# Mars Rover CDR

York Area Rocketry Team

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    - Rover Image Transmission
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- Program Budget
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  - Services
  - Travel expenses
- Summary

# Presentation Outline

| Team Member Name | Section Presenting |
|---|---|
| Adam Winchell | Intro & Rocket Design |
| Zach Ruth | Rocket Design |
| Sarah Staley | System Overview |
| Ryan Shields | System Overview |
| Gabe Berman | Schedule |
| Jakub Becker | Rover Design |
| Michael Geyer | Rover Design |
| Tyler Sengia | Testing & Schedule |
| Hayden Forbush | Budgeting |

# Team Organization

| Team Member Name & Grade | Team Member Role |
|---|---|
| Adam Winchell – 12 | Team Captain |
| Zachary Ruth – 12 | Team Co-Captain |
| Tyler Sengia -12 | Rover Software Developer |
| Michael Geyer -12 | Rover Hardware Developer |
| Ryan Shields -12 | System Developer |
| | |
| Jakub Becker – 11 | Rover Manufacturing |
| Sarah Staley – 11 | Electronics Bay Developer |
| Gabriel Berman -11 | Team Safety Officer |
| Hayden Forbush -9 | Financial Scheduler |

# 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
- UTS – Ultrasonic Sensor
- ICST – Image Capture Storage and Transmission
- TANK – Treaded Automated Navigational Kit

# System Overview

# Mission Summary

Design a rocket and Mars rover to launch to at least 1000 feet and deploy the Mars rover. The Mars rover must be fully contained in the rocket before being deployed. Once deployed, the Mars rover must return to the ground safely. When it lands, the rover will take a picture with a camera. Up to four images will be taken, each image in the forward, left, right, and rear direction. Afterwards, the Mars rover shall release a bright colored marker that can be easily found. The marker must be placed at the point of landing. It cannot be tossed, shot, or projected beyond its landing location. Once released, the rover must then travel 10 feet and release a second marker. The rover then must turn or move 90 degrees in either direction and travel 10 feet. Travel must be completed within ten minutes. Time starts at the time of landing. Method of travel is up to the team.

# System Requirement Summary Rover

- Rover must weigh less than 2 Kg completely within the rocket while working autonomously
- Rover recovery system must be secure and no pyrotechnics are allowed
- 4 pictures will be taken in color at 640x480 or higher
- At landing, the rover must release the recovery system
- Must travel 10 feet or 120 inches then drop a marker
- Travel a minimum of two feet in each segment
- The rover must be able to detect when it has flown and landed
- Travel must be completed within 10 minutes of landing

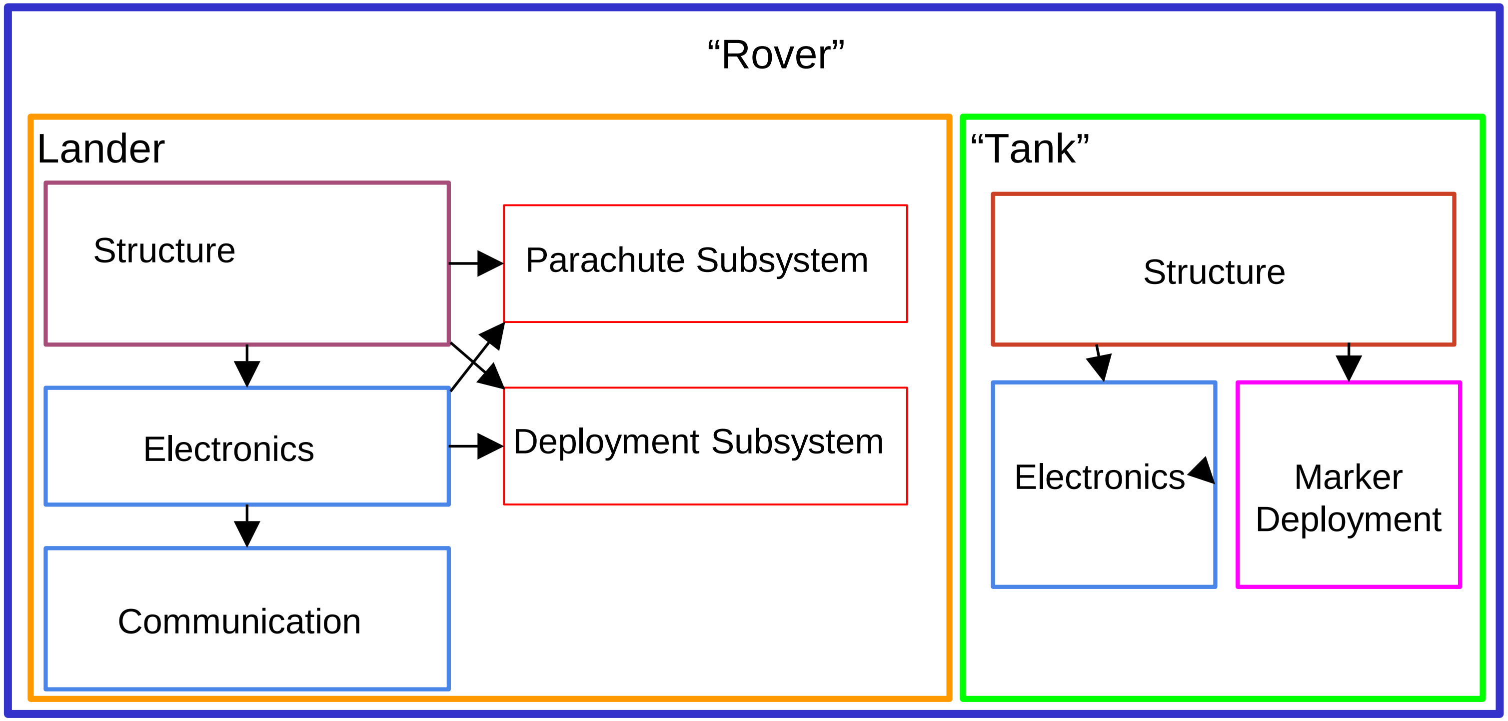
# System Requirement Summary Rocket

- Total installed impulse shall not exceed 2,560 Newton-seconds or a K motor
- All parts of the rocket must safely return under a recovery system
- The airframe, nose cone, fins, bulk plates, and centering rings cannot be made of any types of metal
- The rocket must reach at least 1000 feet
- Must use a commercial altimeter
- Average TWR must be greater than 5:1
- The rocket must use a motor retainer

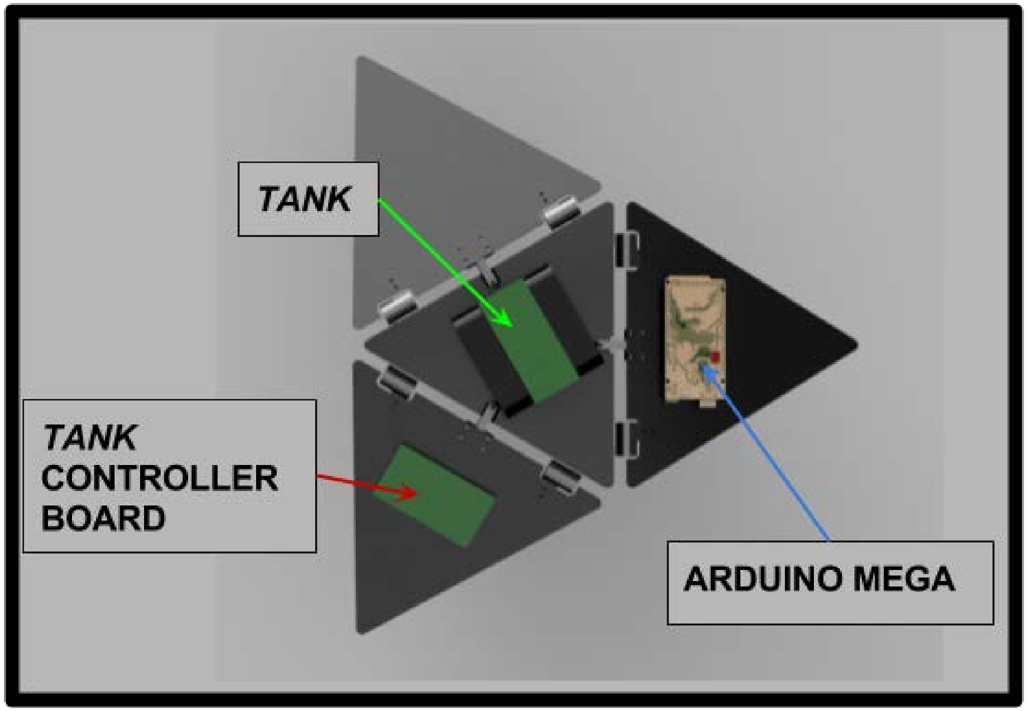
# System Concept of Operations Rover

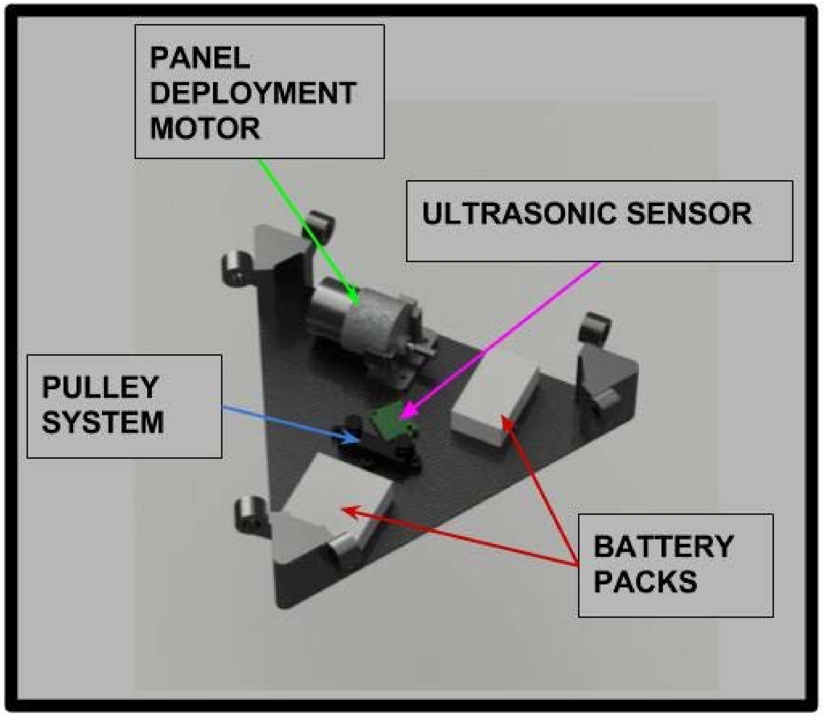
- Provide overview of operations of the system from launch to landing to rover operations.
  - Launch and descent operations
  - Rover Operations
    - Ultrasonic Sensor detects when to release parachute from lander
    - Lander makes contact, arms extend, and lander is righted if landed on side
    - Cameras takes pictures and write them to SD cards
    - Tank protocol begins, and tank drives out of lander
    - Pictures are relayed to ground station
    - Tank stops at 10 ft, moves turret to release marker, turns and continues
  - Post-launch recovery
- Simple flow diagrams and cartoons are a good way to present the CONOPS

# System Level Concept

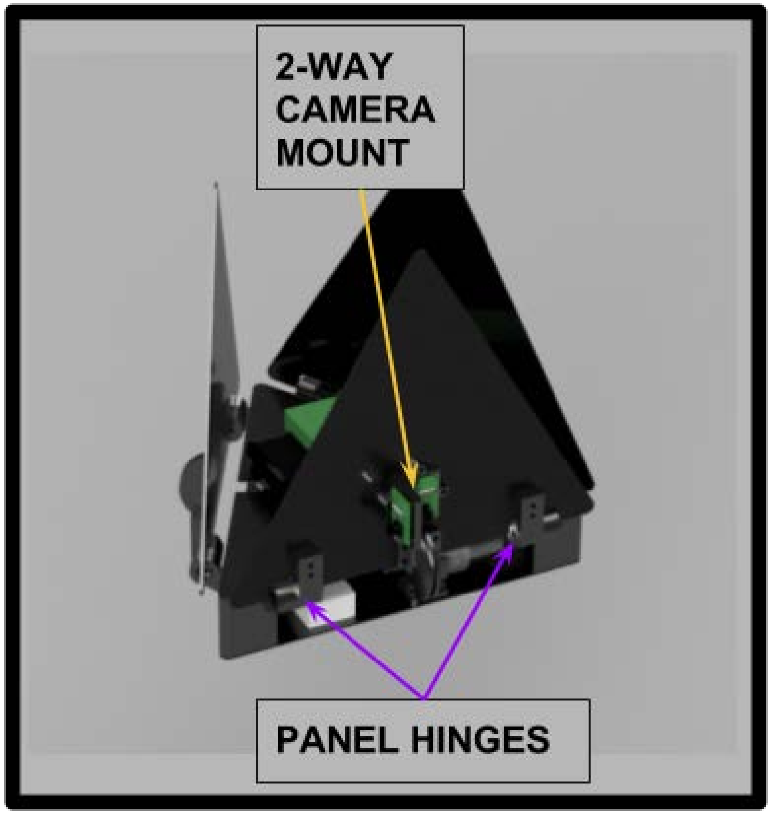


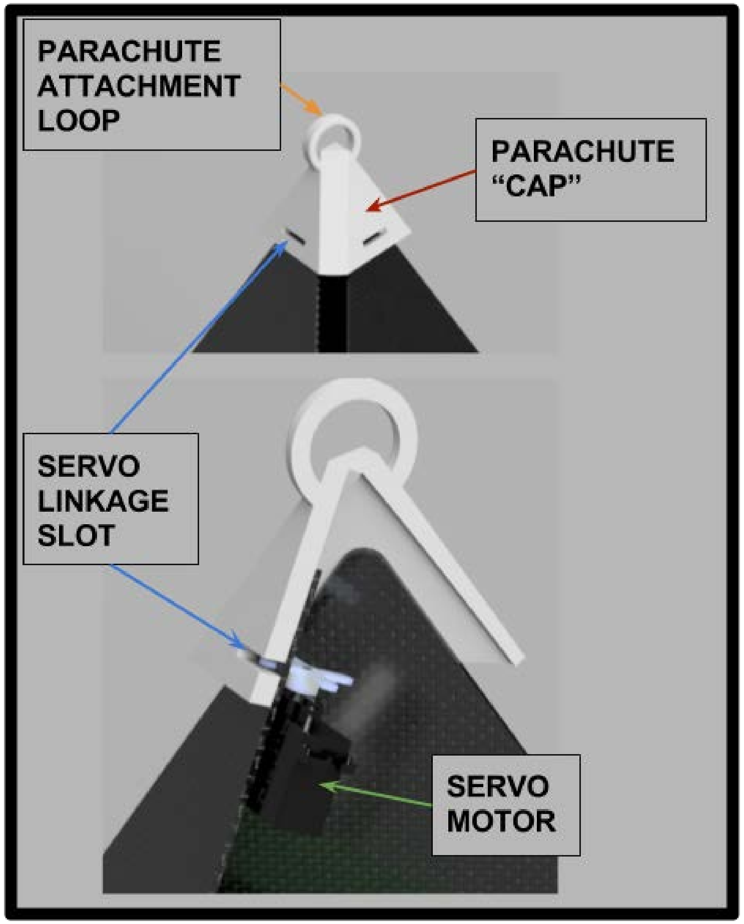
# Physical Layout



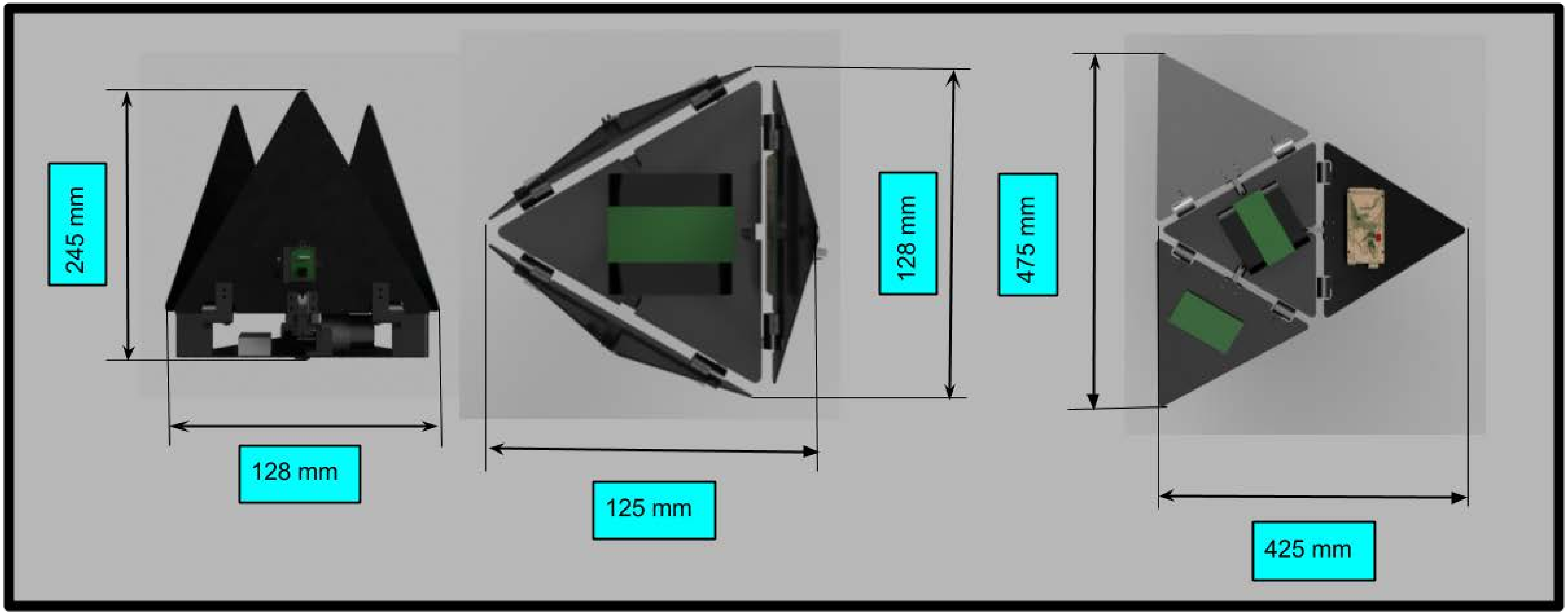



# Physical Layout cont.



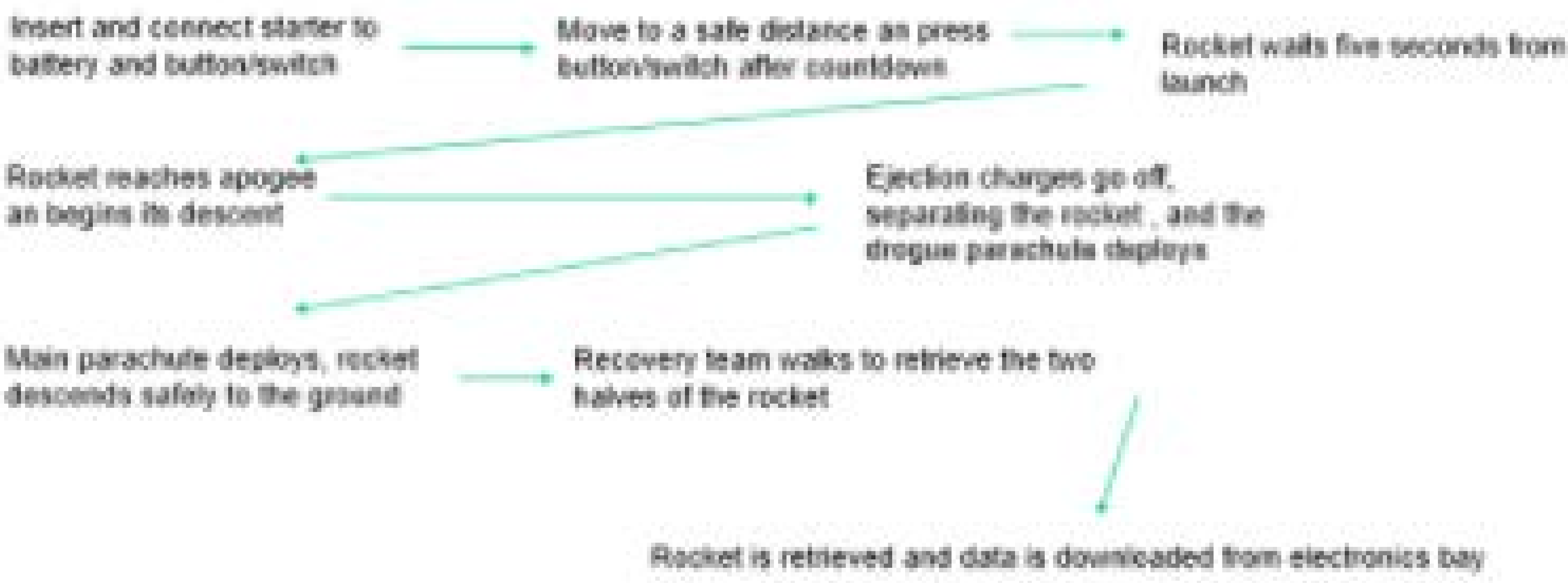



# Physical Layout cont.



# System Concept of Operations Rocket

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

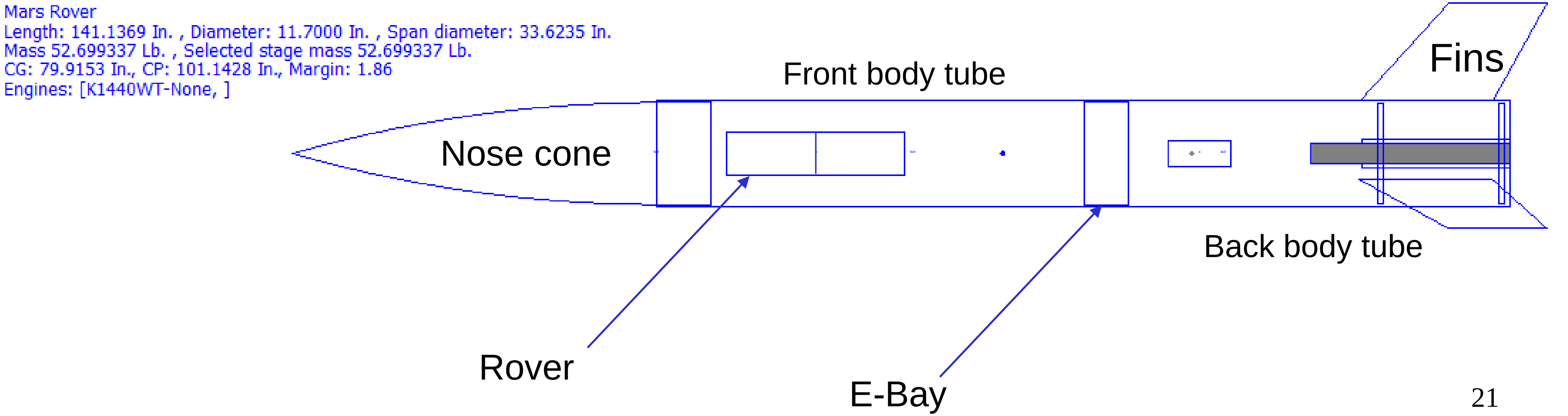


# Post Launch Recovery

- Safety officer and team adviser will go out to retrieve the rocket.
- They will use the tracking receivers in order to locate the rocket sections.
- The electronics will be disarmed using the “Remove Before Flight” keys, and the black powder charges will be checked by the team advisor for any possible dangers.
- The rocket will then be deemed safe to carry, and transport back to base of operations.

# Physical Layout of Rocket

- Diagram of rocket showing major components
  - The rocket will be 141 inches long, and have a 12 inch diameter body tube.
  - The rover will be located in the front half of the body tube, along with the main parachute while the drogue chute will be in the back half of the body tube.
  - The E-Bay will be setting off an ejection charge. This charge will blow off the nosecone, causing it to pull the rover in the sabot out of the front boy tube.



# Physical Layout of Rover

Diagram of rover

- H: 355mm W: 280mm L: 280mm
- Major Components
  - tank - Free from lander, flying during maneuvers
  - tank Controller - Housed in lander, controlled by Arduino
  - Arduino - Housed in Lander, main interface for components
  - Ultrasonic Sensor - Housed in cutout in bottom of lander, senses ground approaching to signal release of parachute
  - Camera - Housed on top of lander
  - Base station - Kept at launch site, used to recover pictures wirelessly

# Rocket Design

# Changes Since PDR - Rocket

- The material used for the body tubes has been changed to phenolic tubing to decrease mass of the rocket and to obtain a TWR of at least 5:1
- Fin design has been changed to move Center of Pressure back, increasing stability and reducing the mass as well.
- The new motor selected is a Cesaroni K1440 White Thunder. This motor will get our redesigned rocket to the target altitude, and it meets the 5:1 TWR requirement

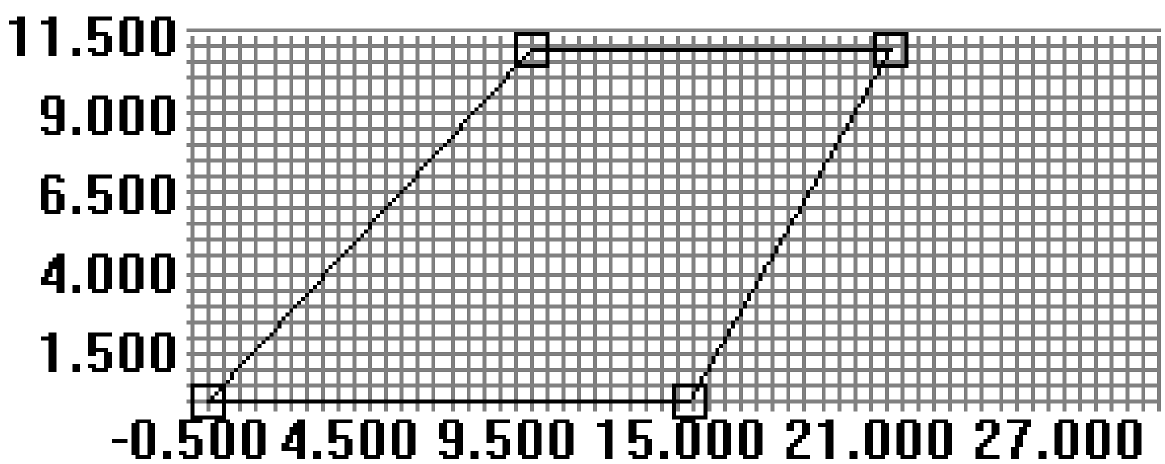
# Changes Since PDR - Rover

- Since the PDR, we opted to switch to a driving tank instead of our flying drone idea. We did this for competition legality and simplicity. We also modified the lander design to a model closer to the Spirit Mars lander. We chose this design because it accommodates our tank more closely.

# Overview of Rocket

- Describe overall rocket design
  - Nose cone connected to front body tube, which is connected to the electronics bay, serving as a tube coupler between the front and back body tubes. Fins are attached to the back body tube, and the motor tube is inserted and mounted inside the back body tube
  - Total Weight – 52.70 lbs.
  - Motor - Cesaroni K1440
  - Diameter – 12”
  - The rocket is built with

    a three-fin-design.
  - 141.13 inches (11 ft. 9 in.)




  - CG is 79.94 inches from the front end and CP is 101.14 inches. This is 21.2 inches apart, and based on the diameter of the rocket, this gives a margin of 1.86.

# Rocket Materials

- Airframe Material - 1/8 inch Phenolic Tubing
- Fin Material - 1/8 inch fiberglass fins
- 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 - Unistrut Rail Buttons
- Active Motor Retention using Aeropack Motor Retainer

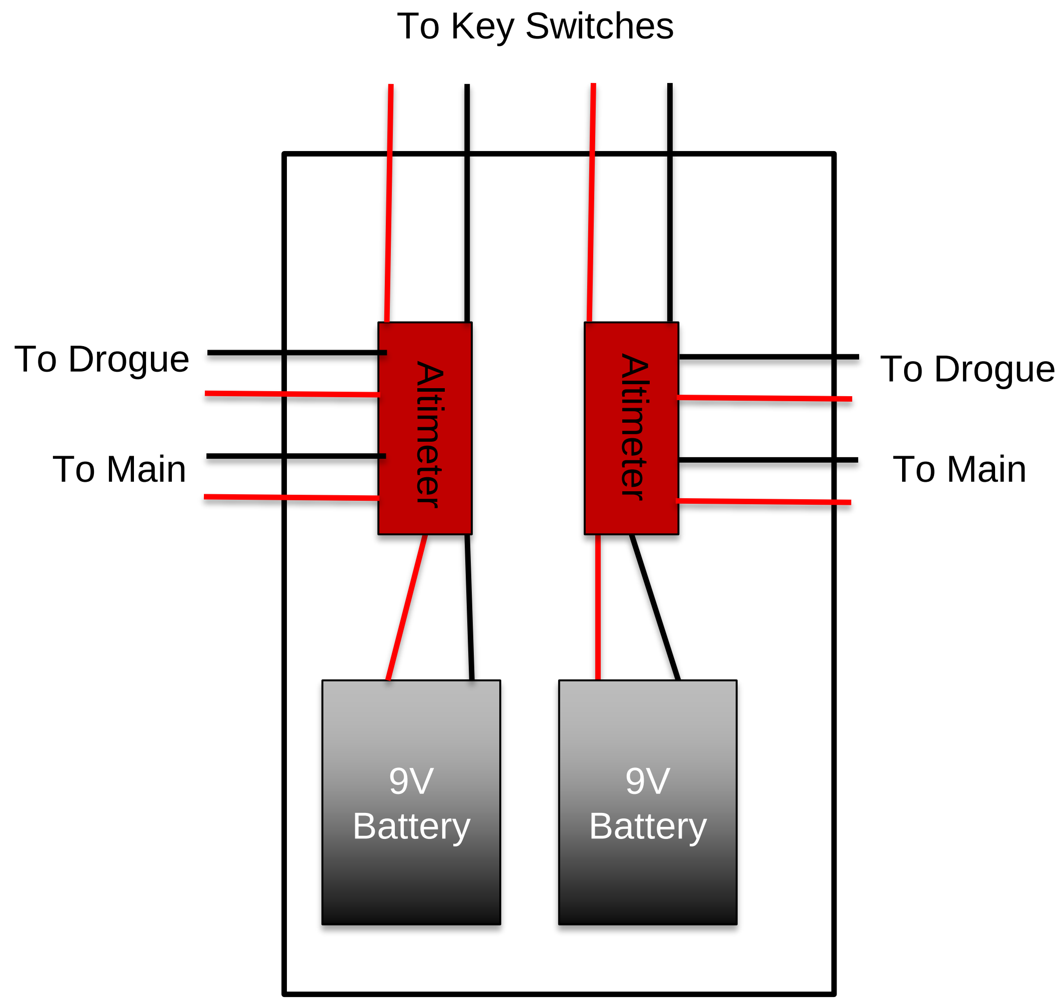
# Rocket Recovery System

- Parachute selection- 10 ft Iris Ultra parachute from Fruity Chutes for main parachute, and 72 inch elliptical for drogue parachute
- Descent Rate Under main- 17.26 ft/s
- Descent Rate Under drogue- 26.16 ft/s
- Harnesses
  - 7/16 inch tubular Kevlar, 25 feet long for front, and 25 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 U-Bolts 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 feet above the ground. It will be  Altimeter-Based Ejections (Primary and Secondary)
  - 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.
- Through online calculation and experience, we will be using 9.6 g of 4F grain size black powder for the front and back half to obtain an ejection pressure of 14 psi. We will testing extensively in ground ejection tests in order to get an exact desired and safe number.

# Wiring diagram of altimeter



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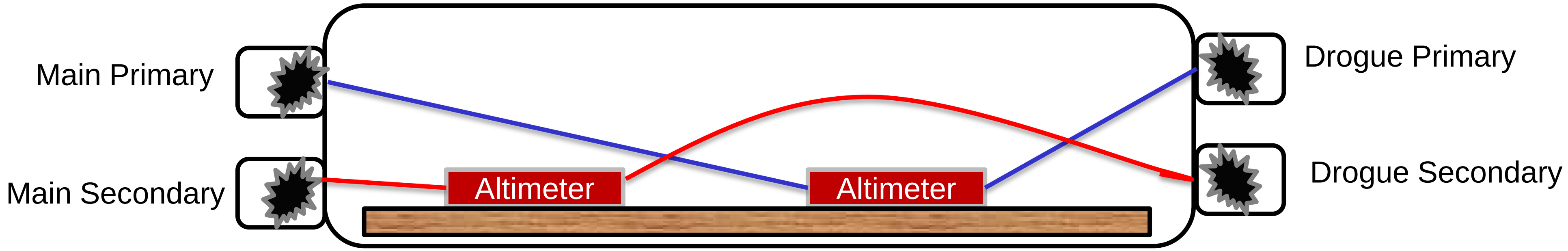


# Rocket Motor Selection

- Primary motor selection – Aerotech K1440 (6.1 : 1 TWR)
- Secondary motor selection – Ceseroni K2000 VMAX (8.5 : 1 TWR)
- RockSim 9 was used for all simulations

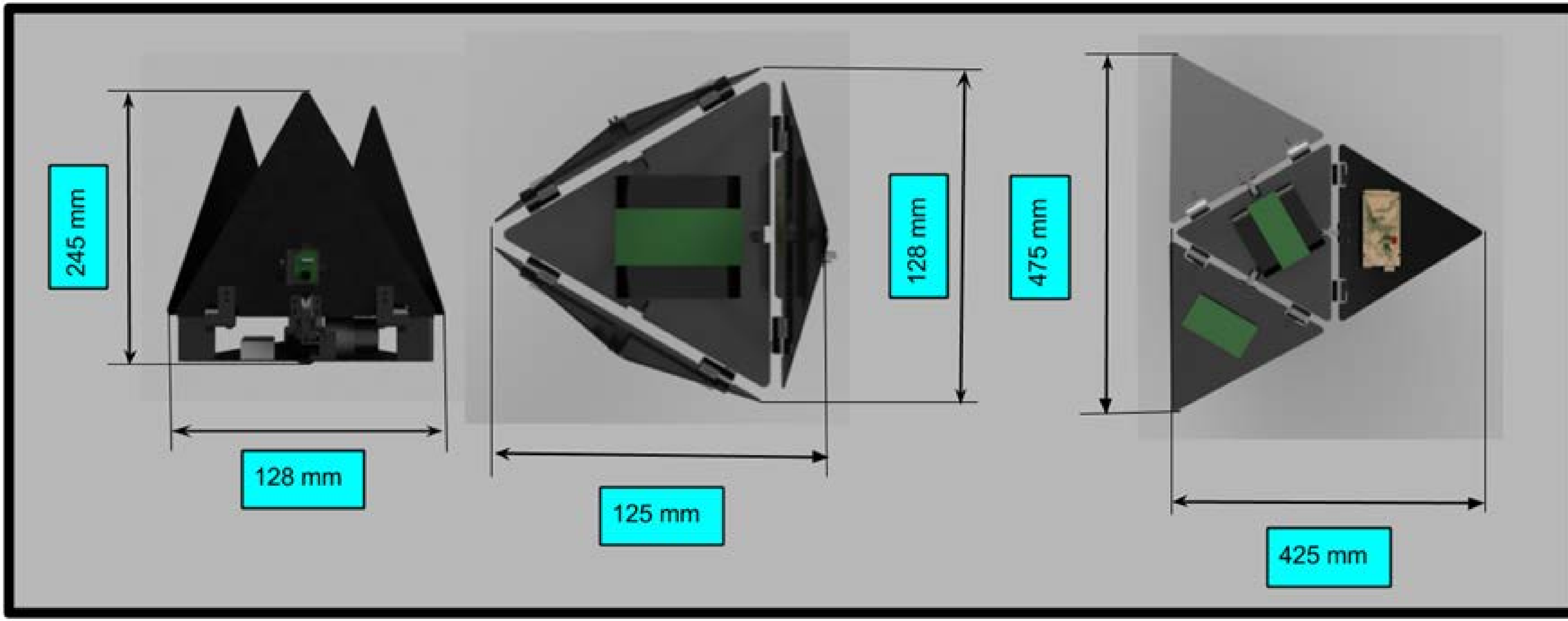
| Engines loaded | Max. altitude Feet | Max. velocity Feet / Sec | Max. acceleration Feet/sec/sec | Time to apogee | Velocity at deploym Feet / Sec | Altitude at deploym Feet |
|---|---|---|---|---|---|---|
| [K1440WT-None] | 1265.36 | 273.53 | 620.48 | 9.36 | 2.80 | 1265.36 |
| [2330-K2000-VM-P-I | 1209.94 | 278.69 | 620.26 | 9.02 | 0.17 | 1209.94 |

# Test Flights

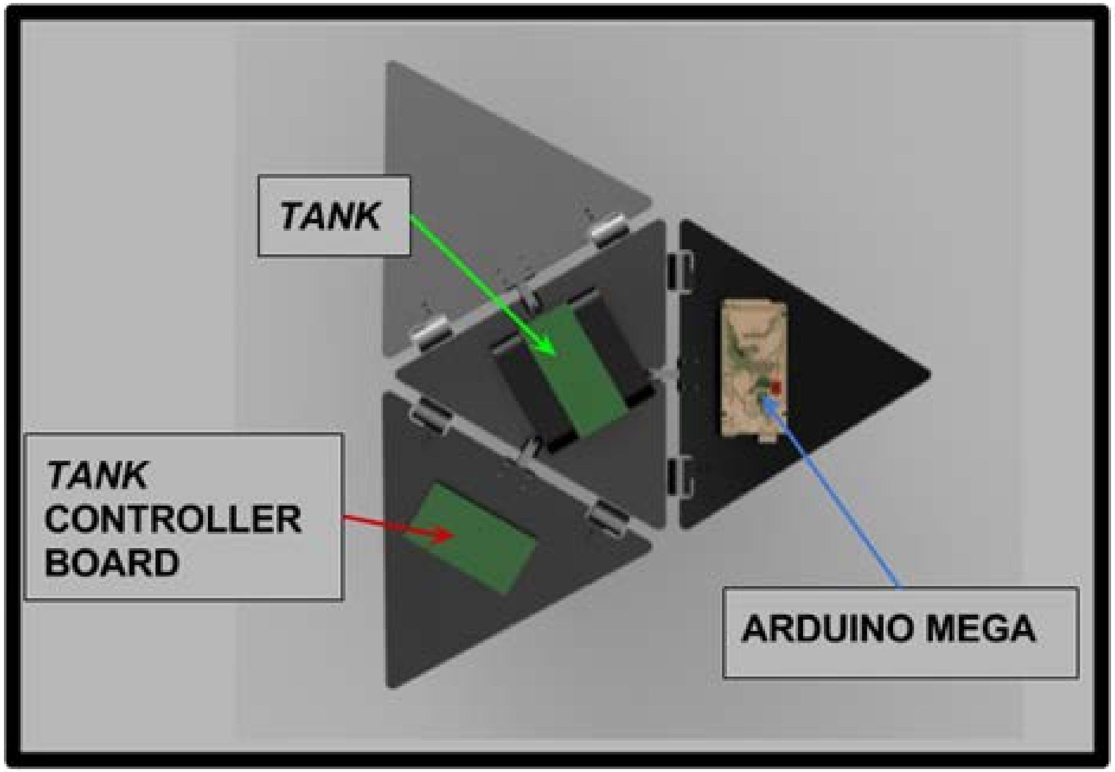
- Show results of any test flights
  - There have been no test flights yet, as our January launch was canceled due to weather. We plan to have a launch on February 17 and 18 and one also in March if needed.

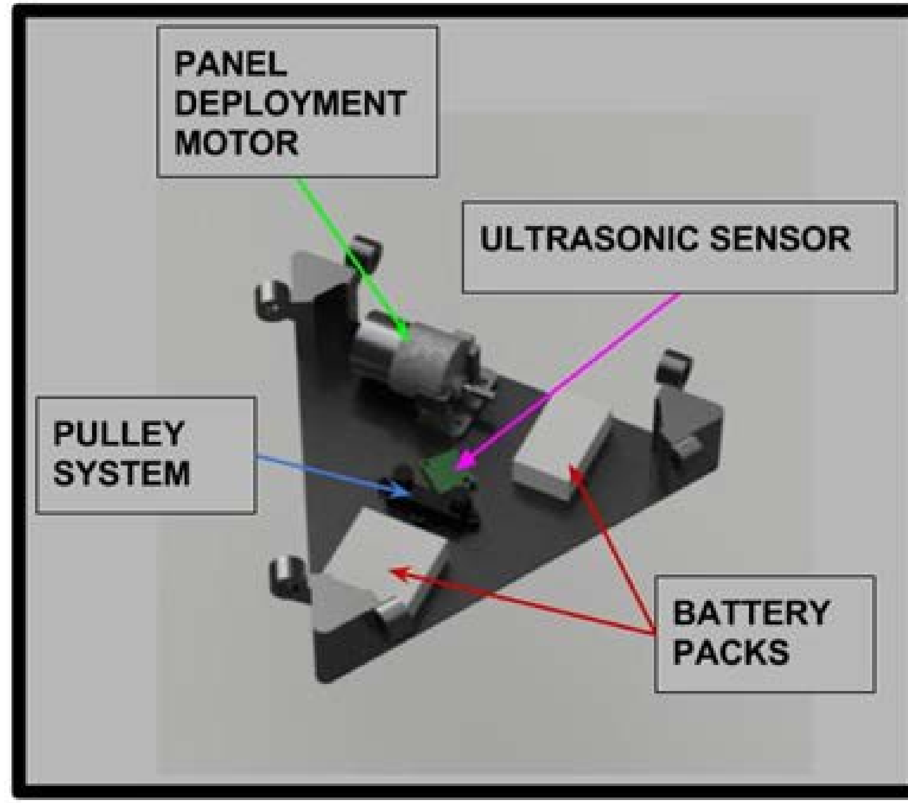
Rover Design

# Rover Design Overview

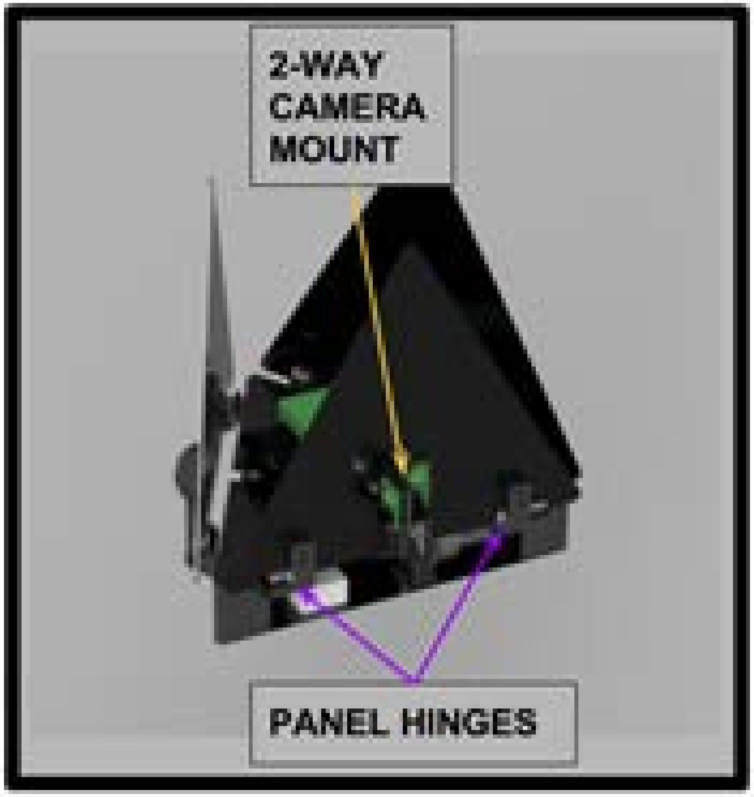


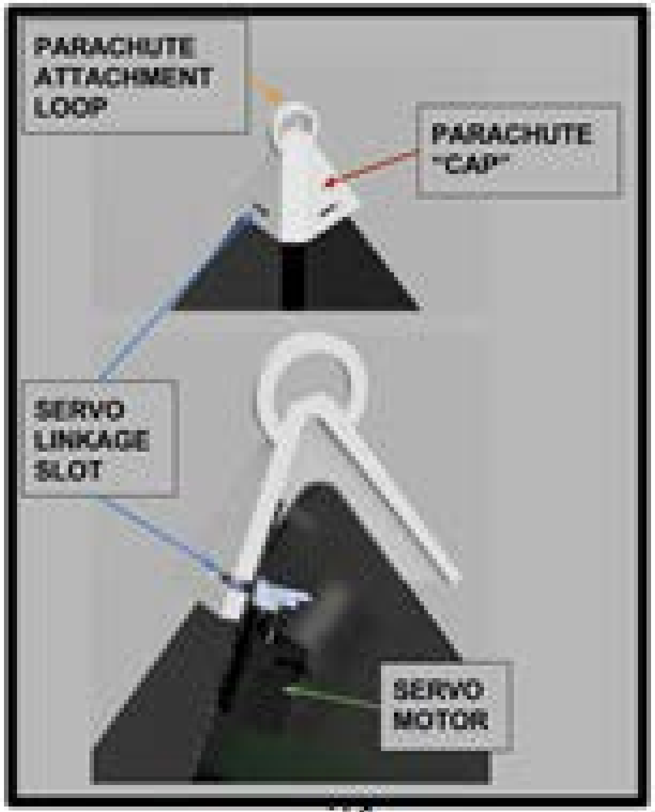
# Rover Design Overview cont.



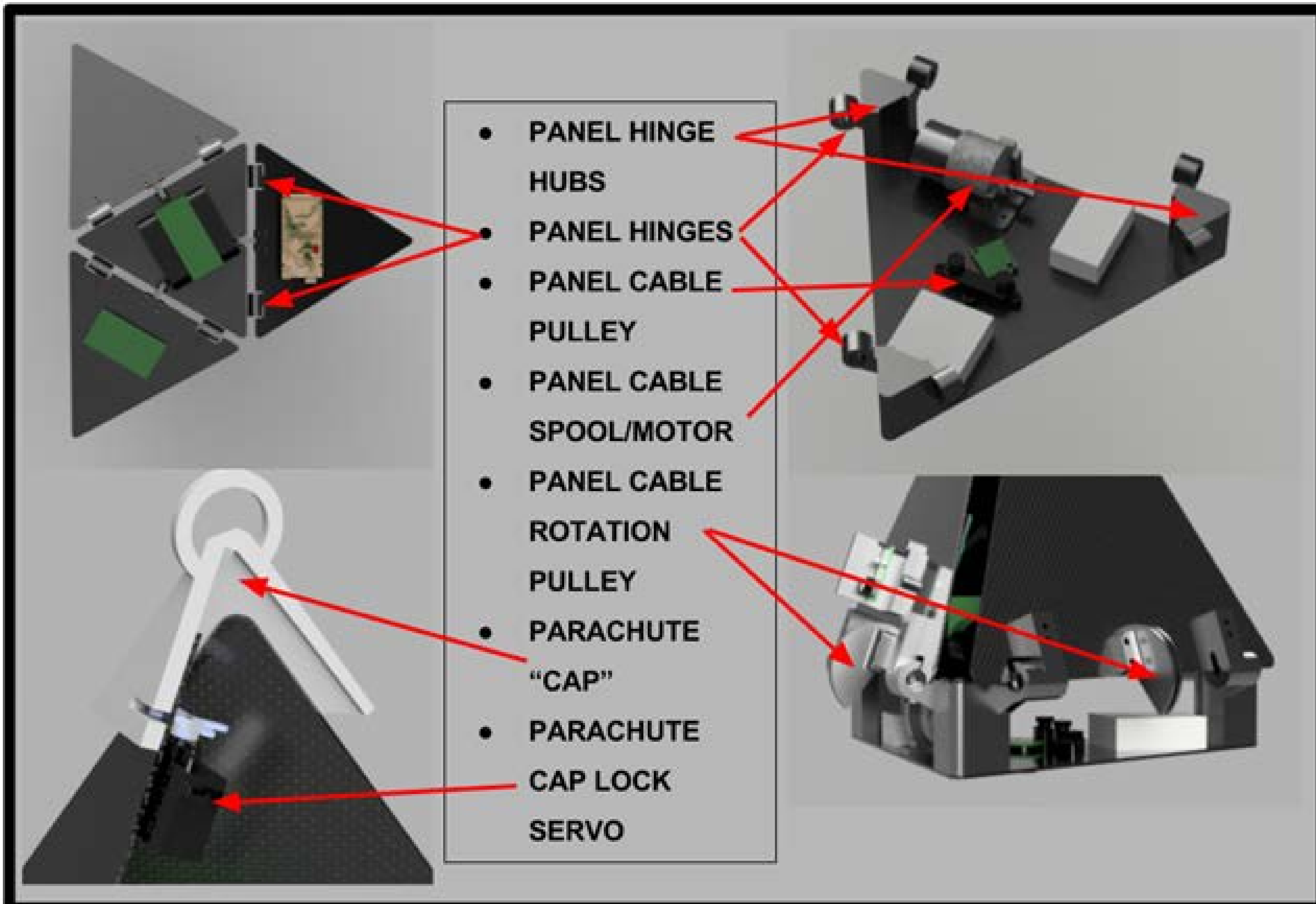
# Rover Design Overview cont.



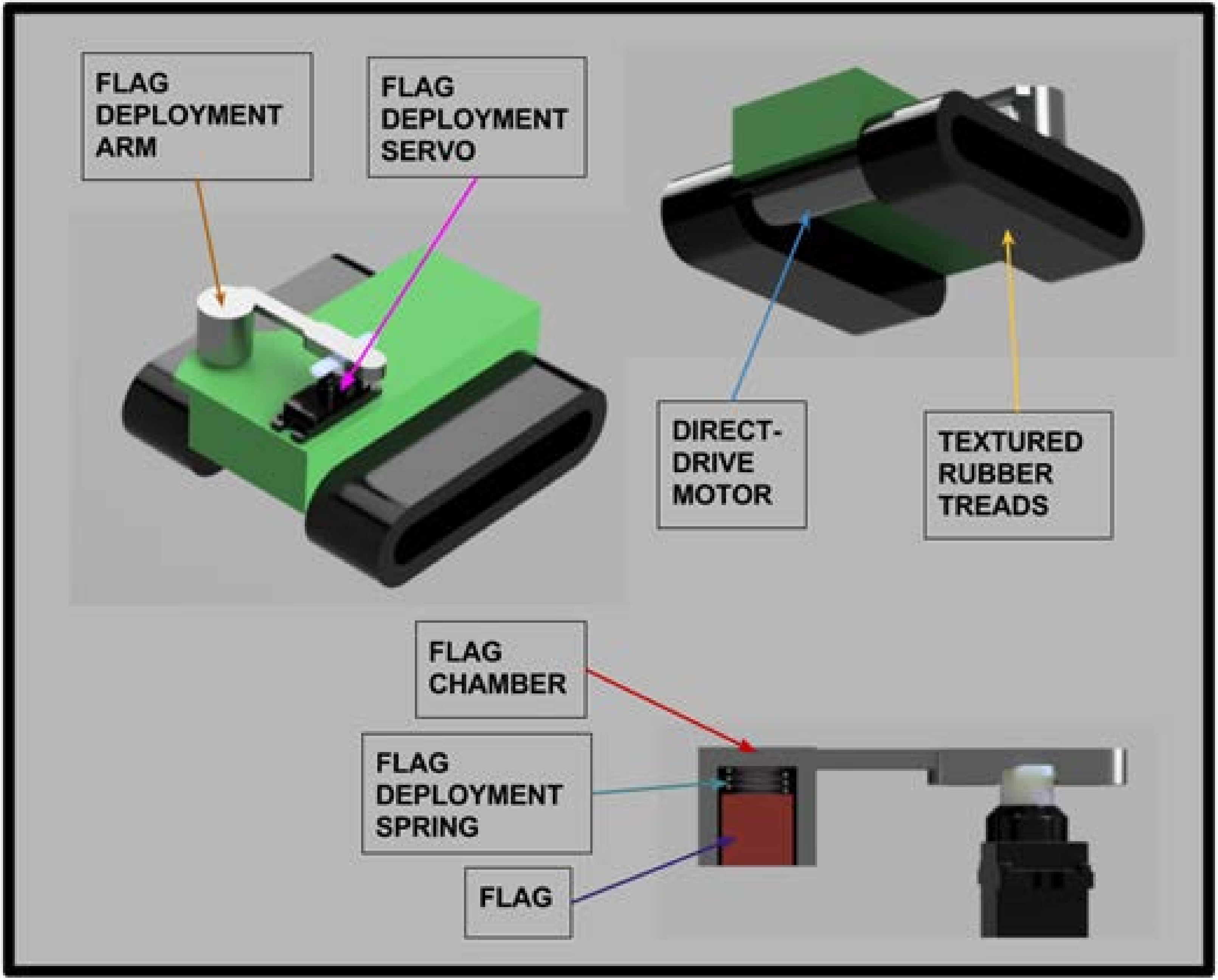



# Mechanical Subsystem

# Mechanical Layout



# Mechanical Layout



# Rover Descent Control

- Descent Control Methods:
  - 50 inch Parachute
    Parachute detached at 10 feet from ground
    Parachute descent rate: 4.9 m/s (16.0 ft/s)
  - Inflatable Drag structure/airbag
    Descent rate: 10.2 m/s (33.5 ft/s)

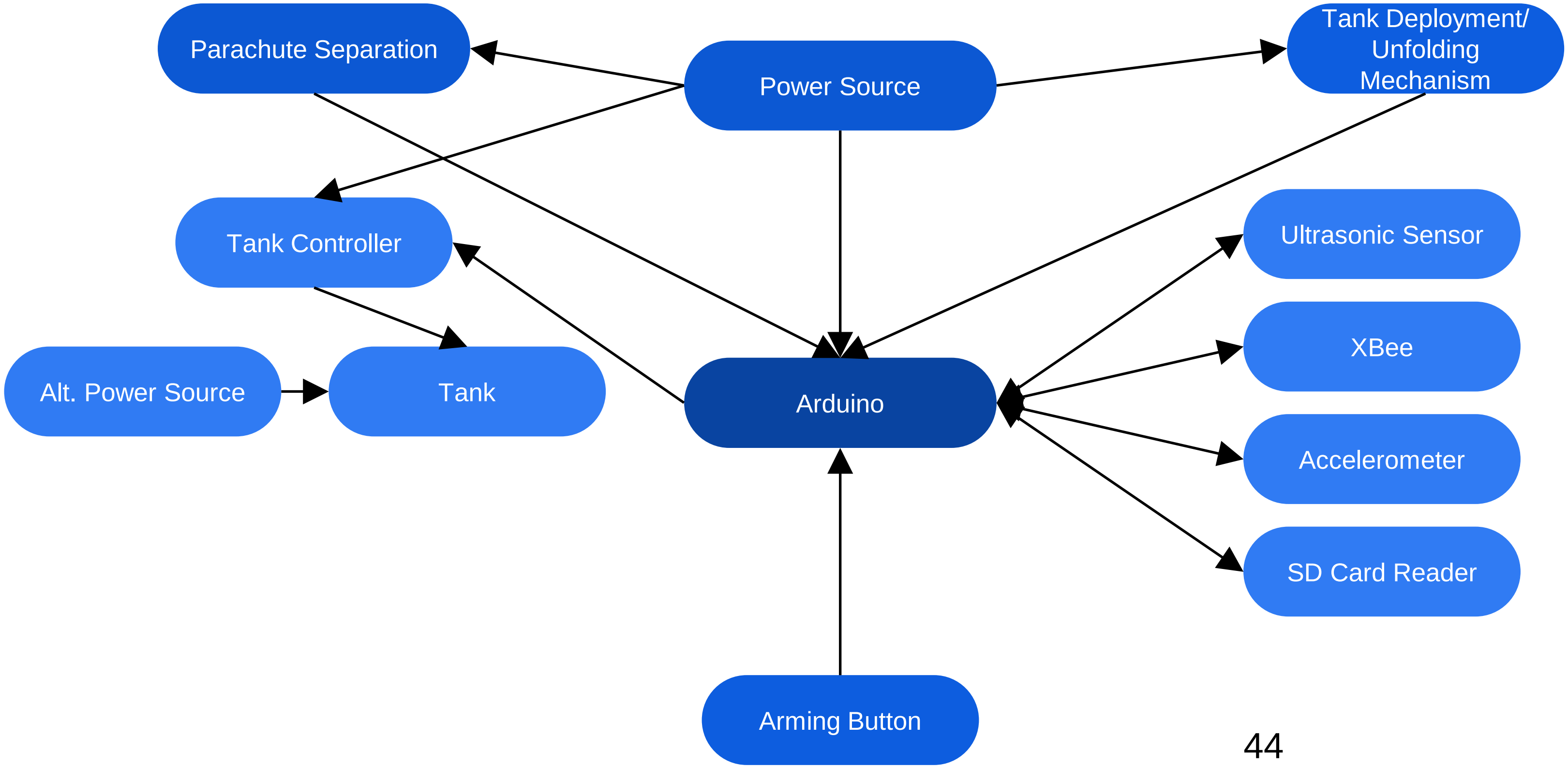
- The parachute was chosen as our descent method for the following:
  - Simplicity
  - Proven results
  - Low descent rate
  - Cost effectiveness

# Rover Mass Budget

| Rover Mass Budget | | | |
|---|---|---|---|
| Component | Mass (g) | total mass (g) | Uncertainty |
| Panels (x5) | 30.9 | 154.5 | 10 |
| Motor | 138.5 | 138.5 | 0.1 |
| 3D printed components | 500 | 500 | 50 |
| Electronics | 290 | 290 | 20 |
| Power Systems | 105 | 105 | 10 |
| TANK | 158 | 158 | 20 |
| TOTALS: | | 1346 | 110.1 |

# Rover Electronics

# Block Diagram

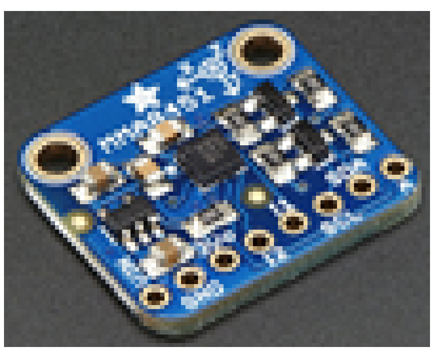


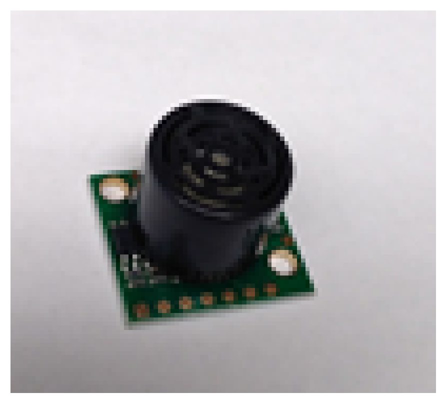
# Rover Electronics

- Electronic block diagram
  - ATMEGA2560 (Arduino), Micro-SD Breakout Board+
  - 256 kB RAM (Arduino)
  - MMA8541 (Accelerometer), PTC06 (Camera), MB1040 (Ultrasonic Sensor)

Sensors Selected For:

- Ease of Use
- Plentiful Documentation
- Accuracy





# Processor and Memory

- Arduino Mega
  - ATmega2560, 256 kB flash, 8 kB SRAM, 4 kB EEPROM
  - Operating Voltage: 5V, Input Voltage: 9V
  - Processor Speed: 16 MHz
  - 54 digital IO pins, 16 analog input pins

# Rover Sensors

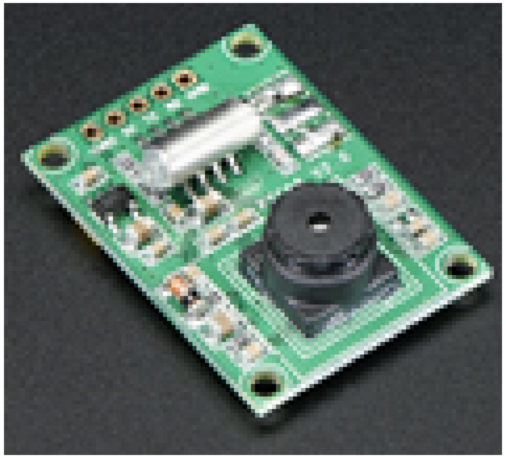
- Identify sensors to be used to determine state of rover
  - Ultrasonic Sensor (MB1040)
    - Range: 15-640cm
    - Working Voltage and Amperage: 5V, 2.0mA
  - Accelerometer (MMA8541)
    - Resolution: 14 bit
    - Working Voltage and Amperage: 1.95V-3.6V, 6μA-165μA
    - 8 pins to Arduino

# Rover Camera

Miniature TTL Serial JPEG Camera with NTSC Video

Selected for ease of use (output in JPEG format) and plentiful examples and documentation

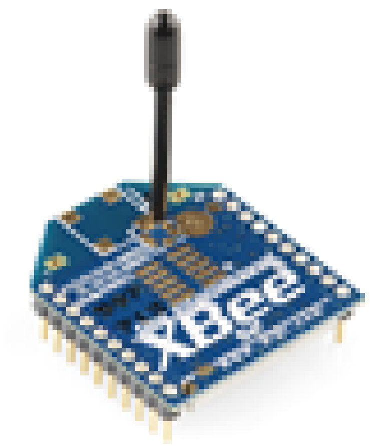
https://www.adafruit.com/product/1386



- Concept currently in use: 4 Cameras mounted in each direction on Lander. Selected for simplicity.
- Alternate concept: 1 Camera mounted on motor, rotates and takes picture in each direction

# Rover Image Transmission

- XBee XB24-Z7WIT-004 "ZigBee" for Lander and Ground Station
  - https://www.adafruit.com/product/968
  - 2mW output
  - Mesh network topology
  - 400ft (120m) range
  - Range Tested
    - Works on line of sight, short range
    - Will need more powerful model



# Image Transmission Trade (cont.)

- 2.4GHz XBee XBP24-AWI-001 "ZigBee" for Lander and Ground Station
  - https://www.sparkfun.com/products/8742
  - 60mW output
  - Mesh network topology
  - 1 mile (1500m) range
  - Has the higher transmission output needed
    - This is the Transmission/Radio model selected for the project

# Rover Power

- Lander
  - 5 NiMH AA Batteries (7.5V), total of 1,200 to 1,900 mAh
  - Mechanical Box Encasement
  - Rechargeable, sufficient power, cost effective
  - Protection circuits
    - Arduino - Reverse Polarity Detection/Short Circuit Protection
- Tank
  - 2 NiMH AA Batteries

# Lander Power Distribution

- Lander Electrical Power System Design
  - Arduino Built-in 5 Volt, 1 Amp Regulator (NCP1117ST50T3G)
  - Jumper cables for distribution to sensors

# Software

# Lander Software Design

**Software States:**

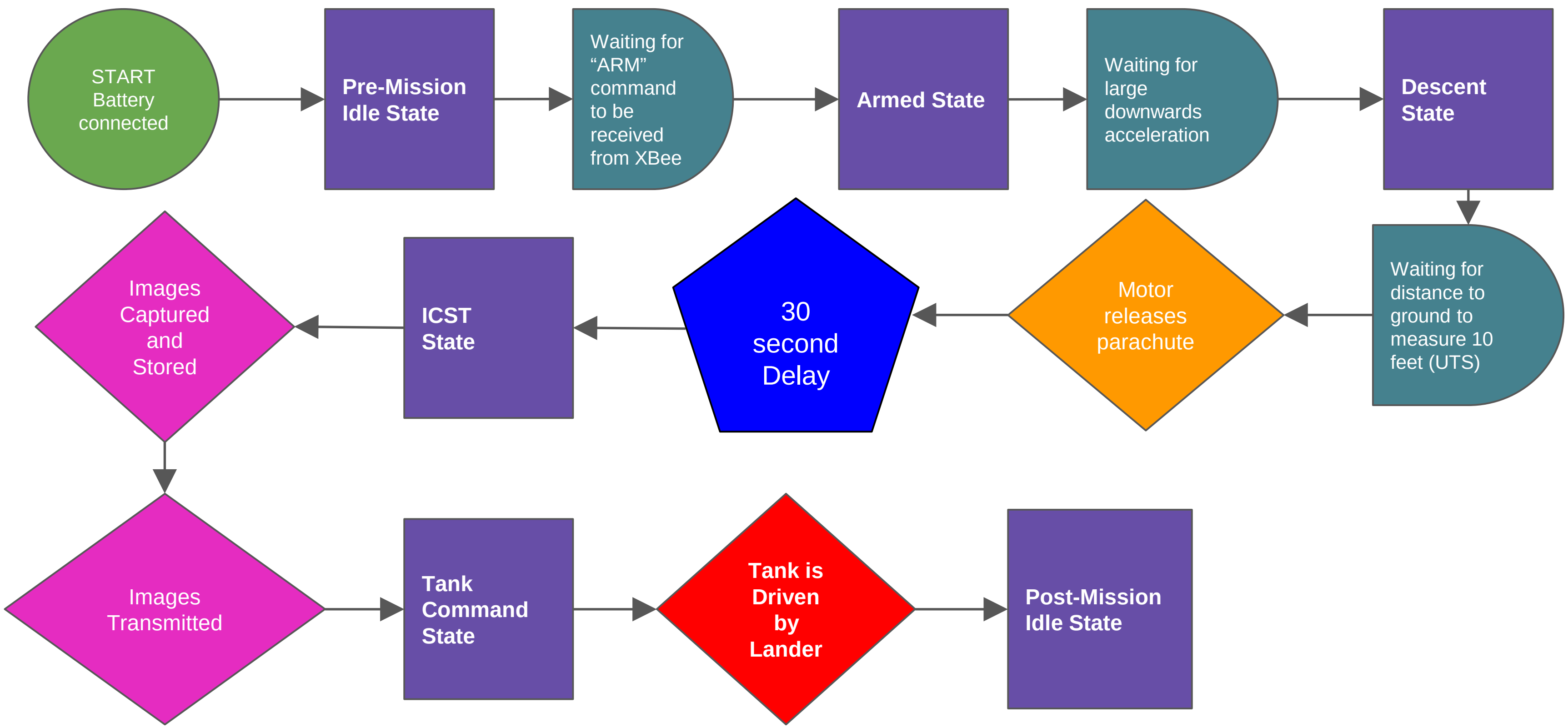
1. Pre-Mission Idle
2. Armed
3. Descent
4. ICST
5. Tank Command
6. Post-Mission Idle

# Telemetry

- Telemetry from the Lander will be 4 images in each direction
- Each image is in a JPEG format with a resolution of 600 x 480 pixels.
- Transmission
  - Picture taken from each camera and stored, Arduino MEGA will read the length of the image file.
  - Send a command to the Ground Station in the following format: "IMG<LENGTH>|"
    The pipe "|" is the command delimiter
    <LENGTH> is the length of the image file in bytes
  - Read the picture file on the microSD card and send each byte through a serial connection (baudrate of 9600) to the XBee.
  - The XBee will then transmit the byte to the Ground Station XBee
  - Ground Station XBee receives the byte and sends it through the serial connection to the UNO, passes through to the Laptop. The Python program reads the byte and writes it directly to a file. This repeats until all bytes of the file have been sent

  - The "ZigBee" protocol is being used, which is based off of IEEE 802.15.4
    Transmission rate is capped at 250kbits/second
    Operates in 2.4 GHz band, uses Offset Quadrature Phase Shift Keying (OQPSK)

# Software Flow Chart



# Software Development Plan

**Software Development Plan**

The purpose of this system is to control the arming of the Lander, release of the parachute from the Lander, the sensing of impact with ground, the capture, storage, and transmission of 4 images, and the deployment and navigation of the Tank.

- This software applies to the Arduino MEGA 256 that is on the Lander.
- Software is used in tandem with the 2018 York Area Mars Rover Team Ground Station Program which sends the arming signal and processes the images.

# Software Development Plan (cont)

**Overview of Required Work**

- Compiled software must fit within the FLASH program memory of the Arduino MEGA 256, which is 248 KiloBytes
- Serial port communication can only on one port at a time (no concurrent writing and/or listening to serial ports)
- Must be able to communicate with four PTC06 serial cameras, an ultrasonic sensor, MMA8541 accelerometer, a microSD breakout board using SPI, a servo motor to release the parachute and control the Tank by varying the voltage levels on the Tank's controller circuit.

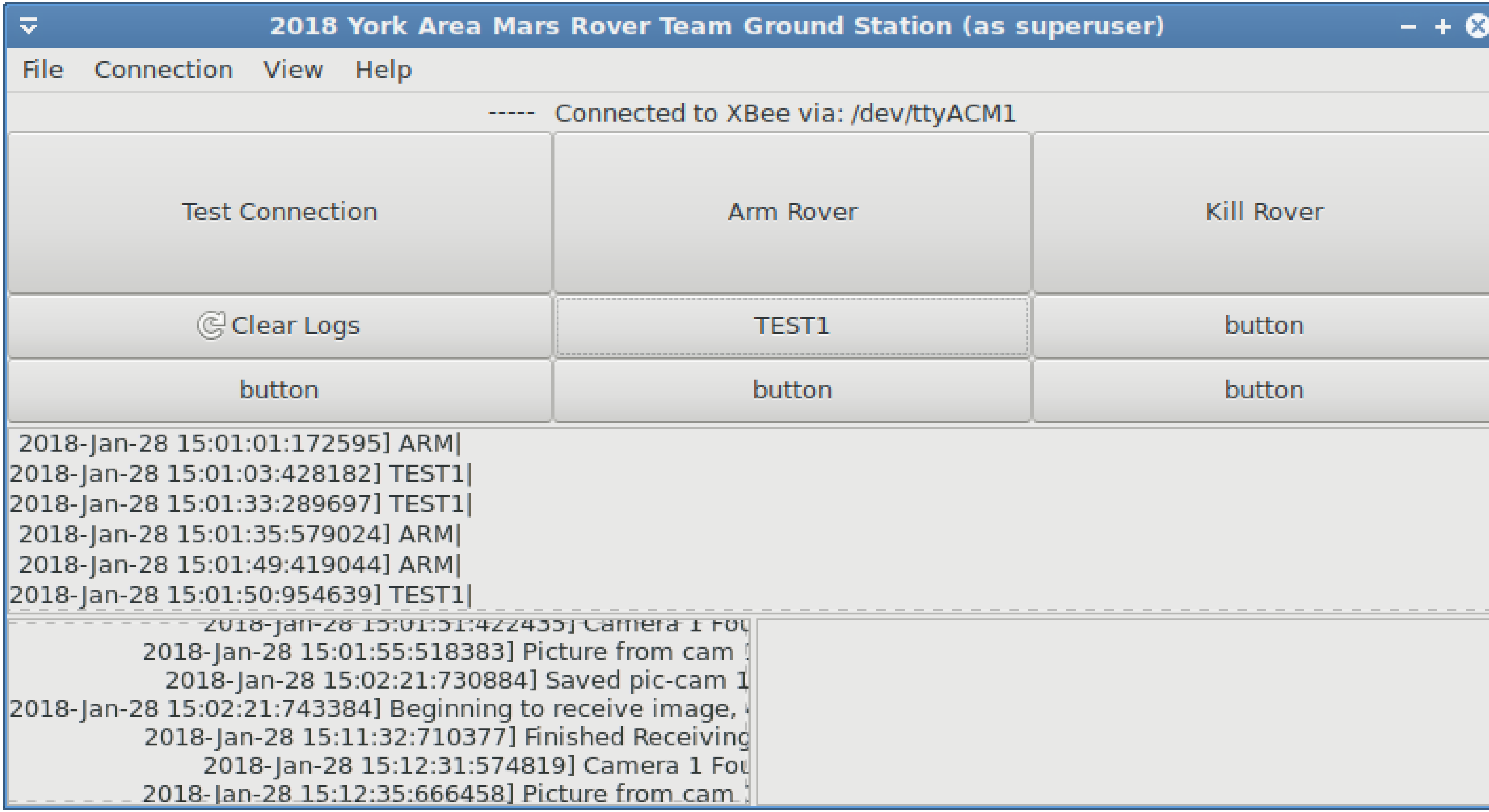
**Completion of Tasks**

- Capture, storage, and transmission of Images, completed December 12th
- Ground Station GUI and command sending, completed December 21st
- Tank navigation and parachute release still uncompleted

# Rover Payload Integration

- Foam Sabot
- Describe process of payload integration
  - Rover is turned on, in the Software “Pre-Mission Idle” State, and placed in the sabot which is then placed in the rocket.

# Software Development Plan (cont.)



# Software Development Plan (cont)

**Ground Station GUI**

Python 3.5 program

Utilizes: PySerial, GTK3

GUI designed using Glade

Communicates over serial to the XBee, which then transmits to the Rover XBee

Saves Images received from Rover

Keeps logs of outgoing and incoming data

Can send commands

ARM - Sets the Rover's software state to the "Armed" State

KILL - Legacy command for previous tank concept (remote kill switch)

Test Commands

"TEST1" - Test of ICST

Test Connection - Sends out "pings" to the Rover and waits for replies. Test connection quality.

# Testing

# Rover Testing

- **Subsystem Testing**
- ●Image capture and saving to SD card
- ●Serial communication over Lander XBee to Ground Station XBee
- **Integration Testing**
- ●Pre-launch Test Program to check sensors and electronics
- **Functional Testing**
- ●Programmed Tank Paths
    - ○The Tank path programs are adjusted from test to test to find the best travel path
- ●Test flight will be done to test if Launch, Descent, and Landing accelerations are recognized/detected
- ●Test flight to test if proximity to ground is detected accurately

# Rocket Testing

- Ejection charge test on December 17
  - One of the bulk heads was damaged on the electronics bay, our design had to be altered
- Dec 19 through Jan 16 – Ebay was strengthened by adding two plywood rings and wooden joists separating them. The bulkheads rest and seal against the wooden ring.
- Flight test planned for January 13 and 14, cancelled due to weather
- Jan 26 – Ejection charges were tested by attaching the rocket to a zipline.  Videos to follow.
- Next flight test planned for February 17 and 18

# Ejection Charge Test (Drogue)

# Ejection Charge Test (Main)

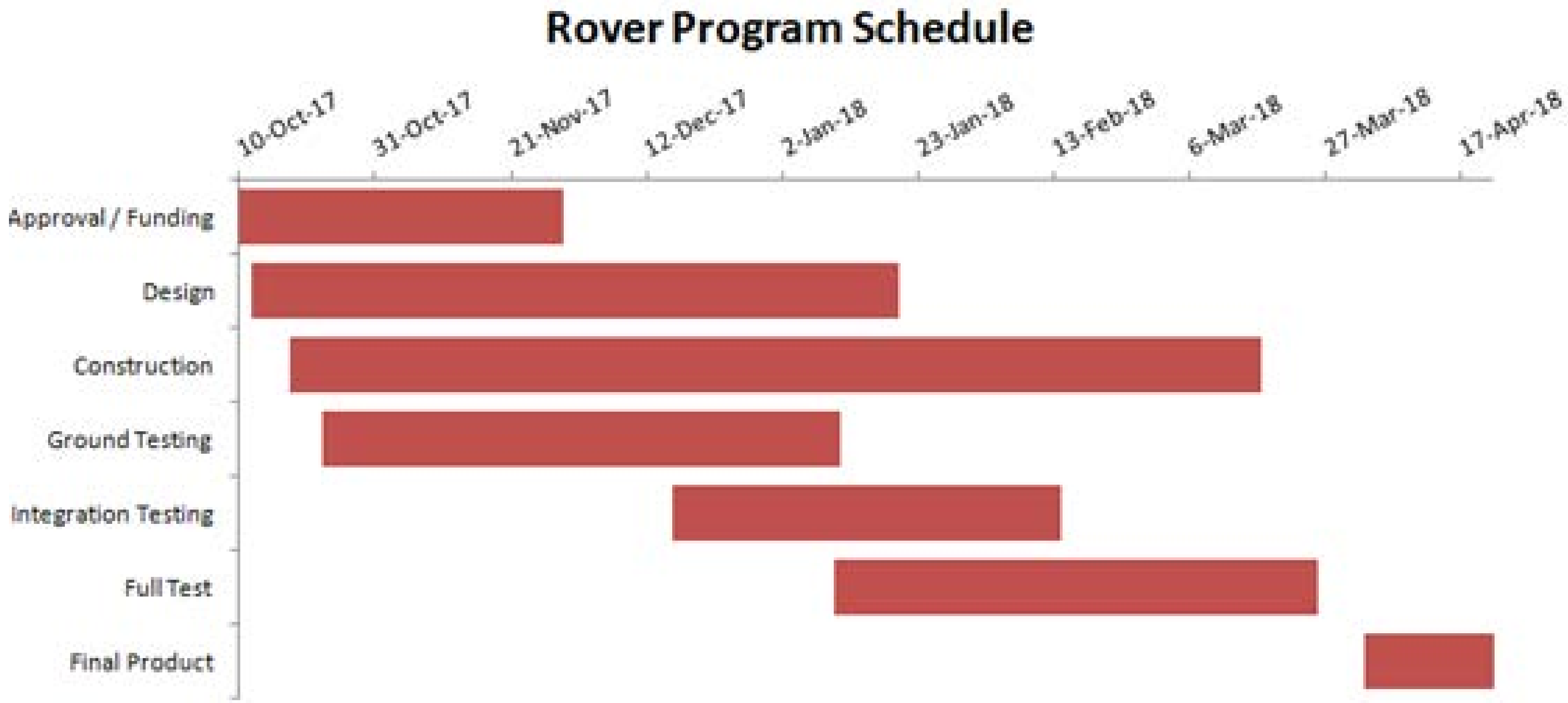
# Flight Operations

- The rocket will have new batteries in the E-Bay before every launch, and before the launch, all altimeters will be tested.
- Freshly charged batteries are put in tank and Lander
  - Test Program is uploaded to Lander to check sensors/connections
- The rover will be incorporated into the rocket by being inside a sabot
- At the launch pad, the key switches will be turned and arm the electronics bay.
- After Rover is placed in payload section:
  - Arming Button is pressed and prep cycle commences

# Rocket Program Schedule

| Start Date | Finish Date | Activities |
|---|---|---|
| | | |
| October 8 | October 11 | Registration for BOR |
| October 20 | | Order places for parachutes |
| October 22 | | Order placed for rocket components |
| October 24 | November 28 | Designing rocket |
| October 30 | | Order placed for k-1000 motors |
| November 20 | December 1 | PDR completed |
| November 17 | | Rocket components recieved |
| November 28 | December 8 | Construction of Rocket Body |
| December 4 | | building session on Rocket, Finns cut and attached |
| December 8 | | Presentation of PDR |
| December 11 | | Parachute recieved |
| December 11 | | build session on rocket, E-bay built and attached |
| December 13 | | Phenolic body tubes ordered |
| December 17 | | Ejection charges tested |
| December 20 | | Phenolic body tubes recieved |
| December 20 | January 16 | redesign of rocket |
| December 28 | | Build session, additions made to finns on first rocket, E-bay reinforced |
| January 12 | | CDR work started |
| January 13 | January 14 | Launch cancelled due to weather |
| January 13 | | Extended build session, second rocket constructed |
| January 16 | | Build session, motor casing and through the wall finns completed |
| January 23 | | CDR meeting |
| January 25 | | CDR completed |
| January 26 | February 1 | Final CDR editing and presentation practice |
| January 28 | | test improved E-Bay with ejection charges |
| January 30 | | CDR practice meeting |
| February 1 | | CDR submitted |

# Payload Program Schedule



# Rocket Program Schedule

| | | |
|---|---|---|
| February 6 | | Build session, second rocket made flight ready |
| February 9 | | Presentation of CDR |
| February 13 | | Build session, measurements taken of rocket to check that it has correct weight and CP |
| February 13 | | present rocket and Spring Grove High School rocketry program to Indian Rock Elementary |
| February 17 | February 18 | Test Launch second rocket, integrate test rover |
| February 27 | | Build session, repair rockets and trouble shoot any noted issues from launch |
| March 6 | | Build session, test integration of Rover into Rocket's compartment |
| March 14 | | Build session, prepare Rocket and Rover for full systems test |
| March 17 | March 18 | Full systems integration test with Rover team |
| March 20 | | Build session, make repairs and trouble shoot any noted issues from launch |
| March 27 | | Build session, begin final measurements and preparation of Rocket |
| April 3 | | Build session, finalize measurements and preparation of Rocket |
| April 10 | | Team meeting, discuss strategy and team roles |
| April 14 | April 15 | Attend Battle of the Rockets |

# Service and Component Schedule

- The rockets components were all received on November 17 2017
- K-1000 motors were ordered on October 30th, and arrived January 5$^{th}$
- K-1440 motors were ordered January 16 and arrived January 24
- Parachutes were ordered October 20th, and arrived December 11$^{th}$
- Phenolic Body tubes were ordered from Public Missiles limited on December 13$^{th}$ and received them December 20$^{th}$
- The body tubes were precut by the company at about the time it was ordered.

# Program Budget

## Components

| Components | Cost |
|---|---|
| Preglassed Phenolic Airframe Tubing | $710.97 |
| Couplers for Bulkhead | $12.09 |
| Centering Rings | $37.77 |
| Coupled Bulkhead Assembly | $57.79 |
| 24" long coupler tube | $0.00 |
| Fiberglass nose cone | $235.99 |
| 24" section of coupler tubing | $40.00 |
| Perfect flight Stratologger CF altimeter (2) | $100.00 |
| 75mm Aeropak motor retainer | $44.00 |
| Phenolic 11.4" Diameter Body Tube (2) | $210.00 |
| CTI Cesaroni K 1440 Motor Casing | $44.00 |
| Shipping and Handling | $50.00 |
| Total | $1,542.61 |

# Program Budget

## Services

| Service | Cost |
|---|---|
| Custom Ariframe cutting and slotting (2) | $41.00 |
| Total | $41.00 |

# Program Budget

## Travel expenses

| Travel Expences | Cost |
| --- | --- |
| Hotel Costs | $2,970 |
| Food Costs | $4,732 |
| Vehicle Expense | $1,343.65 |
| total | $9,046 |

## Grand Total

| | |
| --- | --- |
| Grand Total | $10,629.26 |

# Program budget cont.

| Budget Category | Amount | Source |
|---|---|---|
| ~~Components~~ | ~~$1000~~ | ~~YCAL Innovation Grant~~ |
| Components | $500 | Engineering Society of York |
| Travel and Components | $1000 | Dover Eagle Foundation |

# Payload Summary

●Development moves very fast, every day new ideas arise and changes/additions are made to the design. Some key accomplishments were successfully transmitting images and successful sensor testing. Some issues we ran into were the legality of our “rover”, material requirements, sensor accuracy, and lander layout. The electronics system is in the process of being constructed into its final form, and the lander and rover designs are beginning to be constructed.

# Rocket Summary

- Now we are reconstructing the rocket and so far redesigning the rocket has gone well. It's design so the rocket is lighter, fixing the issue with the CG and the CP. We fixed this issue by enlarging the fins so the CP is behind the CG by at least by a caliber. we are almost complete with making the rocket lighter to fix the 5:1 TWR. Thus far the only tests that have been completed on the rocket is an ejection test that was successful but the first flight is scheduled to happen on our pending February launch.