

# Flight Readiness Review Presentation

Vertical Projectile - AIAA OC Section 2017-2018  
March 15, 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 release the sabot at no lower than 500 ft. Once the payload is below 400 ft, per the RSO's approval, the UAV will be released. The payload and rocket must land within 2500 ft of the launchpad.

# Vehicle

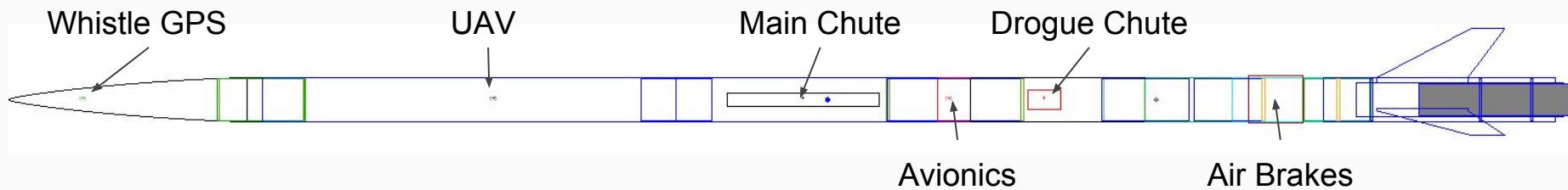
# Vehicle - Design

- Length - 144.75 in
- Diameter - 4 in
- Semi Span of Fins - 3.25 in
- Liftoff Mass - 25.4
- Motor Choice - Cesaroni K661

# Vehicle - Design

- Center of Gravity: 85.9264 in (from nose cone)
- Center of Pressure: 105.3845 in (from nose cone)

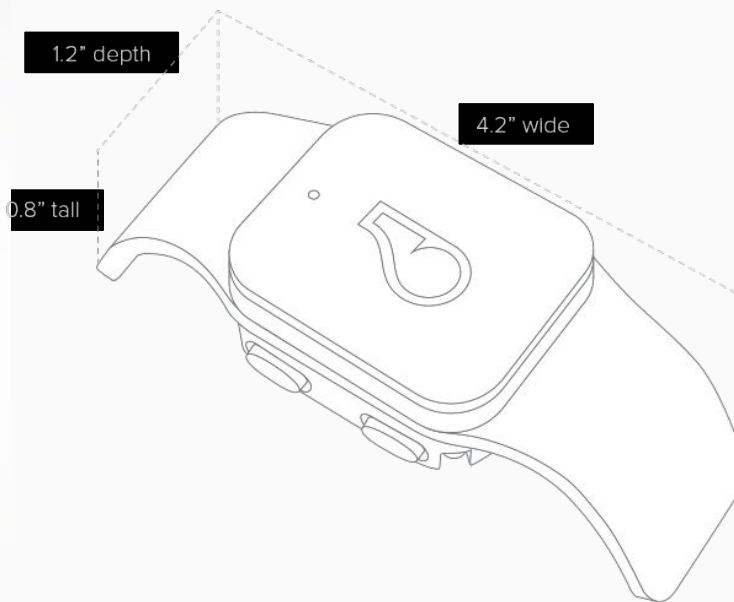
# Vehicle



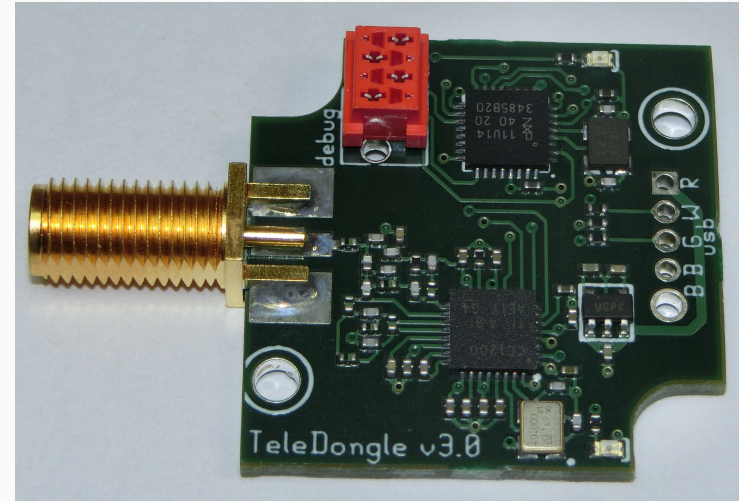
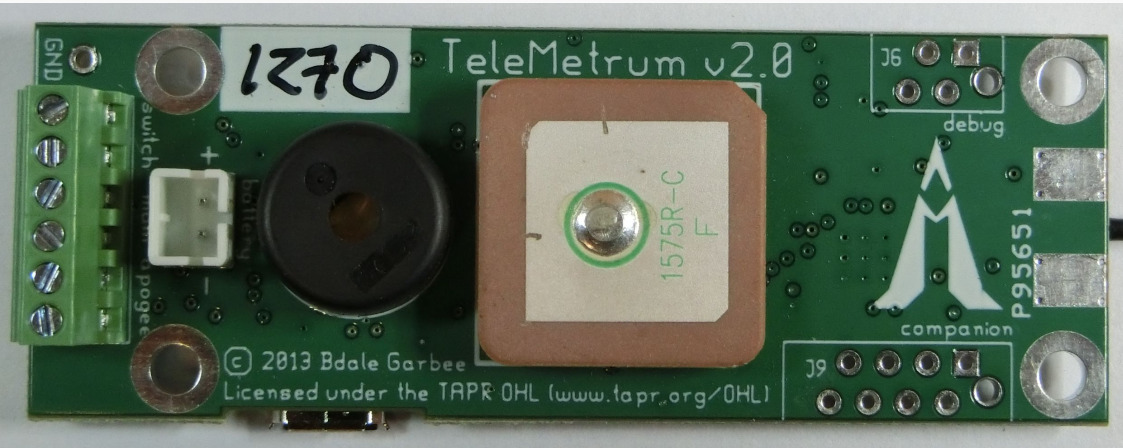
# Vehicle - Subsystems

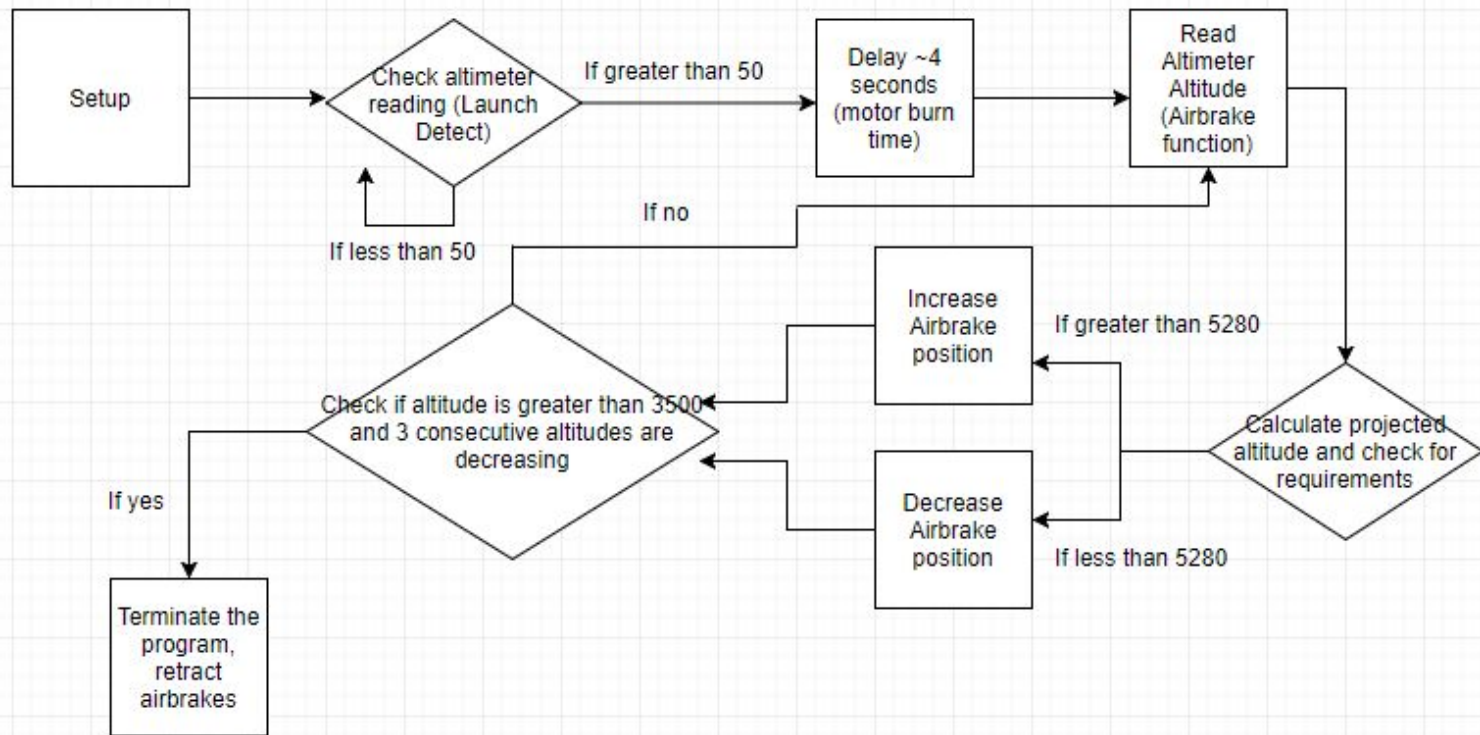


# Vehicle - GPS Tracking Subsystem

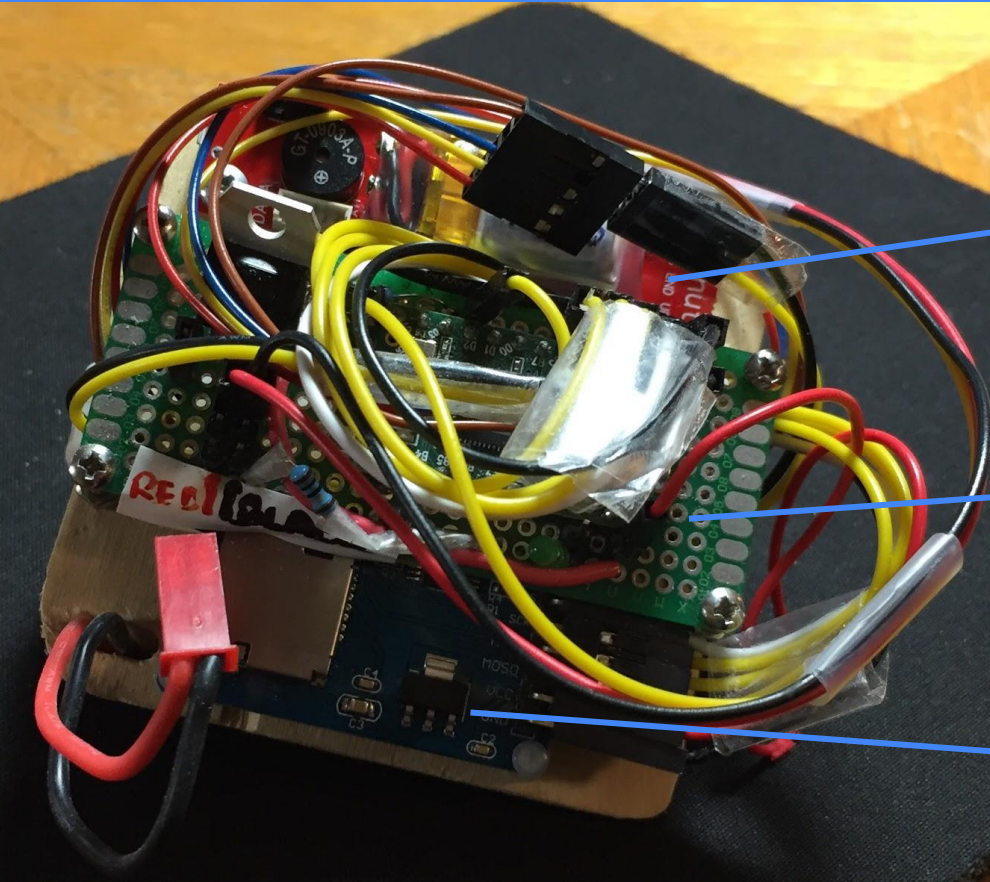


Frequency: 850, 900, 1800,  
1900 MHz





# Key Design Features of Air Brakes



Pnut altimeter

Teensy

SD Card Reader



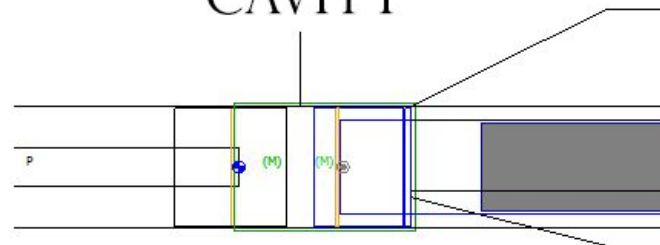
# Vehicle - Air Brakes Subsystem



Dimensions	1.72" x 0.88" x 1.57" (43.8 x 22.4 x 40 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)	<u>611oz/in (44kg.cm)</u>
Travel per $\mu$ s (out of box)	.080°/ $\mu$ sec
Travel per $\mu$ s (reprogrammed high res)	.132°/ $\mu$ sec

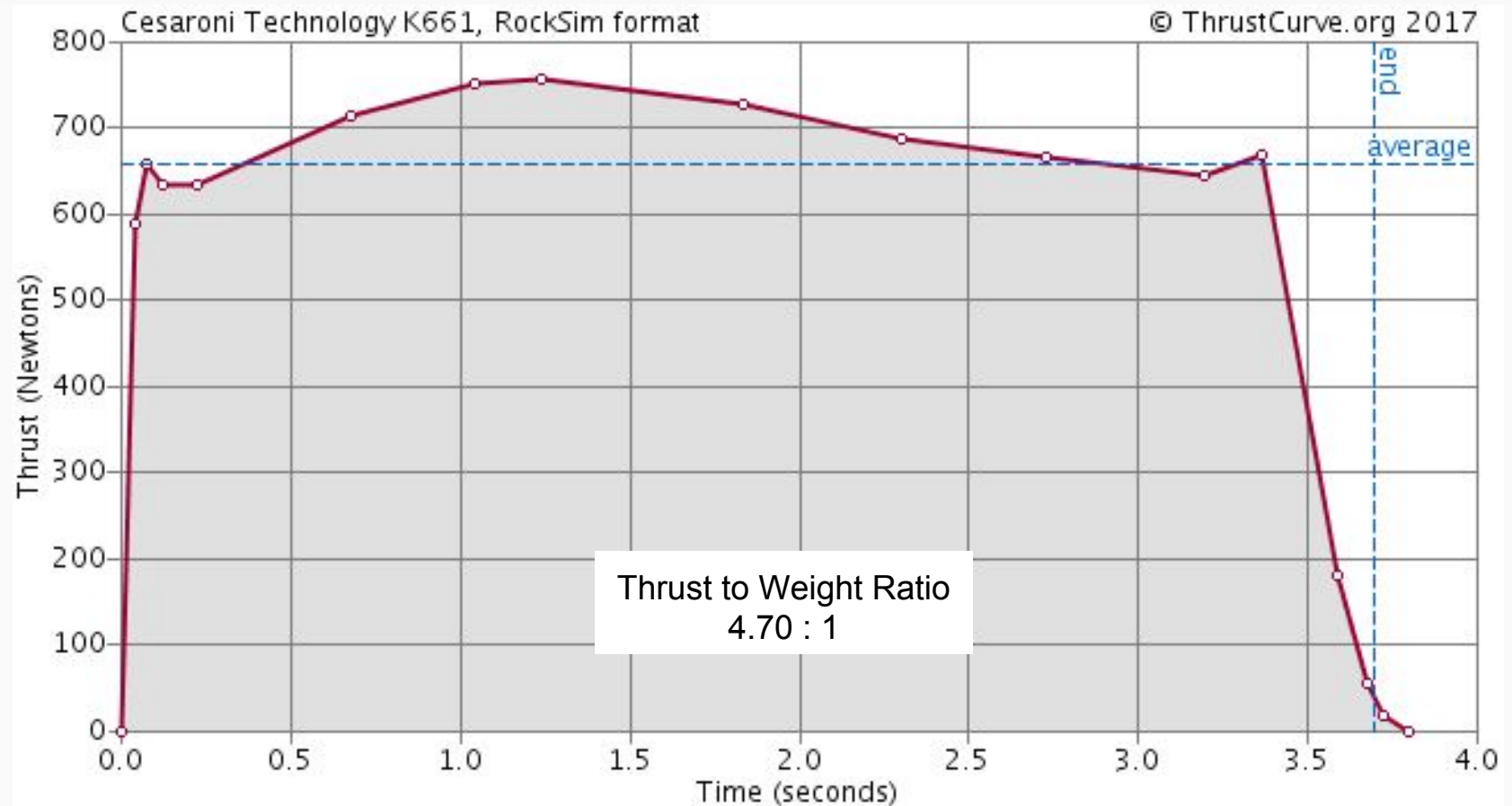


## SERVO OPERATING CAVITY



# Vehicle - Motor

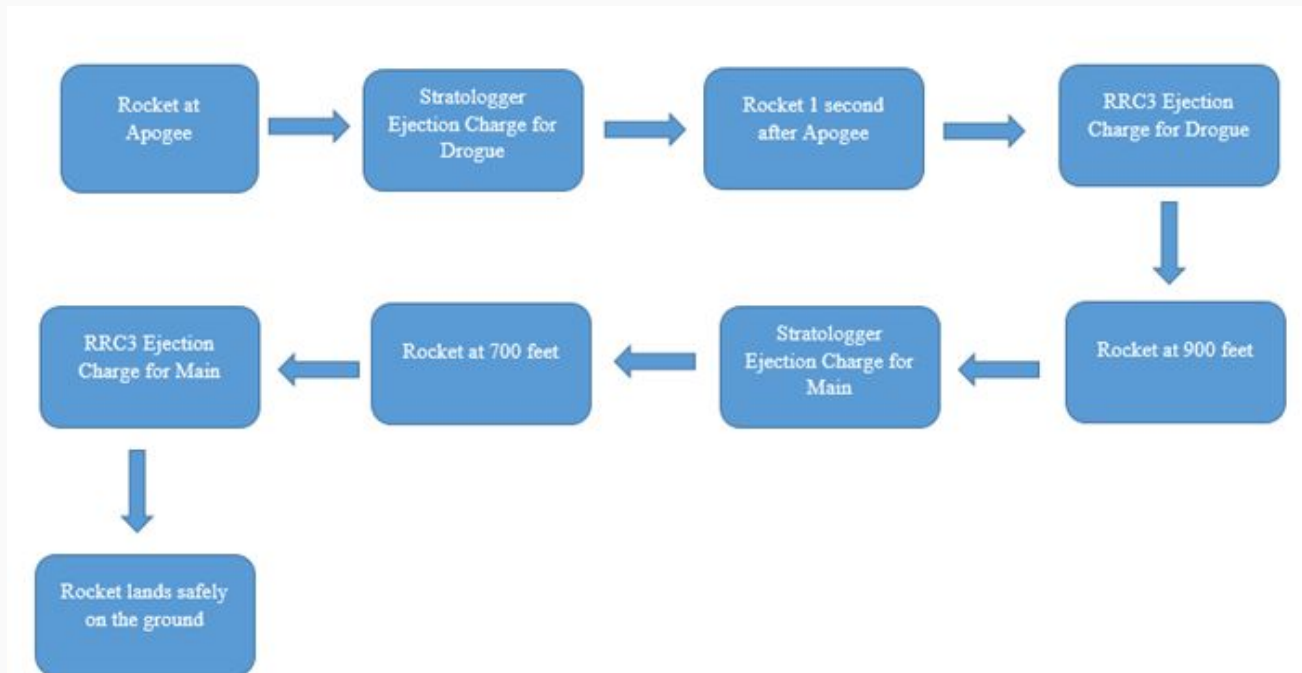
Selected Motor: Cesaroni K661





- 4.70 : 1 thrust-to-weight ratio
- 54.45 fps rail exit on 12' 1515 launch rail
- Stability Margin at rail exit:  
6.30
- Max thrust: 170.43 lbs
- Average thrust: 144.21 lbs
- Predicted apogee, from simulations: 3743'

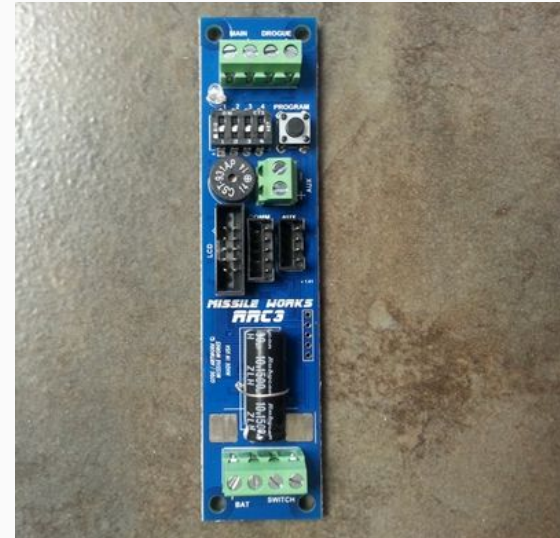
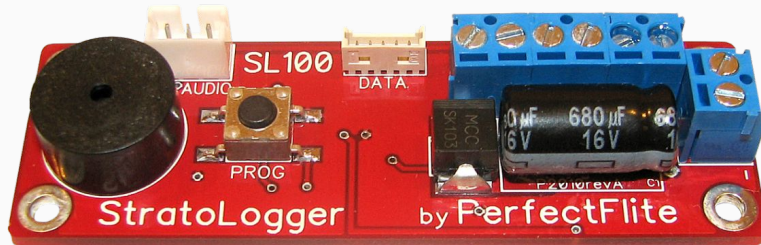
# Vehicle - Recovery Subsystem

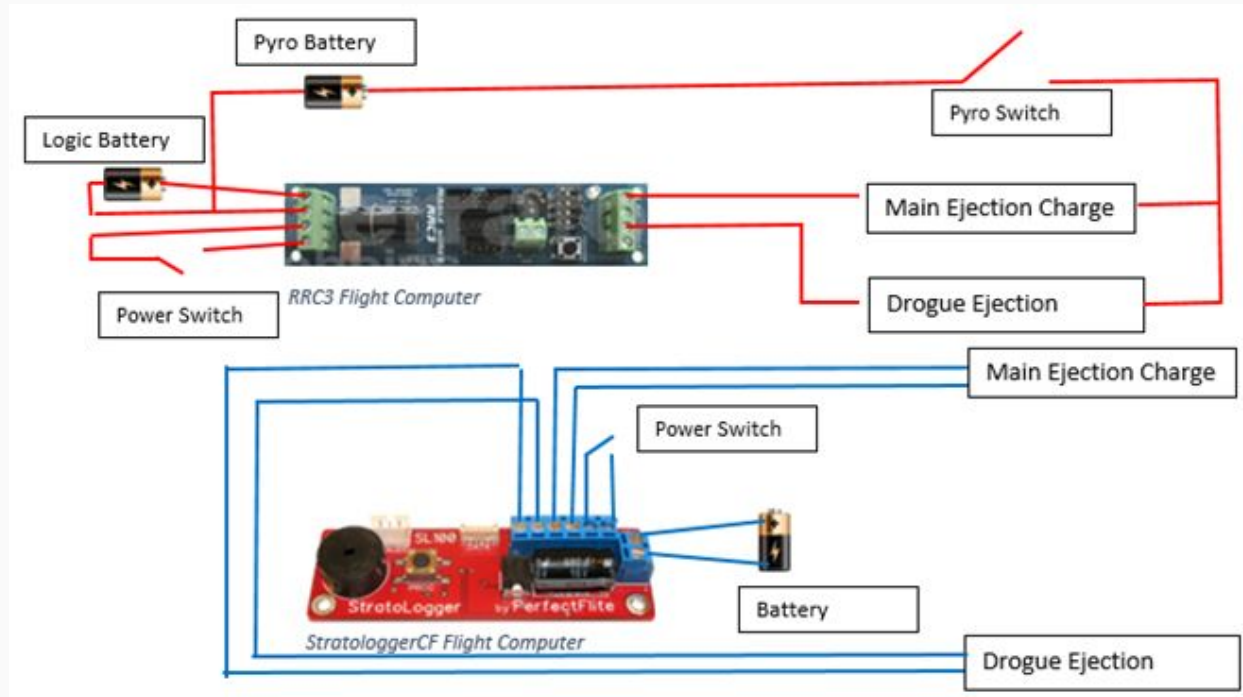


# Vehicle - Recovery Subsystem



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





# Recovery: Parachutes

- 60" Main Chute
  - 23.6 fps
- 18" Drogue Chute
  - 96.77 fps
- 25' recovery harnesses each

# Kinetic Energy - Drogue

Kinetic Energy of Each Section (Ft-lbs)	Section 1	Section 2	Section 3	Section 4
<b>Drogue Chute</b>	806.1	480.29	1108.03	1588.32

# Kinetic Energy - Main

	Section 1	Section 2	Section 3	Section 4
Kinetic Energy of Each Section (Ft-lbs) <b>Main Chute</b>	49.01	29.2	67.37	96.57



# Predicted Altitude

Using conditions from March 4, 2018 flight; assuming constant wind

	5 mph	10 mph	15 mph	20 mph
Predicted Maximum altitude (ft)	3755	3708	3630	3525

# Drift Calculations

Main Chute deploys at 700 ft

Predicted Drift from Launch Pad, Assuming Constant Wind <b>(ft)</b>	5 mph	10 mph	15 mph	20 mph
	218	436	653	871

# Test Plans and Procedures

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 MassThese 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.

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 charges 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.

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.

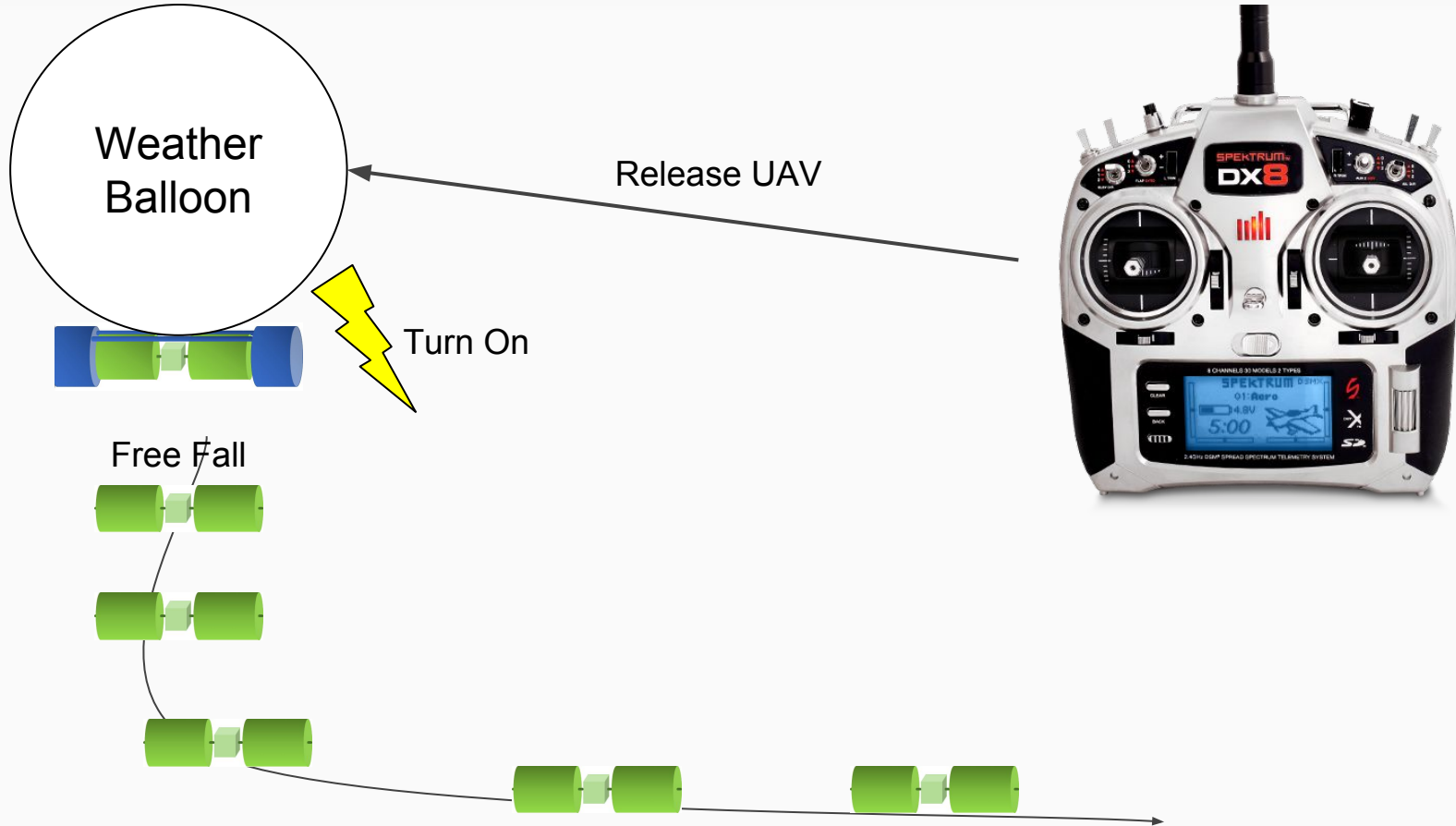
Connect the servo cable to the respective wire on the airbrake electronics. Once the battery is connected, the simple code should just open and close the airbrakes continuously. During this preliminary test, team members in charge of the airbrakes will look for any improper functionality in the rocket. 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.

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.

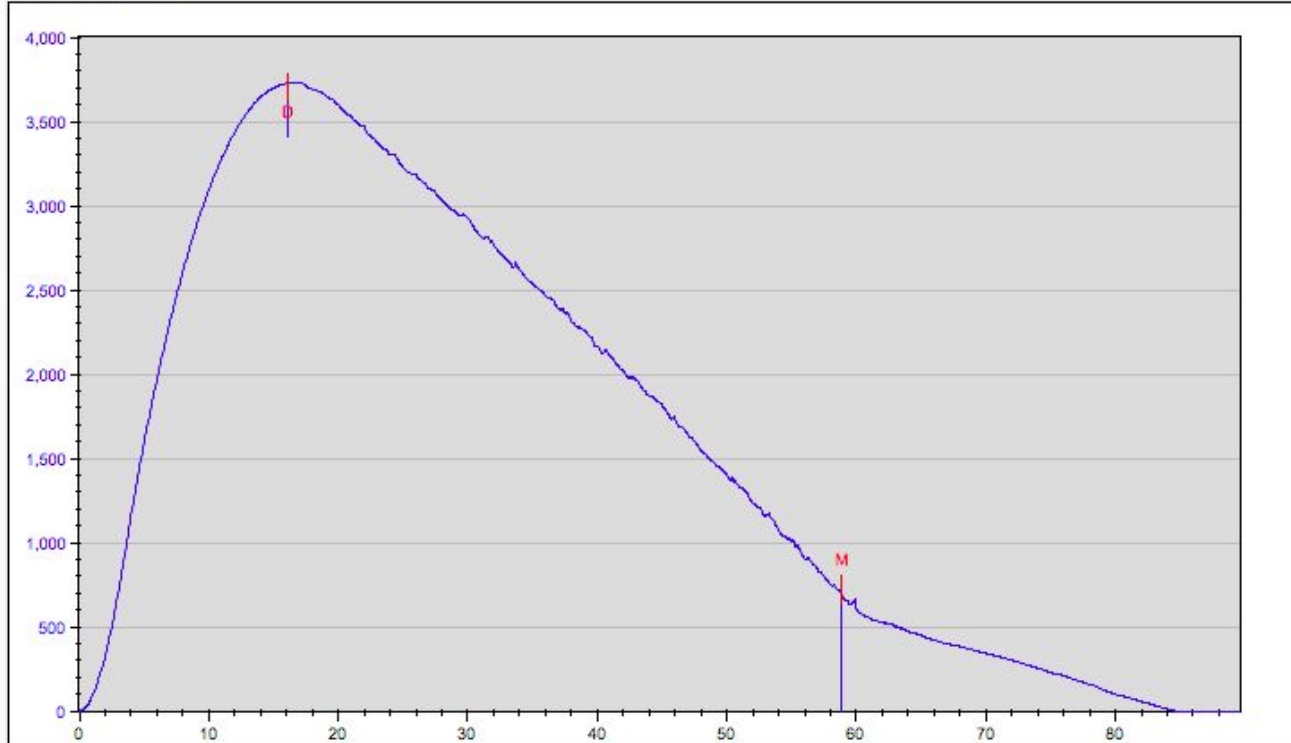
Refreshing location is useful in checking to see if the GPS has changed its position. The GPS will only update the phone if the GPS has left the designated Whistle Zone. The update provides the location of the GPS before it left the Whistle Zone.





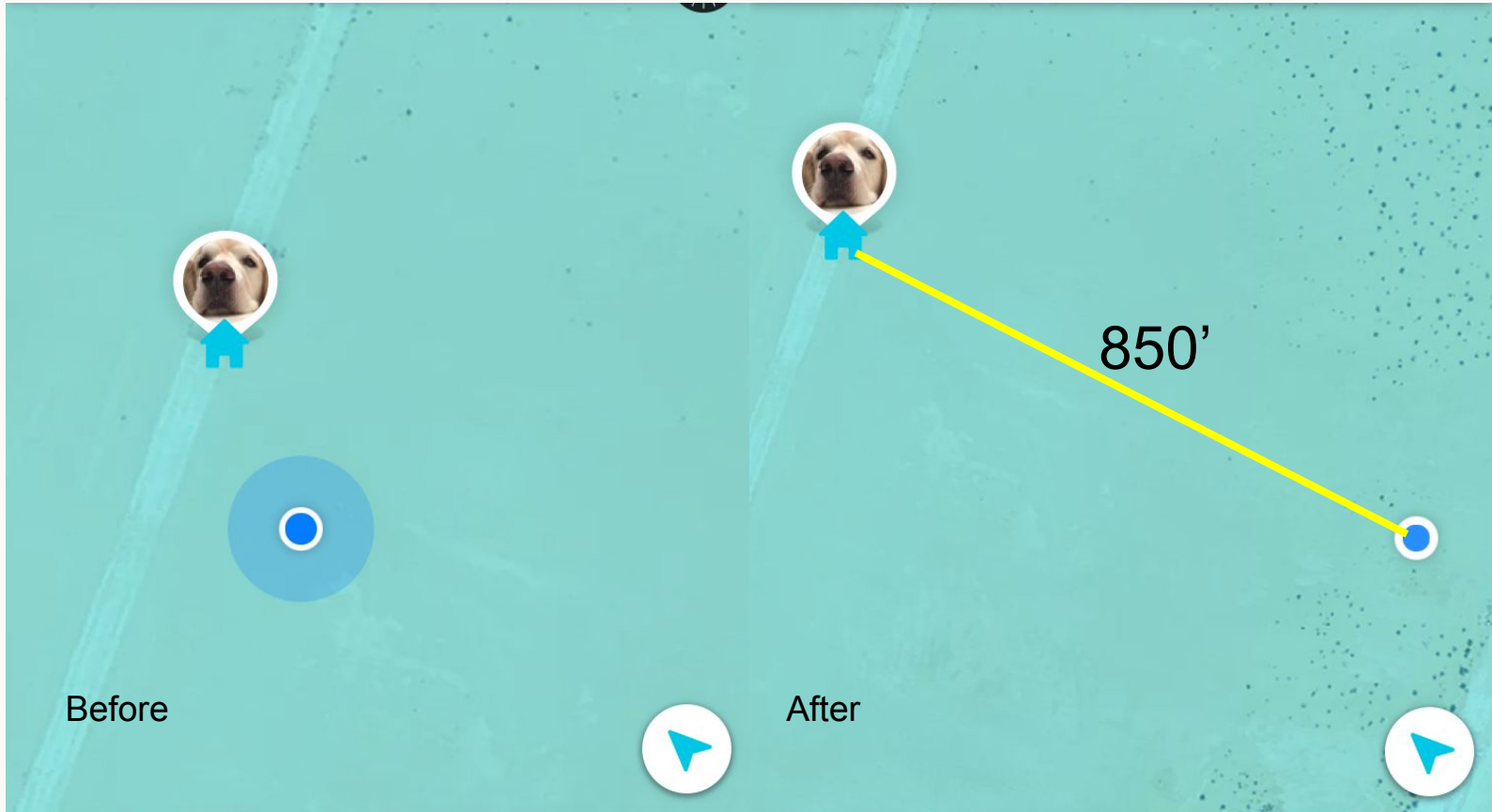
# Full Scale Flight Results

Altitude (Feet)



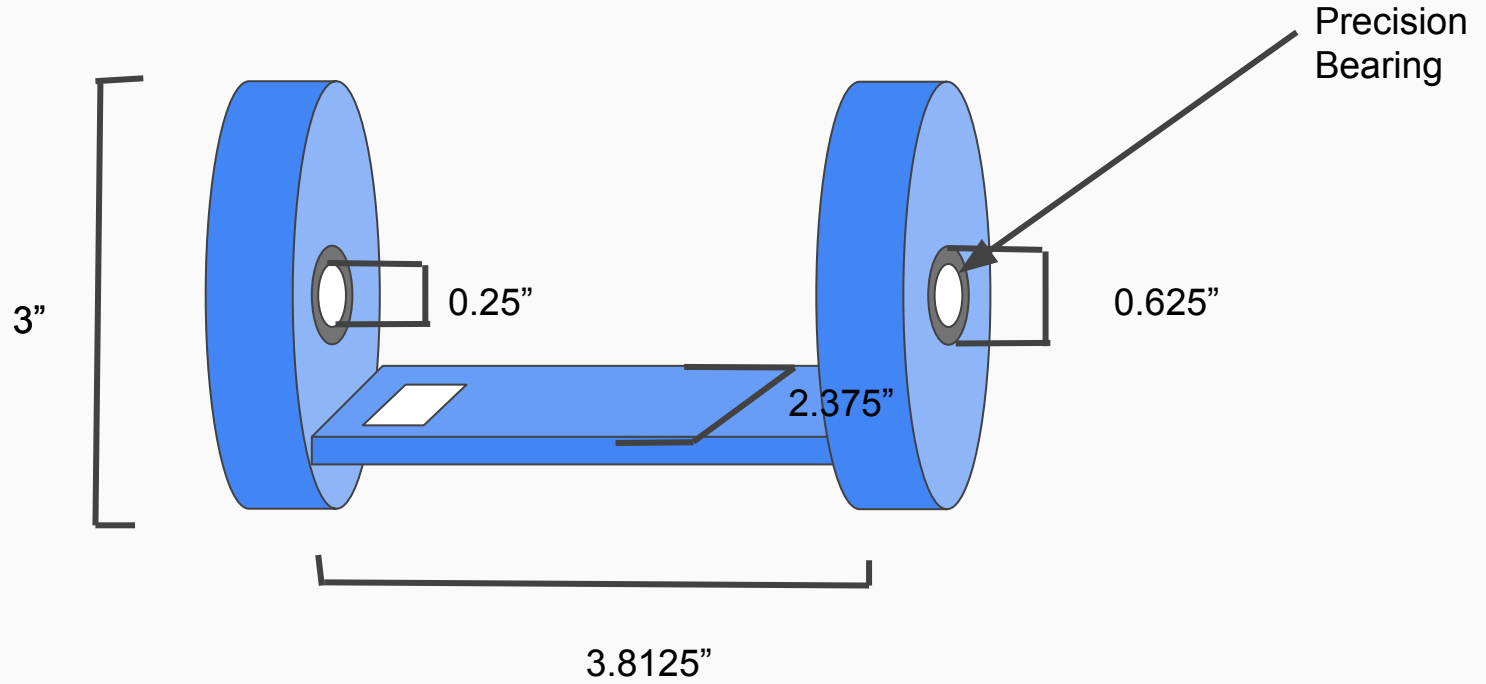
Apogee: 3740 ft  
Main Chute: 700 ft  
Thrust to weight ratio: 4.7 : 1

Target altitude: 5280 ft  
No action from air brakes



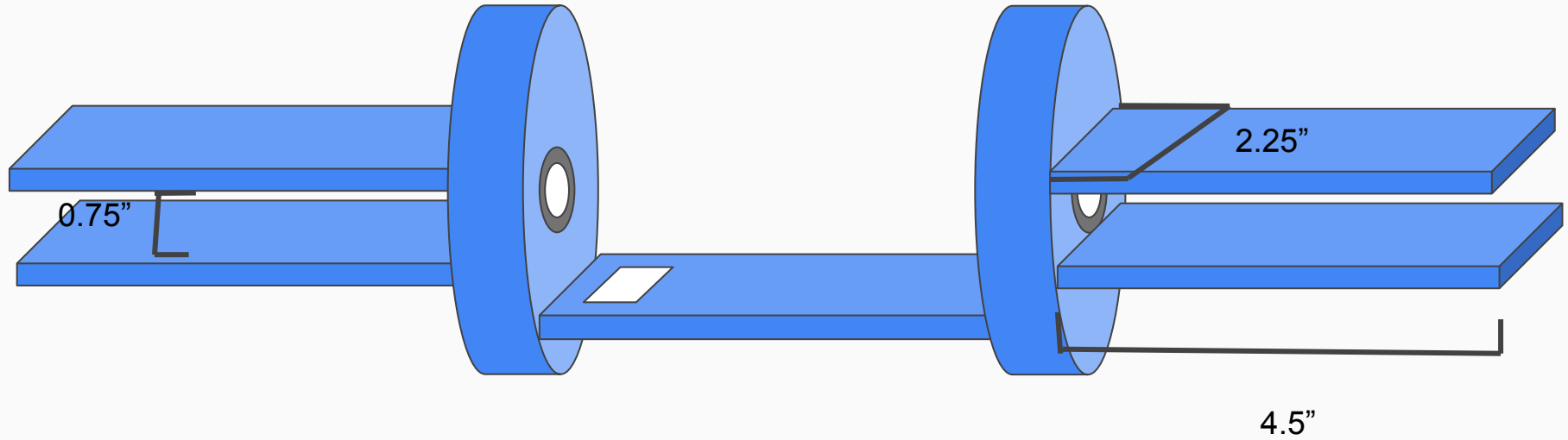
# Engineering Payload

# UAV Carriage



Not to scale

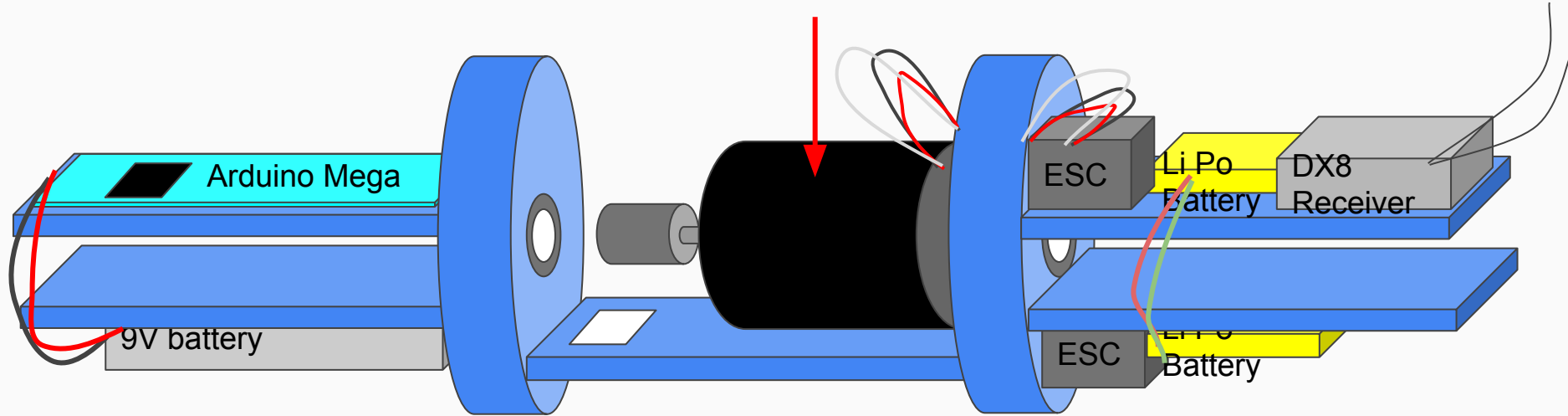
# UAV Carriage



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# UAV Carriage

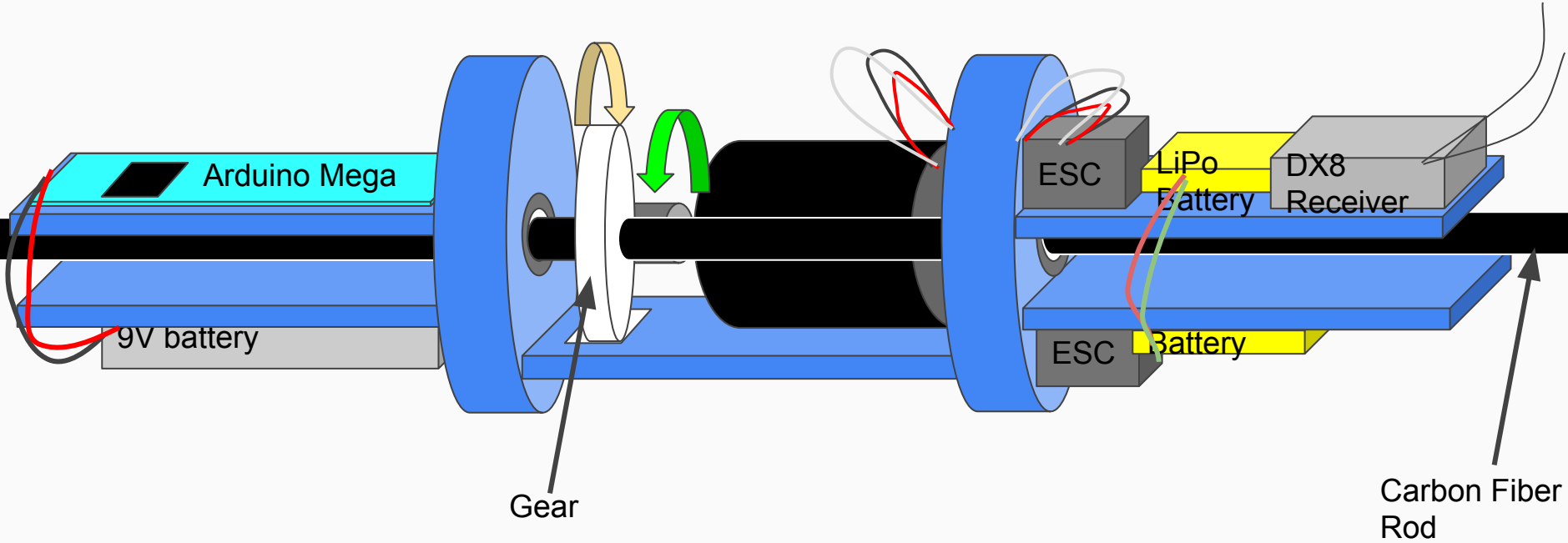
Lift Motor



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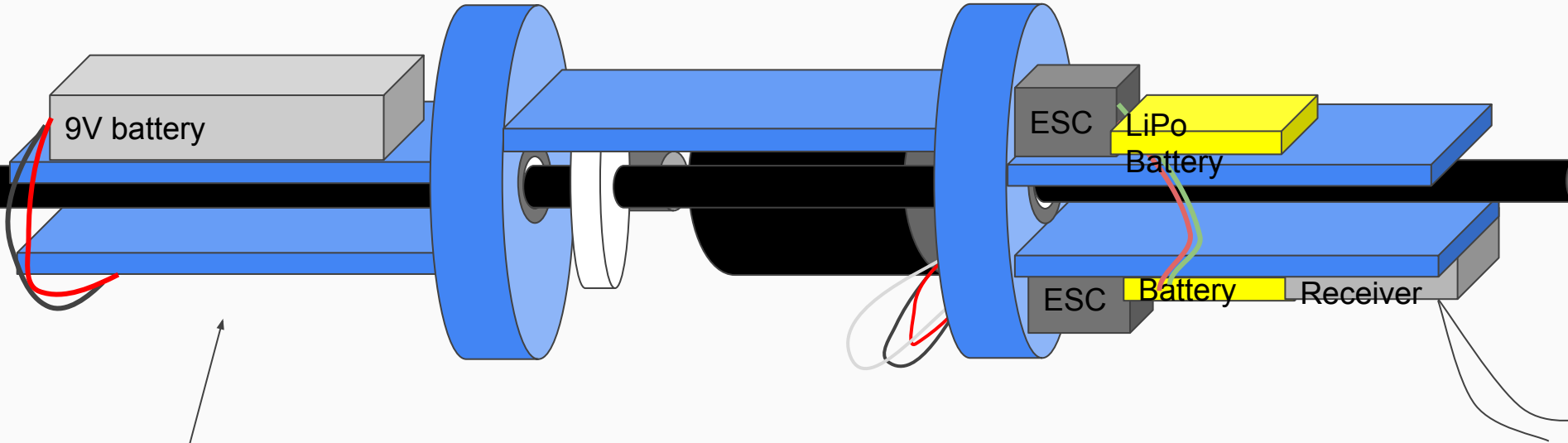


# UAV Carriage



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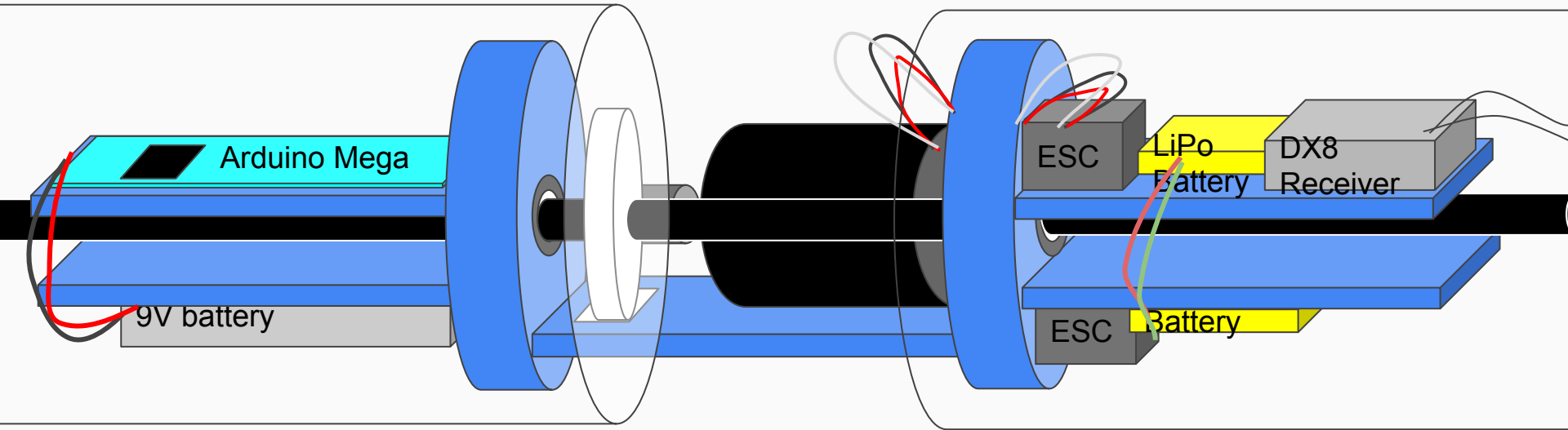
# UAV Carriage (Underside)



Arduino Mega

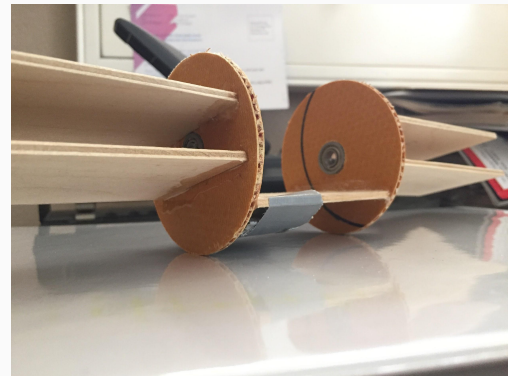
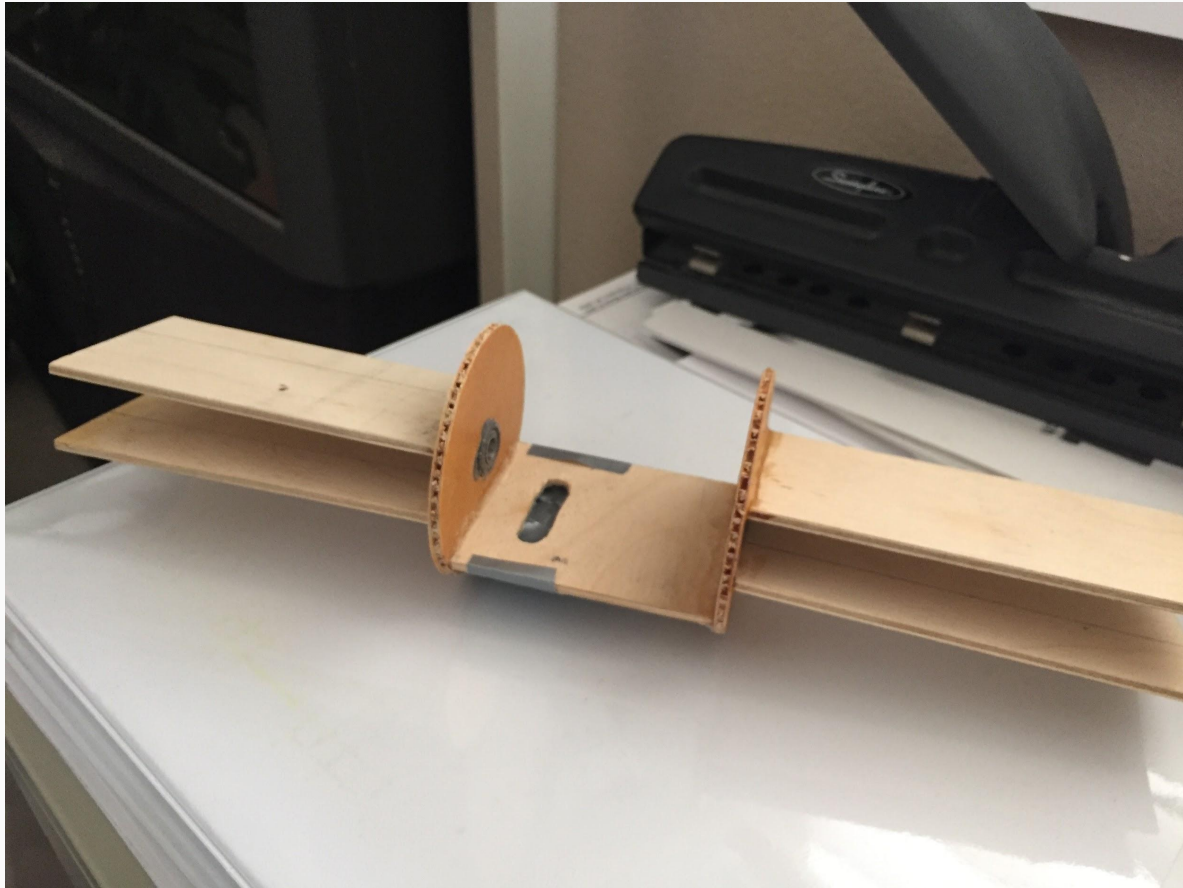
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# UAV Carriage

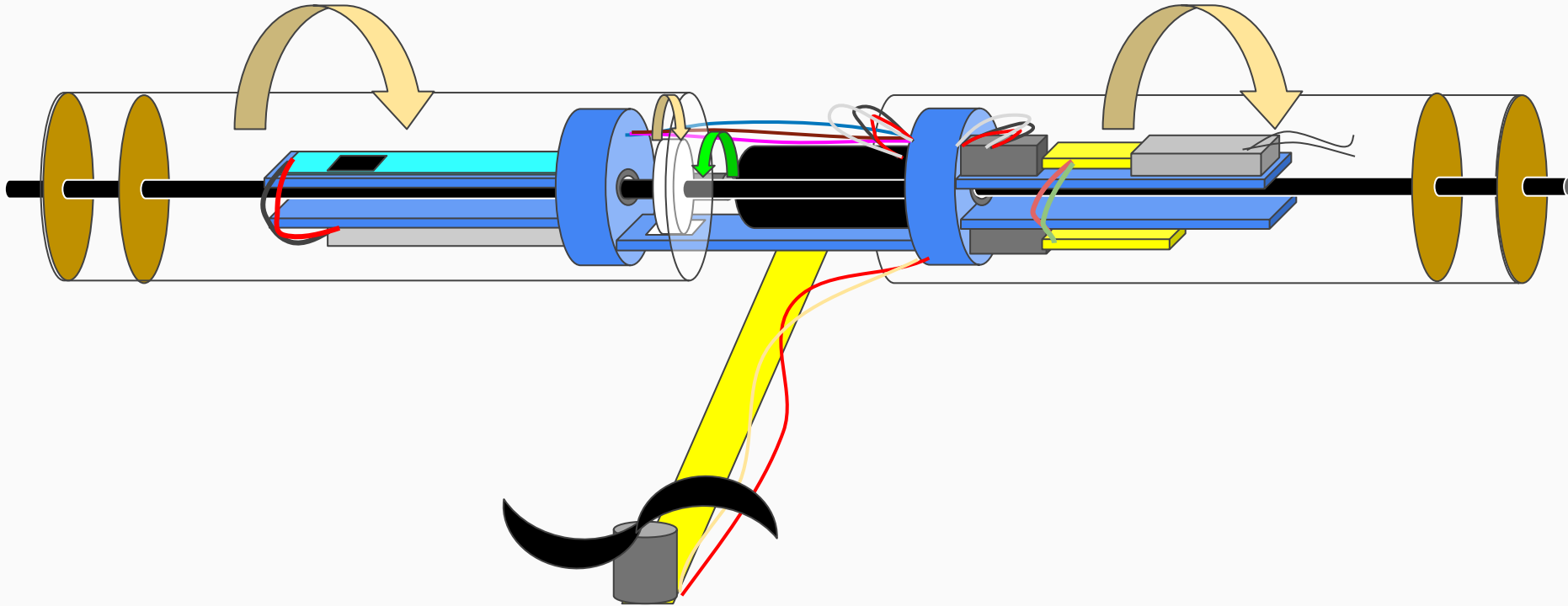


DX8 is responsible

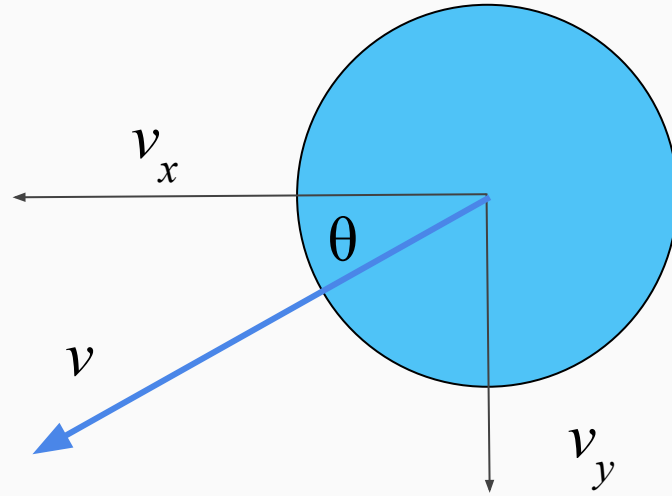
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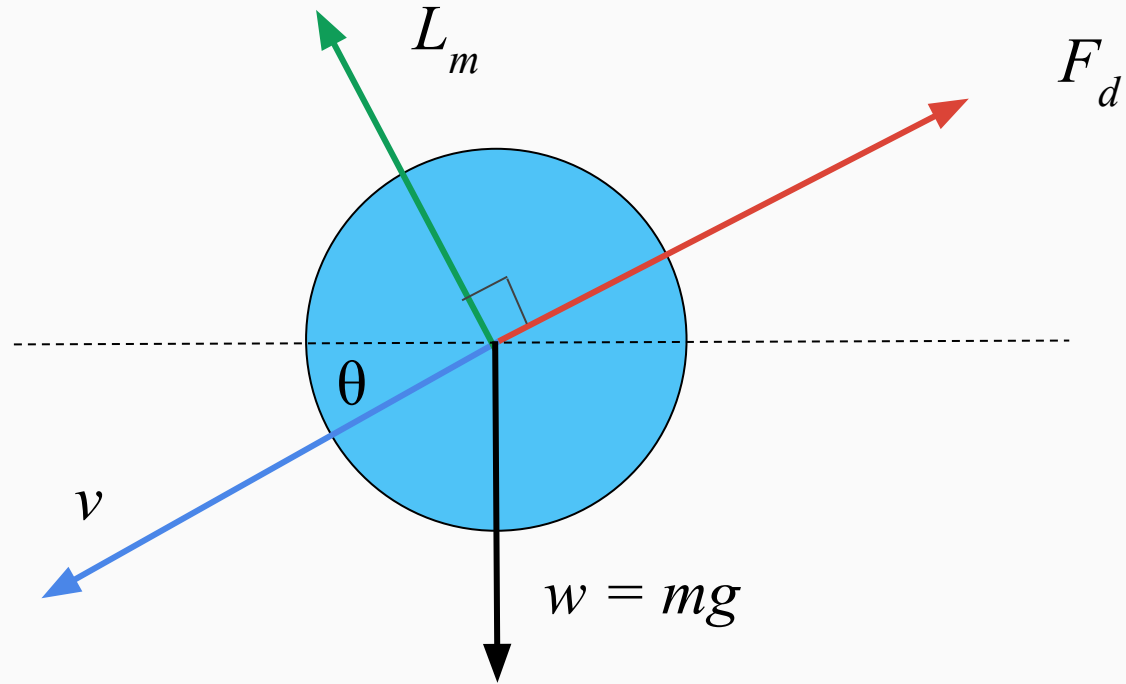


# UAV - Creating Active Lift



Not to scale





$$mg = L_m \cos \theta + F_d \sin \theta$$

$$L_m = \rho 4\pi^2 \omega r^2 VL$$

$$F_d = 2\rho rLV^2 c_d$$

$$mg = (\rho 4\pi^2 \omega r^2 VL) \cos \theta + (2\rho rLV^2 c_d) \sin \theta$$

$$m = \frac{2\rho LrV}{g} [2\pi^2 \omega r * \cos \theta + Vc_d * \sin \theta]$$



**MAIN**

Primary = 700ft  
Secondary = 500gt

Payload = 400ft  
+ Hall Effect

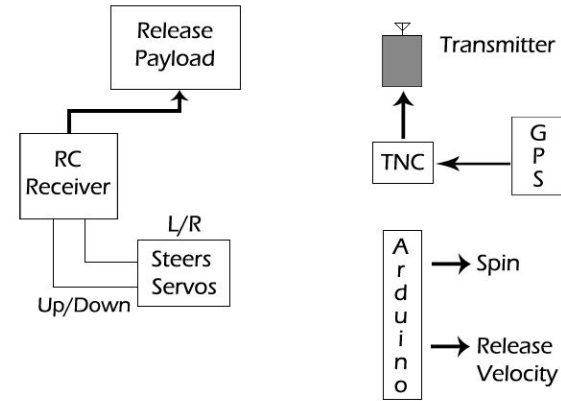
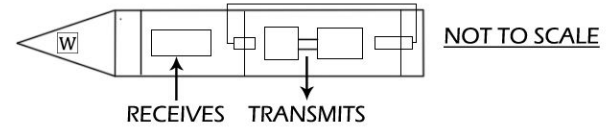
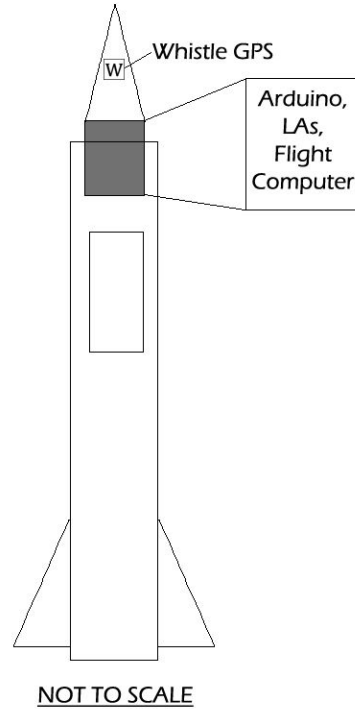
↓  
Shows payload deployment

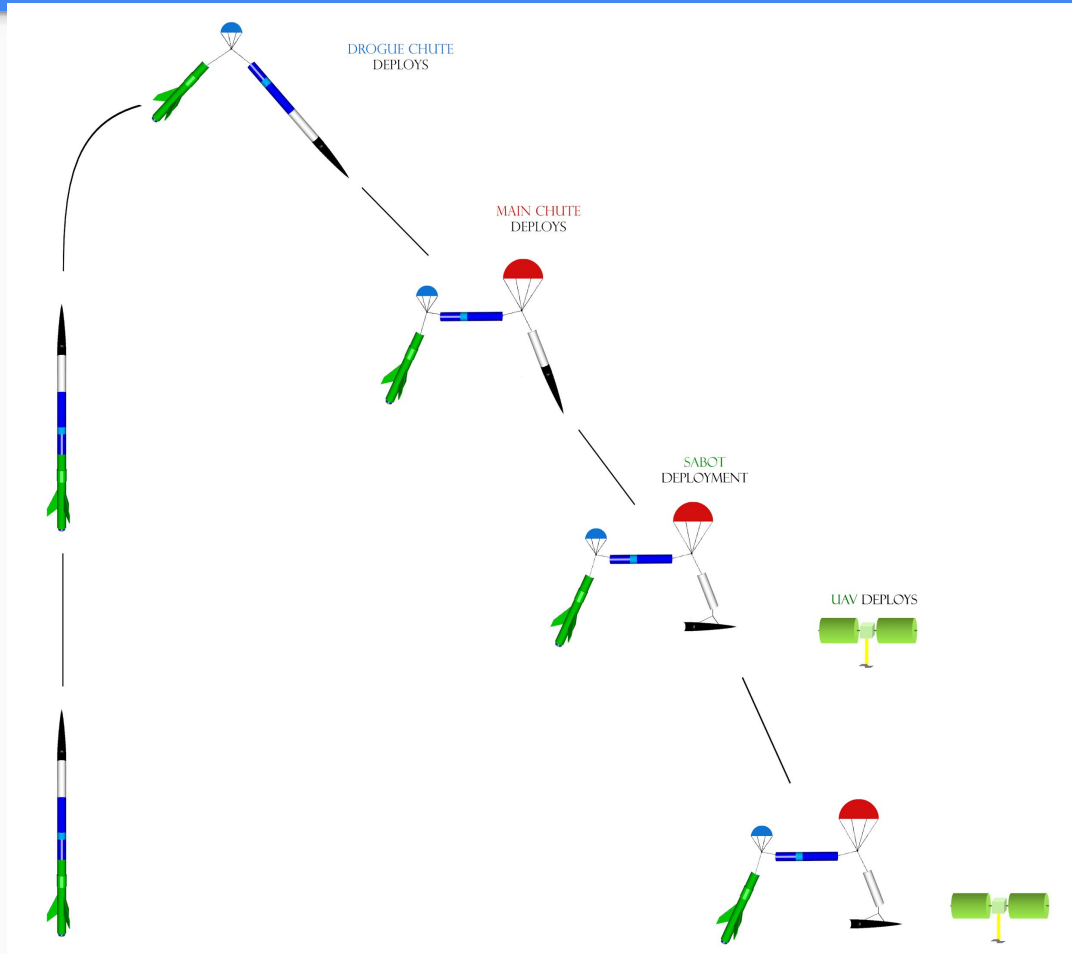
**GROUND STATION**

Baofeng — Mobilinkd — Aprisdroid Compatible Phone

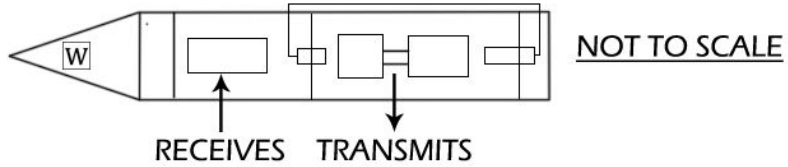
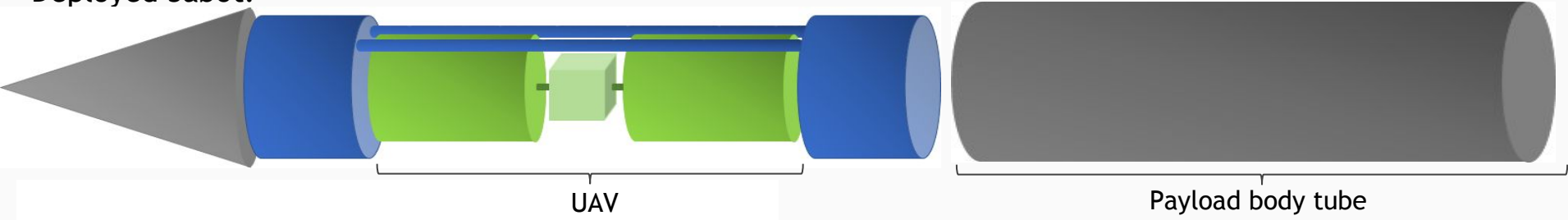
\*How to issue commands to rocket

Addition to Ground Station: TeleDongle (GPS)

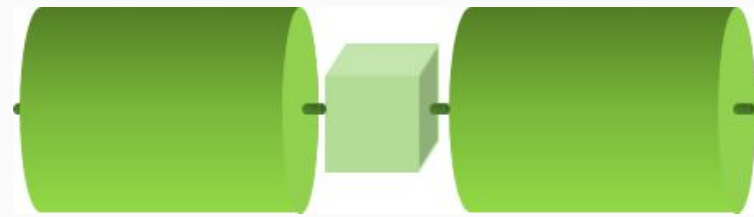


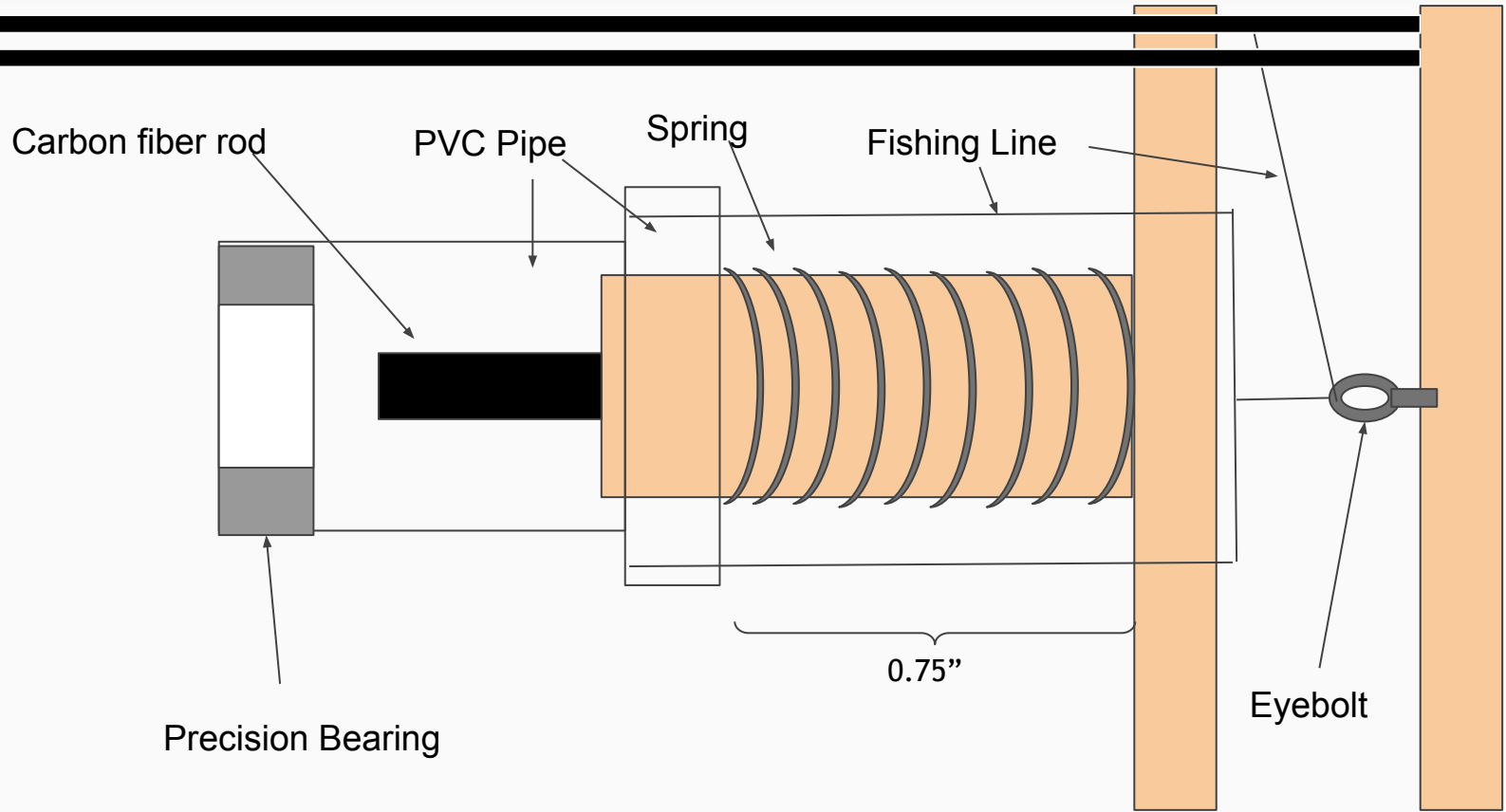


Deployed Sabot:

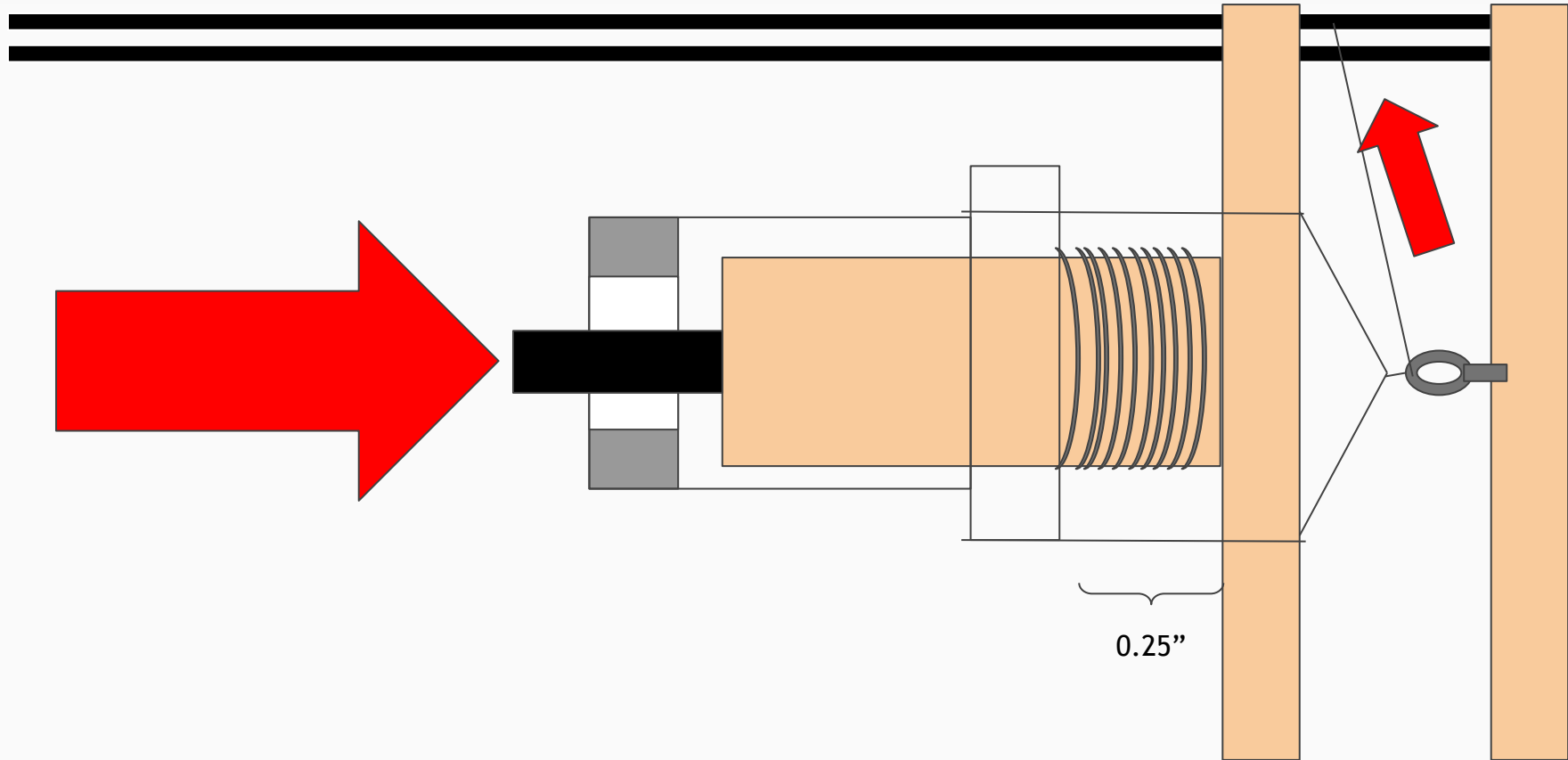


Ballast Arm Removed for Visual Clarity

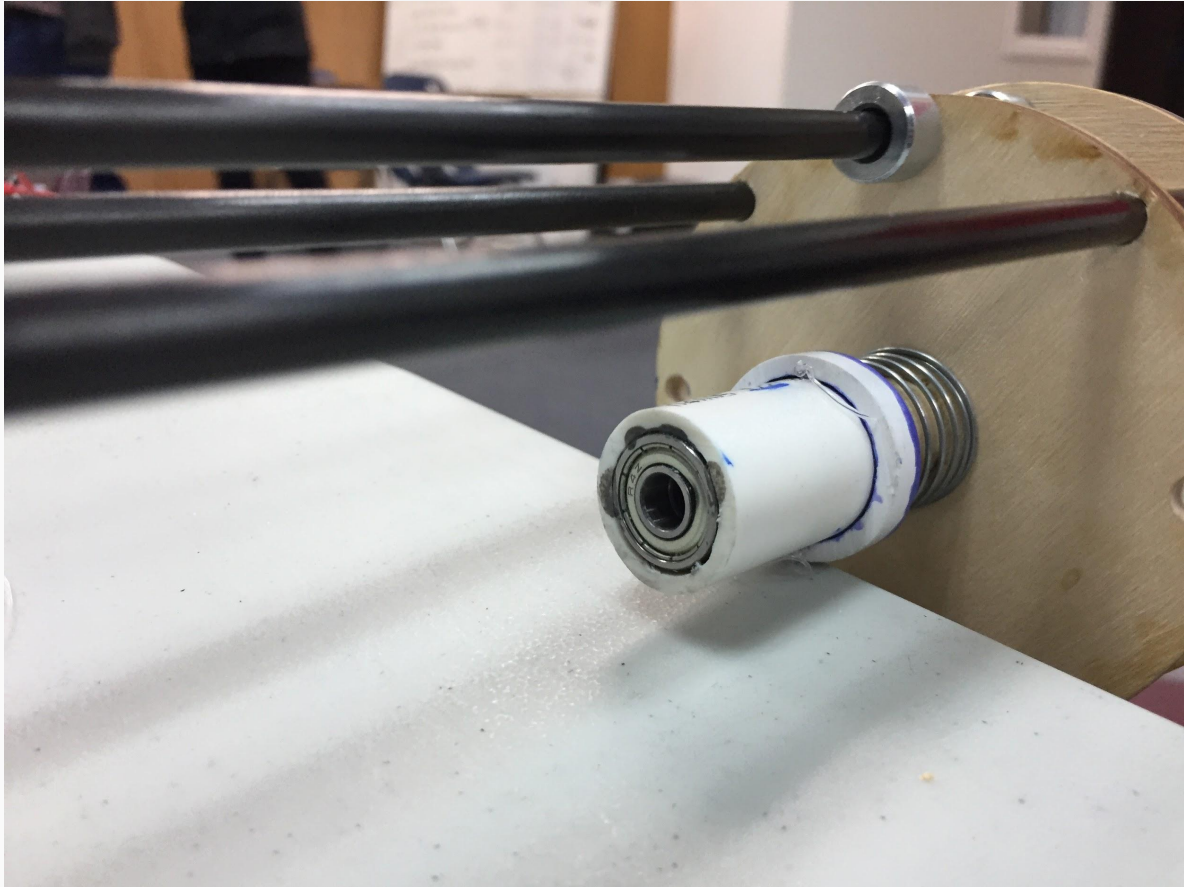




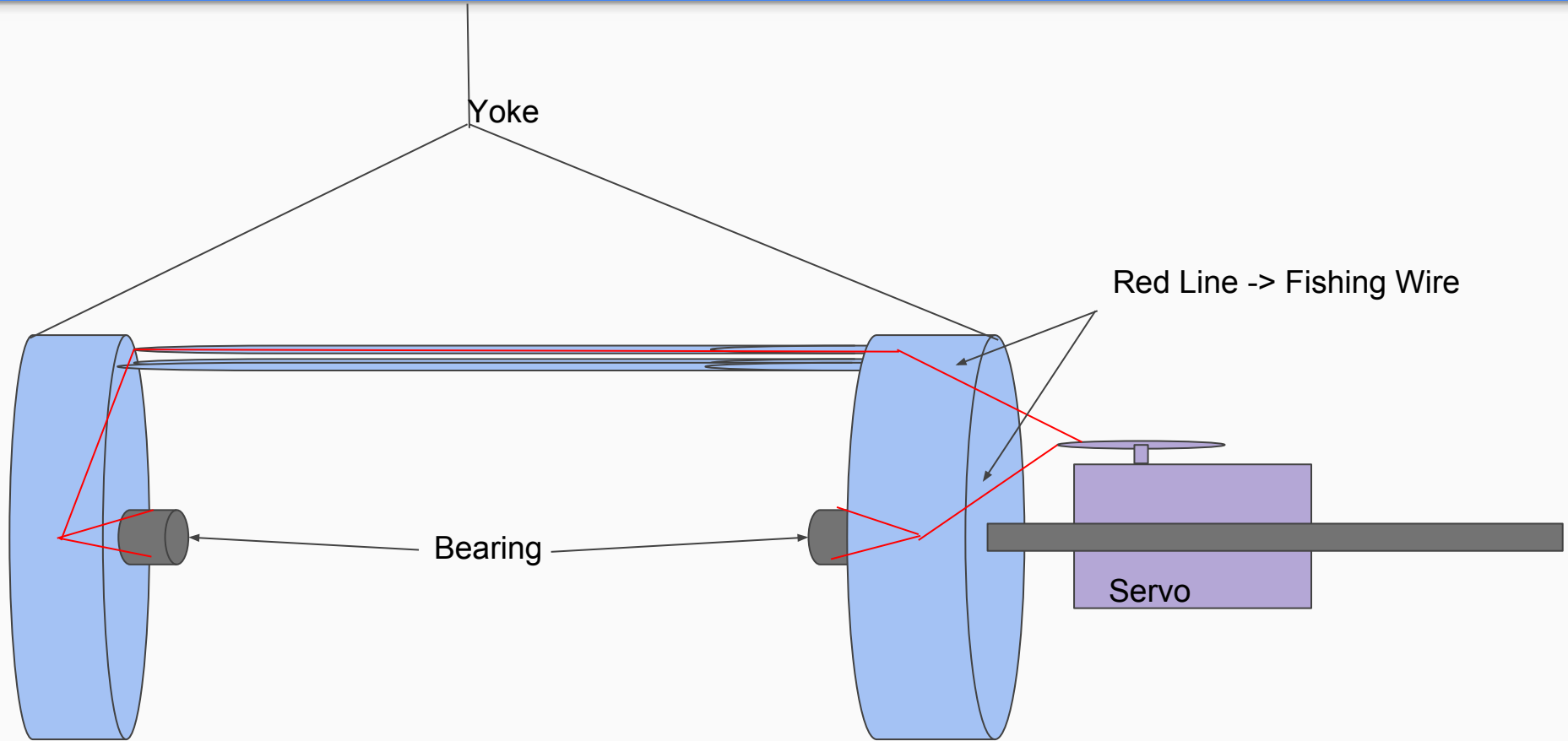
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# Sabot - Release Mechanism

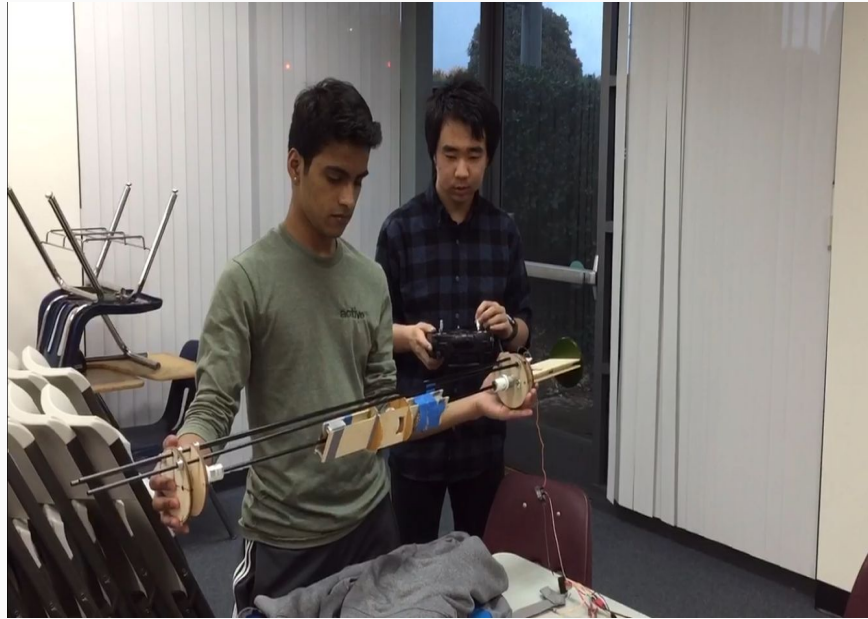


# Sabot

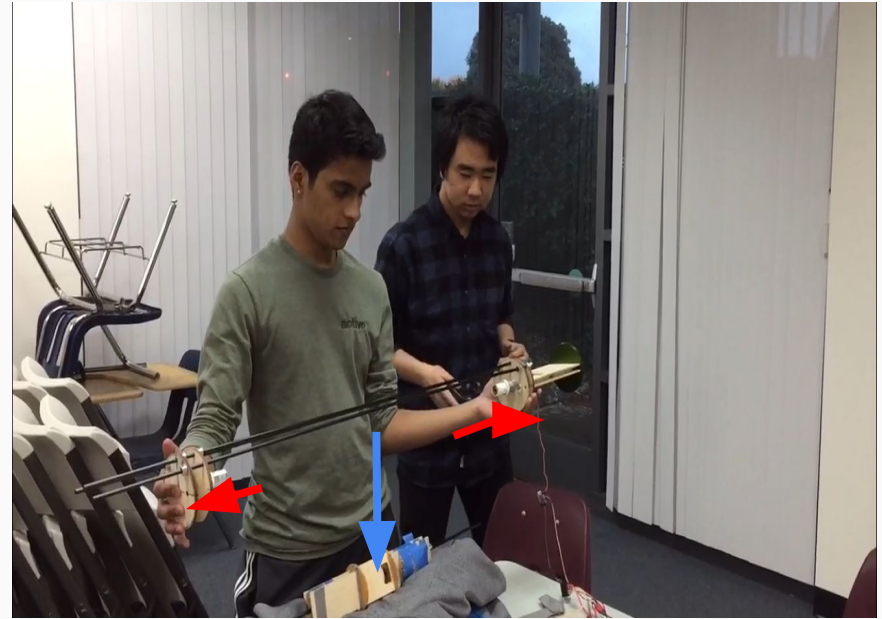




# UAV Disengagement



Before

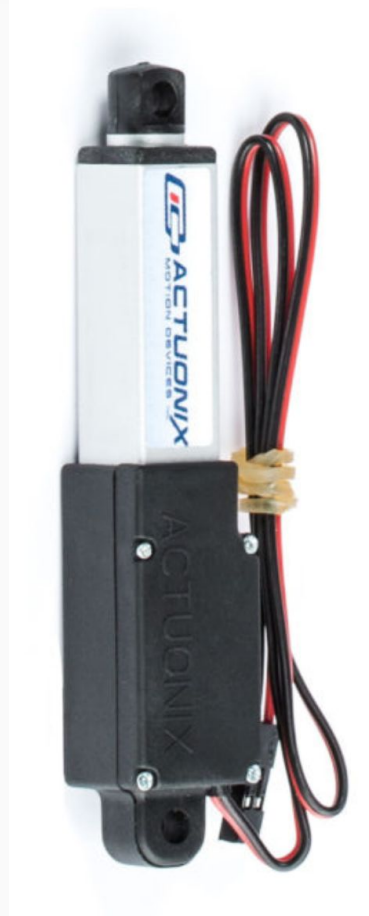


After

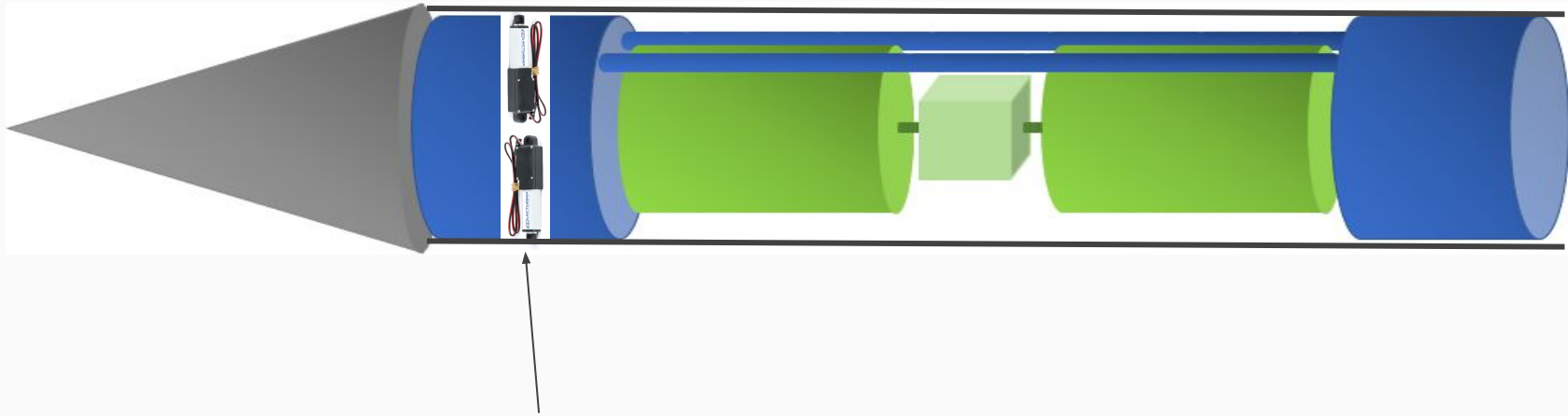
## UAV Disengagement - Video



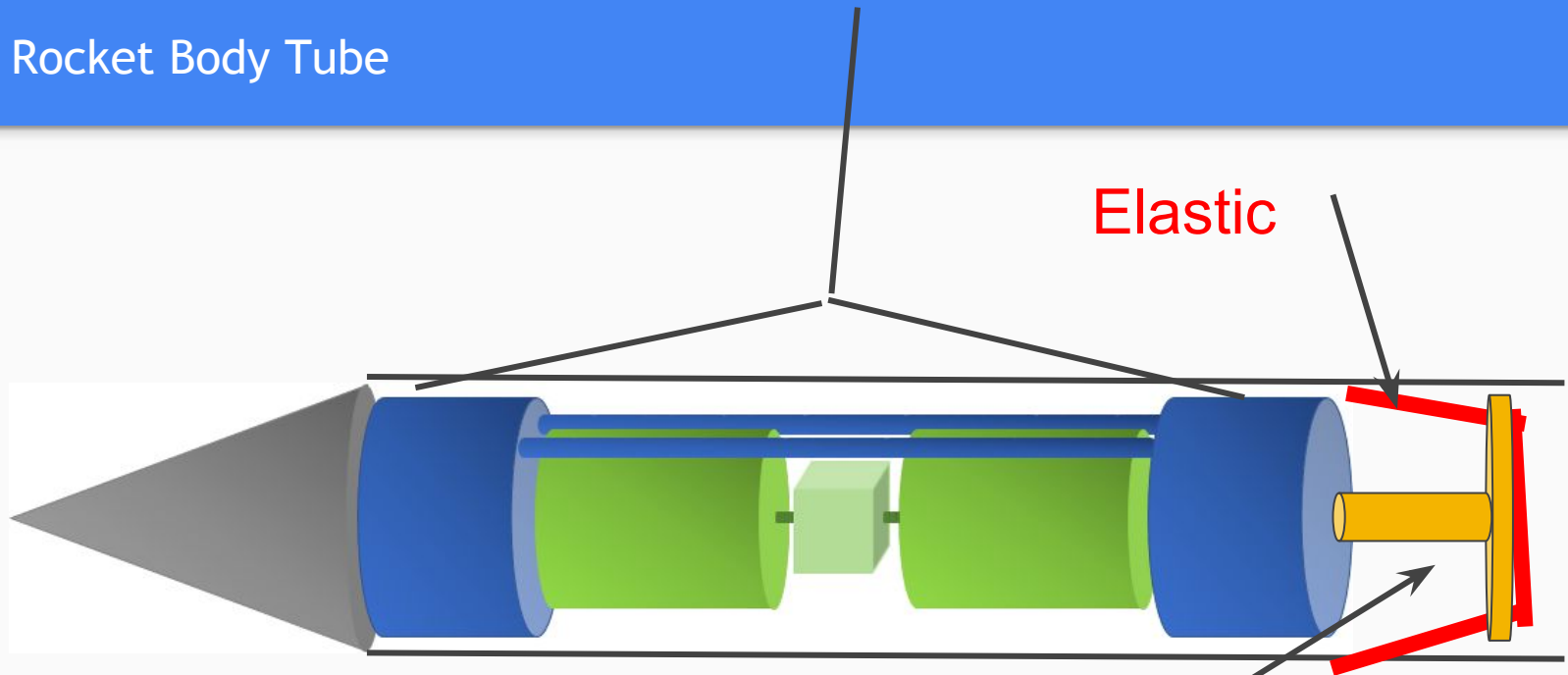
<https://youtu.be/GDfWTki-i4k>



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



Ballast Arm Removed for Visual Clarity

Piston

Not to scale

<p>1. Risk - The engine does not ignite while conducting the launch of the rocket.</p> <p>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.</p>	<p>4. Risk - The rocket body caves in, or collapses on itself.</p> <p>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.</p>	<p>7. Risk - The electronic matches fall out of their designated place.</p> <p>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.</p>
<p>2. Risk - The engine does not fit (too loose or tight) in the motor casing.</p> <p>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.</p>	<p>5. Risk - The quick links are not attached properly.</p> <p>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.</p>	<p>8. Risk: Motor explodes</p> <p>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</p>
<p>3. Risk: Airbrakes do not function while in flight.</p> <p>Mitigation: When electronics are activated at ground level, a test for airbrake function will be performed. The airbrake motors will be checked prior to assembling the whole rocket.</p>	<p>6. Risk - The shear pins do not shear due the ejection charge.</p> <p>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.</p>	<p>9. Parachute was not packed correctly and does not deploy</p> <p>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.</p>

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

# Interfaces



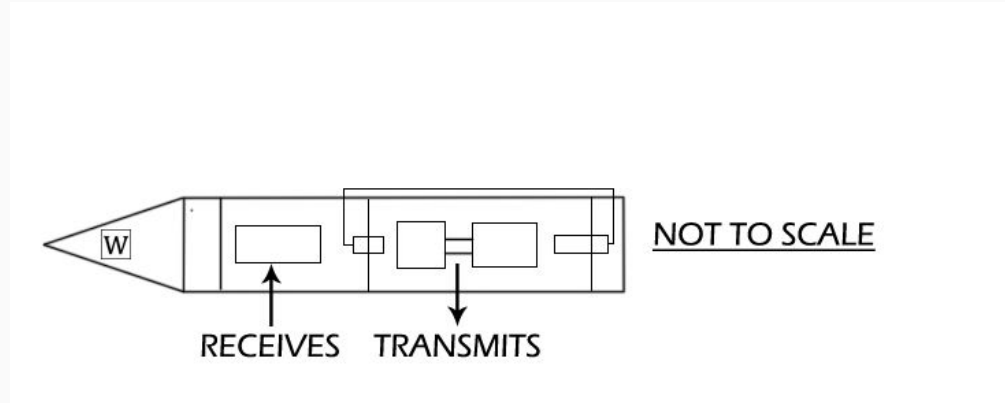
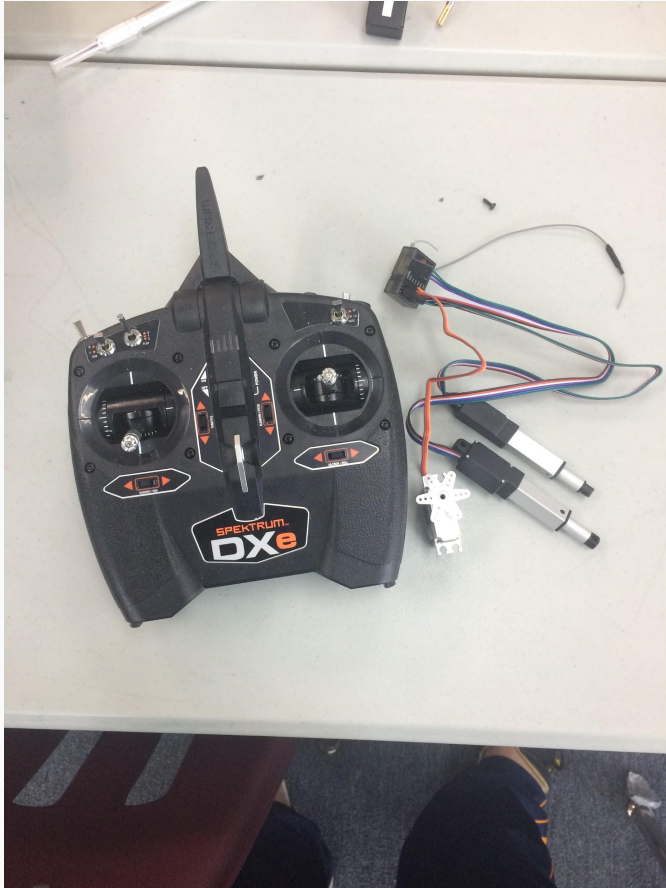


- 2 receivers (frequencies)
- Receiver 1
  - Servo in sabo to release UAV
- Receiver 2
  - Steering left/right in UAV
  - Turn on/off propeller motor
  - Turn on/of lift motor





# DX3 Controls



- Shear Pin Placement
- Screw Placement
- Separation Points

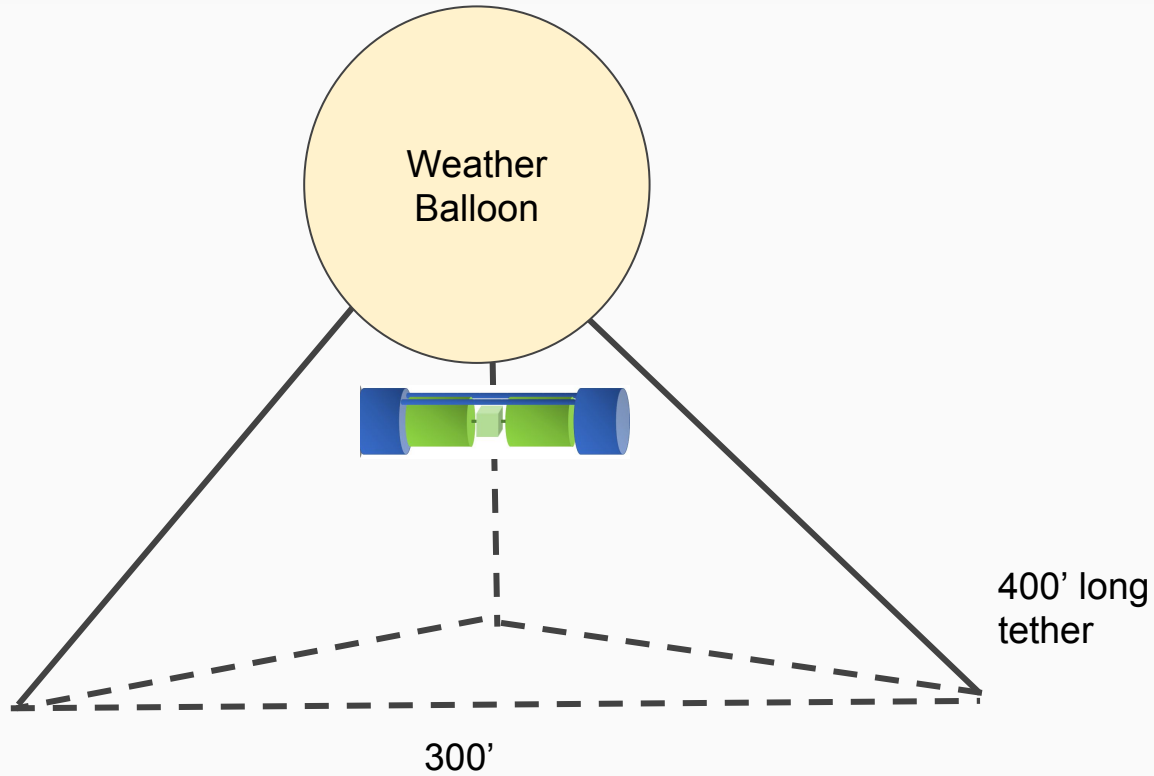


# Tracking

- Whistle GPS for tracking launch vehicle
- TeleGPS for tracking UAV
  - Track via TeleDongle

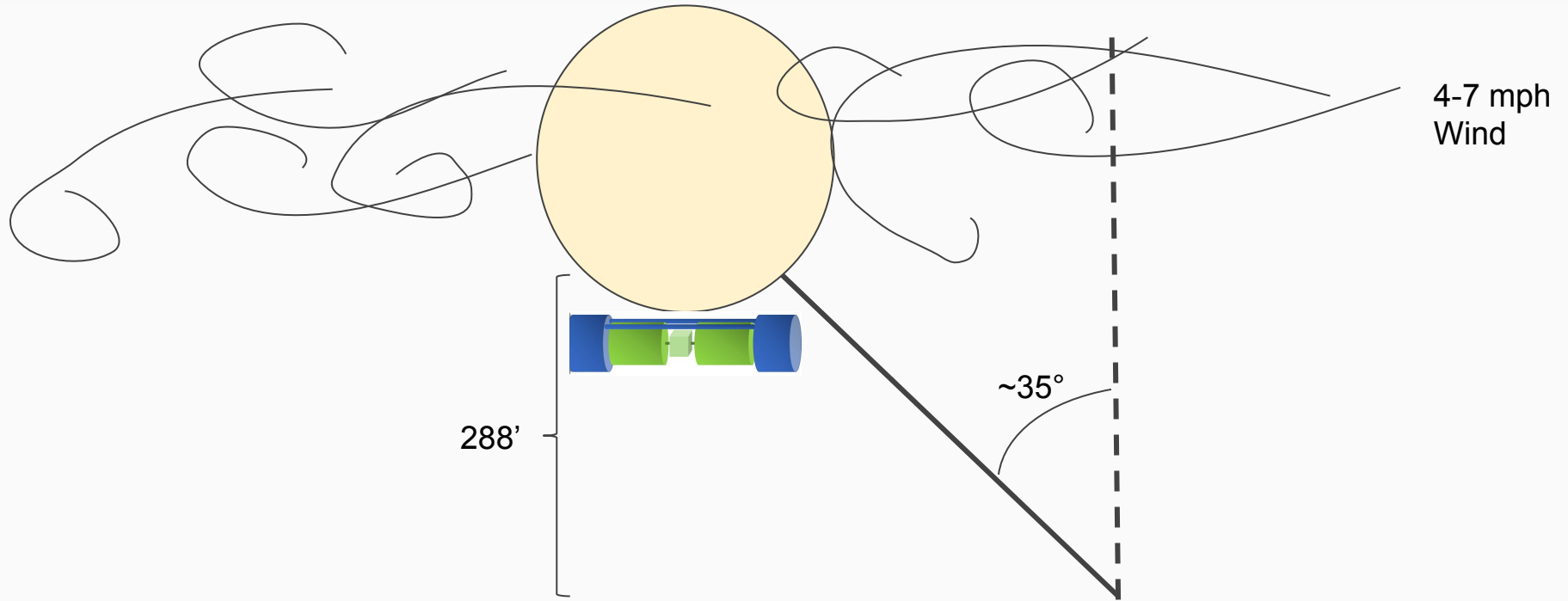
Balloon Test - March 11, 2018

# Balloon Test - March 11, 2018 - Setup



Not to scale

# Balloon Test - March 11, 2018 - Setup



288'

$\sim 35^\circ$

4-7 mph  
Wind

Not to scale

# Ballon Test - March 11, 2018 - Video

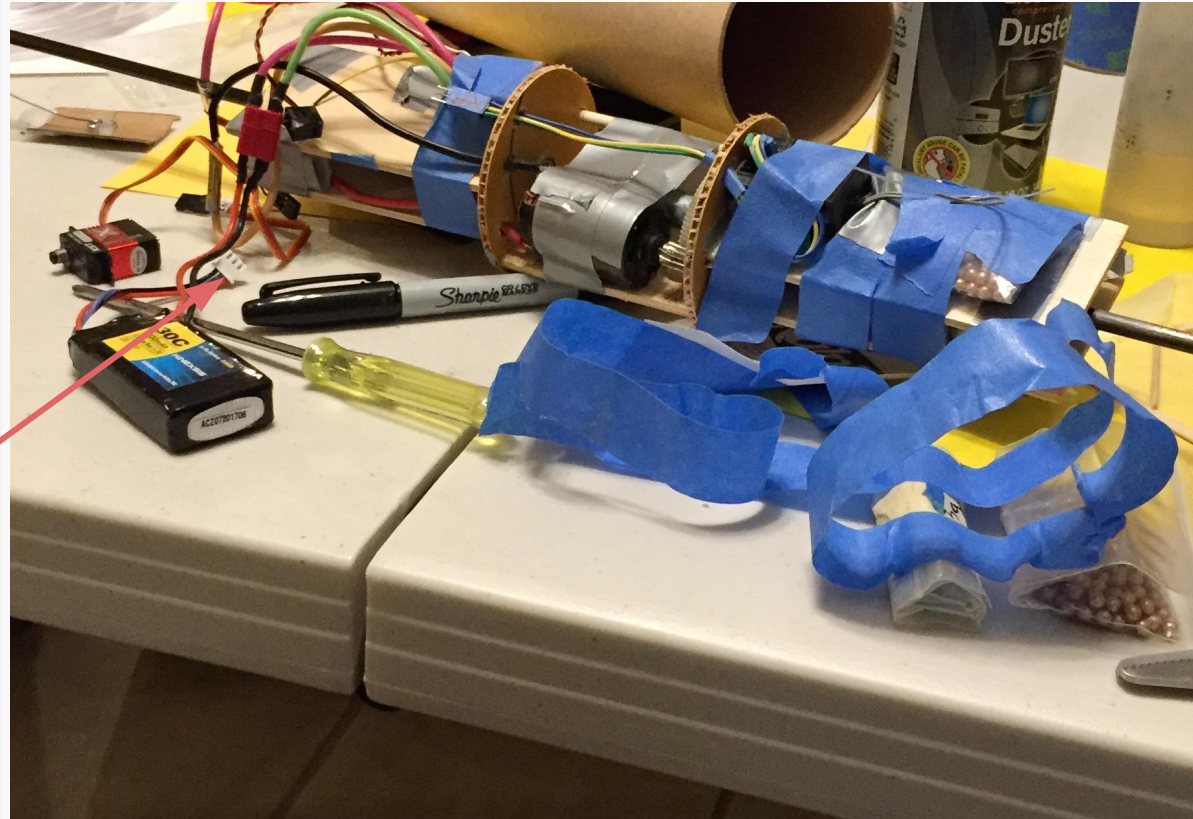


<https://youtu.be/r66m71XxLEw>



# Ballon Test - Results

1. Flight time - 4.23 sec
2. Gear stopped being in contact with lift motor
3. Damage to carriage
4. Minor damage to battery's charging port



Moving Forward

# Issue 1

The Magnus Effect Payload may be unsafe to fly for the final test in SoCal and at Huntsville

# Issue 2

Rocket is Overweight

# Current Design

Payload: Magnus Effect UAV

Length: 144.75"

Rail Exit Velocity: 54.45 fps

Static Stability margin: 4.93

Gross Liftoff Weight: 30.64 lbs or 13900 g

TTW: 4.70:1

Max Altitude: 3734 ft

# Constants used in Mitigations

- 12' 1515 rail
- K661
- Most of the rocket body
- March 4, 2018 flight conditions

# Design Option 1: Shorter Rocket, New Harnesses

Payload: Magnus Effect UAV

Rail Exit Velocity: 54.45 fps

Length: 134.75"

Gross Liftoff Weight: 29.65 lbs

TTW: 4.86:1

Max Altitude: 3986 ft

3' Tubular nylon, 22' Kevlar



# Design Option 2: Shorter Rocket, Passive CanSat

Payload: CanSat

Rail Exit Velocity: 56.68 fps

Length: 134.75"

Gross Liftoff Weight: 28.68 lbs

TTW: 5.03:1

Max Altitude: 4208 ft

Constraints of CanSat: max 400 g; 4" OD x 12" Length; no active lift



# Design Option 3: Shorter Rocket, Active CanSat

Payload: CanSat

Rail Exit Velocity: 56.68 fps

Length: 130.75"

Gross Liftoff Weight: 28.26 lbs

TTW: 5.03:1

Max Altitude: 4208 ft.

# Design Option 4: Even Shorter Rocket, Passive CanSat, New Harnesses

Payload: CanSat

Rail Exit Velocity: 57.79 fps

Length: 120.75"

Gross Liftoff Weight: 27.68 lbs

TTW: 5.20:1

Max Altitude: 4455 ft

# Design Option 5: Even Shorter Rocket, Active CanSat, New Harnesses

Payload: CanSat

Rail Exit Velocity: 57.79 fps

Length 120.75"

Gross Liftoff Weight: 27.68 lbs

TTW: 5.20:1

Max Altitude: 4455 ft.

# Summary of Mitigation for Issues

<b>Change</b>	<b>Benefit</b>
Change to CanSat	600 g lighter
Change Recovery Harness	160 g lighter
Shorten Main Chute Tube (26" to 16")	290 g lighter
Shorten Payload Housing Tube (38" to 24")	292 g lighter

# Test Plan for New Design

- Fly Lighter weight rocket meeting the 5:1 TTW at FAR this Sat.
  - CanSat will have partial electronics and ballasts to maintain the stability margin
- No new changes will be made between this saturday and the huntsville flight
- If time permits, payload electronics will be include RC control, with a second balloon test before huntsville

Thanks! Questions?