# GoatBusters Planetary Lander

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 |

# 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 |

WPI

# Rocket System Requirement Summary

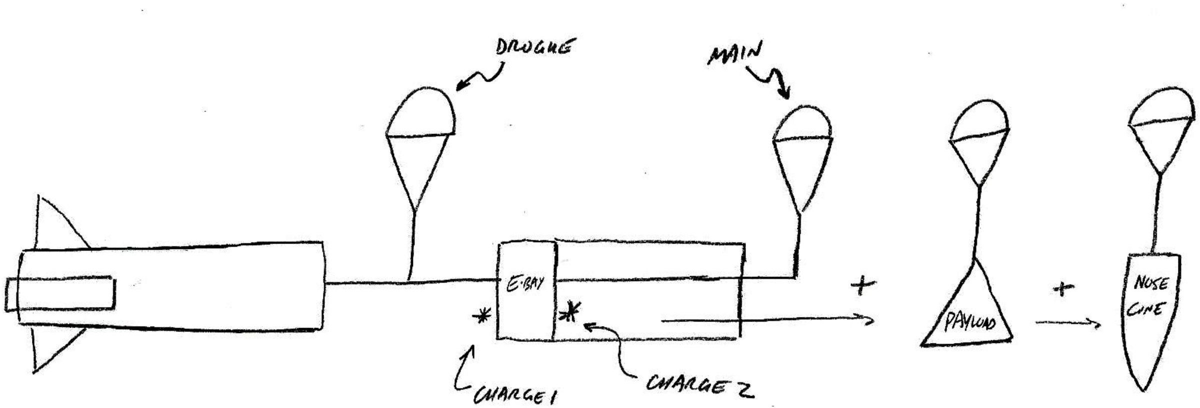
| Req # | Requirement |
|---|---|
| 1 | Motor must not exceed 1280 N-s |
| 2 | Must reach 1000 ft |
| 3 | Must use a motor retainer |
| 4 | All common rules must be followed |

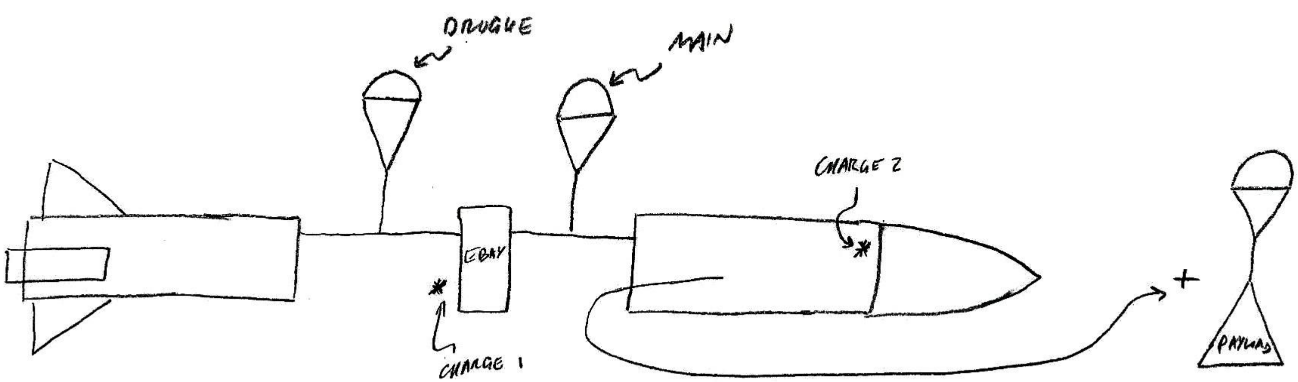
# Ground Station System Requirement Summary

| Req # | Requirement |
|---|---|
| 1 | Display telemetry in real time |
| 2 | Display all image received |
| 3 | Operate solely on battery power |
| 4 | Man portable |
| 5 | Antenna must be hand held |
| 6 | Count telemetry packets received |

# System Level Trade and Selection: Rocket

Preliminary Rocket Concepts Considered: Four vs. Three parachutes



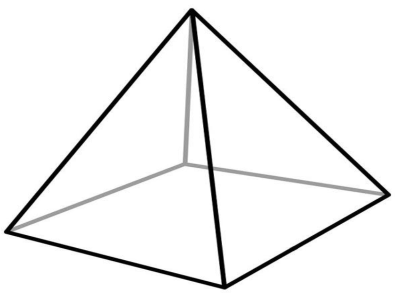



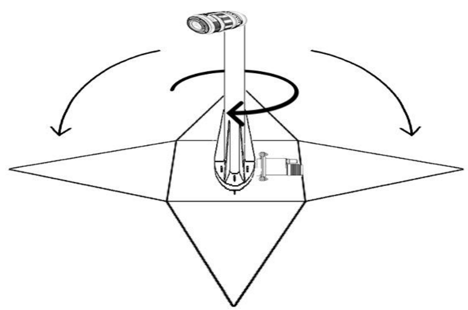

| | Pros | Cons |
|---|---|---|
| **4 Parachute Option** | Simple wiring | More materials<br>Larger mass |
| **3 Parachute Option** | Fewer separated pieces | Complex, single-use wiring |

# System Level Trade and Selection: Lander

Preliminary Lander concepts considered:

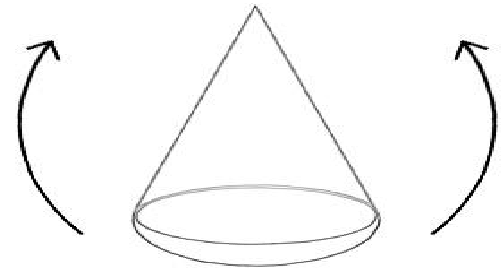
- Pyramidal Lander e.g. Mars Pathfinder





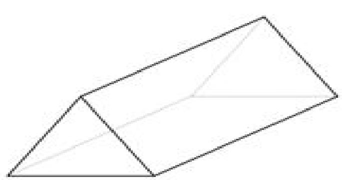
The operation of deploying the lander sides will function to right the lander.

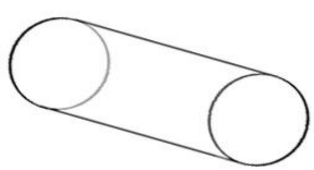
- Pyramidal Lander weighted rounded base



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

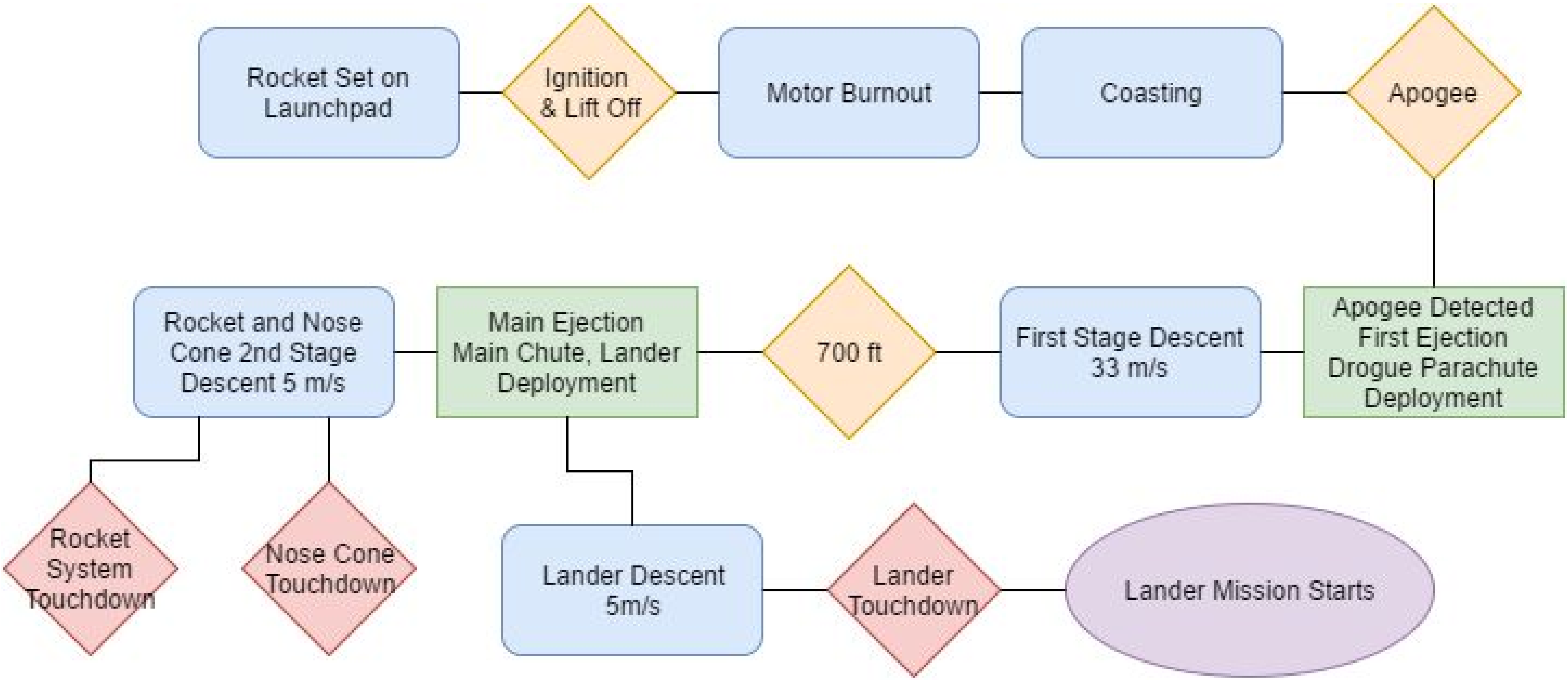
- Cylindrical/Triangular Prism Lander





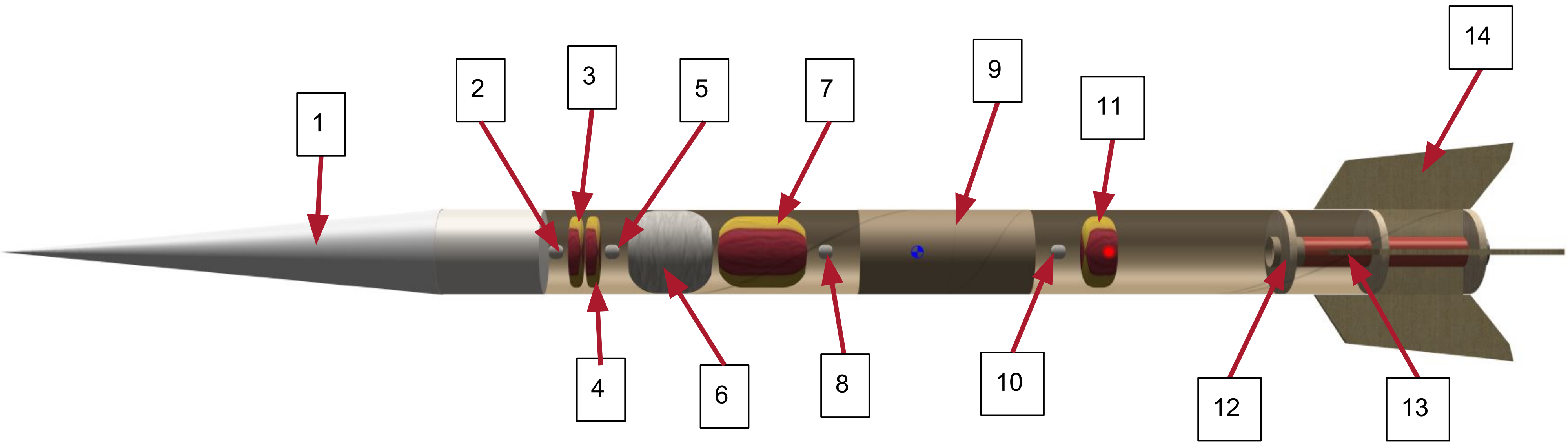
Internal payload free moving within a cylinder so as to always be upright.

# Rocket Concept of Operations



# Lander Mission Concept of Operations

# Rocket Physical Layout

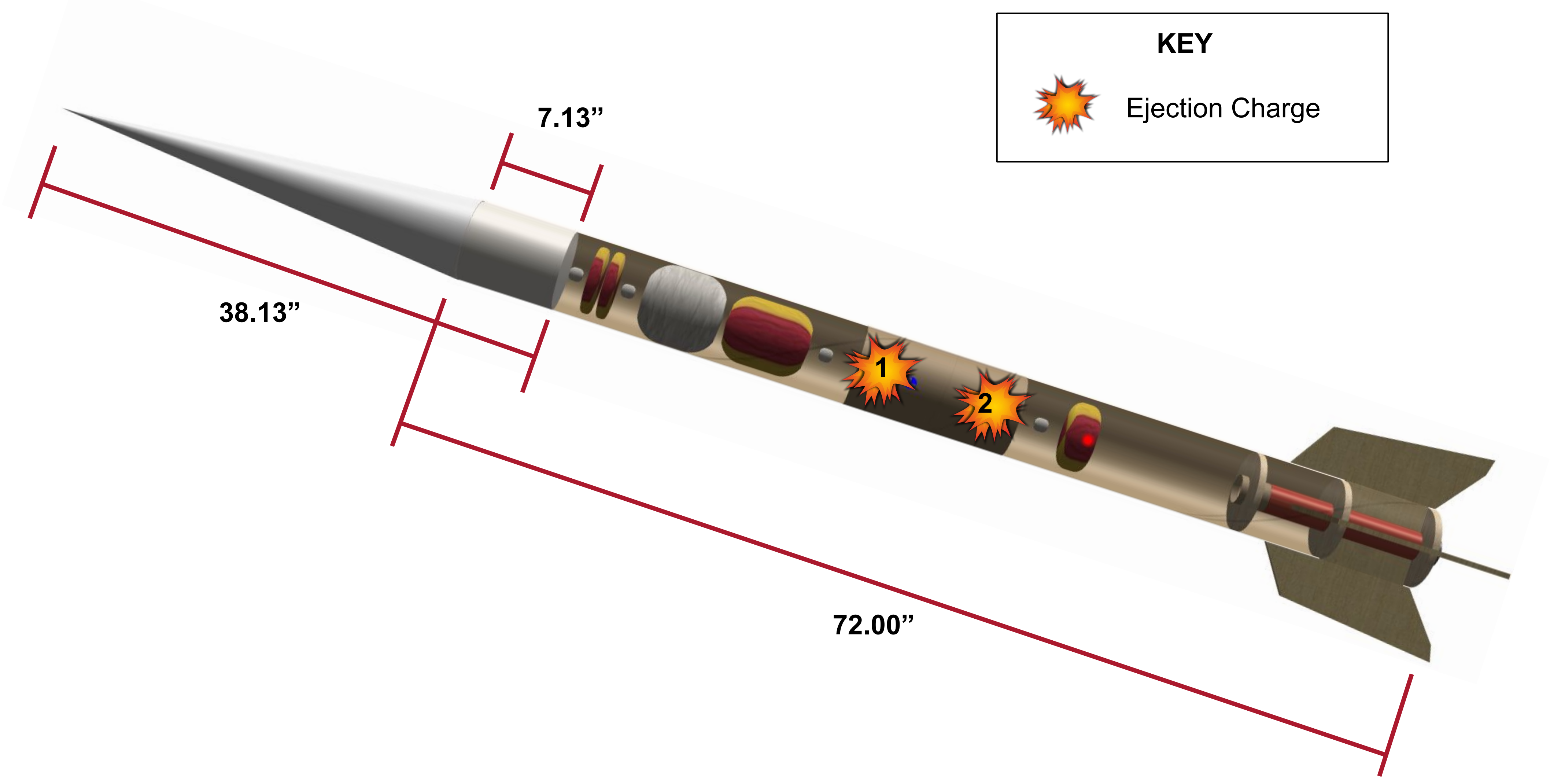



| Component Number | Component Name |
|---|---|
| 1 | Conical Nose Cone |
| 2 | Nose Cone  Shock Cord |
| 3 | Nose Cone Parachute |
| 4 | Payload Parachute |
| 5 | Payload Shock Cord |

| Component Number | Component Name |
|---|---|
| 6 | Payload |
| 7 | Rocket Main Parachute |
| 8 | Rocket Main Shock Cord |
| 9 | Electronics -Bay |
| 10 | Drogue Shock Cord |

| Component Number | Component Name |
|---|---|
| 11 | Drogue Parachute |
| 12 | Centering Ring |
| 13 | Motor Tube |
| 14 | Fin |

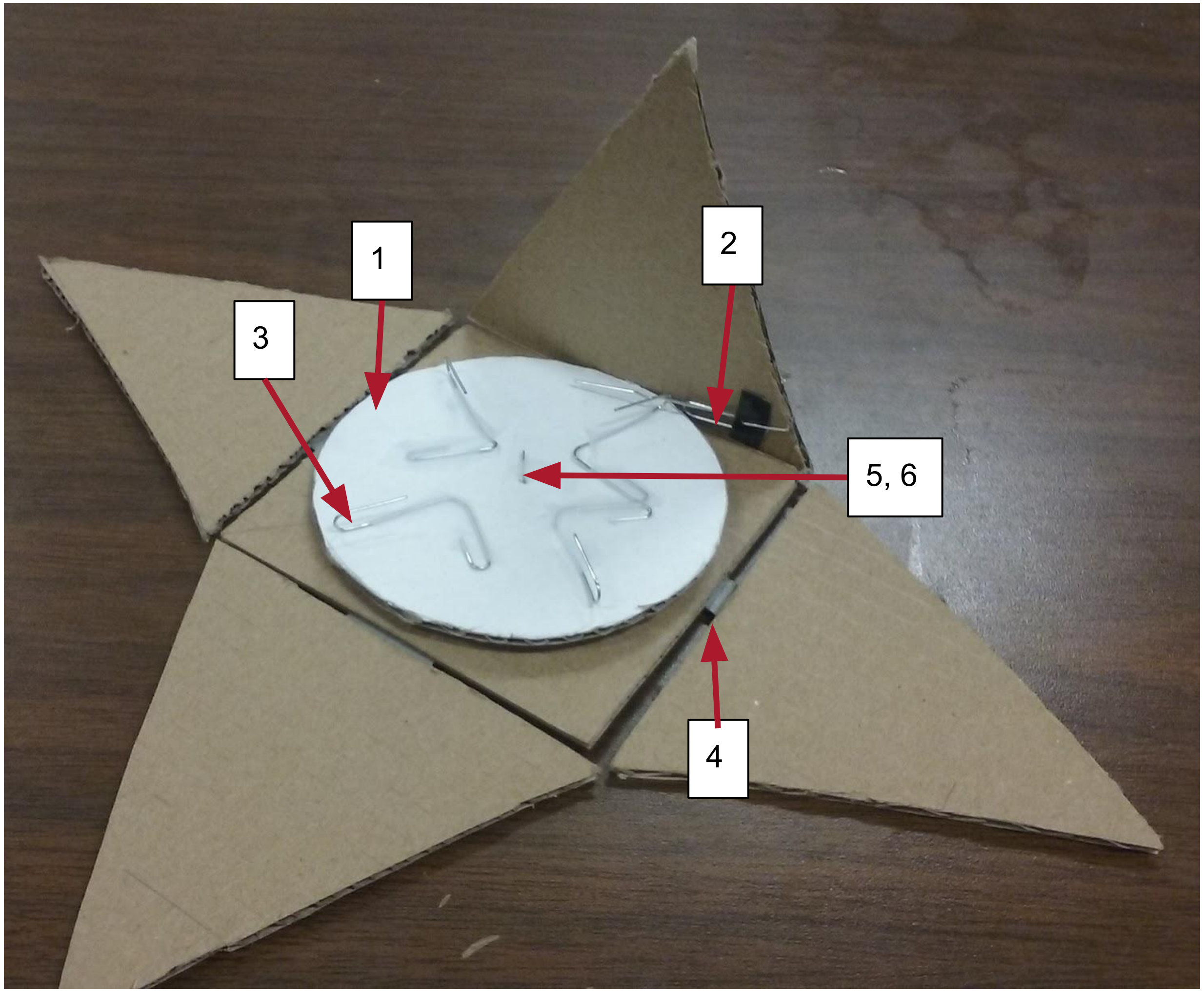
# Rocket Physical Layout Cont.



# Lander Physical Layout

Dimensions: 4” x 4” x 6”

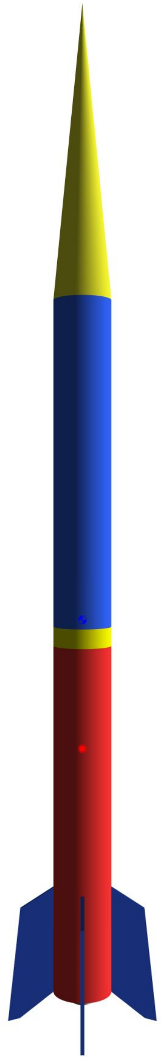
| Component Number | Component Name |
|---|---|
| 1 | Rotating inner disk |
| 2 | Restraining hooks |
| 3 | Hook eyes |
| 4 | Torsion springs<br>(not present) |
| 5 | Servo to spin disk<br>(not present) |
| 6 | Camera mast<br>(not present) |



# Rocket Design

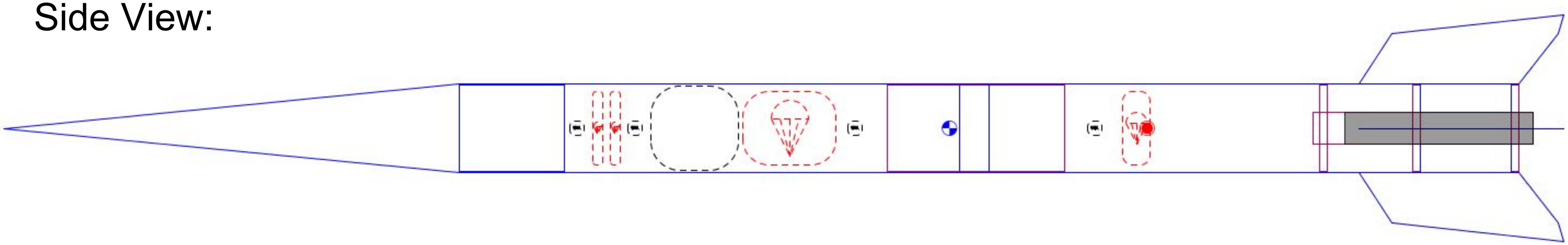
# Overview of Rocket Design

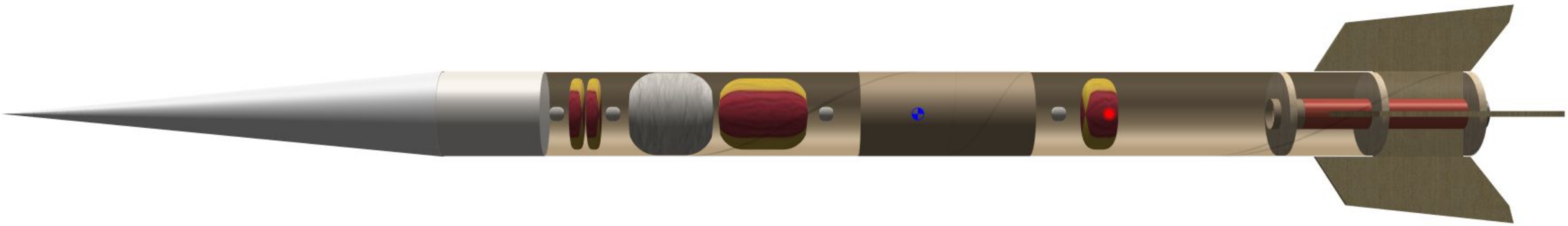
- Rocket weight: 6.47 kg
- Motor: Cesaroni Technology Inc. J760WT
  - Alternate: Cesaroni Technology Inc. J745WW
- Airframe: 6”x 72”, 0.074” wall
- 4 Fins: ~15” long x ~6” radially
- Full Rocket Length: 105.9” (8.8’)
- Nose Cone:
  - Nose Length: 31”
  - Shoulder Length: 7.13”
- Distance between CP and CG: 13.78” (35 cm)
- Stability: 2.3 cal



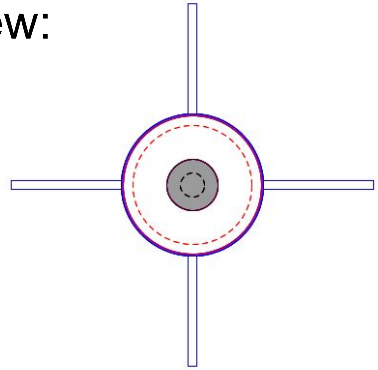
# Overview of Rocket Design

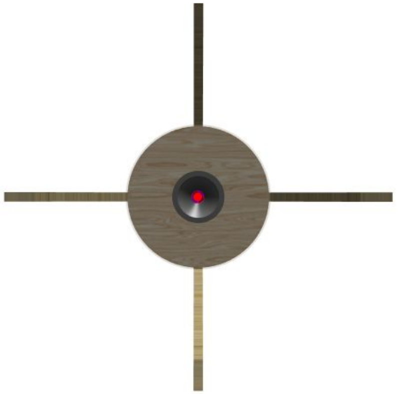
Side View:





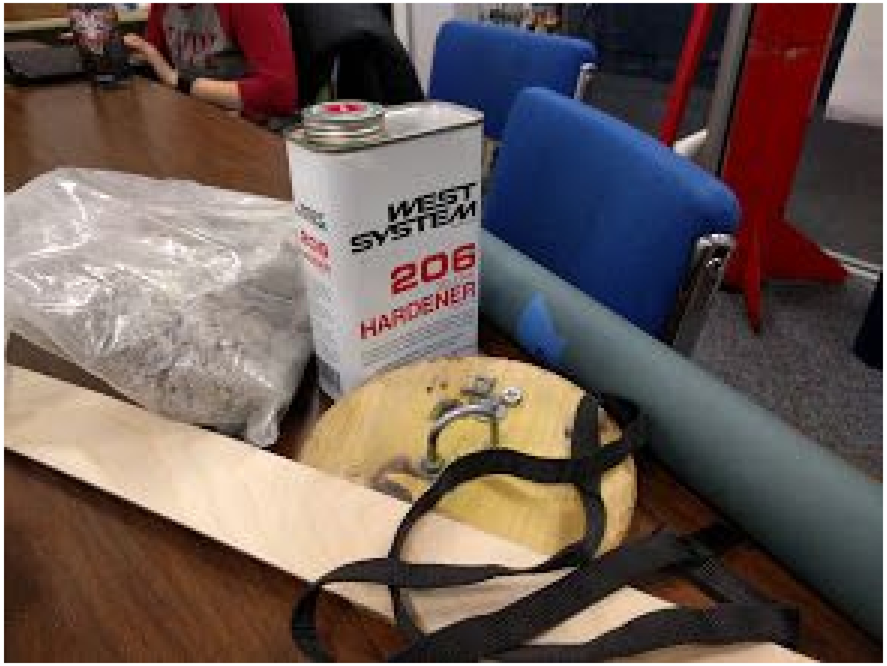
Bottom View:





# 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

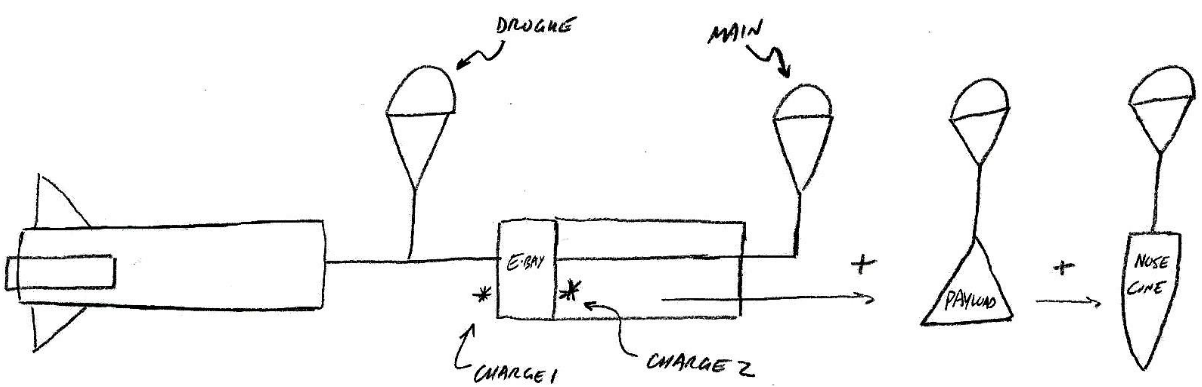


# Rocket Recovery System: Parachutes

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

  (72” Rocket Body 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



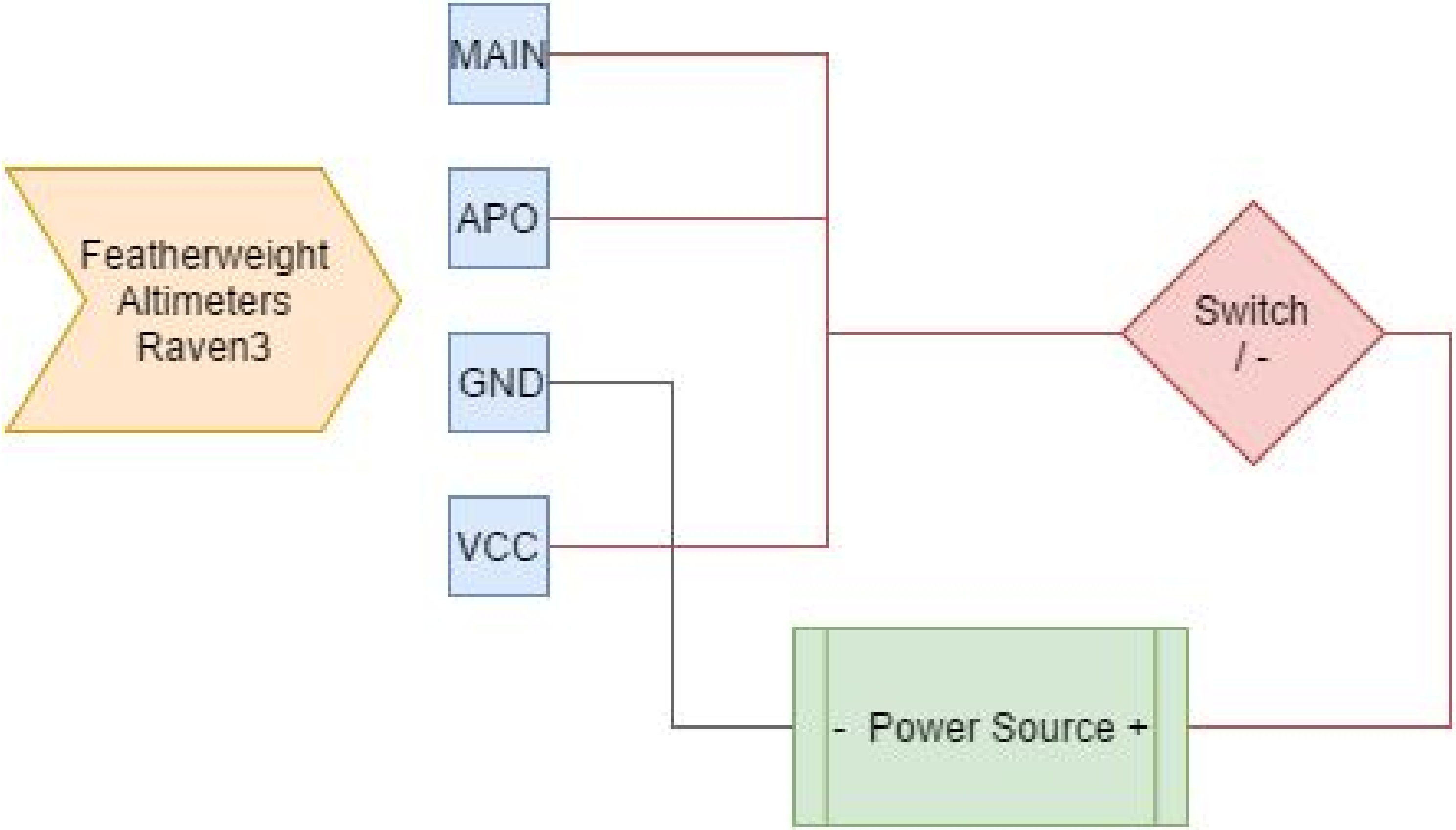
# Rocket Recovery System Harness

- 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: Dog Barf

# 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 plastic sandwich bag, which is then taped shut.
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

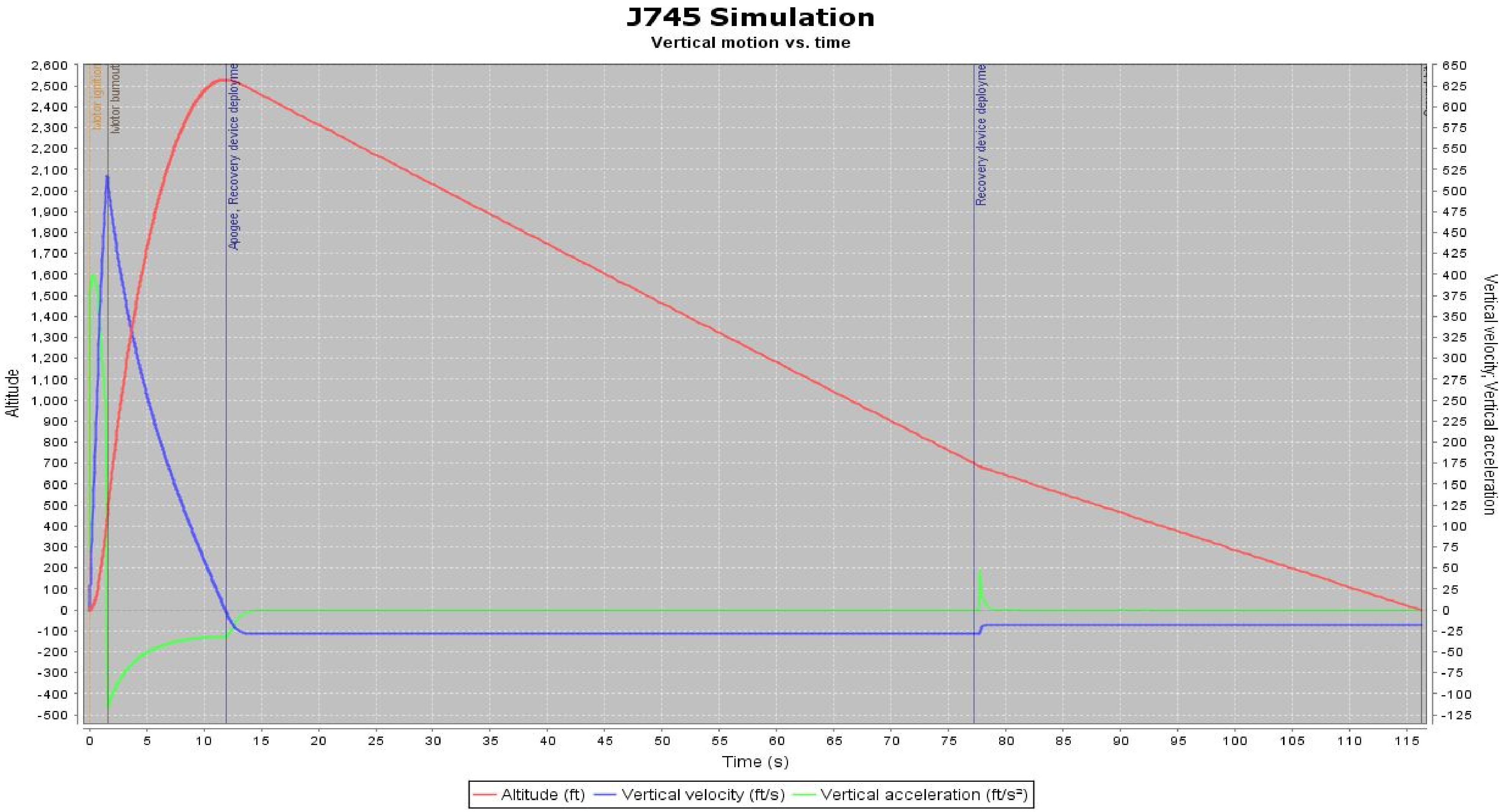
# Rocket Motor Selection

- 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

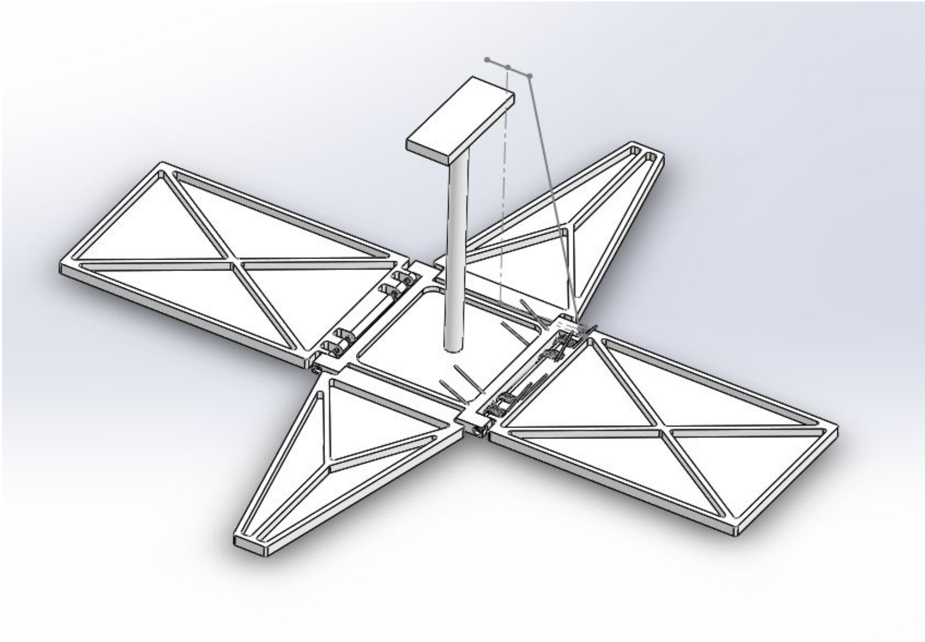
# J745 Simulation



# Lander Design

# Lander Design Overview

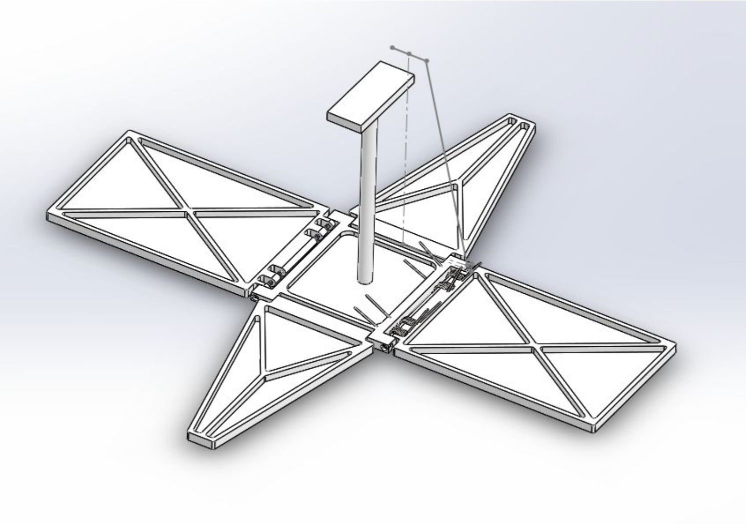
- 4” long × 4” wide × 6” high
- Nylon frame
  - Sturdy and lightweight
- Rotating Inner disk
  - Carries electrical components
  - Rotates to release the side panels and change angle of camera
- Mass of lander
  - 847.6 grams
    - Frame: 590 grams
    - Electronics: 257.6 grams



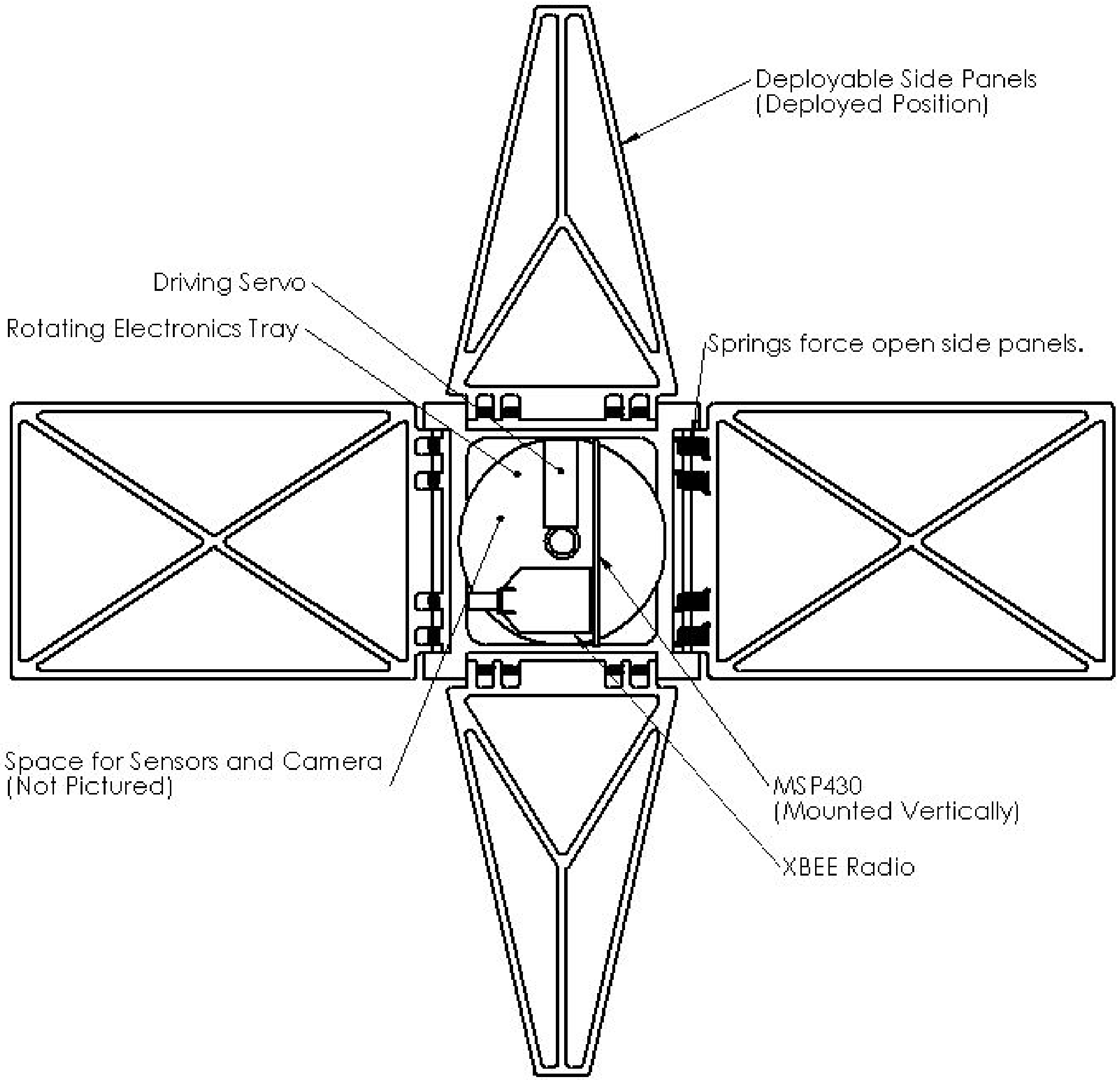
# Lander Design: Mechanical Subsystem

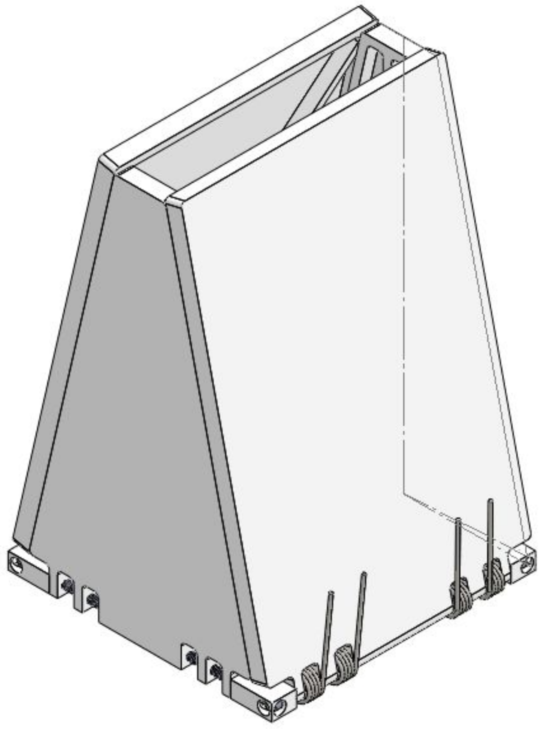
# Mechanical Layout and Component Trade and Selection

- 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 Trade and Selection

- Methods Considered
  - 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
  - Servo is attached to each side panel in order to force the panels open, thus uprighting the lander
- Method Selected: Rotating Inner Section
  - 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 Trade and Selection

- Options Considered
  - 36” parachute deployed after lander ejection
    - Descent rate: 15-20 ft/s for a 1 kg lander (from *spherachutes.com*)
  - Pathfinder style
    - Descent Rate: freefall
    - Impractical on Earth
    - would fail competition guidelines
- Final Selection: Parachute
  - Reliable, safe, feasible, affordable

# 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 |
| Pressure Sensor | 0.6 | Weight taken as a high estimate based on experience |
| Temp/Humidity Sensor | 25 | Weight taken as a high estimate based on experience |
| | | |
| **Total** | **812.6** | |
| **Margin** | **187.4** | |

# Lander Design: Electronics

# Lander Electronics

# Processor and Memory Trade and Selection

- 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
- Arduino Uno
  - 8-bit ATmega328P
  - 16 MHz
  - 32 KB Flash and 2KB RAM
  - ~5-20 mA, ~45-60 uA in low power mode
  - Hardware interrupts for digital I/O
  - 10 Bit ADC
  - Hardware support for UART
  - Debugging over USB 2.0
- Raspberry Pi Zero
  - 32-bit Broadcom BCM2835
  - 1 GHz
  - 512MB RAM - enough to store many 640x480 pictures
  - 40 digital I/O pins
  - ~100 mA
  - Runs a full operating system - no true low power mode
  - No hardware interrupts
  - No analog inputs

# Lander Sensors Trade and Selection

- 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

- Radio Options
  - XBee Pro 63mW PCB-Antenna Series 2B (1 mile range)
  - XBee 2mW Wire-Antenna Series 2 (400 feet range)
- Operational Data Rate & Frequency
  - 1 mile: 250 kbps at 2.45 GHz
  - 400 feet: 250 kbps at 2.45 GHz
- Selection: To Be Determined
  - Must meet the required specifications, be inexpensive, and be compatible with MSP430F5529LP Microprocessor
  - A test will be conducted to determine the actual range at which the 400 ft when transmitting to the ground station large antenna

# Lander Radio Antenna Trade and Selection

- XBee transmitters have built-in antennae - additional selection unnecessary
  - Both radio/antenna models include standard omnidirectional antenna
  - Both mounted on baseplate
  - Both have ~5dBi loss

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# 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 or 290 mA active depending on model |
| RHT03 Temperature/humidity sensor | 50 µA, 1 mA active |
| TSL2561 luminosity sensor | 15 µA, .5 mA active |
| GP-20U7 | 40 mA |
| **Average assuming 20% uptime for peripherals w/ low power modes** | **48 mA or 98 mA depending on XBee model** |

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

# Additional Sensors

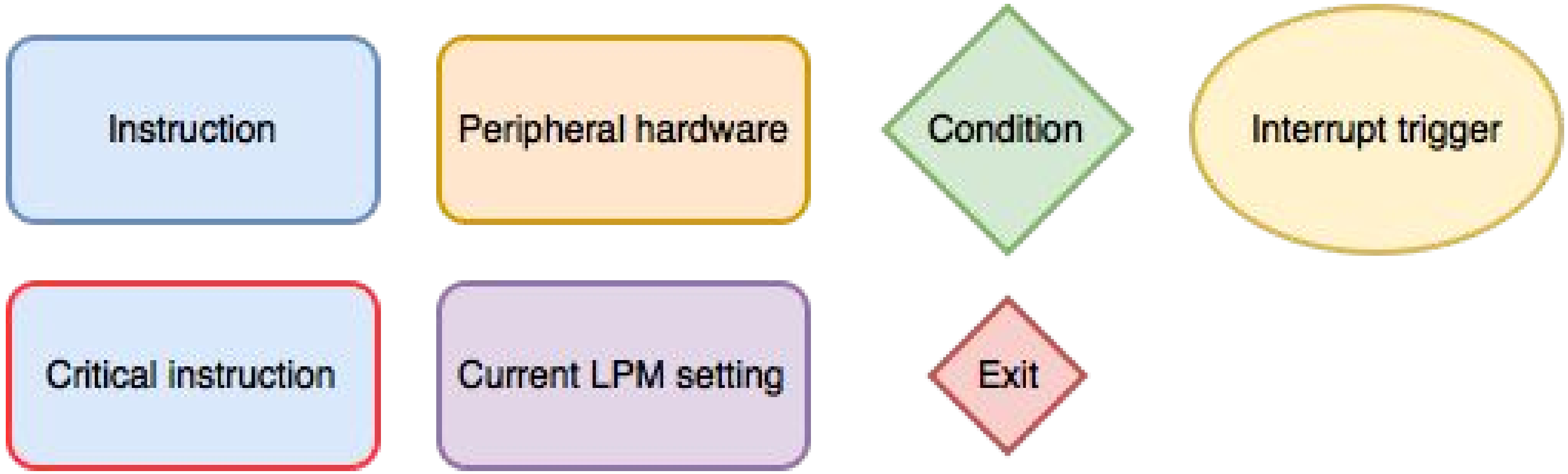
- ov7670 FIFO camera
  - Takes 640x480 photographs
  - Can take images in a compressed YCbCr format that packs two 24-bit images into a single 16 bit image
    - Sacrifices edges of colors
    - Edges in luminance (much more visible) completely preserved
  - Hardware FIFO storage
    - Enables low RAM 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

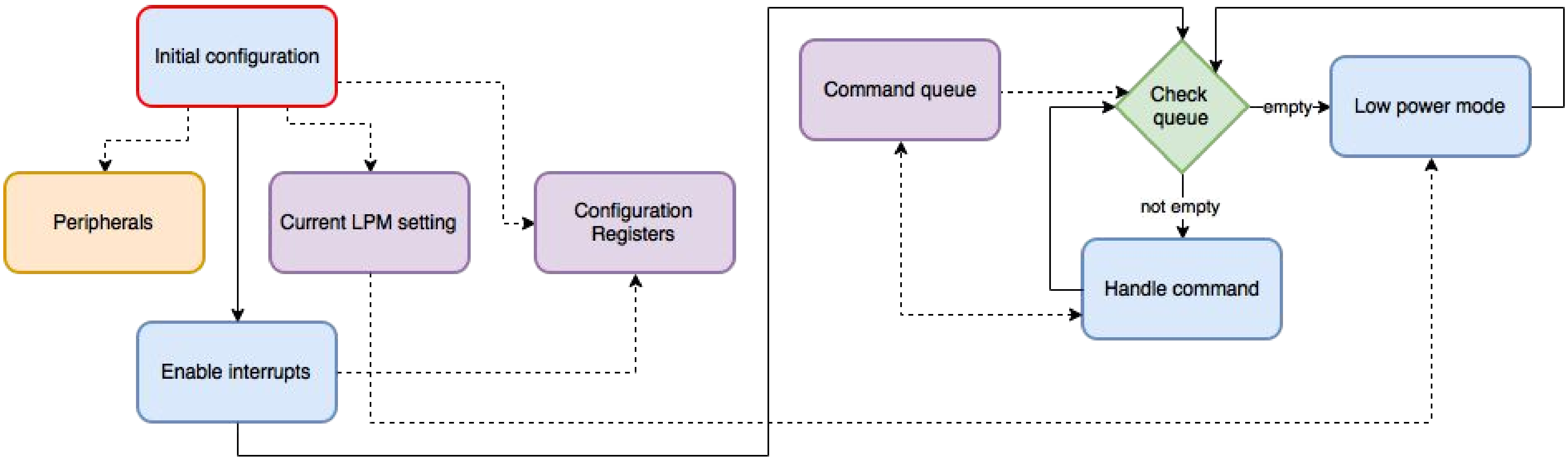
# Lander Software Design

- 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

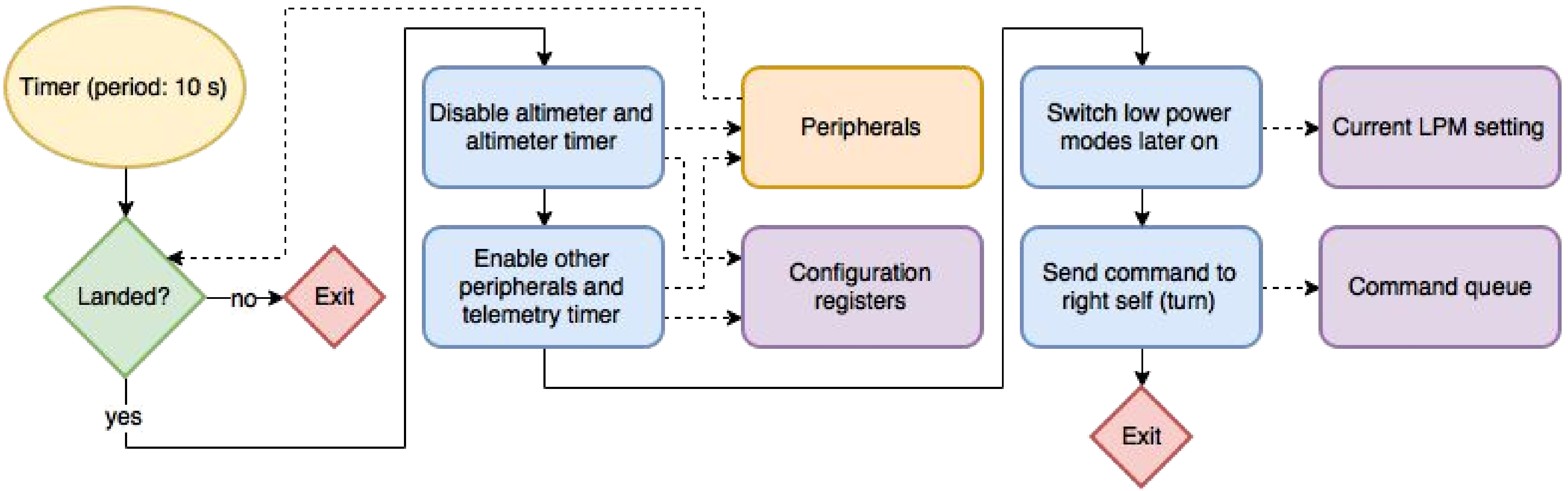
# Flowchart Key



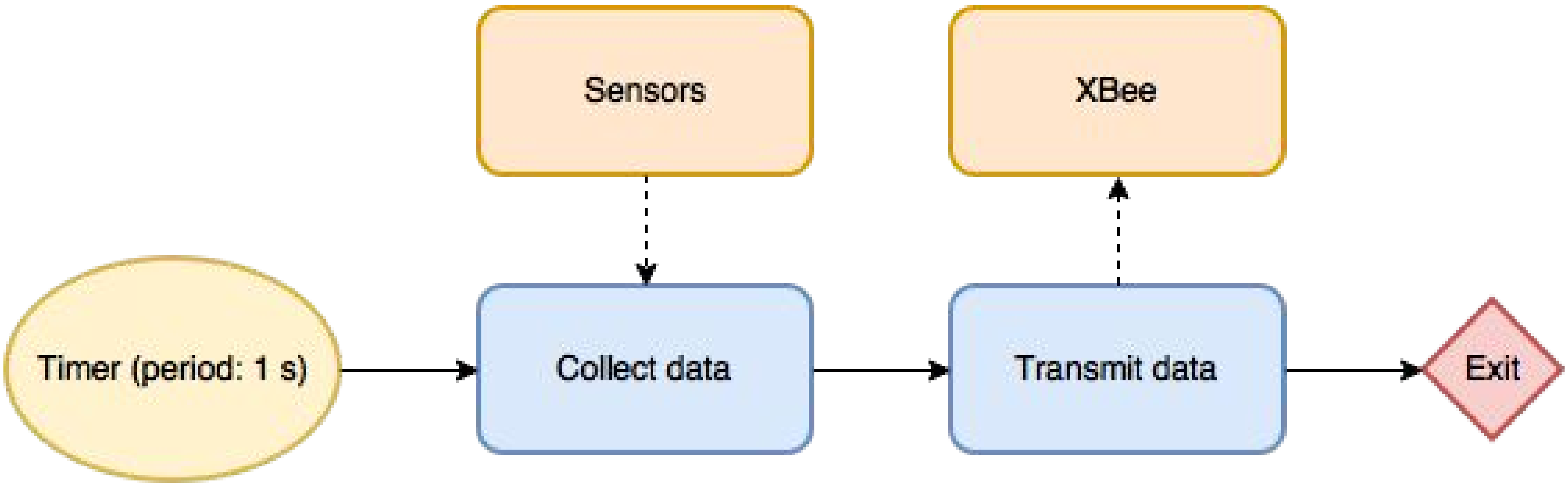
# Main Structure



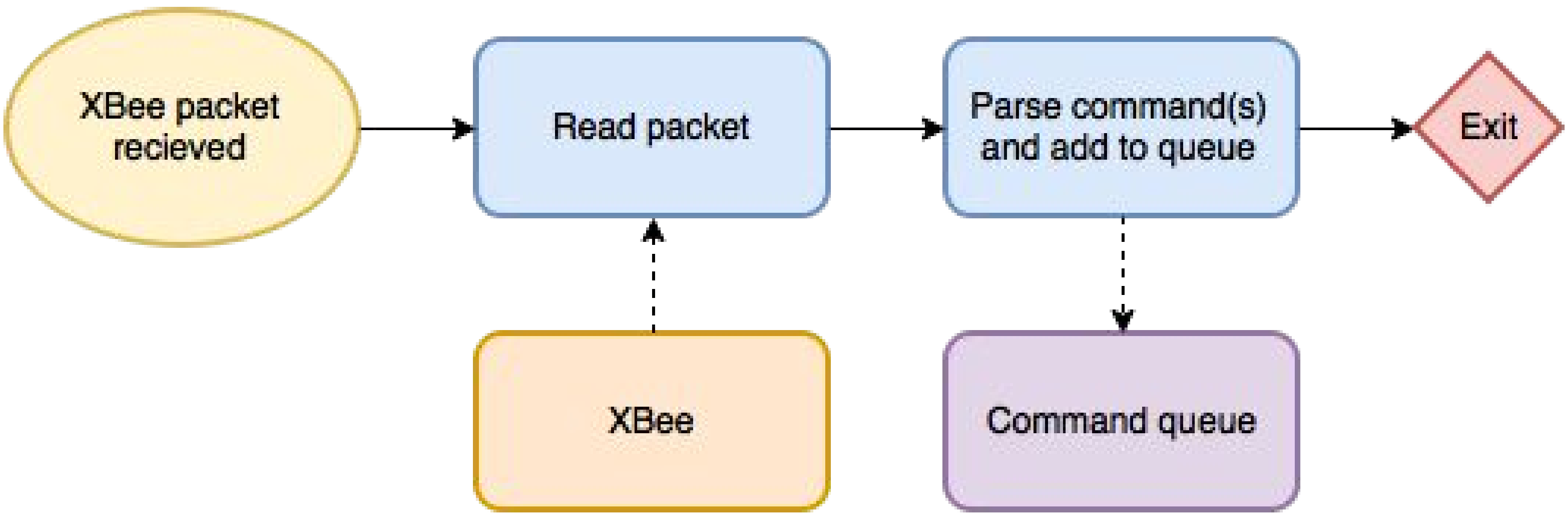
# Altimeter ISR



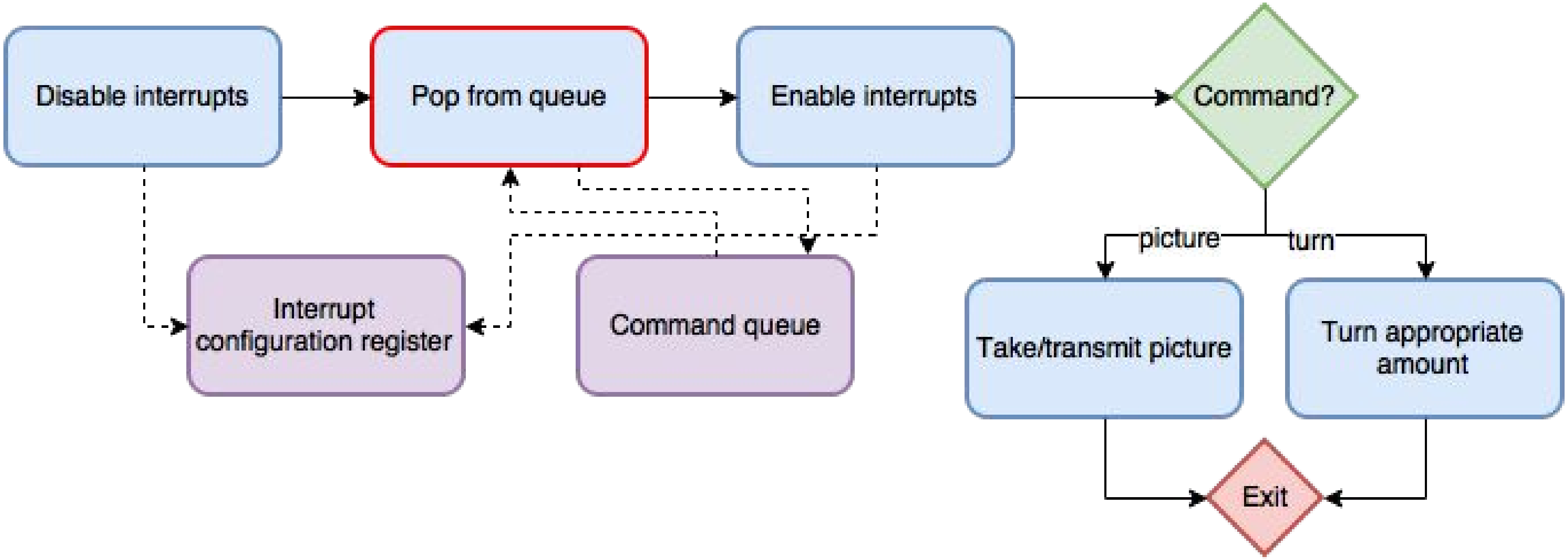
# Telemetry ISR



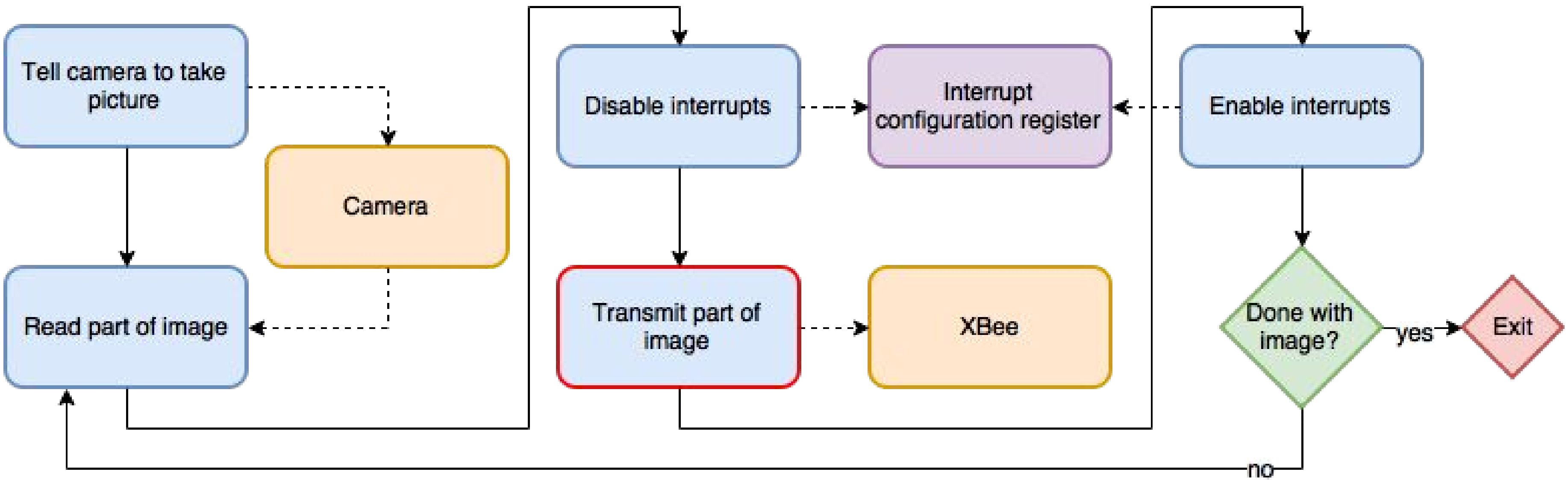
# XBee Receive ISR



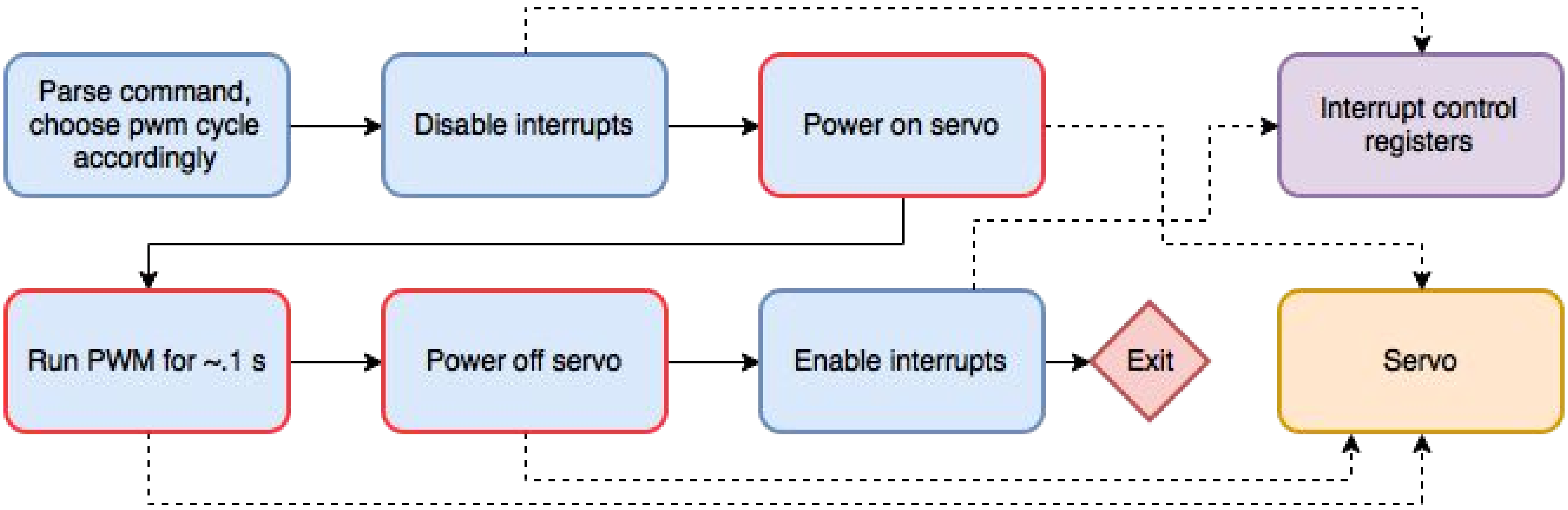
# Handle Commands Subroutine



# Picture Subroutine



# Turn Subroutine

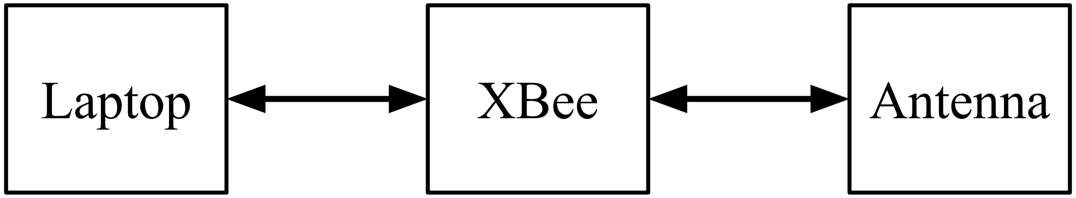


# Software Development Plan

- 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

# Ground Station

# Ground Station Design




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

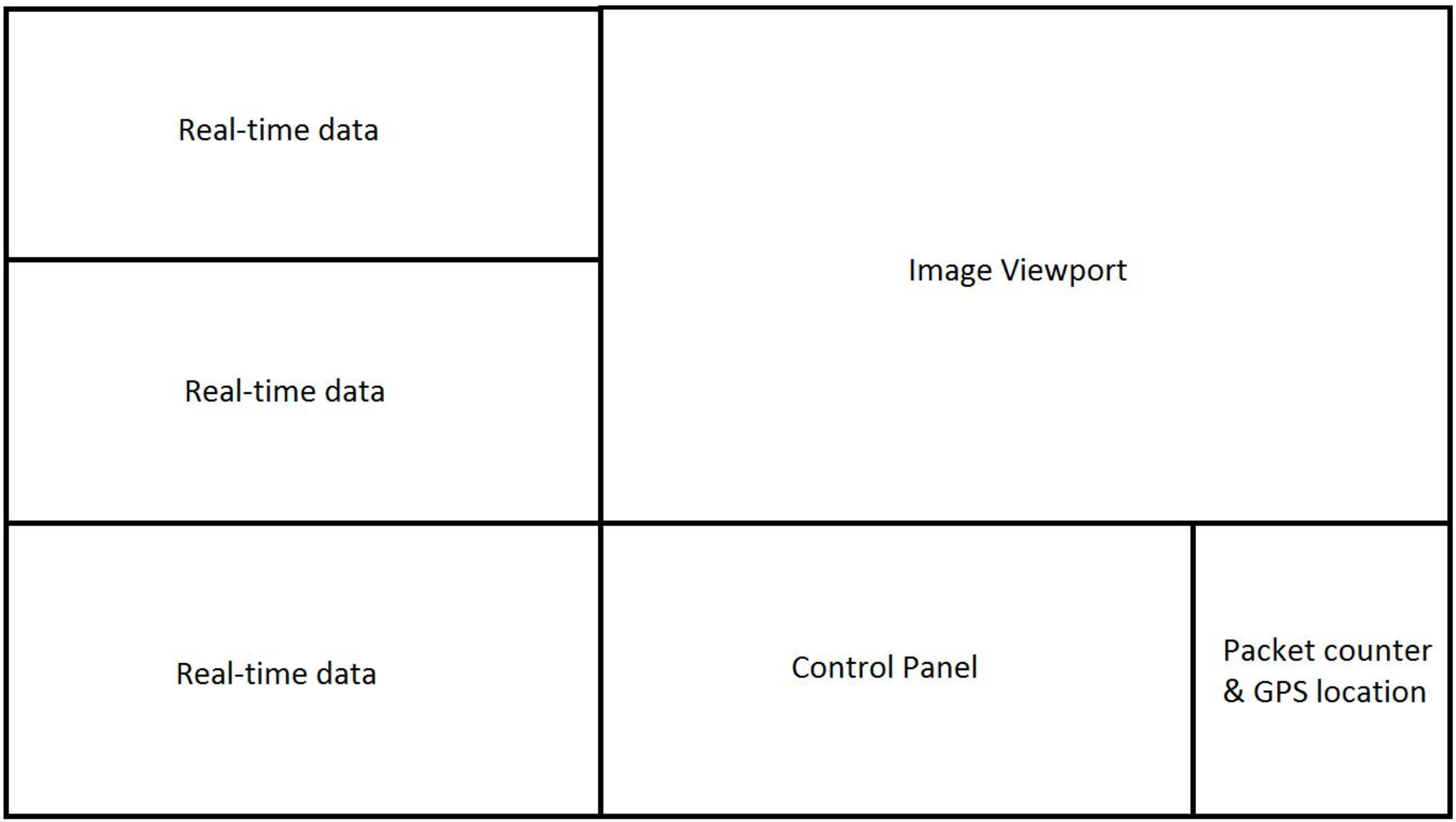
# Ground Station Antenna Trade and Selection

- 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

# 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

# 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.
  - Lander close up and preparation to be loaded on rocket.
  - Add rover protection (Dog Barf onto the rocket)
  - Attach Lander Parachute to Lander
  - Insert Rover in Rocket 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 | | | | | | | | | | | | | | | | | | |

# 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<br>(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 |

# 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 |

# 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 | ~1300 USD |

All Program Budget for Rocket, Payload, Ground Station and Travel expenses will be covered by WPI Student Government Association (Funds from WPI Student Activities fee)

# Summary: Rocket Subsystem

- Rocket has been designed and proved in OpenRocket computer simulations and is ready for construction
- Inventory taken of existing components
- Ordered needed rocket components
- Upcoming:
  - Laser cutting fins & centering rings
  - Testing

# Summary: Ground Station Subsystem

esigned and all the main components
r testing and software implementation

antenna on order
n range

# 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
- 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?”

*“What is engineering without solving problems, and what is Aerospace Engineering without Explosions?”*