# Tacho Lycos
# CDR Presentation

January 14, 2019

# Overview

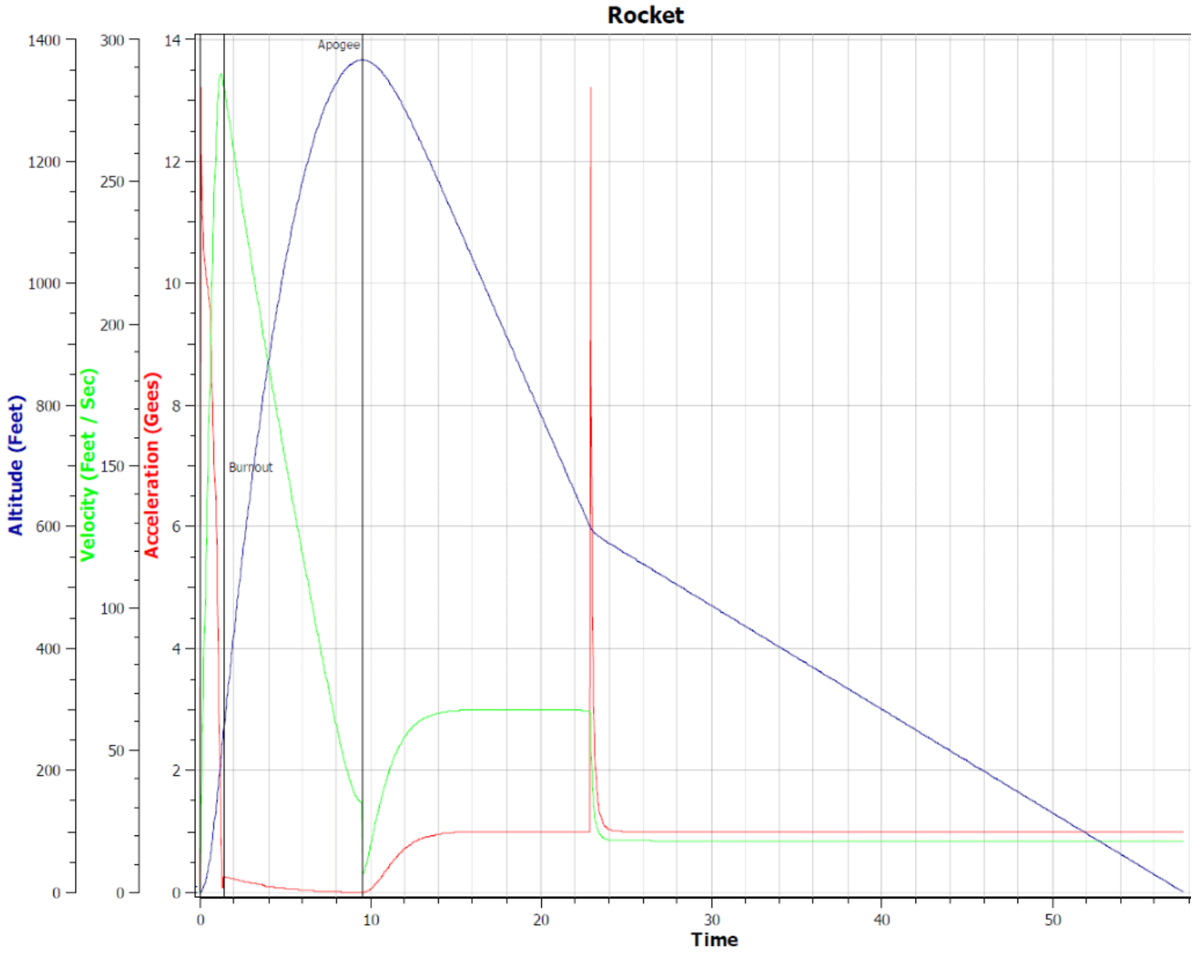
- Subscale Launch Results
- Vehicle Design
- Propulsion
- Structures
- Recovery and Avionics
- Payload
- Requirements Verification

# Subscale Launch Results

# Launch Overview

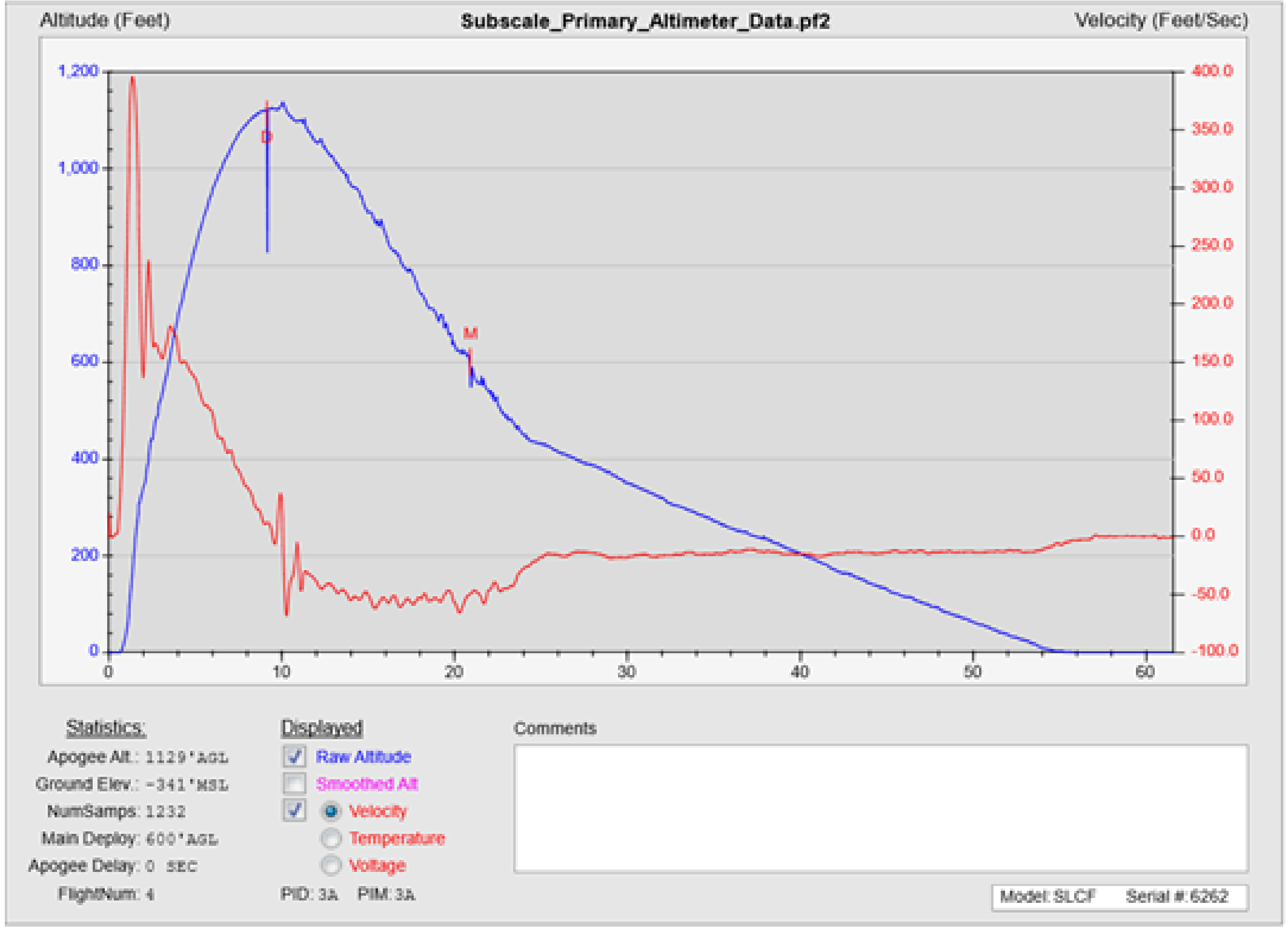
- Subscale sized based on PDR leading alternative
- Body diameter of 4 inches
- Launched Nov 17 in Bayboro, NC with average windspeed of 4.3 mpg
- Used an 8 ft 1515 rail set at 5 deg downrange
- RockSim predicted apogee of 1366 ft, max velocity of 73 fps, drogue parachute descent rate of 64 fps, and main parachute descent rate of 17 fps

# RockSim Simulation



# Flight Results

- Apogee: 1129 ft
- Max velocity: 400 fps
- Drogue descent rate: 53 fps
- Main descent rate: 17 fps
- Apogee difference of ~15% likely due to weathervaning



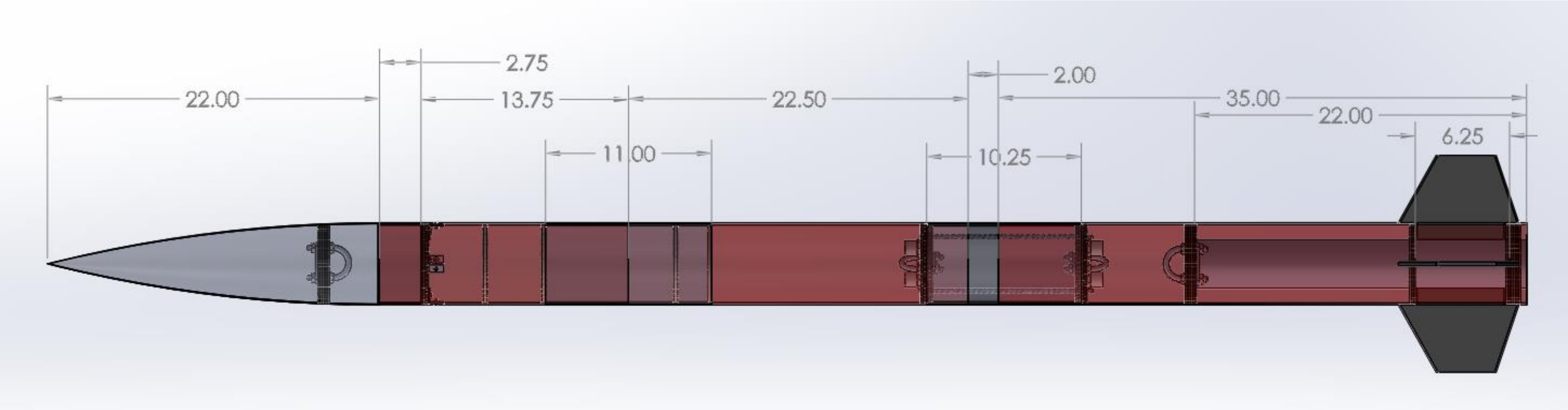
# Impact to Full-Scale Design

- Increased fin area to prevent low altitude weathervaning
- Reduced payload mass budget
- Change of motor due to decreased mass
- Addition of ballast at CG due to change of motor

# Vehicle Design

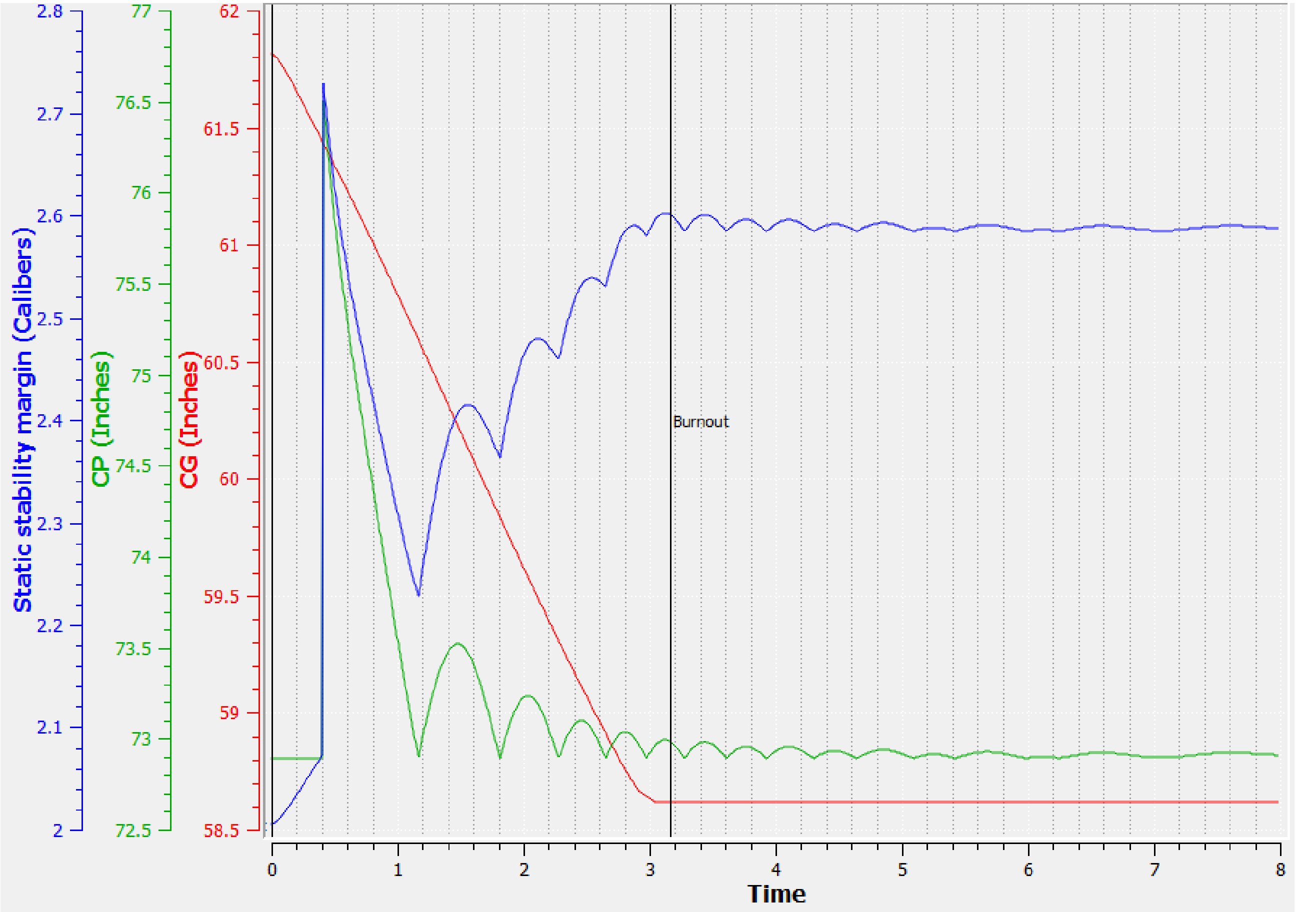
# Dimensions

- Length: 99 in
- Diameter: 5.5 in
- Body Material: Fiberglass
- Launch weight: 41.9 lb
- Empty weight: 37.8 lb
- Weight of ballast: 0.2 lb



# Aerodynamics

- CP: 72.89 in
- CG: 61.81 in
- Stability margin on launch rail: 2.01



# Mass Margin

- The nominal mass of the launch vehicle is 41.9 lb
- The mass margin for the launch vehicle is 43.5-41.3 lb
  - Complies with team derived requirement for apogee range

# Propulsion

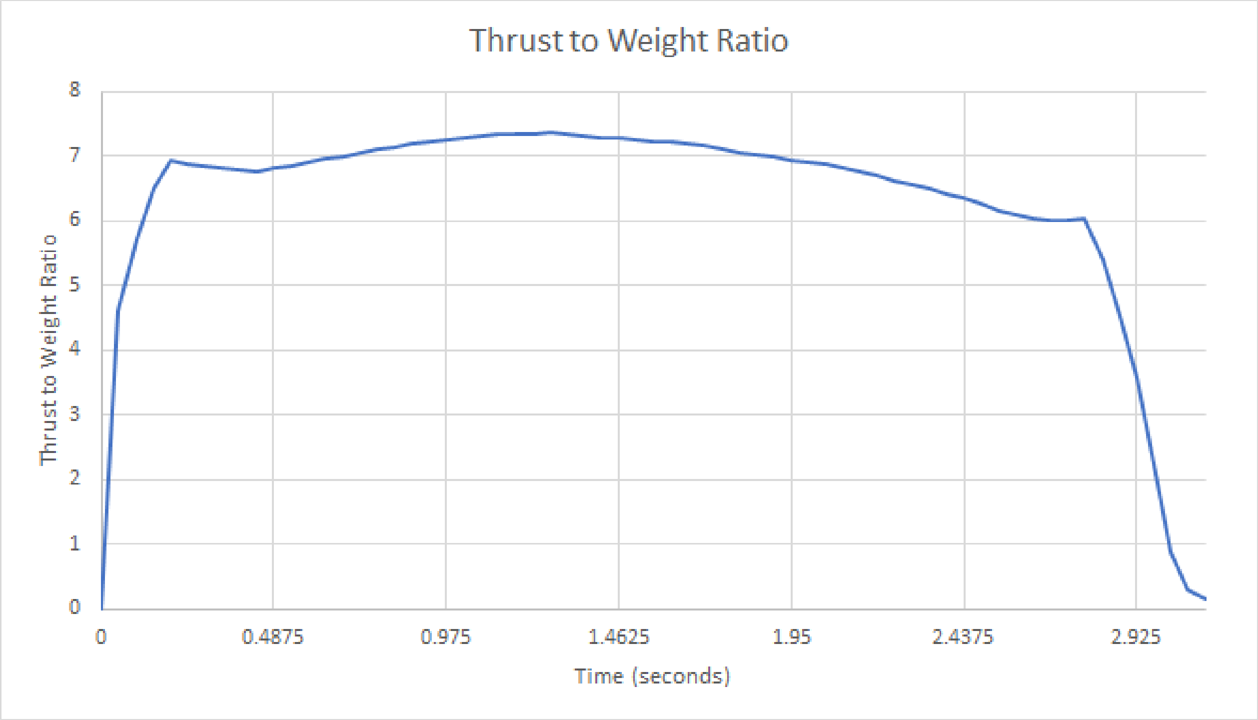
# Motor Selection

- Payload weight reduction required lower impulse motor
- Motor is now Aerotech L1150R

| Wind Speed (mph) | Apogee (ft) |
|---|---|
| 0 | 4165 |
| 5 | 4112 |
| 10 | 4033 |
| 15 | 3930 |
| 20 | 3804 |

# Motor Performance

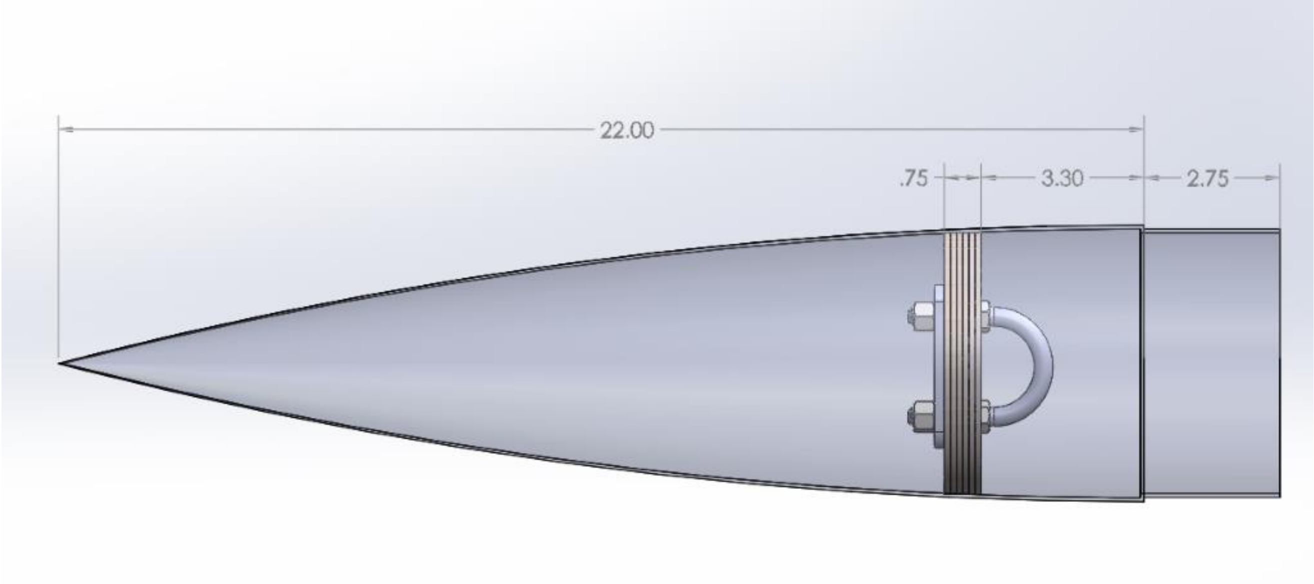
- Thrust to Weight Ratio at rail exit: 6.8
- Rail Exit Velocity: 66 fps



# Structures

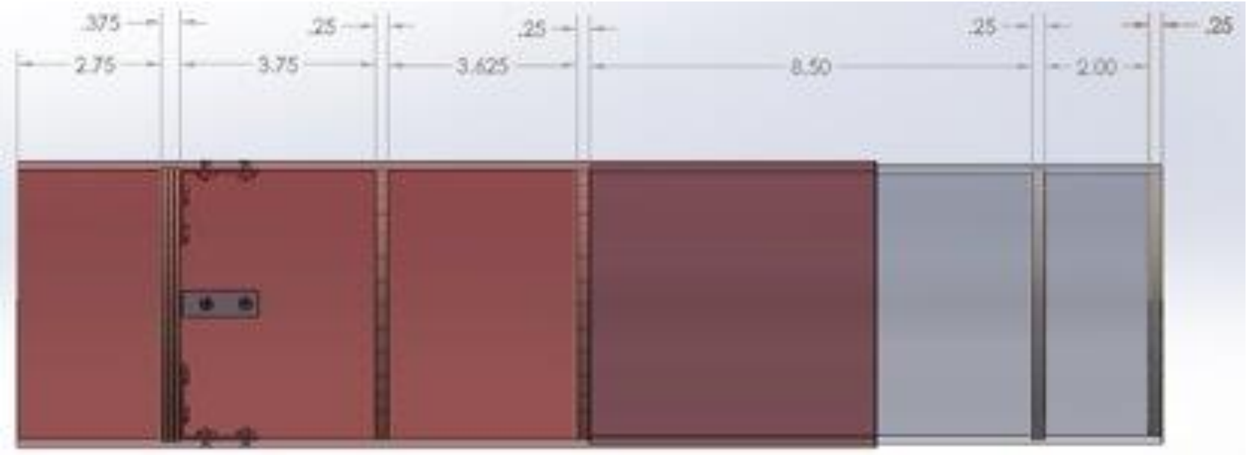
# Nosecone

- Fiberglass
- Permanent bulkhead
  - Recessed approximately 6.05 inches from shoulder
  - 0.75 inch thick
  - Will have U-bolt installed for attachment to main parachute
  - FoS of 2.36
- 4:1 ogive shape
- Testing will be done on this configuration



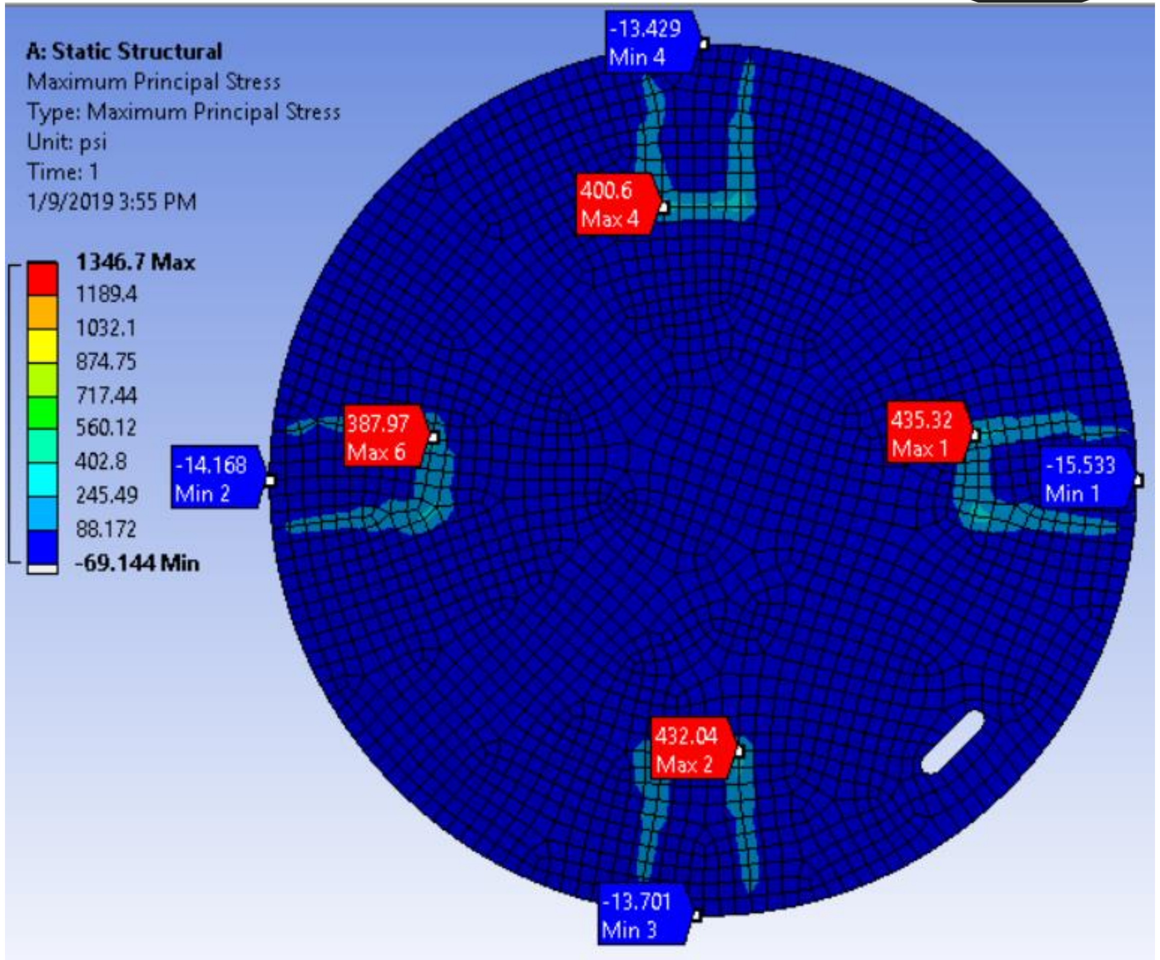
# Payload Bay

- Removable bulkhead mounted on L-brackets located 2.75 inches from forward end
- Four centering rings distributed throughout to support payload pod
- Shock cord to main parachute routed through bulkhead and centering rings



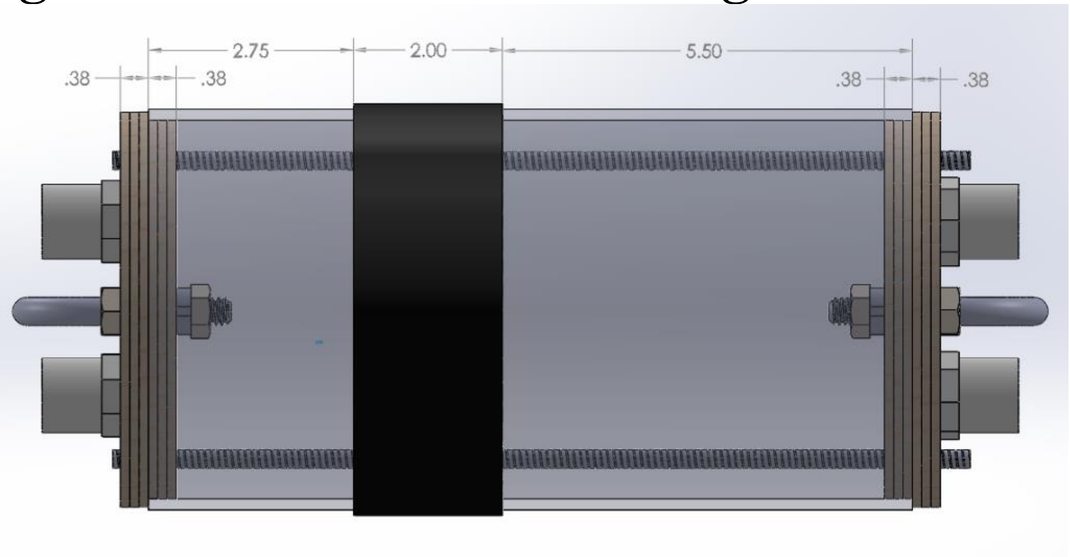
# Payload Bay Bulkhead

- Mounted on four evenly distributed L-brackets – each flange 1 x 0.5 inch
- L-brackets attached to bulkhead and body using #6-32 stainless steel screws
- FoS of 2.3
- Will support payload deployment system



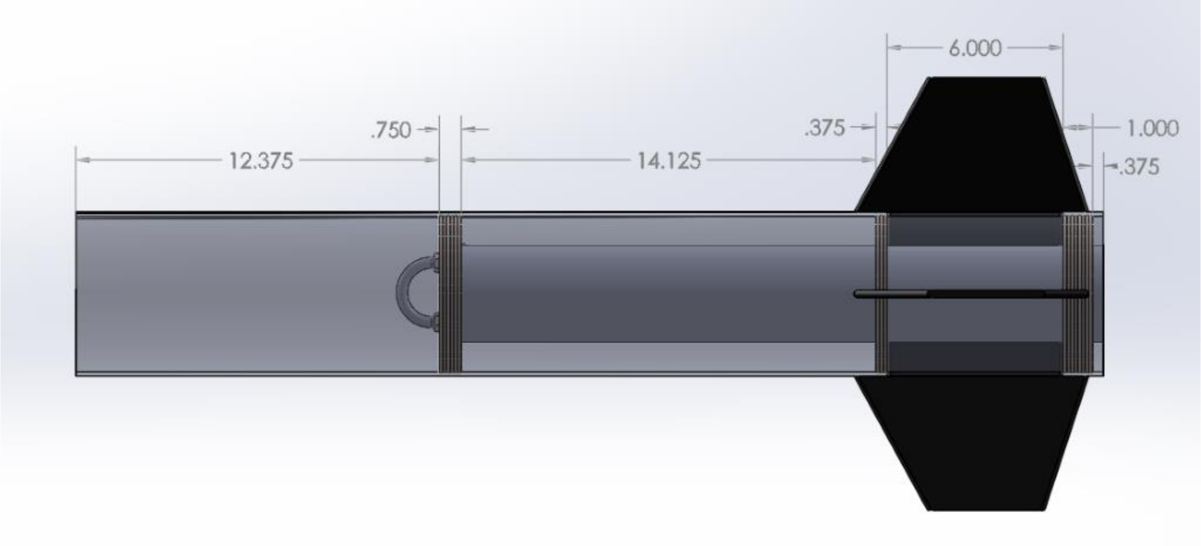
# AV Bay

- 10.25 inch coupler section with 2 inch body tube section
- Bulkheads have 3 layers matching body ID and 3 layers matching coupler ID
  - Will each have a U-bolt securing either the main or drogue parachute
  - FoS of 2.64
- Two ¼ inch threaded rods secure bulkheads and AV sled



# Fin Can

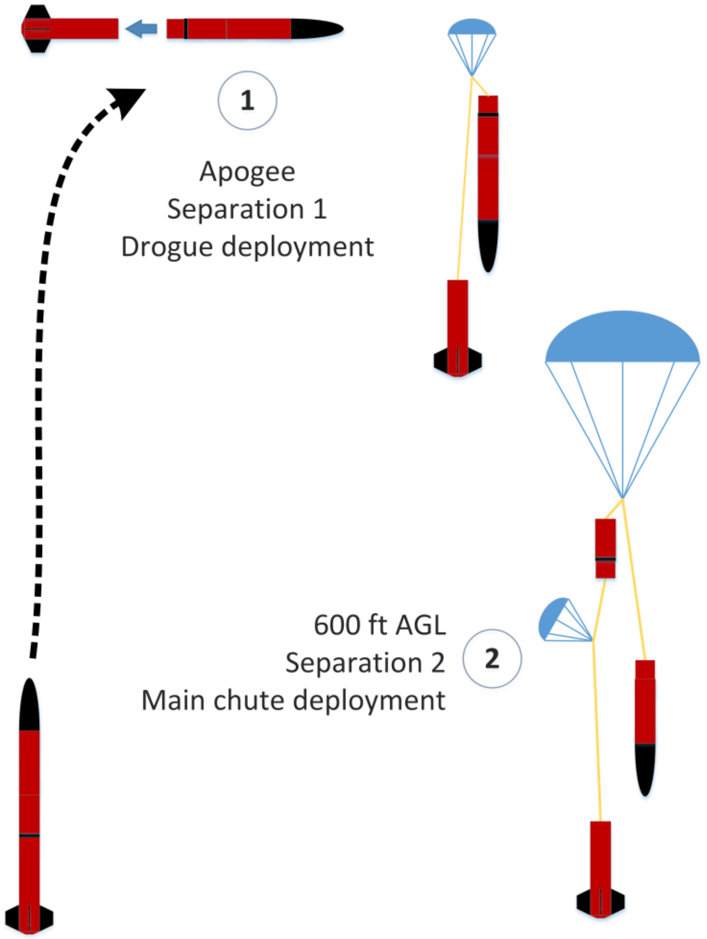
- 12.5 inch section to house drogue parachute
- Motor tube secured by 1 inch thick engine mount recessed 0.375 inch into aft end of fin can
- 0.375 inch thick centering ring and 0.75 inch thick bulkhead
- U-bolt in bulkhead that is secured to drogue parachute



# Recovery and Avionics

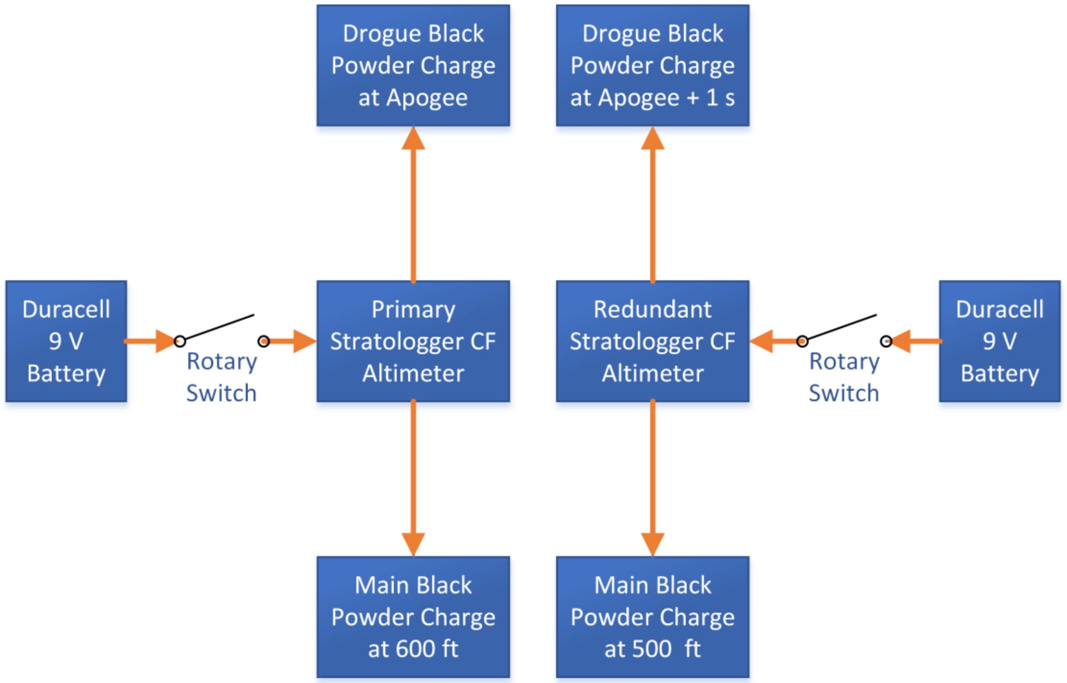
# Recovery Overview

- Drogue deployed at apogee
  - Redundant charge at apogee + 1 second
- Main parachute deployed at 600 ft AGL
  - Redundant charge at 550 ft AGL



# Avionics

- Dual-redundant recovery avionics system
- Primary and redundant PerfectFlite StratoLoggerCF altimeters
- Primary altimeter deploys drogue at apogee and main at 600 ft AGL
- Redundant altimeter deploys drogue at apogee + 1 second and main at 550 ft AGL

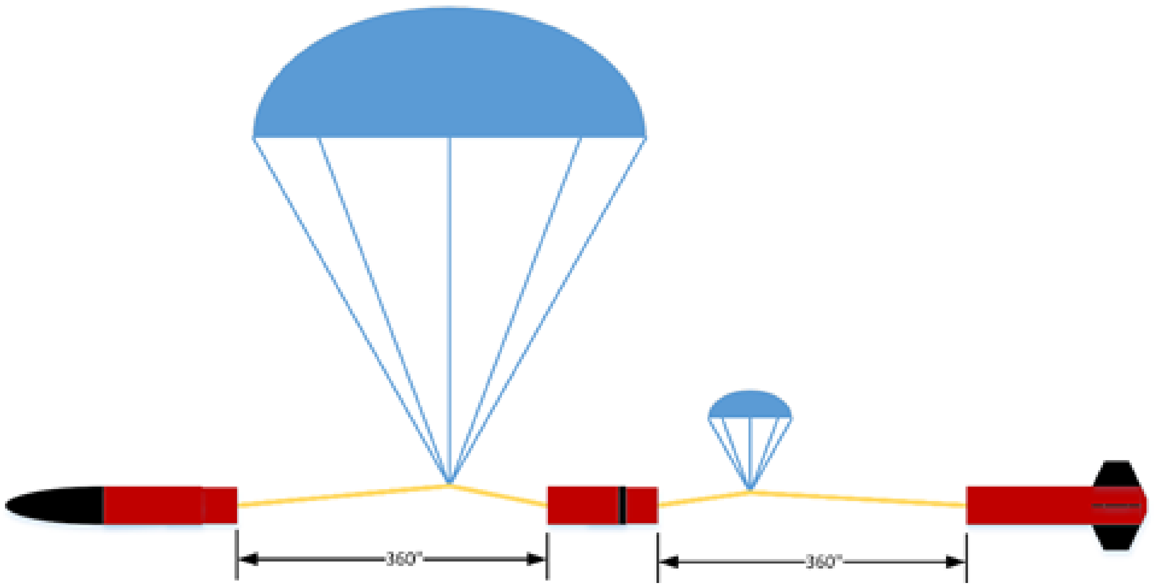


# Parachutes

- **Drogue:** 24 inch Fruity Chutes Compact Elliptical
  - Diameter: 24 inches
  - Drag coefficient: 1.47
  - Descent velocity: 79 ft/s
- **Main Parachute:** 84 inch Fruity Chutes Iris UltraCompact
  - Diameter: 84 inches
  - Drag coefficient: 2.10
  - Descent velocity: 17 ft/s

# Recovery Harness

- 5/8 inch tubular Kevlar
- Rated for 2000 lb
- The length of cord between the tethered sections for both the drogue and main is 360 inches



# Wind Effect on Apogee, Descent Time, and Drift

| Wind Speed | Apogee | Descent Time | Drift Distance |
|---|---|---|---|
| 0 mph | 4311 ft AGL | 79 s | 0 ft |
| 5 mph | 4300 ft AGL | 79 s | 577 ft |
| 10 mph | 4262 ft AGL | 78 s | 1148 ft |
| 15 mph | 4195 ft AGL | 77 s | 1703 ft |
| 20 mph | 4100 ft AGL | 76 s | 2236 ft |

- The recovery system for the launch vehicle:
  - Meets 90 second descent time limit
  - Meets 2500 ft drift limit

# Kinetic Energy under Drogue

- The launch vehicle descends at a velocity of 79 ft/s under the 24 inch Classic Elliptical drogue.

| Section | Mass | Kinetic Energy |
|---|---|---|
| Nosecone | 0.3744 slugs | 1171 ft-lb |
| Midsection | 0.2685 slugs | 839 ft-lb |
| Fin Can | 0.4267 slugs | 1135 ft-lb |

# Kinetic Energy at Landing

- All sections meet 75 ft-lb KE limit with the main parachute

| Section | Mass | Kinetic Energy |
|---|---|---|
| Nosecone | 0.3744 slugs | 66 ft-lb |
| Midsection | 0.2685 slugs | 47 ft-lb |
| Fin Can | 0.4267 slugs | 75 ft-lb |

# Payload

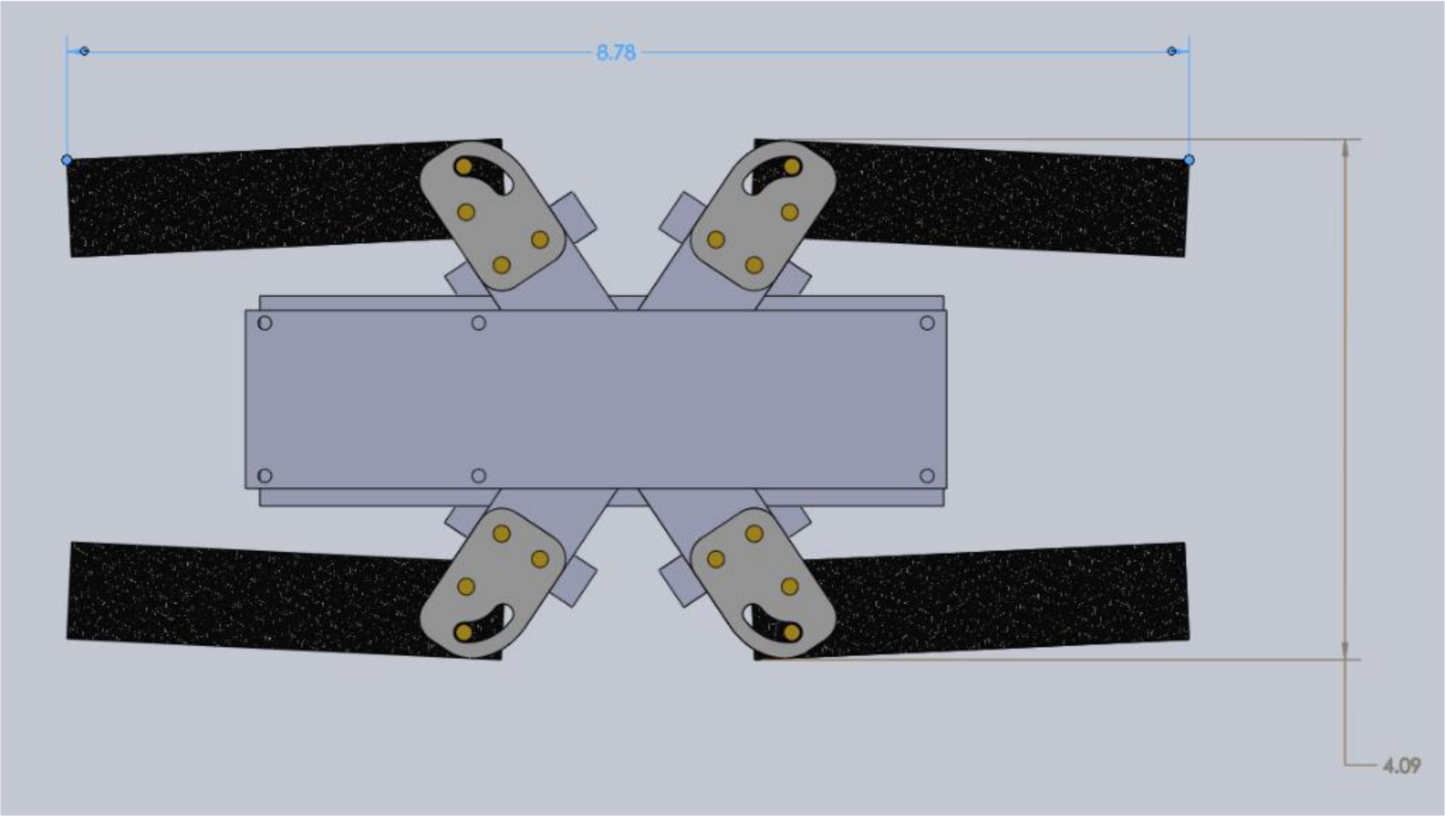
"The Eagle and the Egg"

# Payload Design

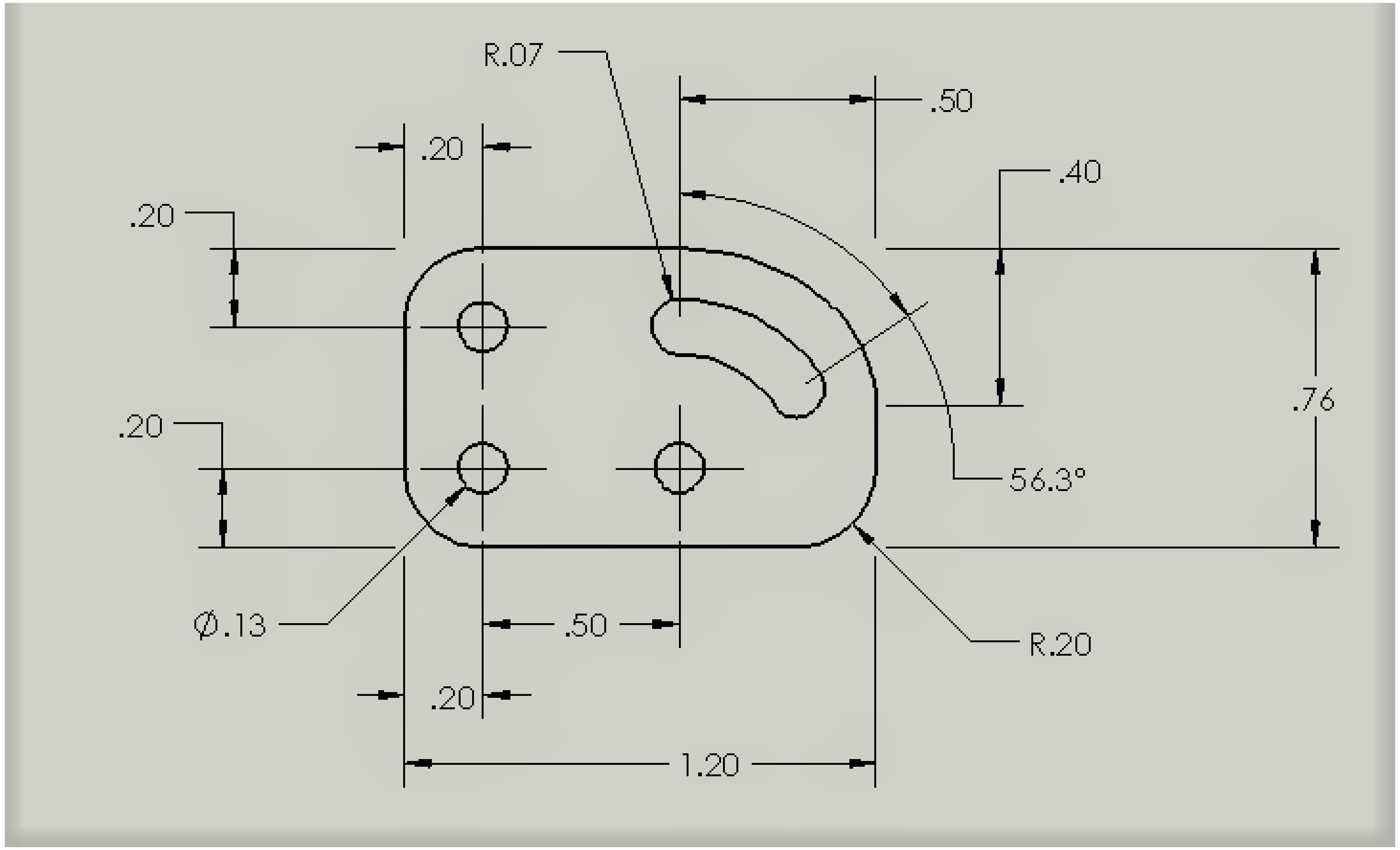
- Payload UAV will use a QAVR-220 carbon fiber quadcopter frame
- To fit the UAV into the proposed 5.5 inch rocket body, a set of hinges will be added to the arms, allowing them to fold
  - Proposed hinge design allows arms to decrease UAV width from about 8¼" to nearly 4"
  - This allows space for the payload deployment system to be more flexible in design process

# Hinge Design

- Hinge mechanism can be 3D-printed for rapid prototyping and construction
- Two hinges will sandwich each quadcopter arm, creating a pivot joint close to the body
- Arms will fold slightly further than parallel to UAV center section
- Two-blade propellers will be used as they can sit parallel to rocket body as well

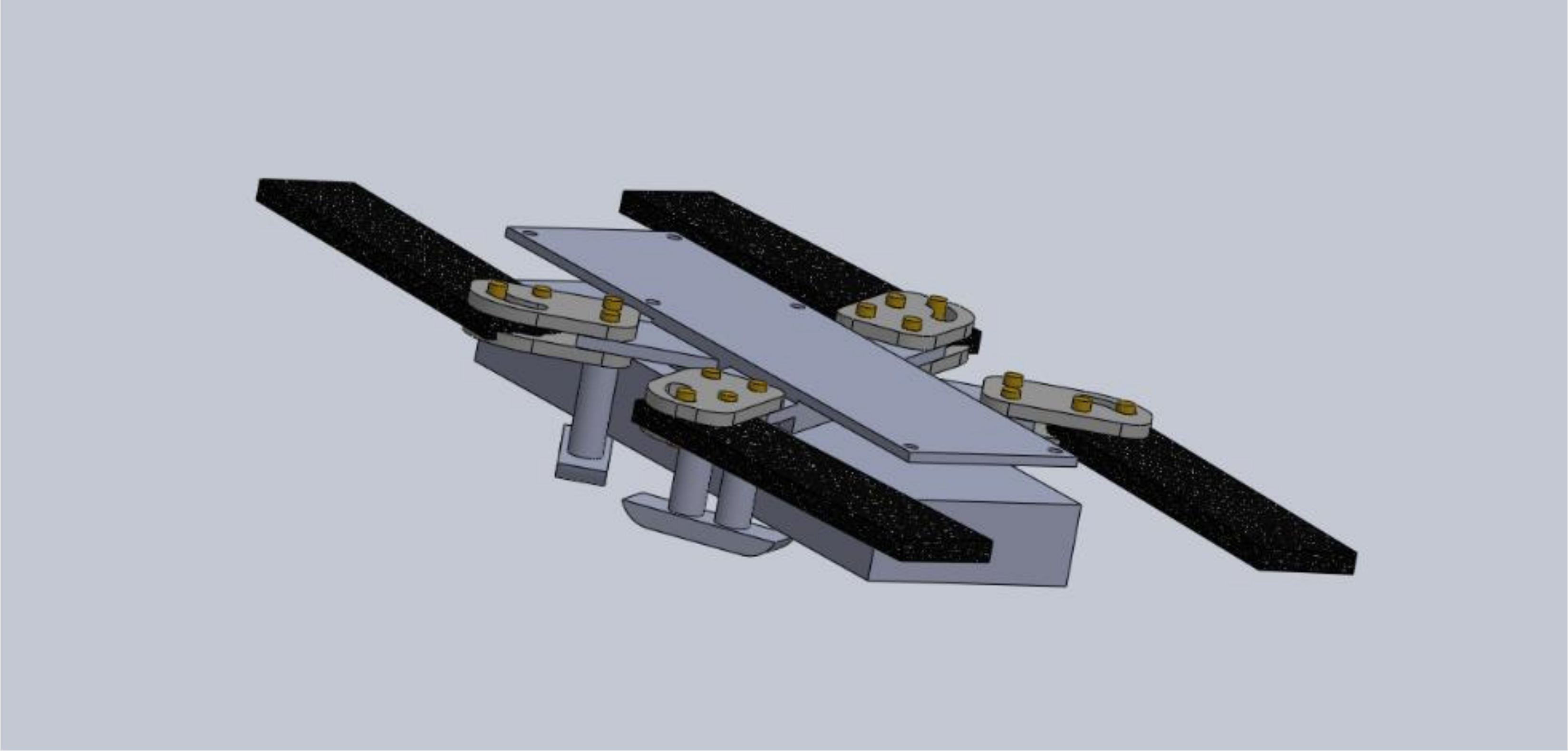


# Hinge Design



# Power Cell Protection

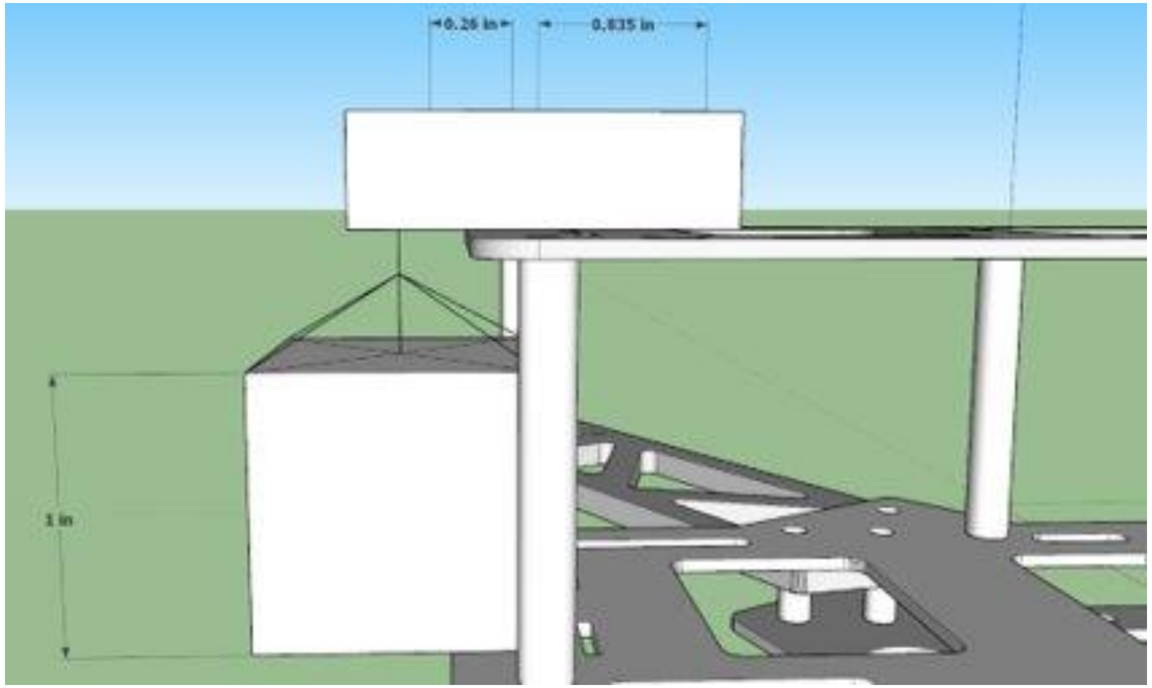
- Rails are placed on the underside of the UAV to provide protection
- Battery will be held under the chassis by hook-and-loop fasteners

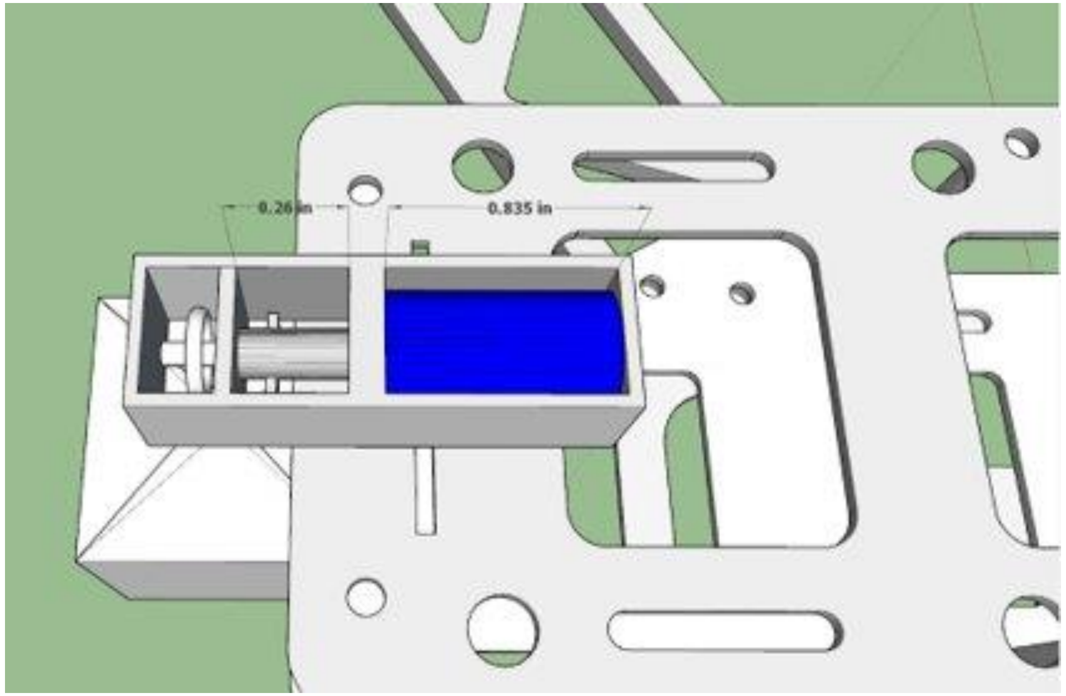


# Beacon Delivery System

- The Navigational Beacon will be suspended from a 5V solenoid actuator
- When activated, the solenoid will push its arm forward, activating the deployment system

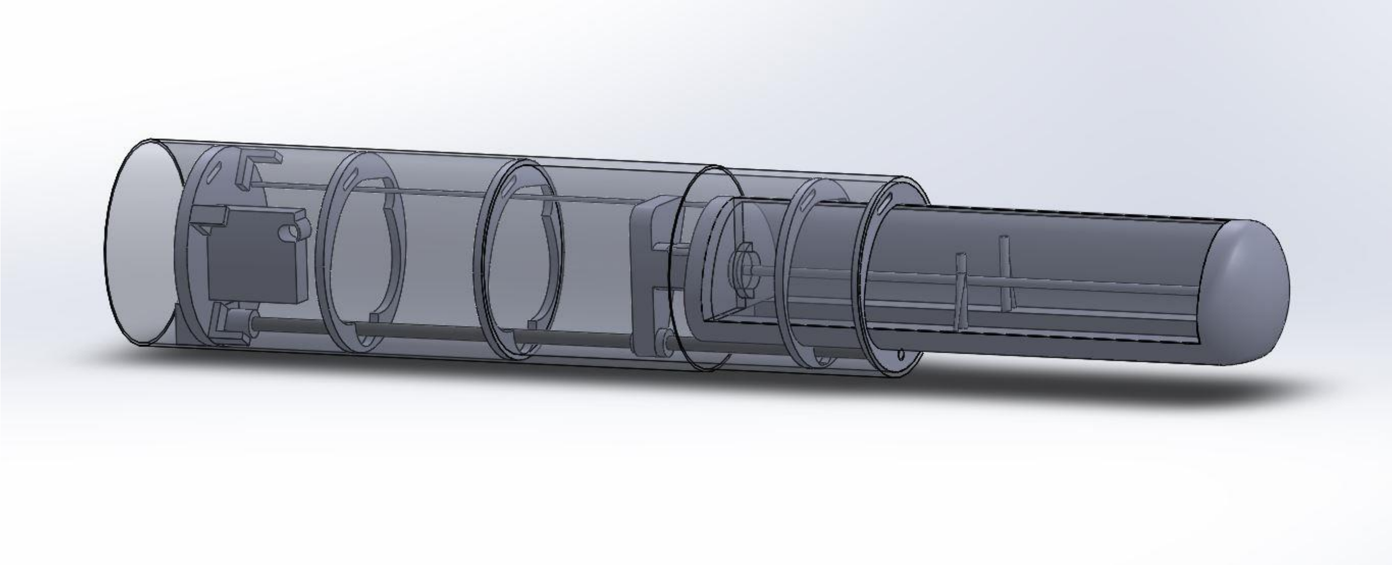
# Beacon Deployment System



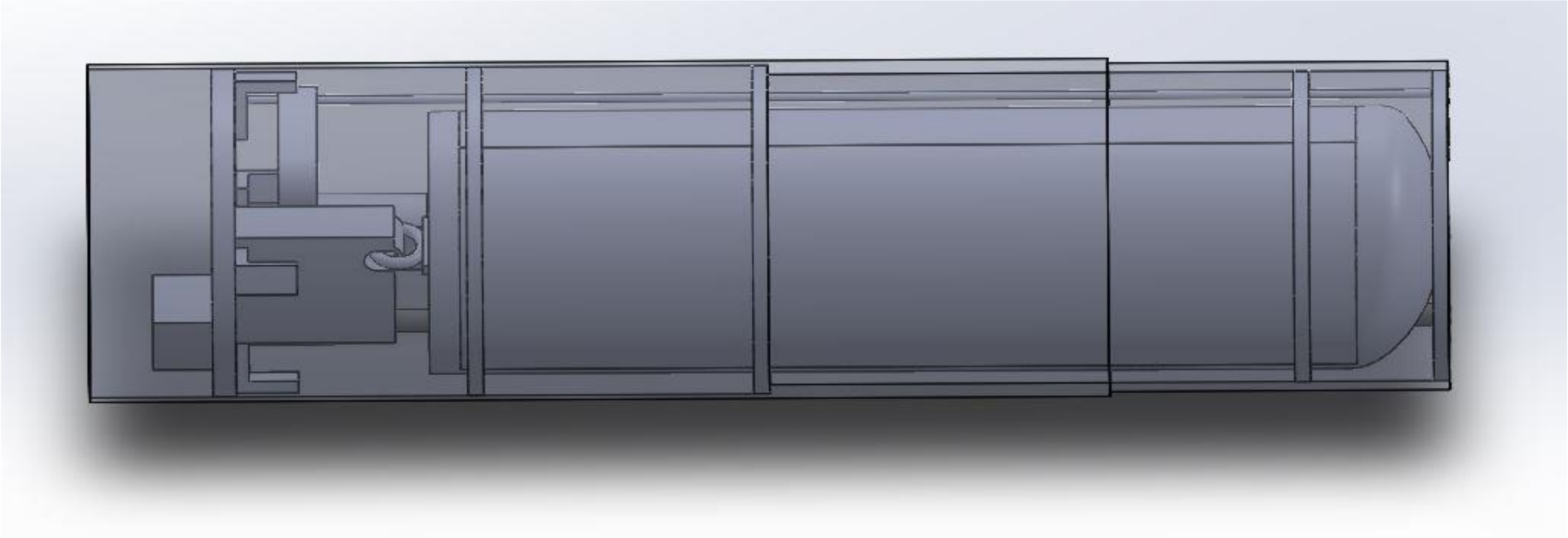
# Payload Deployment

- Components:
  - Removable Bulkhead
    - L-brackets, latch, stepper motor, Arduino Uno, and battery
  - Lead Screw with Collar
  - Auxilliary Rod
  - "Pusher"
    - Cantilevered Rod
  - Payload Pod
    - Flap Openers



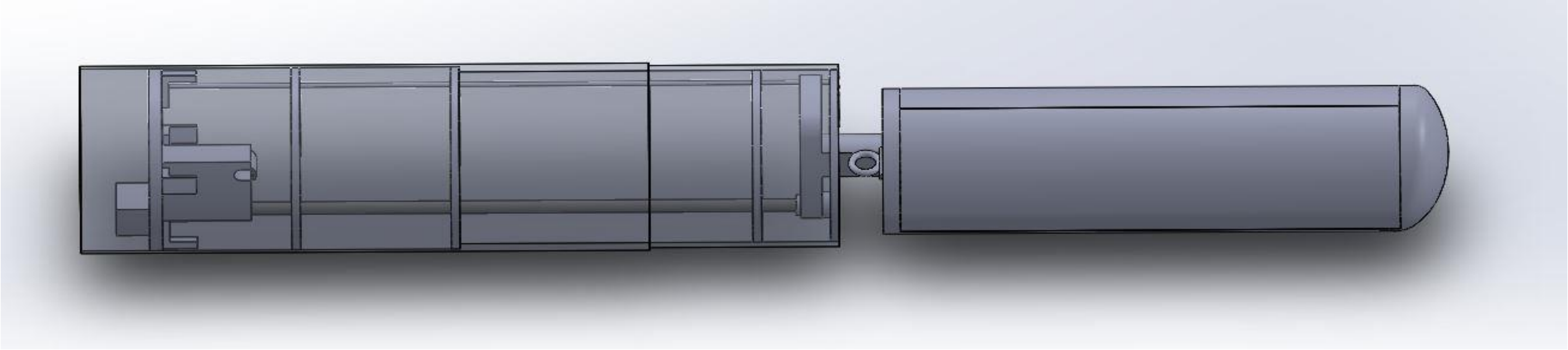
# Steps 1 to 3: Landing, Latch, and Signal

The launch vehicle lands, the signal is sent, the Arduino opens the latch and starts the stepper motor.



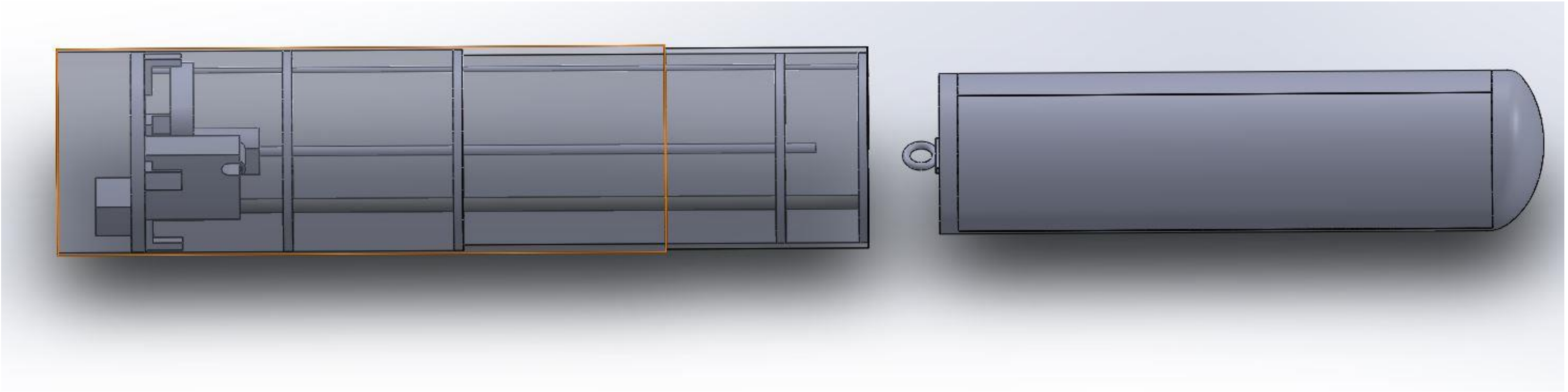
# Step 4: Suspended Pod

The pod is now outside of the payload bay but is held up and held closed by the cantilevered rod. It rotates heavy side down.



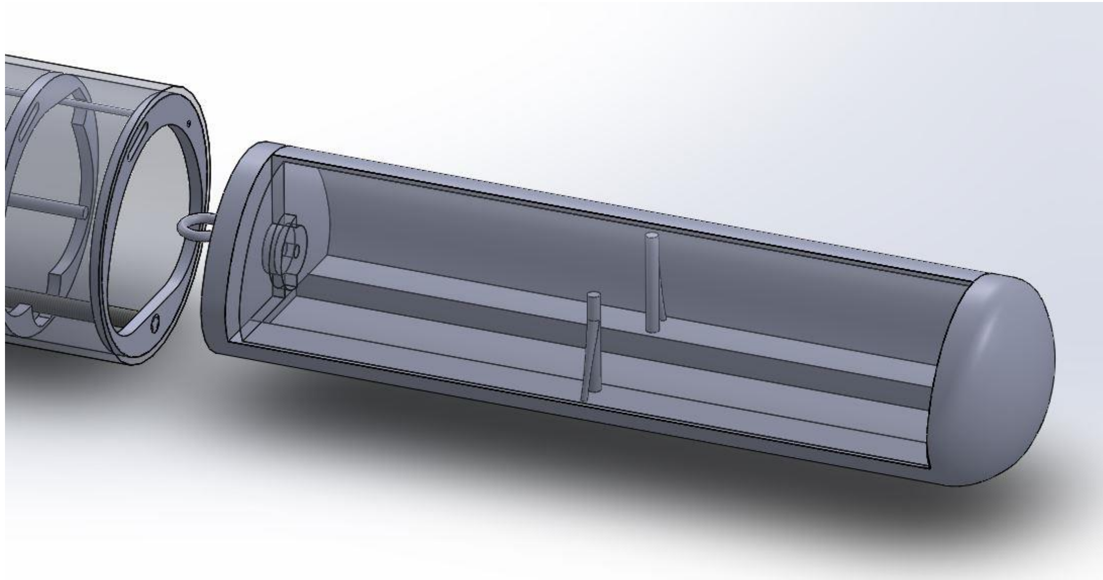
# Step 5: Pusher Retracts

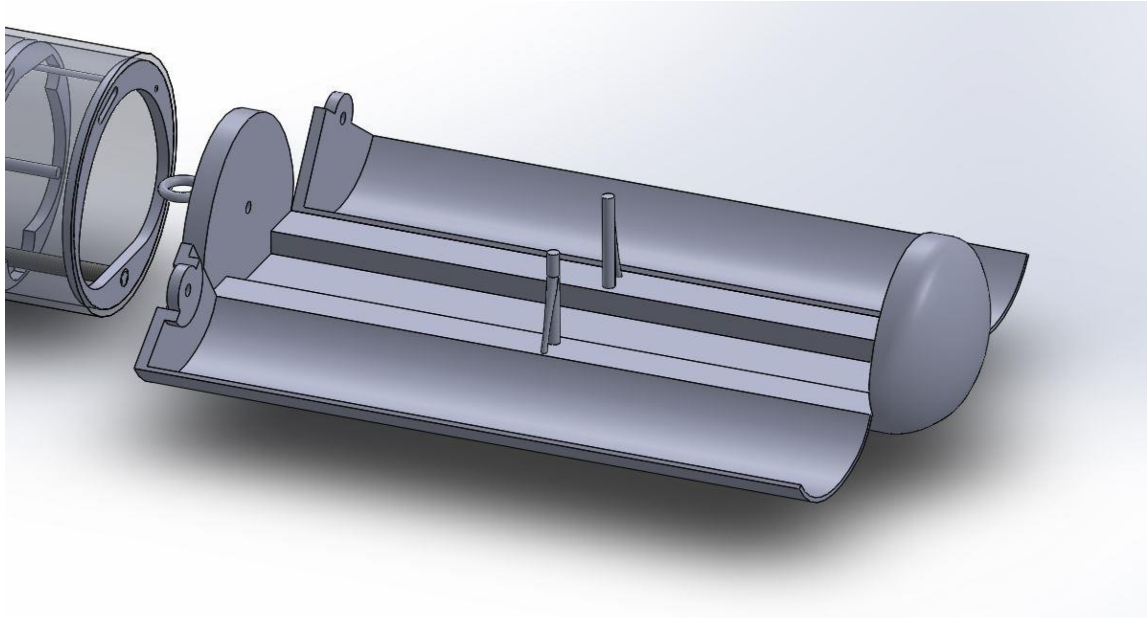
The pusher, on a time delay, retracts back into the body tube.  The pod is stopped either by the centering ring or elastic.



# Step 6: Pod Drops and Opens

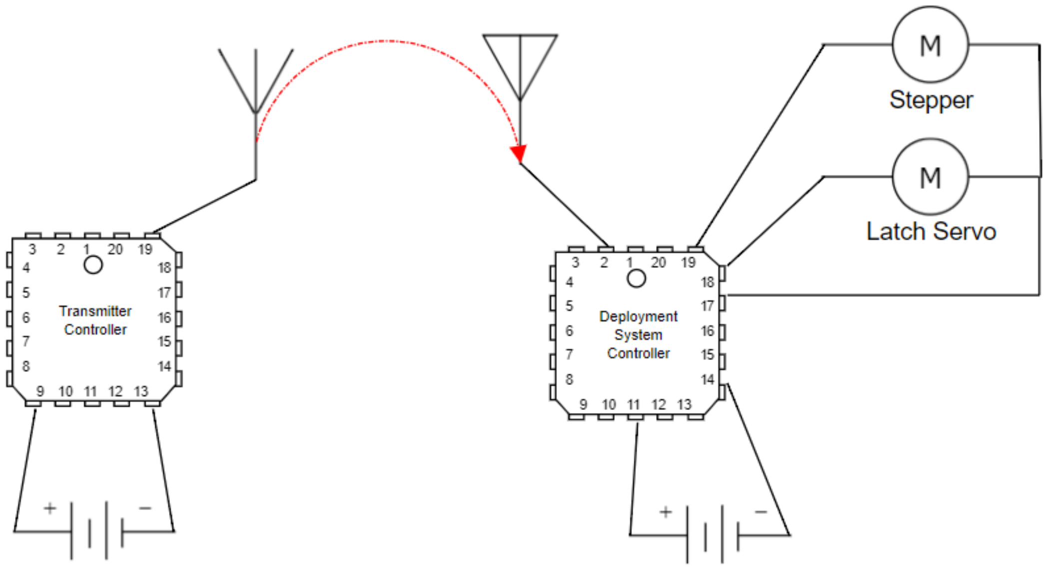
With the rod retracted, the pod drops to the ground and the flaps are pushed open. The UAV is now revealed.





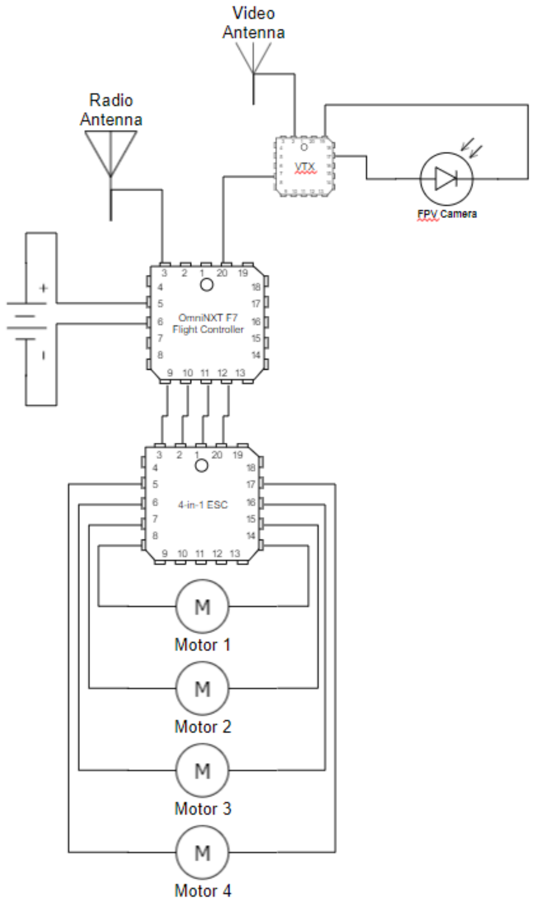
# Payload Deployment Electronics

- Payload will be deployed with separate electronic system
- Deployment system will utilize a 433 MHz transmission frequency



# Payload Control

- UAV low-power state will be configured to a physical switch on the radio transmitter
- UAV will utilize a 2-2.4 GHz radio band
- Video system shall use one of 32 available frequencies



# Requirements Verification

# Team Derived Requirements - Vehicle

- The launch vehicle shall utilize a motor compatible with a motor casing already in the team's possession
  - Allows more budgetary freedom
  - The team will use a motor compatible with the Aerotech 75/3840
- The launch vehicle shall have a static stability margin between 2.0 and 2.3 upon rail exit
  - A stability margin of 2.0 is necessary to meet the NASA SL requirement
  - The max 2.3 value prevents undesirable weathervaning in high winds

# Team Derived Requirements - Recovery

- The launch vehicle shall use recovery devices that the team owns
  - Allows more budgetary freedom
  - The team will use 84 inch main parachute and 24 inch drogue
- The launch vehicle shall use U-bolts for all shock cord attachments
  - Reduces the chance of recovery failure
  - No single point of failure
- Drogue descent velocity shall be less than 100 fps
  - Minimizes deployment shock at main deployment

# Team Derived Requirements - Payload

- The UAV shall be capable of flying 1.5 miles in unfavorable wind conditions
  - Ensures that the UAV will be able to reach the FEA in poor conditions
  - Prepares for the worst-case scenario
- Flight time of at least 5 minutes
  - Maximum necessary flight time to reach the FEA
- The UAV and retention system shall weigh less than 5 lb
  - Keeps stability within the chosen range

# Bulkhead Failure Testing

- This test will study the adherence between plywood bulkheads and fiberglass tubing
- Procedure:
  - A bulkhead is constructed of 6 layers of 1/8 inch plywood and a U-bolt is attached
  - The bulkhead is epoxied into a length of body tube
  - A 0.5 inch thick aluminum bulkhead is attached at the end of the body tube
  - After curing for 24 hours, the U-bolt is attached to the universal testing machine
  - A pulling load is applied until failure to mimic in-flight forces
- The bulkhead is satisfactory if it withstands a load of at least 468.88 lb

# Black Powder Ejection Demonstration

- This demonstration will verify the functionality and sizing of black powder charges prior to launch
- Procedure:
  - The launch vehicle is assembled following launch day procedures with mass simulators replacing avionics and payload
  - Black powder charges are installed by folloing the e-match and black powder installation checklists
  - The launch vehicle is taken outside and set against a wall horizontally
  - The ejection testing switch is connected to one e-match via alligator clips
  - Power is applied and the switch is flipped after a five second countdown
  - A single black powder charge will go off. The process is repeated for all charges
- Success is defined if full separation is observed between the AV bay and Fin Can and the Main Parachute Bay and Nosecone

# Payload Retention Testing

- This will test the functionality of the payload latch under sample loads between 25 and 35 lb
- Procedure:
  - A cord is attached to the payload latch to hold the weights
  - The weight is released on the cord slowly
  - After 1 second, the weight is removed
  - This is repeated for weights between 25 and 35 lb in 5 lb increments.
- Success is defined as no visual and/or auditory signs of failure

# Adverse Conditions UAV Flight Test

- This test simulates a more realistic flight environment for the UAV and tests UAV performance in realisitc conditions
- Procedure:
  - An anemometer is used to measure wind speed and wind speed must be greater than 10 mph to proceed
  - A quarter mile is measured and marked in a large open field
  - The battery is connected to the UAV and all system's functionality is verified
  - The UAV is flown in loops across the quarter mile track
  - The number of loops and time of flight are recorded when the battery reaches 85% discharge
  - Repeated for three fully charged batteries
- Success is defined by a flight time of over 5 minutes

# Questions?