Critical Design Review Presentation

Vertical Projectile - AIAA OC Section 2017-2018
January 29, 2018

Mission Statement

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The rocket must transport its payload safely to a target altitude of exactly 5280 ft, deploy its drogue chute at apogee, descend to 700 ft, deploy its main chute, and then deploy the payload at or below 400 ft, per the RSO’s approval. The payload and rocket must land within 2500 ft of the launchpad.

Vehicle

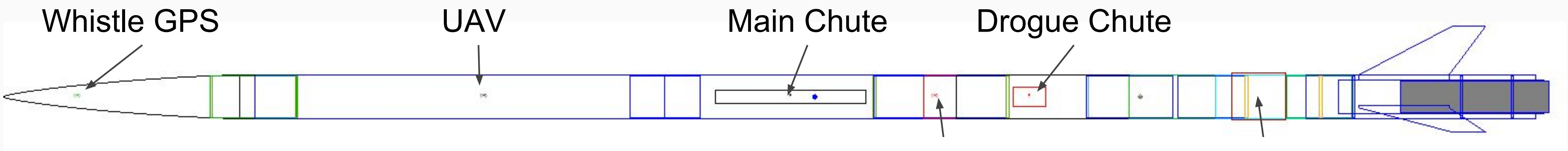
Vehicle - Design

- Length - 142.75 in
- Diameter - 4 in
- Semi Span of Fins - 3.25 in
- Liftoff Mass - 25.4
- Motor Choice - Cesaroni K661

Vehicle - Design

- Center of Gravity: 74.5915 in (from nose cone)
- Center of Pressure: 105.3845 in (from nose cone)

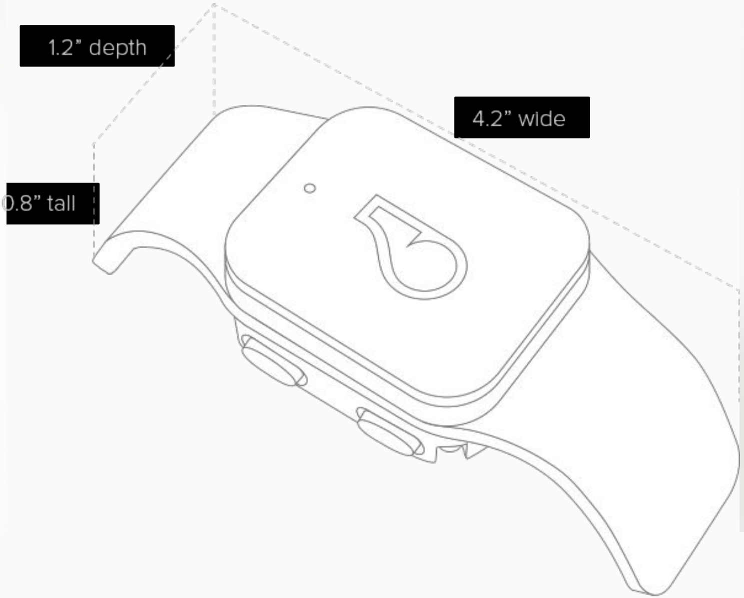
Vehicle


Whistle GPS
UAV
Main Chute
Drogue Chute
Avionics
Air Brakes


1
2
3
4

Vehicle - Subsystems

Vehicle - GPS Tracking Subsystem

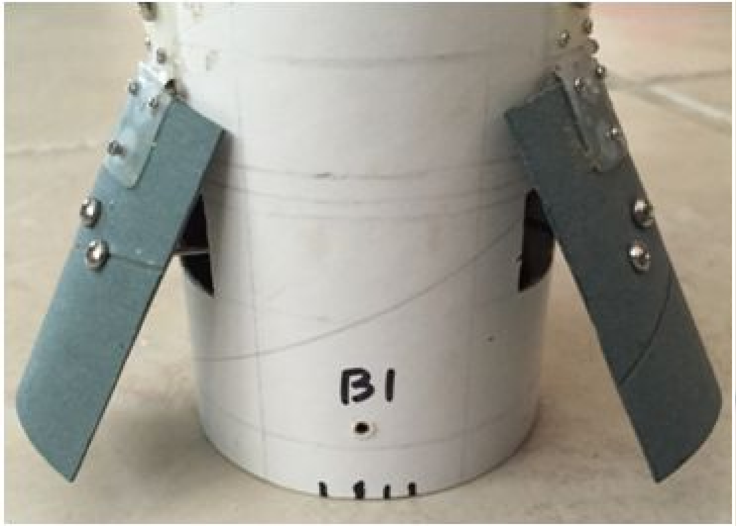


Frequency: 800 or 1900 gHz

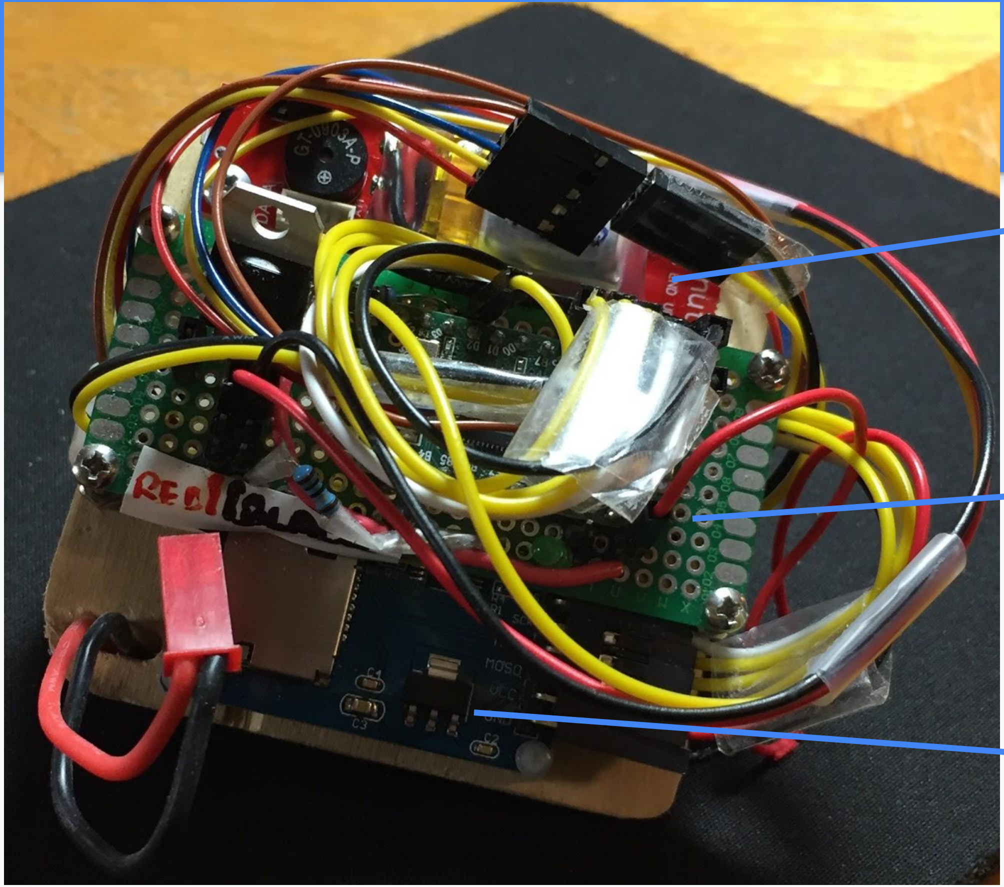
GPS for Payload

- Parallax GPS in the rocket
- Mobilinkd and BaoFeng and APRSdroid system on the ground

Vehicle - Airbrake Subsystem



Key Design Features of Air Brakes

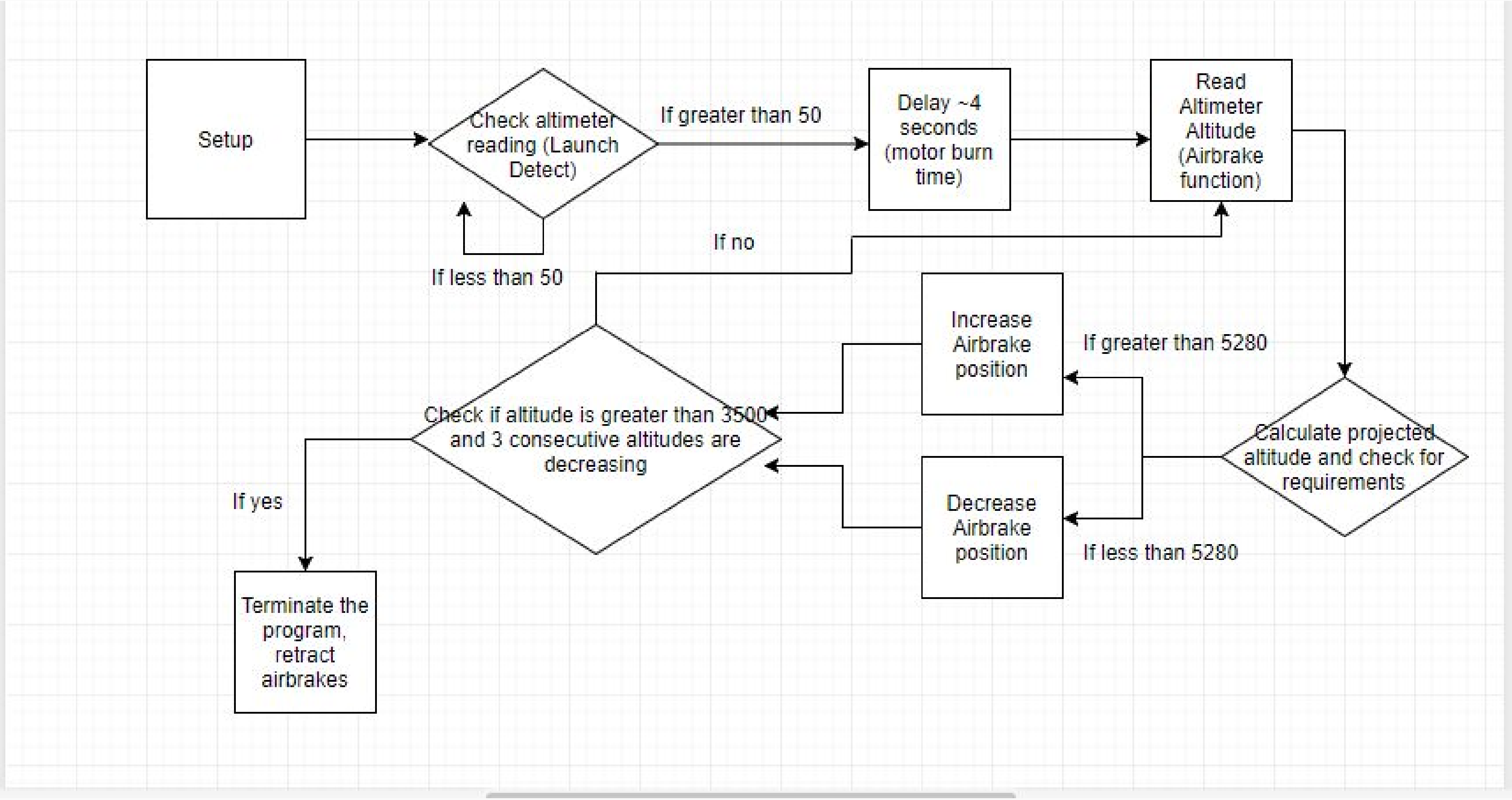


Pnut altimeter

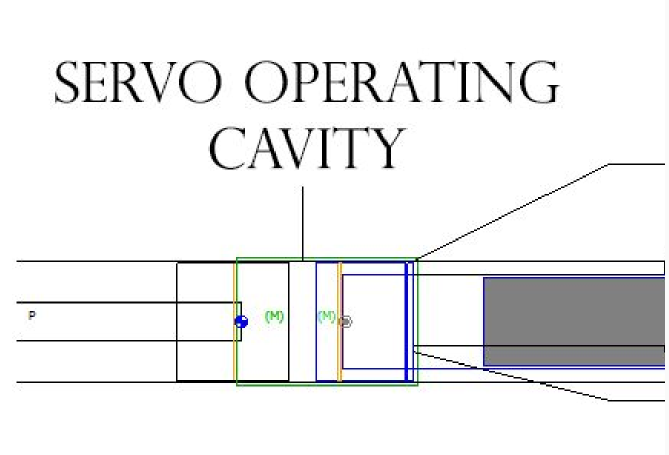
Teensy

SD Card Reader

Airbrake Algorithm Flowchart



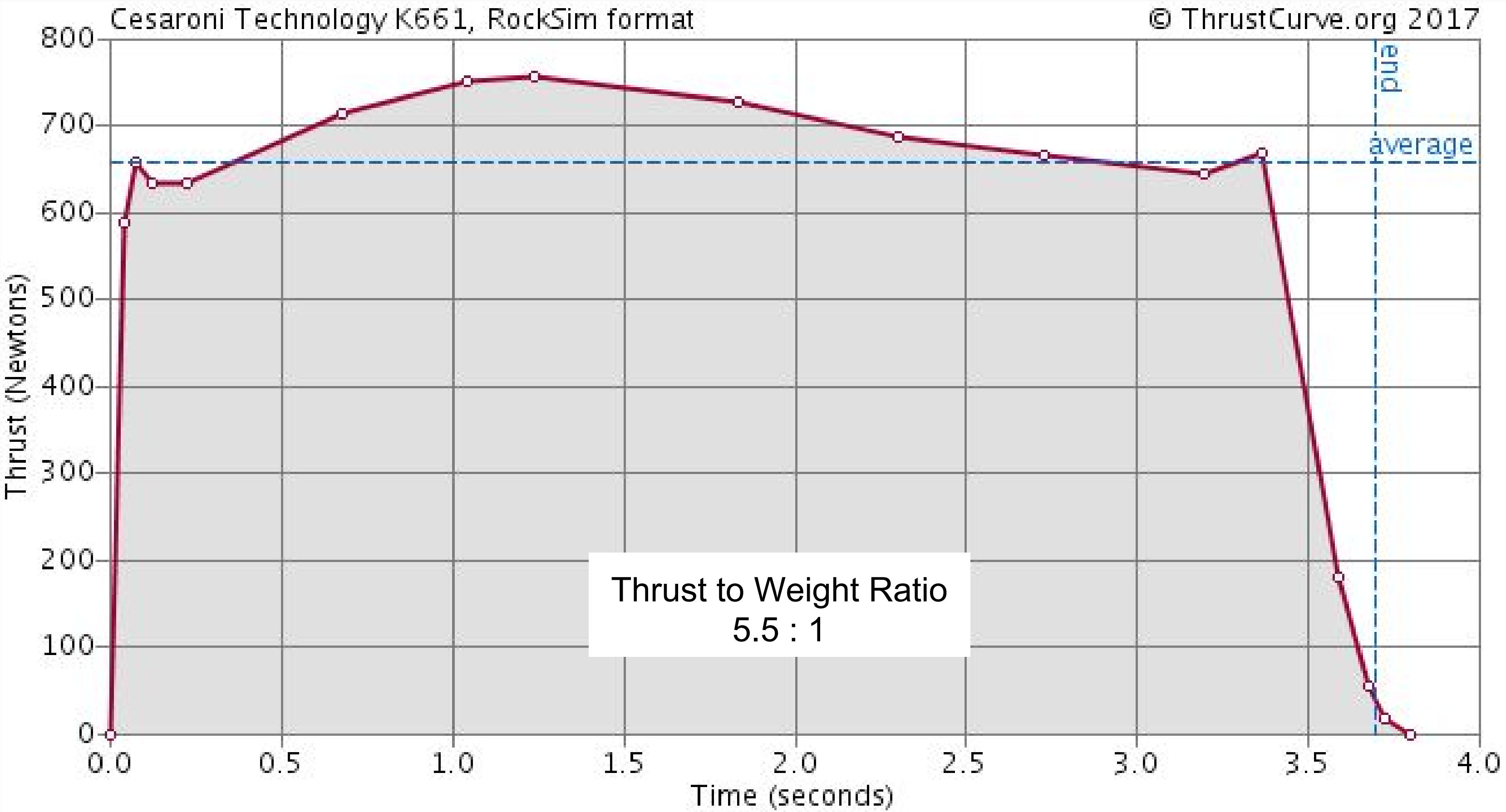
Dimensions	1.72" x 0.88" x 1.57" (43.8 x 22.4 x40 mm)
Product Weight	2.76 oz (78.2g)
No-Load Speed (6.0V)	0.21 sec/60°
No-Load Speed (7.4 V)	0.17 sec/60°
Stall Torque (6.0V)	500oz/in (26 kg.cm)
Stall Torque (7.4V)	611oz/in (44kg.cm)
Travel per µs (out of box)	.080°/µsec
Travel per µs (reprogrammed high res)	.132°/µsec



Vehicle - Motor

Selected Motor: Cesaroni K661

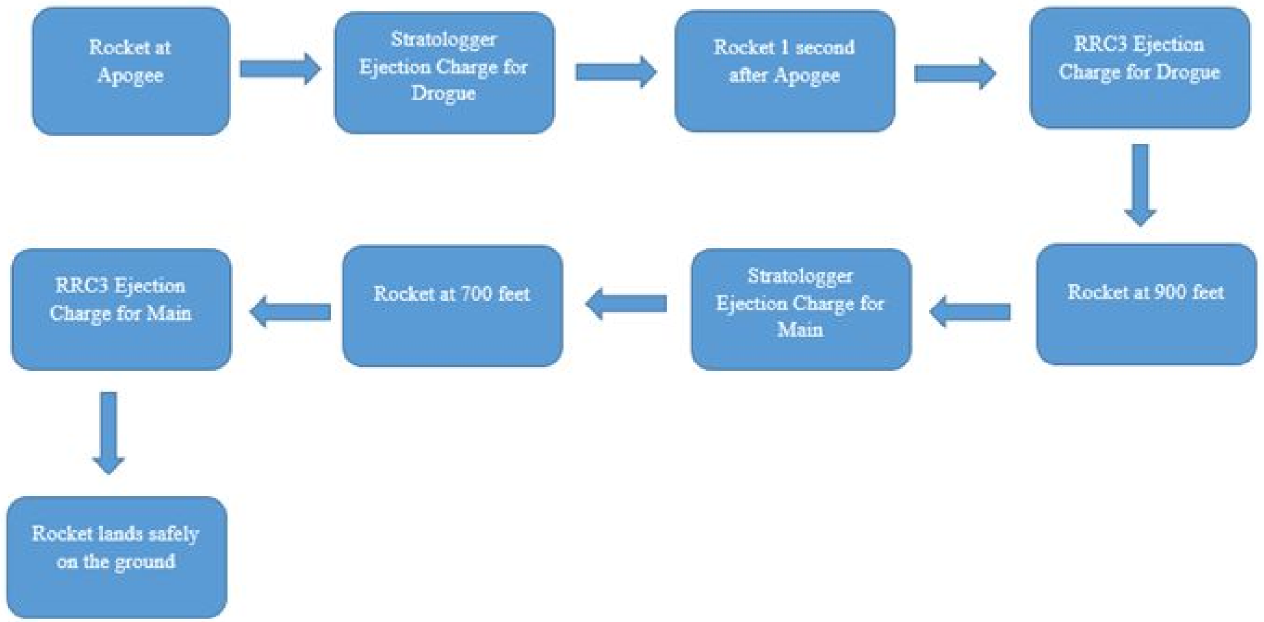
Thrust Curve



Motor-vehicle ascent data

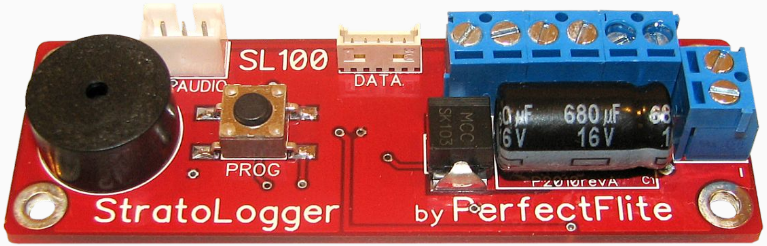
- 5.5 : 1 thrust-to-weight ratio
- 49.31 fps rail exit on 8’ launch rail
- Stability Margin at rail exit:
  9.56 calibers
- Max thrust: 170.43 lbs
- Average thrust: 144.21 lbs
- Predicted apogee, from simulations: 5348 ft

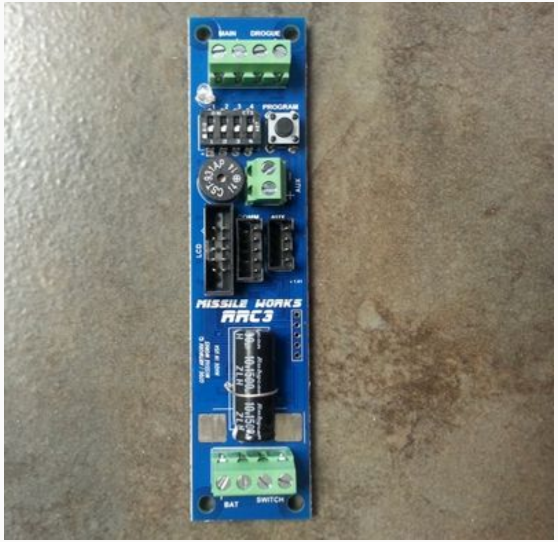
Vehicle - Recovery Subsystem



Vehicle - Recovery Subsystem

- Primary set of recovery electronics - Stratologger CF Flight Computer
- Backup set - RRC3 Flight Computer





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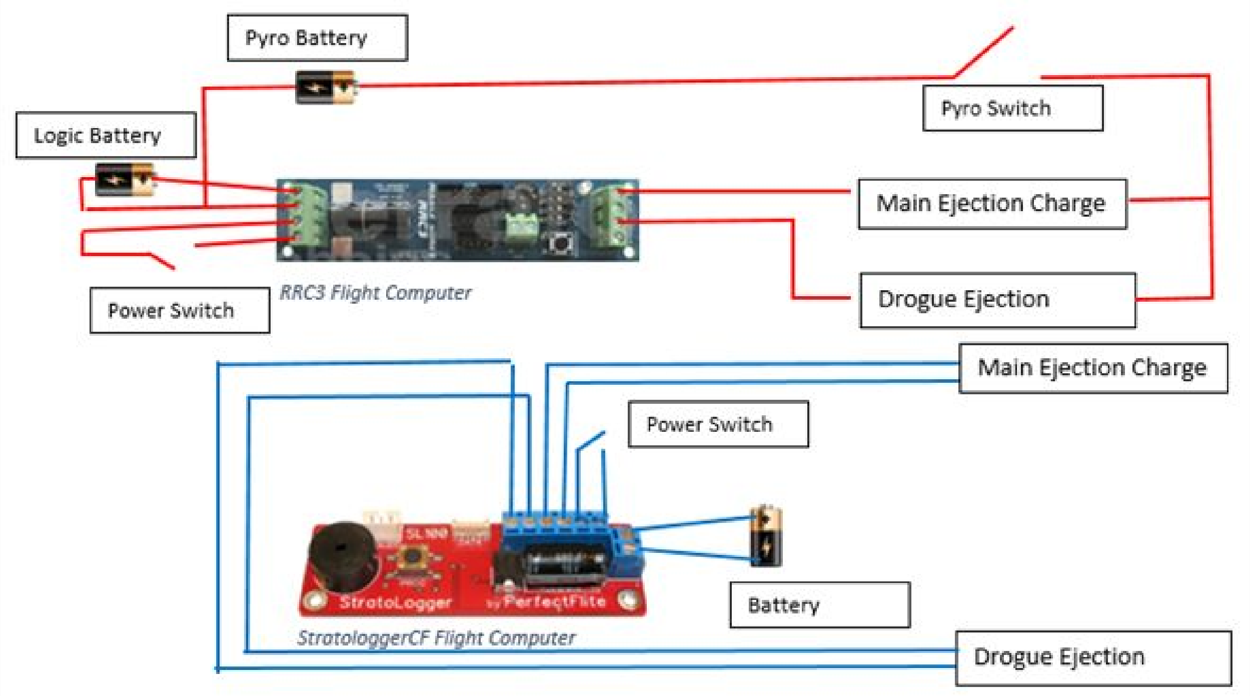


Recovery: Parachutes

- 60” Main Chute
- 18” Drogue Chute
- 25’ recovery harnesses each

Kinetic Energy - Drogue

Kinetic Energy of Each Section (Ft-lbs) **Drogue Chute**	Section 1	Section 2	Section 3	Section 4
	422.47	332.43	846.67	926.50

Kinetic Energy - Main

Kinetic Energy of Each Section (Ft-lbs) **Main Chute**	Section 1	Section 2	Section 3	Section 4
	25.45	20.02	51.00	55.80

Drift Calculations

Main Chute deploys at 700 ft

Predicted Drift from Launch Pad, Assuming Constant Wind **(ft)**	5 mph	10 mph	15 mph	20 mph
	635	1271	1907	2542

Test Plans and Procedures

Vehicle Test Plan

To verify that the vehicle is ready, it is necessary to design a subscale model of it. We used a 3” subscale rocket and verified that the design and its subsystems are safe for the flight of the fullscale.

Test Objective:
To verify the functionality and safety of the rocket

Success Criteria: The rocket has a suitable stability margin (greater than or equal to 2 calibers), was flown and recovered successfully, met the minimum rail exit velocity (52 ft/s), and flew the avionics and air brakes subsystems.

Test Plan:

1. Design a full-scale and subscale rocket. Simulate. If the rockets do not meet the Student Launch handbook’s criteria, then revise and simulate again.
2. Pick suitable motors for each rocket.
3. Build the subscale rocket. Measure for:
    a. Center of Gravity, relative to nose cone
    b. Total Mass

    These details should be inputted in RockSim to receive a better prediction of the subscale’s flight.
    This should also include the rocket’s air brakes and avionics.
4. Test the recovery system and air brakes.
5. Fly the subscale, with the air brakes and avionics on board and active.
6. The following depends on the flight’s results
    a. If the rocket has crashed, diagnose what went wrong, redesign if necessary, rebuild, and fly again.
    b. If a subsystem did not function at all, diagnose what went wrong, redesign if necessary, and fly again.
    c. If the rocket is successful, then record the results in the Critical Design Review.

Testing for the avionics bay is fairly straightforward, as it requires the team to listen to a specific series of beeps from the flight computers to ensure their functionalities.

For the stratologger, there should be seven sets of beeps, in the following manner:

Present number - 1 through 9
Main Deploy Altitude
Long beep if Apogee delay set
Altitude of last flight (Warble = Power lost)
Battery Voltage (needs to be about 9V)
Continuity beeps (repeats every 0.8 seconds)

- Zero beeps = no continuity
- One beep = Drogue OK
- Two beeps = Main OK
- Three beeps = Drogue + Main OK (ideal scenario)

For the RRC3, the continuity check is the following:

5 second long beep (init mode)
10 second baro history init time (silence)
Settings beep (when enabled) or POST fault code beep (if a fault, see POST fault codes)
10 second launch commit test time (silence)
Launch Detect mode (continuity beeps)

- A long beep indicates no continuity on any event terminal.
- One short beep indicates continuity on only the drogue terminal.
- Two short beeps indicate continuity on only the main terminal.
- Three short beeps indicate continuity on the main and drogue terminals.

Energetics Test Plan

We will perform ground tests to verify our calculations of how much black powder is safe to use on a rocket. In an isolated area, we will test different masses of black powder changes and remotely detonate these charges with a 9 Volt current.

If the rocket deploys its respective parachutes without exploding the body tubes, then we will have found the correct mass of the black powder that is safe to use on the flight. If the rocket is unable to deploy a parachute, then we will increase the mass of the black powder used and check to see if there is continuity with the recovery electronics and the electric match that detonates the black powder.

We will find the minimum amount of black powder that is safe for use.

This ground test will be used on the full-scale and scale model of the rocket.

If we have calculated the correct mass, then it doesn’t pop out, we need to find out why. Account for nylon screws and the force of the black powder and the friction that results from the avionics bay rubbing against the body tube.

Air Brake Test Plan

First, check the module to see any possible structural damages. Tighten all screws, from the hinges of the airbrakes to the arms of the servo. If not already uploaded, the airbrake test code should be uploaded to the Teensy via laptop. We then perform two tests with two codes.

Connect the servo cable to the respective wire on the airbrake electronics. Once the battery is connected, the simple code should just open and close the airbrakes continuously. During this preliminary test, team members in charge of the airbrakes will look for any improper functionality in the rocket. If no issues have come up after one minute of running the code, remove the battery connection from the Teensy and upload the flight code.

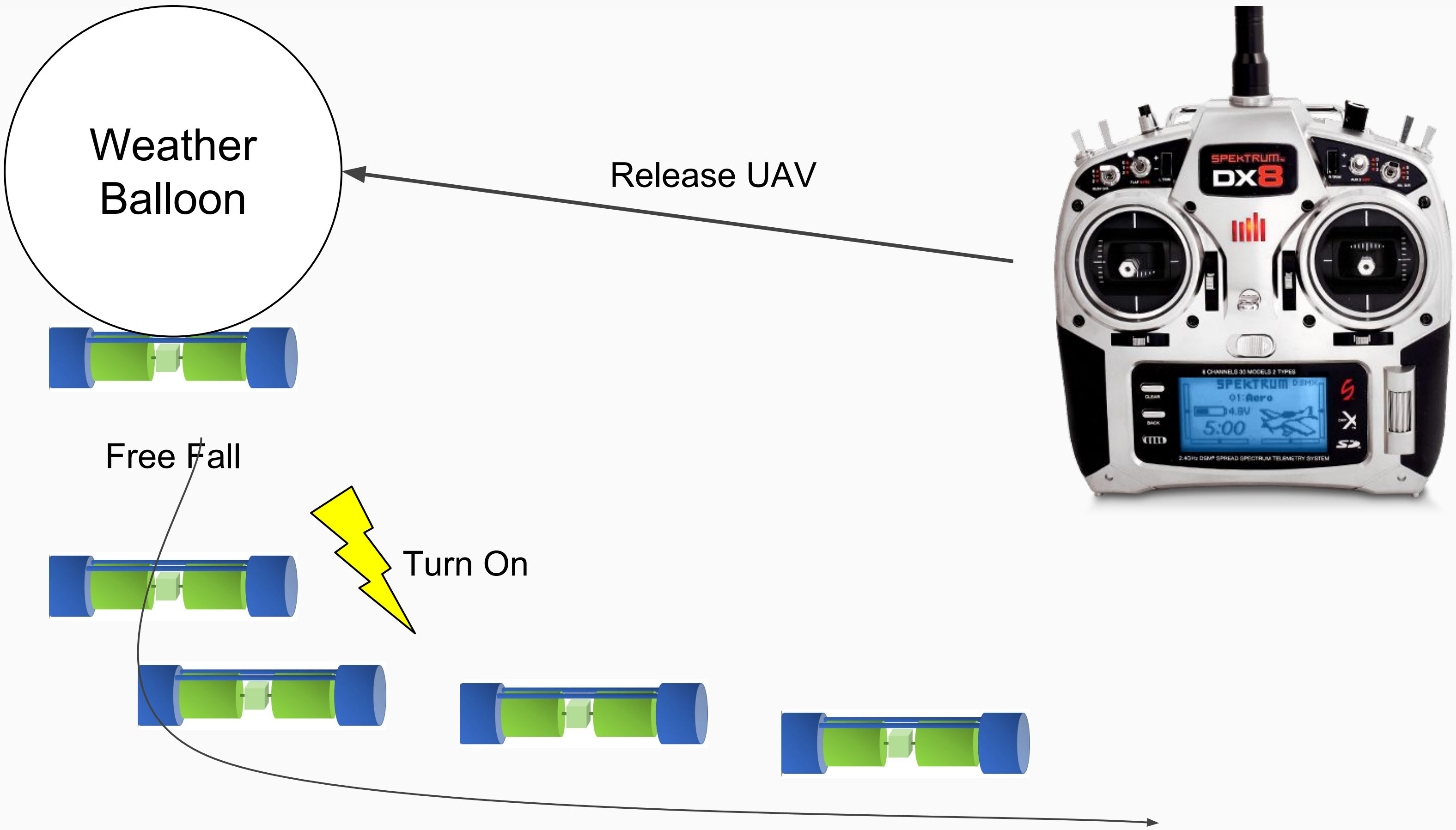
Connect the servo cable to the respective wires on the airbrake electronics. Connect the other respective cable to the Pnut altimeter, and then place the Pnut in the vacuum chamber. Finally, connect the Lipo battery source to the designated location on the Teensy board. Turn on the vacuum chamber. As pressure changes in the chamber, the airbrakes should open and close irregularly to adjust the simulated altitude. If the airbrakes and servo do respond, the airbrake module is ready for flight.

GPS Test Plan

To test the GPS, one must turn on the Whistle GPS app and set up the Whistle Zone, a circle with a one mile radius. After the Whistle Zone is set up and the base station is in place, a team member can drive up to a mile with the GPS, and the phone should be able to track the pathway of the car.

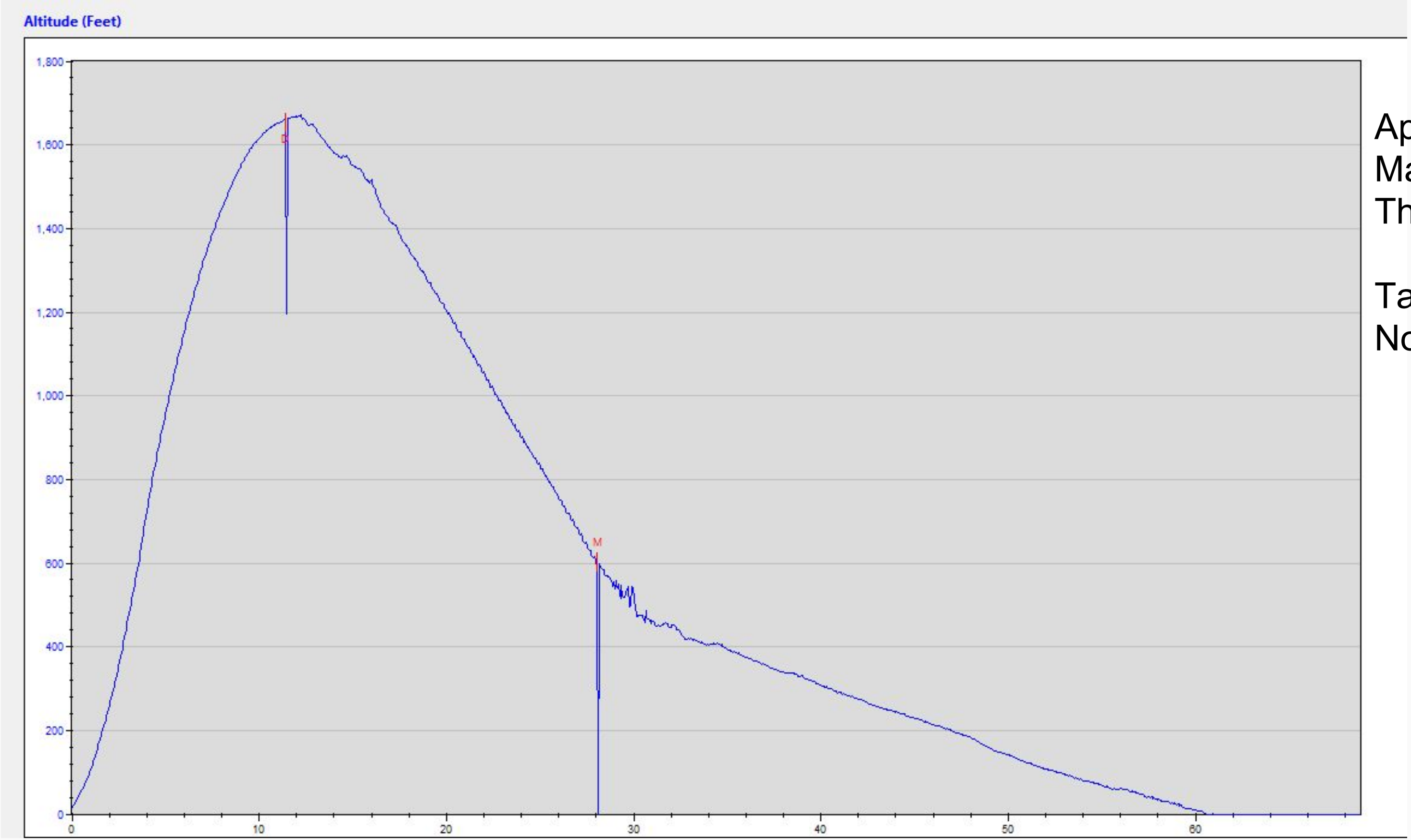
Refreshing location is useful in checking to see if the GPS has changed its position. The GPS will only update the phone if the GPS has left the designated Whistle Zone. The update provides the location of the GPS before it left the Whistle Zone.

Payload Test Plan



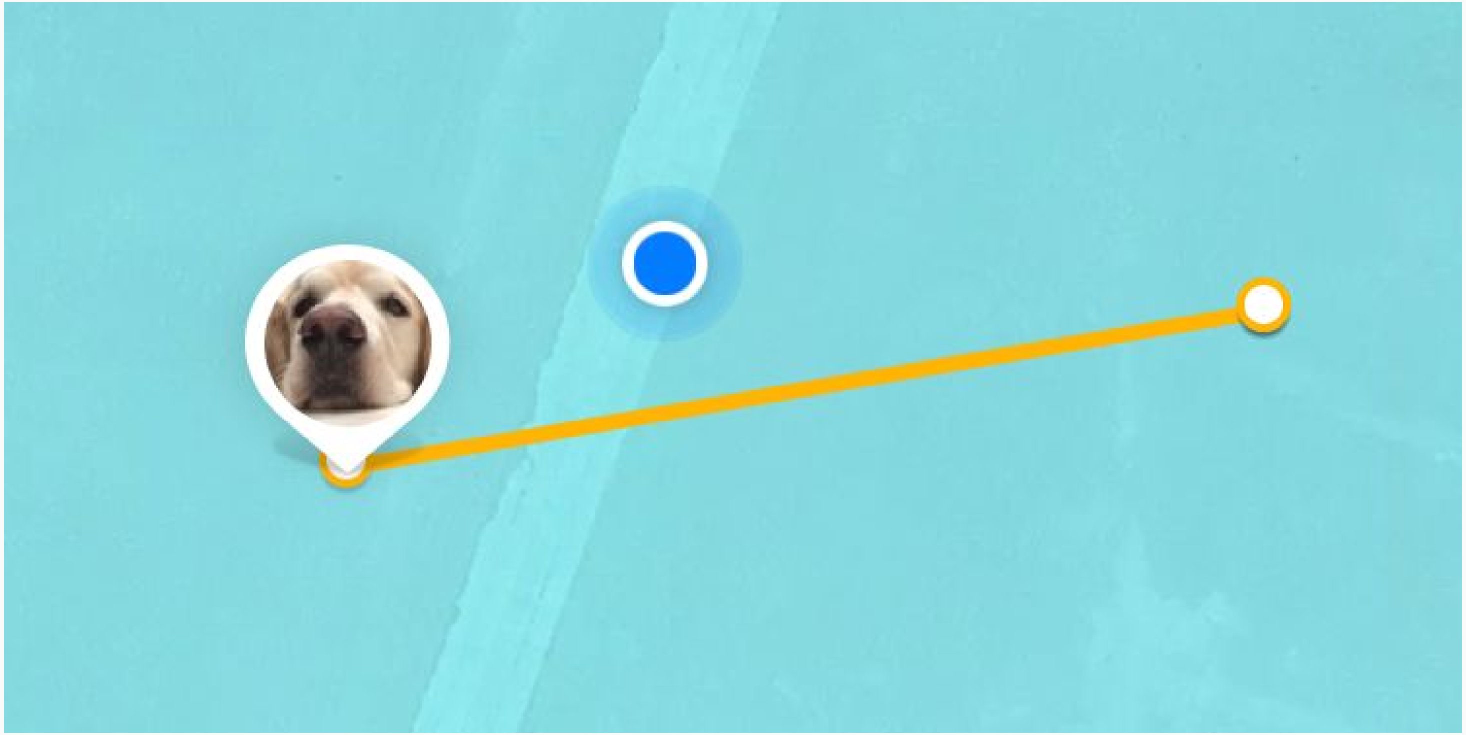
Subscale Flight Results

Subscale Flight Results - Avionics Diagram

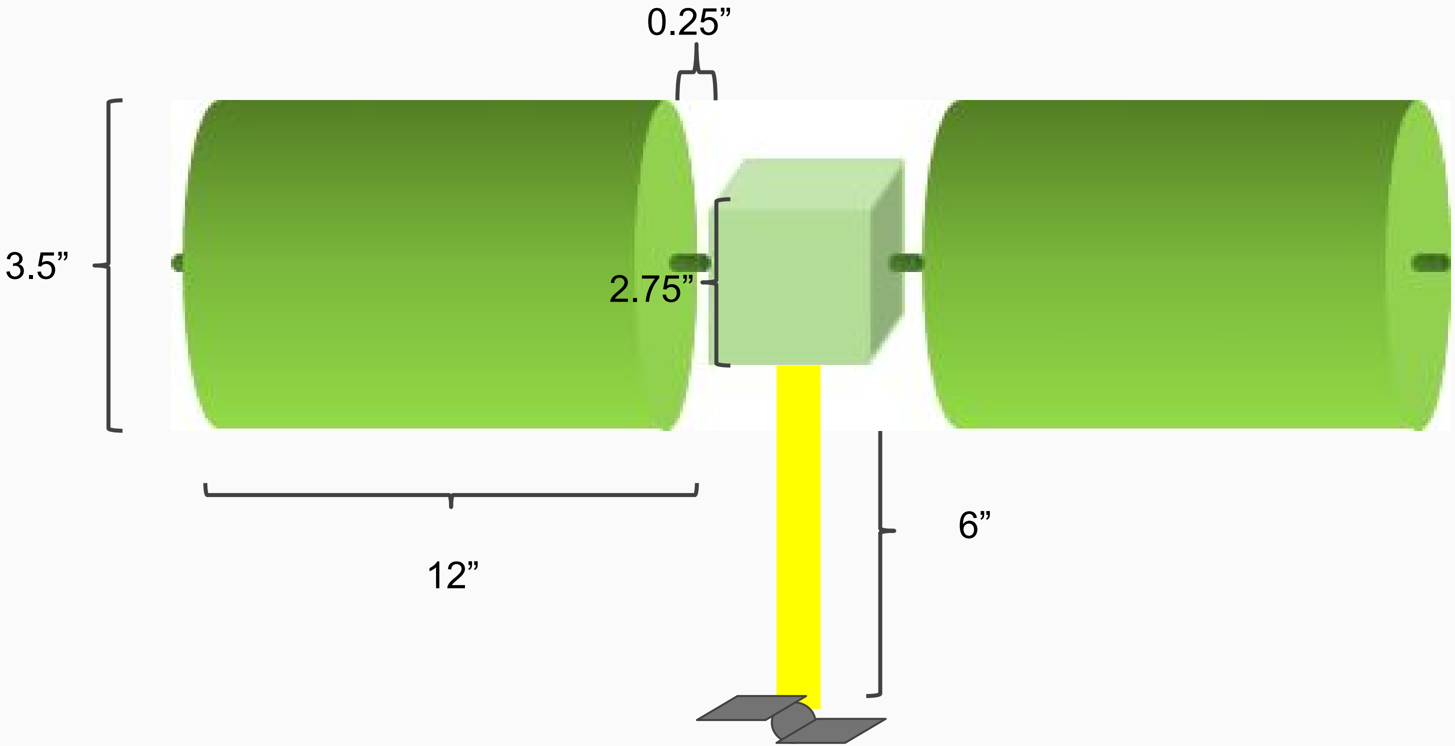


Apogee: 1668 ft
Main Chute: 600 ft
Thrust to weight ratio: 3:1

Target altitude: 1800 ft
No action from air brakes



Engineering Payload



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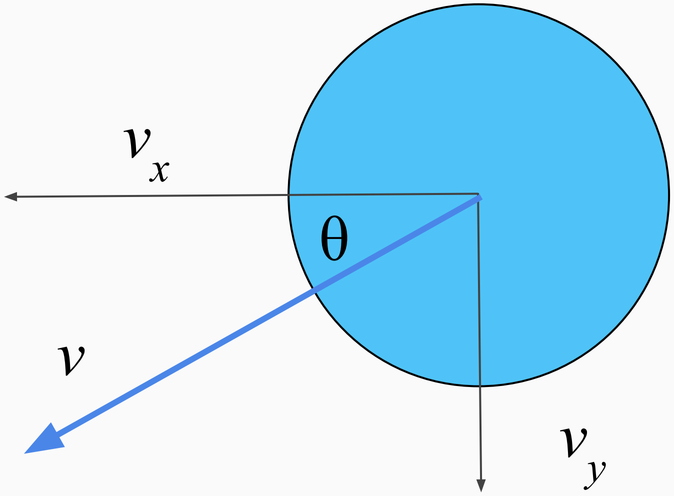
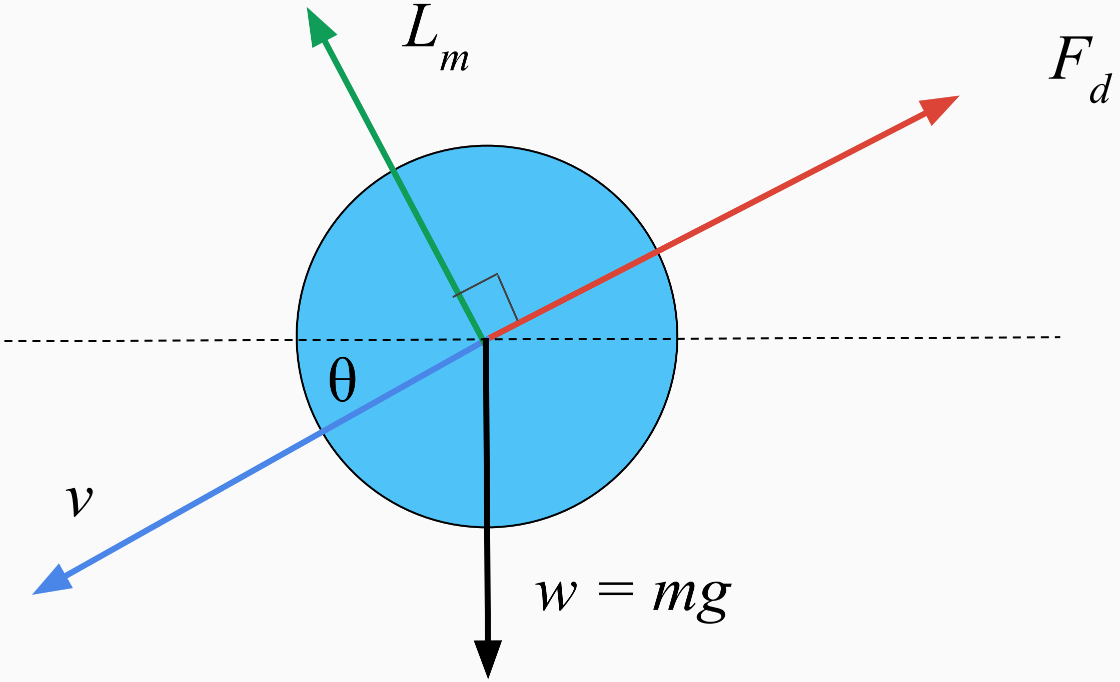
UAV Free-body Diagram





L_m
F_d
θ
v
$w = mg$

Calculating Mass of Payload

$$\boxed{mg = L_m \cos\theta + F_d \sin\theta}$$

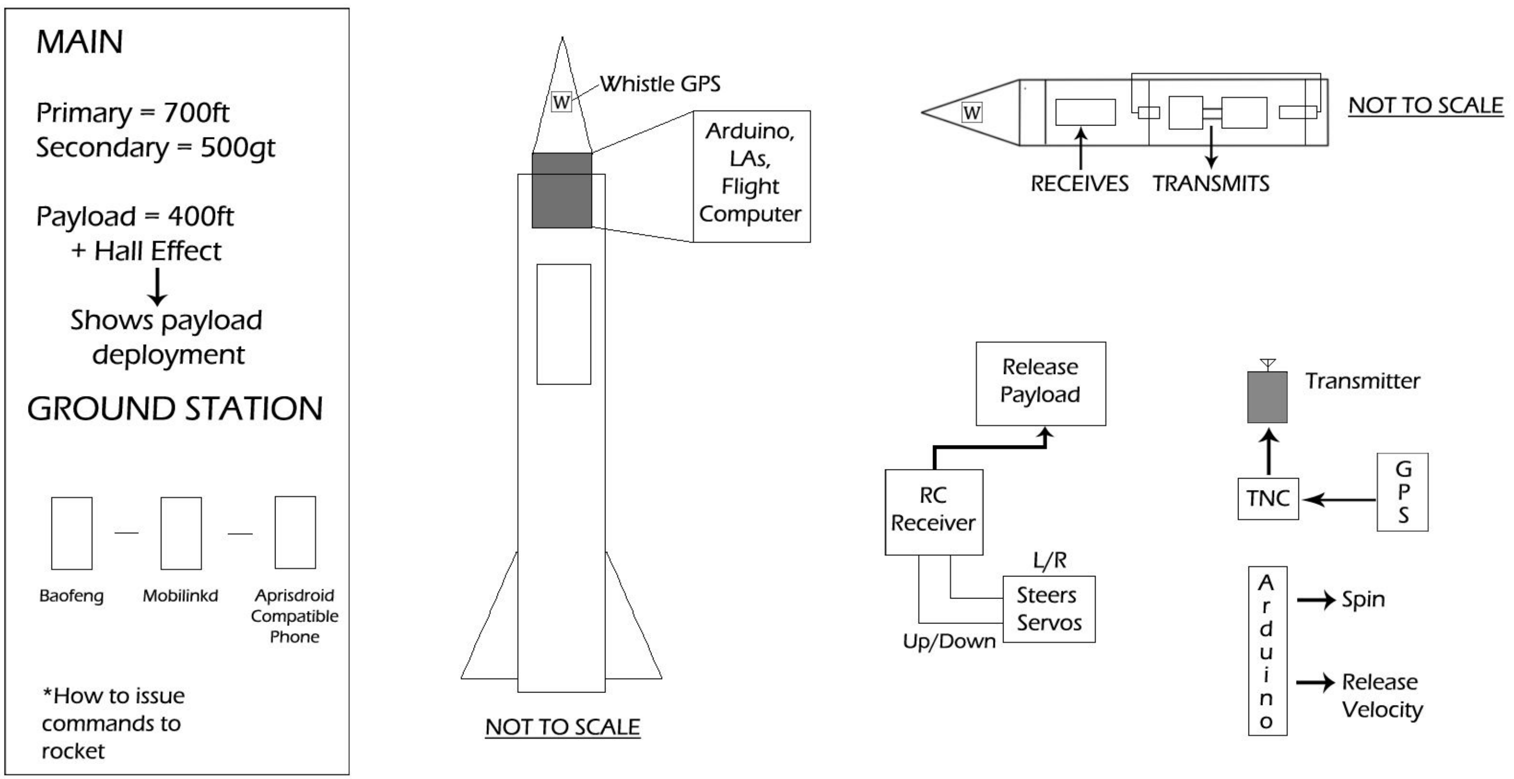
$$\boxed{L_m = \rho 4\pi^2 \omega r^2 V L}$$

$$\boxed{F_d = 2\rho r L V^2 c_d}$$

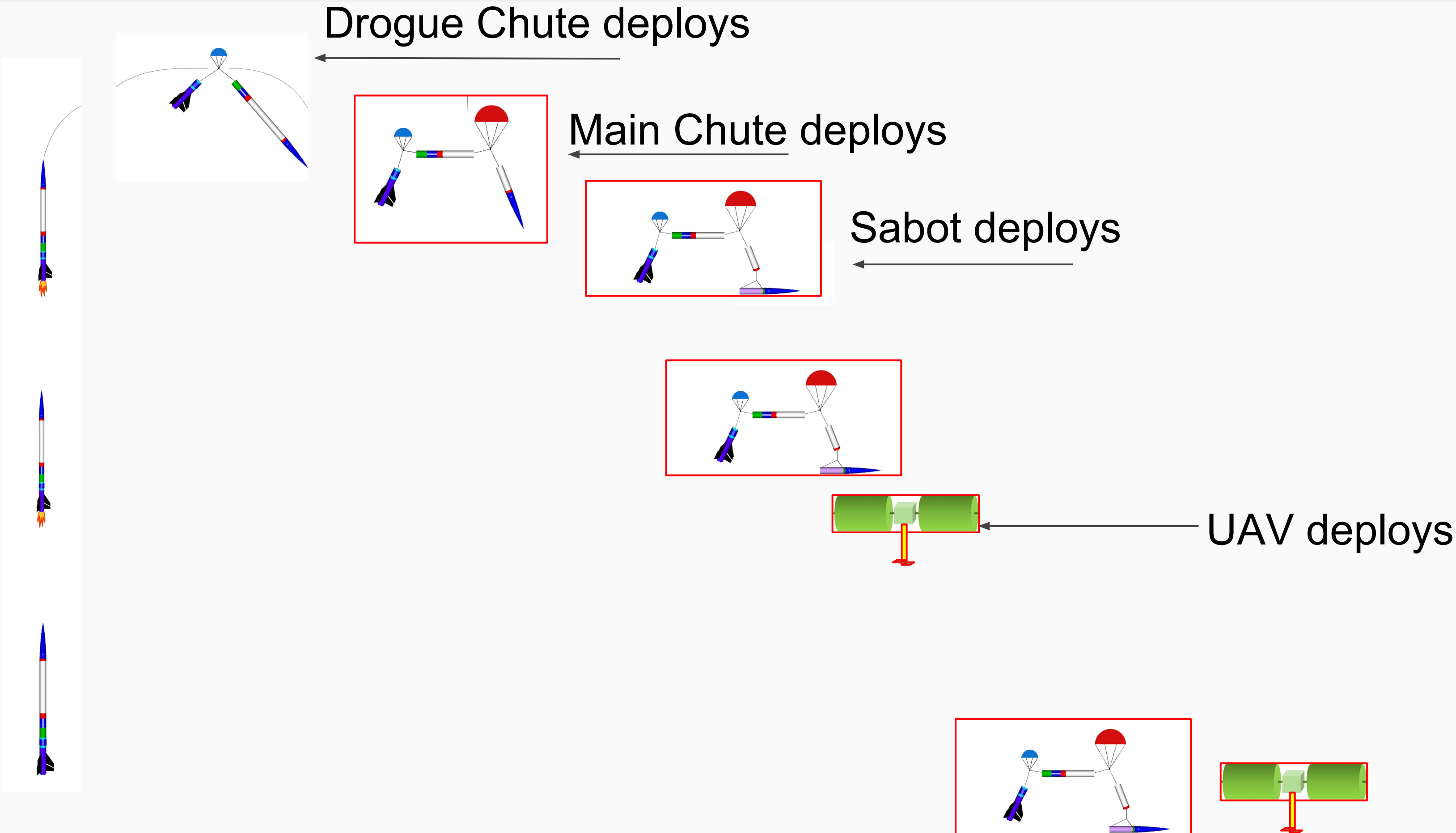
$$mg = \left(\rho 4\pi^2 \omega r^2 V L\right)\cos\theta + \left(2\rho r L V^2 c_d\right)\sin\theta$$

$$\boxed{m = \frac{2\rho L r V}{g}\left[2\pi^2 \omega r * \cos\theta + V c_d * \sin\theta\right]}$$

Slingshot system

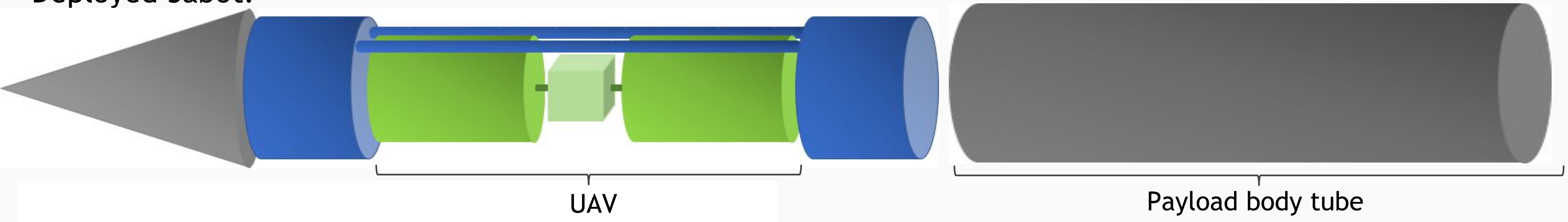


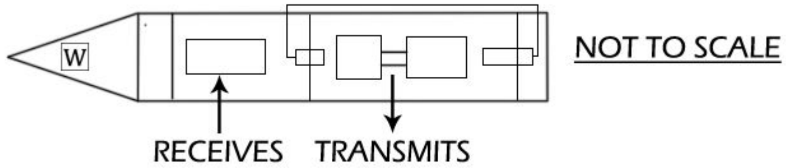
Flight Diagram - Overview



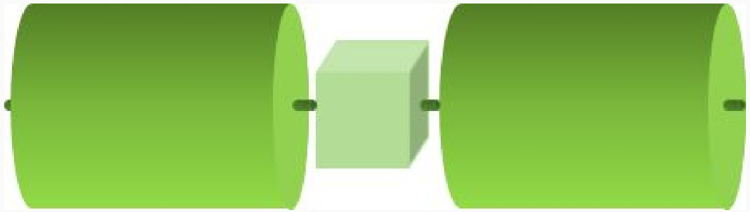
UAV Deployment

Deployed Sabot:





Ballast Arm Removed for Visual Clarity



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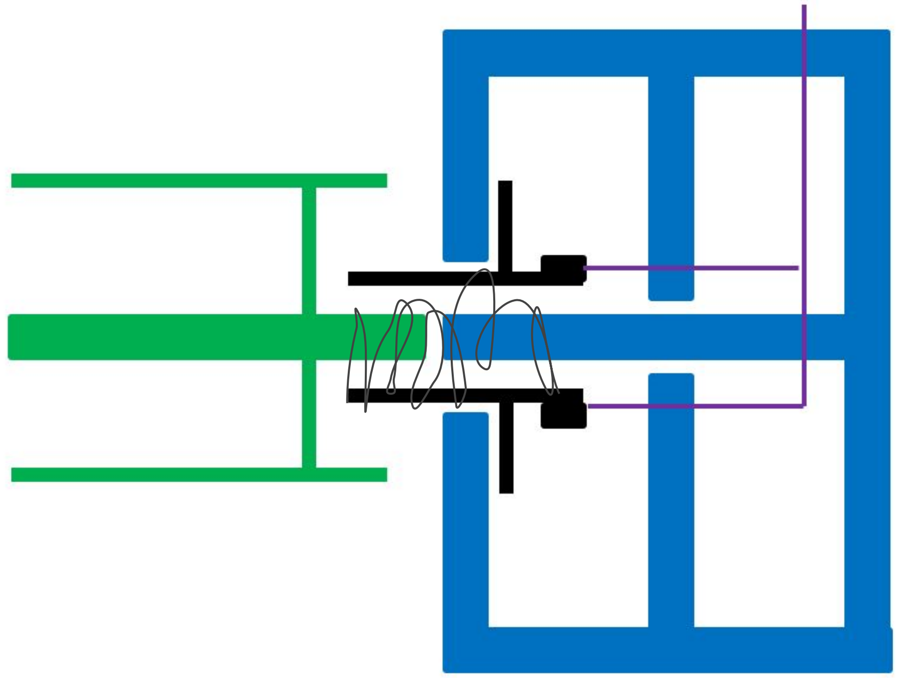

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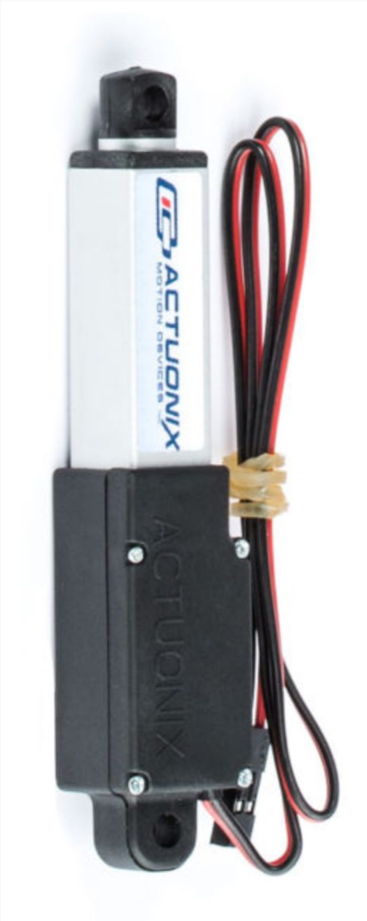
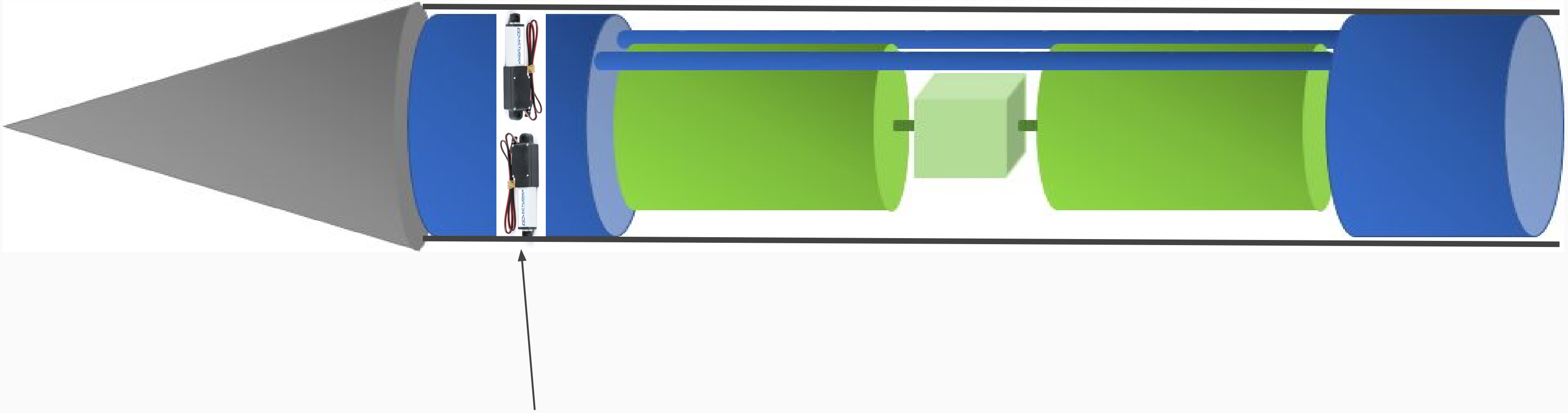
Linear Actuator



Gearing	50:1	Mass	34 g
Stroke	30 mm	Repeatability	±0.2 mm
Voltage	6VDC	Max Side Load (extended)	40 N
Peak Power Point	17 N @ 14 mm/s	Closed Length (hole to hole)	82 mm
Peak Efficiency Point	10 N @ 19 mm/s	Potentiometer	3kΩ±50%
Max Speed (no load)	25 mm/s	Max Input Voltage	7.5V
Max Force (lifted)	22 N	Stall Current	460mA
Back Drive Force (static)	12 N	Standby Current	7.2mA

Linear Actuators



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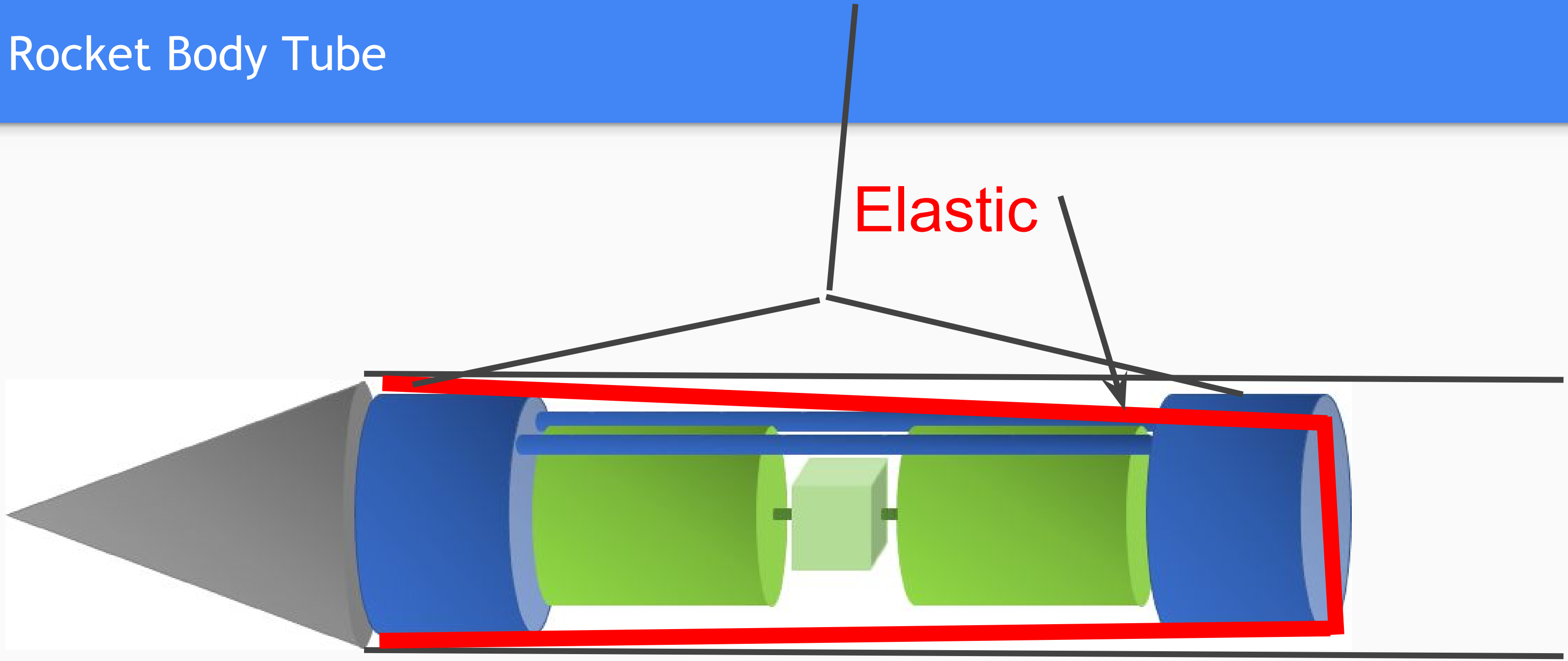


Ballast Arm Removed for Visual Clarity

Not to scale

Vehicle Risk Mitigation and Payload Risk Mitigation

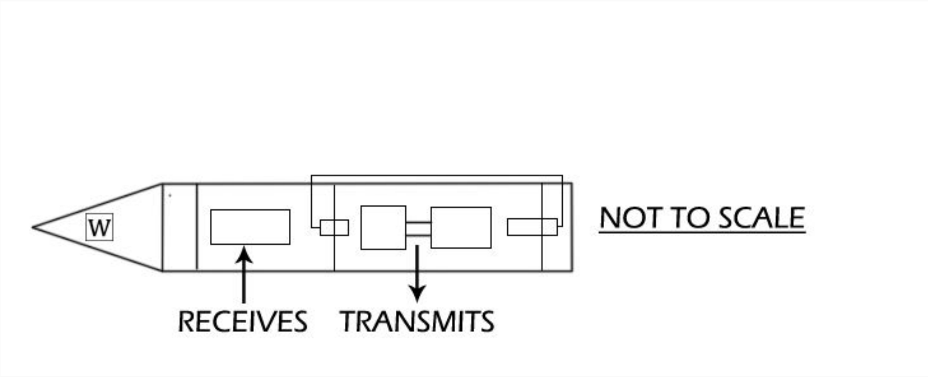
1. Risk - The engine does not ignite while conducting the launch of the rocket. Mitigation - Prior to launch, multiple team members will check to make sure the igniter is properly inserted in the engine to its full length, ensuring ignition of the motor.	4. Risk - The rocket body caves in, or collapses on itself. Mitigation - The team will use fiberglass for the body tube, a material capable of withstanding outside forces. Inside, flight boards, bulkheads, and centering rings will help to maintain the circular frame of the body tube.	7. Risk - The electronic matches fall out of their designated place. Mitigation - Before placing the shear pins, the matches will be checked to ensure that they have been tightened down to remain in place. This task will be placed on a checklist that members will go through while preparing the rocket for launch.
2. Risk - The engine does not fit (too loose or tight) in the motor casing. Mitigation - The team will make sure the engine is inserted in the proper motor casing, and cannot be shaken or pulled out with ease. The team will also check when the motor casing is inserted into the motor mount.	5. Risk - The quick links are not attached properly. Mitigation - The team will double check all connections to ensure that the rocket is assembled completely before preparing the rocket for launch. These tasks will be written on a checklist, which members who checked the task will sign off to take responsibility.	8. Risk: Motor explodes Mitigation: Detailed instructions will be followed step by step when building the motor. Team members will be required to maintain focus and detail while putting together the motor
3. Risk: Airbrakes do not function while in flight. Mitigation: When electronics are activated at ground level, a test for airbrake function will be performed. The airbrake motors will checked prior to assembling the whole rocket.	6. Risk - The shear pins do not shear due the ejection charge. Mitigation - When purchasing the pins, the team will note the force required to shear them. The team will perform black powder ground tests to make sure the ejection charges exert more force than the pins can withstand. To ensure shearing, the backup charge will have a greater amount of black powder.	9. Parachute was not packed correctly and does not deploy Mitigation: The team will check to make sure the parachuted is fitted correctly into the body of the rocket prior to launch. However, if the primary ejection charge does not separate the rocket, backup ejection charges with greater amounts of black powder will allow the parachute to deploy.

1. **Risk**: The automation of the payload stops working **Mitigation**: Switch to RC	4. **Risk**: RC is still not safe in presence of crowd **Mitigation**: Deploy emergency parachute	7. **Risk**: Payload fails to have controlled descent. **Mitigation**: Immediately deploy parachute with autonomous sensor
2. **Risk**: Batteries are not fully charged **Mitigation**: Charge the batteries to max before the flight.	5. **Risk**: Steering rotor fails, resulting in loss of control of payload. **Mitigation**: Deploy parachute remotely	8. **Risk**: Payload ejects above 400 ft, which is illegal for RC aircraft **Mitigation**: Immediately deploy parachute, turn off auto and RC controls.
3. **Risk**: Payload does not eject **Mitigation**: Check if the supply wire is securely attached from the 5 volt pin of the teensy to the Sensor.	6. **Risk**: Batteries fail **Mitigation**: Use Voltmeter to check if the battery is fully charged before the flight.	9. **Risk**: Power fails entirely despite charging; power disconnect mid-flight **Mitigation**: Keep an independent power source and receiver for emergency parachute deployment for redundancy

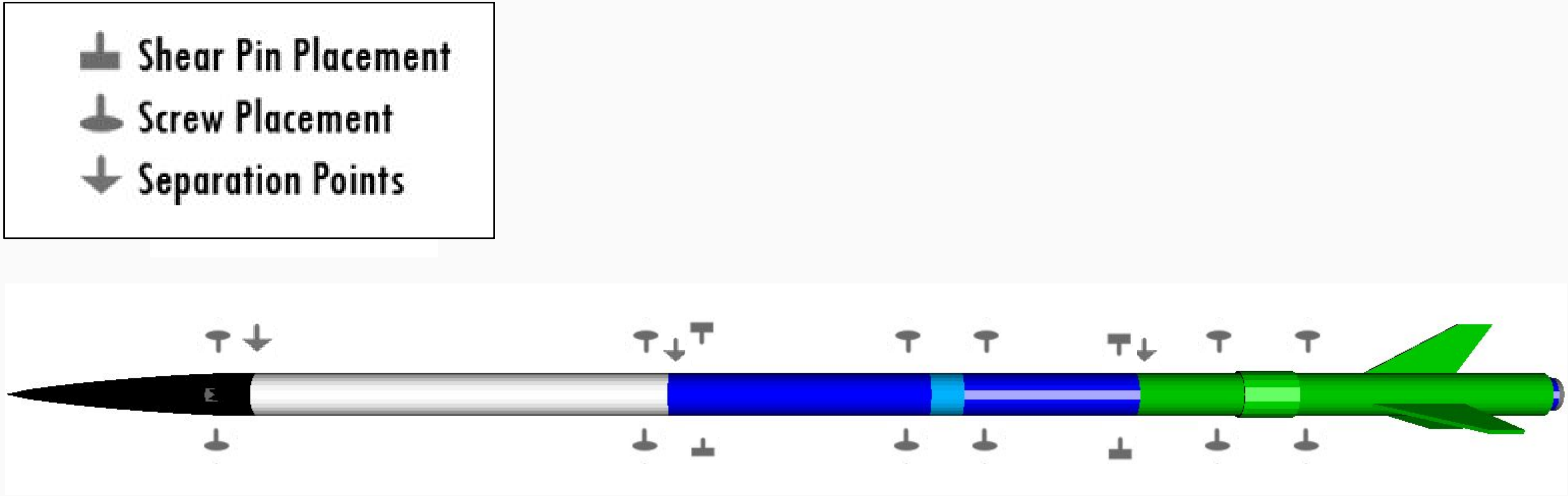
Interfaces

DX8

- 2 receivers (frequencies)
- Receiver 1
  - Servo in sabo to release UAV
- Receiver 2
  - Steering left/right in UAV
  - Turn on/off propeller motor
  - Turn on/of lift motor



Internal Interfaces in Launch Vehicle



Safety

Safety

Risk	Mitigation
Impact to the body	Gloves, apron, goggles
Cut or puncture	Gloves and Apron
Chemicals – fumes and/or direct contact	Gloves, respirator, goggles
Heat/cold	Gloves
Harmful Dust and small particles	Mask and Goggles
Loud noises	Earplugs

- The following items will be present and available for team member use whenever they are working, constructing the vehicle or payload, or launching.
  - Safety goggles
  - Rubber gloves
  - Protective aprons
  - Ear Plugs
  - Leather gloves
  - Respirators / Dust Masks

Safety

Eye protection must be worn whenever there is a danger of:

- Dust, dirt, metal, or wood chips entering the eye. This can happen when sawing, grinding, hammering, or using power tools.
- Strong winds during a launch (common at Lucerne Dry Lake)
- Chemical splashes when using paints, solvents, or adhesives
- Objects thrown (intentionally or inadvertently) or swinging into a team member

These types of gloves must be worn to protect the team member's hands whenever there is danger of contact with a hazardous material:

- Latex or rubber gloves for possible contact with hazardous chemicals such as adhesive, paint, or thinners, or dangerous solid materials.
- Leather gloves to protect against impact, cuts, or abrasions (e.g. in the use of some power tools such as grinders)

Safety

Team members will always work in a clean, well-ventilated area. Protection for a team member's lungs (dust mask or respirator) must be used when:

- Working with chemicals emitting fumes (e.g. paints and solvents). In this case, the team member must wear a respirator.
- Working in an environment where there is dust (e.g. sanding and working with power tools). The team member must wear a dust mask.

Body protection, such as an apron must be worn whenever there is danger of:

- Splashes or spills from chemicals
- Possible impact from tools

Ear protection (plugs or ear muffs) must be worn whenever there are loud noises present, which include:

- Using loud power tools or hammers
- Launching larger rocket motors at launches

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Recovery Risk Mitigation

1. Risk: Backup ejection charges do not ignite. Mitigation: Check to make sure the RRC3 is beeping in the specific sequence as denoted in the manual.	4. Risk: Drogue chute flies at wrong altitude Mitigation: Double check that the Stratologger and RRC3 both are beeping in their specific sequences.	7. Risk: Main chute doesn't deploy Mitigation: Backup Flight Computer and ejection charges should take care of this.
2. Risk: The Batteries of Backup Electronics Fall out Mitigation: Use battery holders and zip ties to ensure that the batteries do not fall out, and double check the sturdiness of these before every launch.	5. Risk: Airbrakes fail to close, interfering with recovery Mitigation: Double check that the LED light is blinking on the Arduino. Also, make sure the most recent code is uploaded in the Arduino.	8. Risk: Stratologger CF Flight Computer is not turned on Mitigation: The team will have three members check the Stratologger to see if it is beeping in its specific sequence, and they will affirm its status by signing their name in the checklist.
3. Risk: The Backup RRC3 Flight Computer is not turned on Mitigation: The team will have three members check the Flight Computer to see if it's beeping and affirm its status by signing their name in the checklist.	6. Risk: Drogue doesn't deploy Mitigation: Double check that the electronics are turned on and beeping, and have three people sign the checklist to affirm. Also, back up ejection charges will take care of this.	9. Risk: Main batteries fail Mitigation: Use fresh batteries and make sure the electronics will power up first in a test second before flight.

Project Risk Identification

Risk	Likelihood	Impact	Mitigation Technique
Time	M	H	If we do not have enough time, then there is nothing to do other than to work harder and reduce quality. To prevent this, we will create a coherent work schedule, divide the work evenly, and clearly delineate the formatting of the deliverables for uniformity in advance. Failing to meet deadlines in time may result in the termination of the SL team's participation.
Budget	M	M	If we run out of funds, we can either fundraise or gather money from within the team. The first method would guarantee a minimum $100 profit. The second would guarantee a minimum $700.
Functionality	L	H	If functionality within the project decreases, then we can mitigate this risk by providing clear work schedules and creating team activities to relax.
Resources	L	M	If we run out of resources, we can buy more and use our funds.

Key	
L	Low
M	Mediu m
H	High

Thanks! Questions?