-coupler/
Parachutes	Already own	http://spherachutes.com/items/list.htm
Centering Ring (Birch Plywood--1/2in thickness, 2ft x 4ft)	$19.95	http://www.homedepot.com/p/Birch-Plywood-Common-1-2-in-x-2-ft-x-4-ft-Actual-0-476-in-x-23-75-in-x-47-75-in-1503004/202088758
Fins (Birch Plywood--1/4in thick, 2ft x 4ft)	$12.42	http://www.homedepot.com/p/Birch-Plywood-Common-1-4-in-x-2-ft-x-4-ft-Actual-0-195-in-x-23-75-in-x-47-75-in-1503008/202088745
Motor (Cesaroni Technology Inc. J760WT)	$102.30	http://cart.amwprox.com/index.php?option=com_virtuemart&view=productdetails&virtuemart_product_id=233&virtuemart_category_id=6
Motor Tube	Already own	
Raven 3 altimeter	$155	http://www.shop.featherweightaltimeters.com/product.sc;jsessionid=A12FDEBE047F183768446B6574A60EAC.qscstrfrnt02?productId=7&categoryId=1
Parachute Protectors	$21.98	https://www.apogeerockets.com/Building_Supplies/Parachutes_Recovery_Equipment/Reusable_Wadding/Sunward_18in_Parachute_Protector

Program Budget: Lander

Part	Cost	Website
MSP430F5529LP	$12.99	http://www.ti.com/tool/MSP-EXP430F5529LP#buy
XBEE 1 mile range with built in antenna	$41	https://www.sparkfun.com/products/10418
XBEE 400 ft range with built in antenna	$23	https://www.sparkfun.com/products/10414
ov7670 FIFO	$11.50	http://www.ebay.com/itm/like/222089147466?lpid=82&chn=ps&ul_noapp=true
RHT03 temp/humidity sensor	$10	http://cdn.sparkfun.com/datasheets/Sensors/Weather/RHT03.pdf
Photodiode?	<$1	digikey
Basic resistors/caps/etc	~$0	
Adafruit TSL2561 Digital Luminosity/Lux/Light Sensor Breakout	$6	https://www.adafruit.com/product/439

WPI

Program Budget: Lander (Cont'd)

Part	Cost	Website
GPS	$16	https://www.sparkfun.com/products/13740
Case Material: Polycarbonate	$13.29	https://www.mcmaster.com/#standard-plastic-sheets/=150yf5t
Main battery	$9.95	http://www.batteryspace.com/NiMH-Battery-Pack-3.6V-1600-mAh-Prewired-with-Hitec-connector.aspx
Second battery for battery measurement	$8.45	http://www.batteryspace.com/custom-nimh-3-6v-280mah-1-3aa-stick-battery-with-tabs.aspx
Motor		
Spring	$4.04 each	http://www.centuryspring.com/torsion-spring-to-1045.html
Solar Panel	$3.95 each	http://store.sundancesolar.com/powerfilm-3v-22ma-flexible-solar-panel-sp3-37/
Altimeter for Lander	Already own	https://www.pololu.com/product/2126

Program Budget: Ground Station

Part	Cost	Website
Laptop	Donated	
XBEE 1 mile range with RPSMA connector	$45	https://www.sparkfun.com/products/10419
N-female to RPSMA male	$4.75	http://www.showmecables.com/product/N-Female-to-Reverse-Polarity-SMA-Male-Adapter.aspx
Sparkfun XBEE explorer	$25	https://www.sparkfun.com/products/11812
HyperLink T-2400F Antenna	Already owned	

Program Budget: Travel Expenses

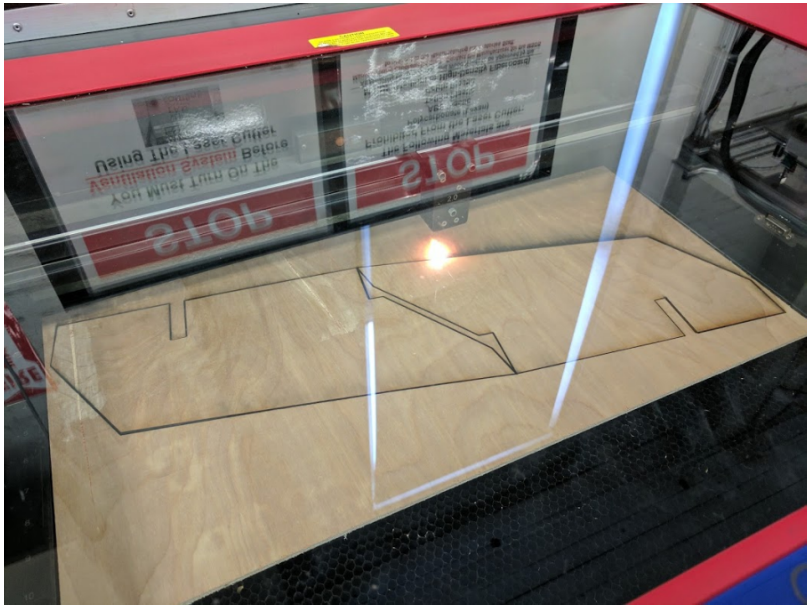
Travel Expense	Cost	Total
Food	20 USD per person per day	400 USD
Lodging	60 USD per night per 2 people	600 USD
Transportation	TBD School Organized Bus	~500USD
	Total	~1500 USD

All Program Budget for Rocket, Payload, G

Travel expenses will be covered by WPI Student Government Association (Funds from WPI Student Activities fee)

Summary: Rocket Subsystem

- Rocket has been designed and simulated in OpenRocket
- Components ordered and received
- Assembled rocket electronics bay
- Laser cut fins and centering rings
- Upcoming:
  - Full assembly
  - Test flights following end of snowy season



Summary: Ground Station Subsystem

- Ground Station base has been constructed
- Testing of antenna range was successful
- All connecting wires have arrived and work with the other electronics
- Software needs to be written

Summary: Lander Subsystem

- Lander has been designed and all the main components are on order
  - Mechanical Systems to be manufactured
  - Structure will be built
  - Electronics will be put together, sensors will be checked for proper functionality
  - Code Development start

Summary: Team Logistics

- Transportation and Lodging details are being worked out with WPI Student Activities Office
- Budget Financial Request has been submitted and will be heard this week. Decision on approval or revocal will be released within a week.
- Class 1 certification for various members are in the works
- Excited for actual construction to begin, after design phase
  - Looking forward to encountering problems
- “What is engineering without solving problems, and what is Aerospace Engineering without Explosions?”