Tacho Lycos FRR Presentation

March 18, 2019

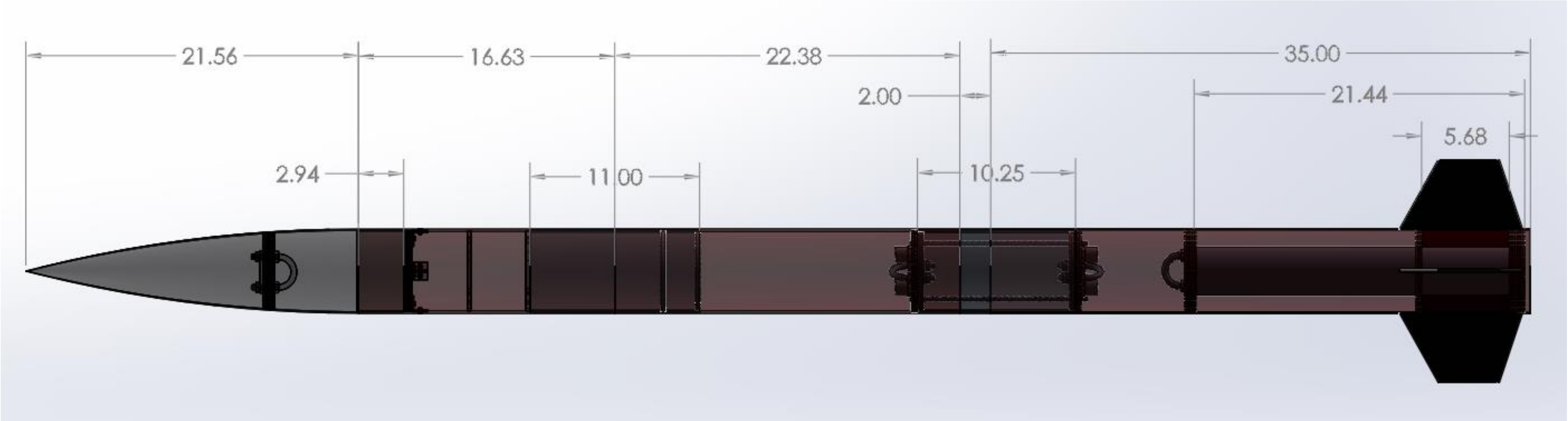
Overview

- Vehicle Design
- Propulsion
- Recovery and Avionics
- Payload
- Demonstration Flight Results
- Requirements Verification

Vehicle Design

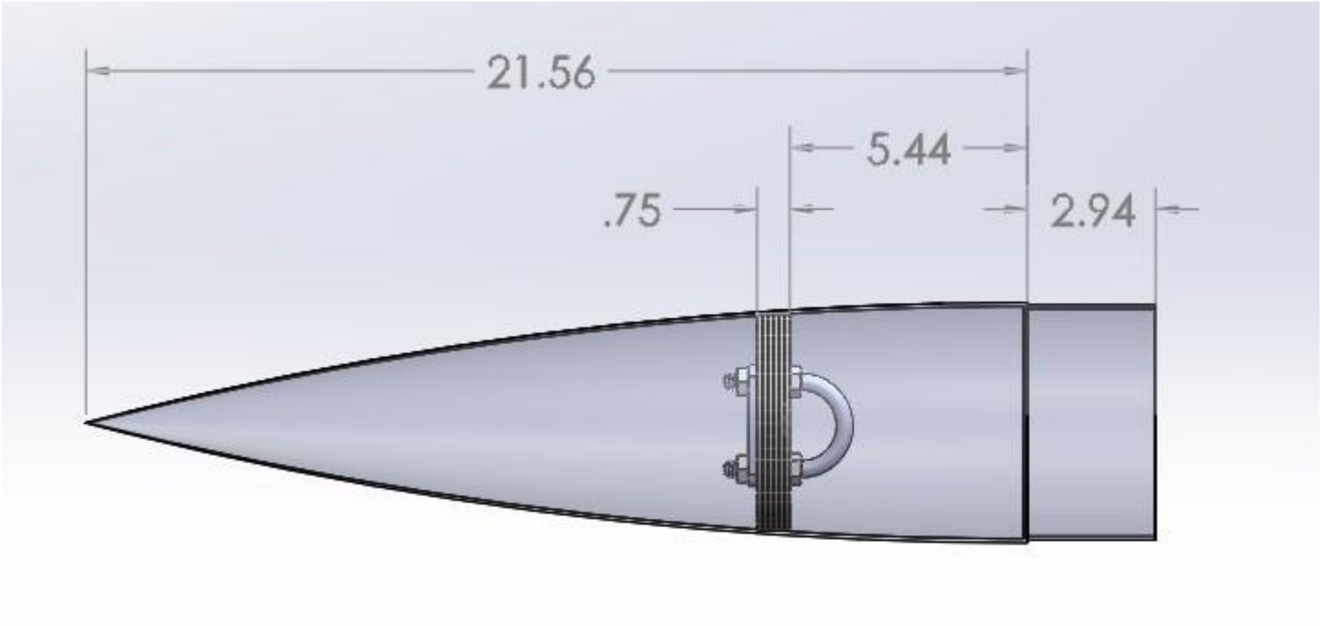
Dimensions

- Length: 97.57 inch
- Diameter: 5.5 inch
- Body Material: Fiberglass
- Launch weight: 39.2 lb
- Empty weight: 27.4 lb
- Weight of ballast: 1.25 lb



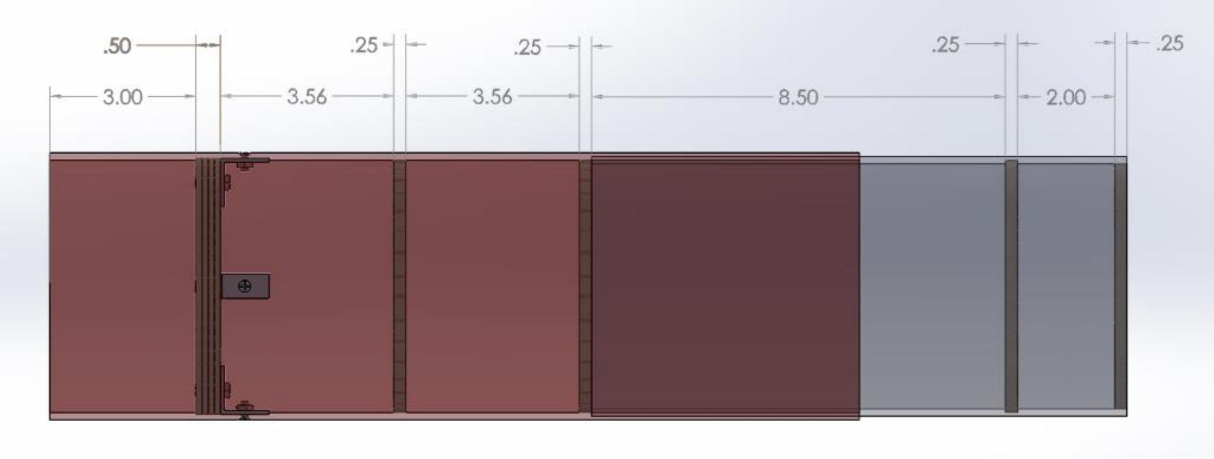
Nosecone

- Fiberglass
- 4:1 ogive shape
- Permanent bulkhead
  - Recessed 8.38 inches from shoulder
  - 0.75 inch thick
  - U-bolt installed for attachment to main parachute
  - Testing indicated no additional method to secure bulkhead is necessary
- 0.5 lb nose ballast
- Weight: 3.1 lb



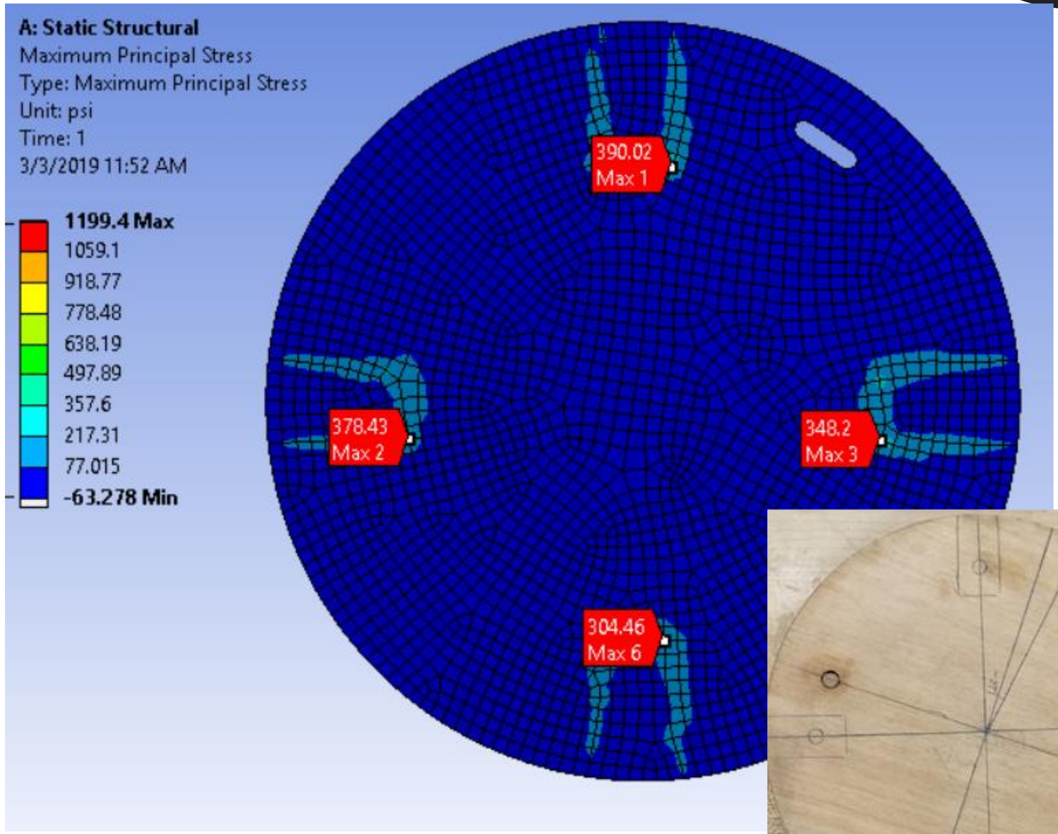
Payload Bay

- Removable bulkhead mounted on L-brackets located 3 inches from forward end
- Four centering rings distributed throughout to support payload pod
- Shock cord to main parachute routed through bulkhead and centering rings
- Weight: 8.2 lb



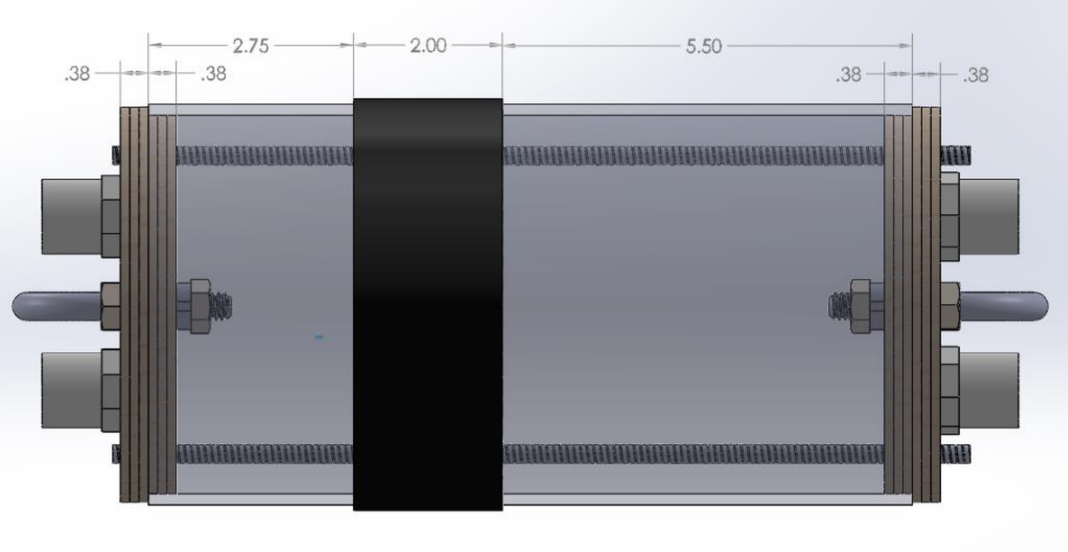
Payload Bay Bulkhead

- 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 2.56
- Will support payload deployment system



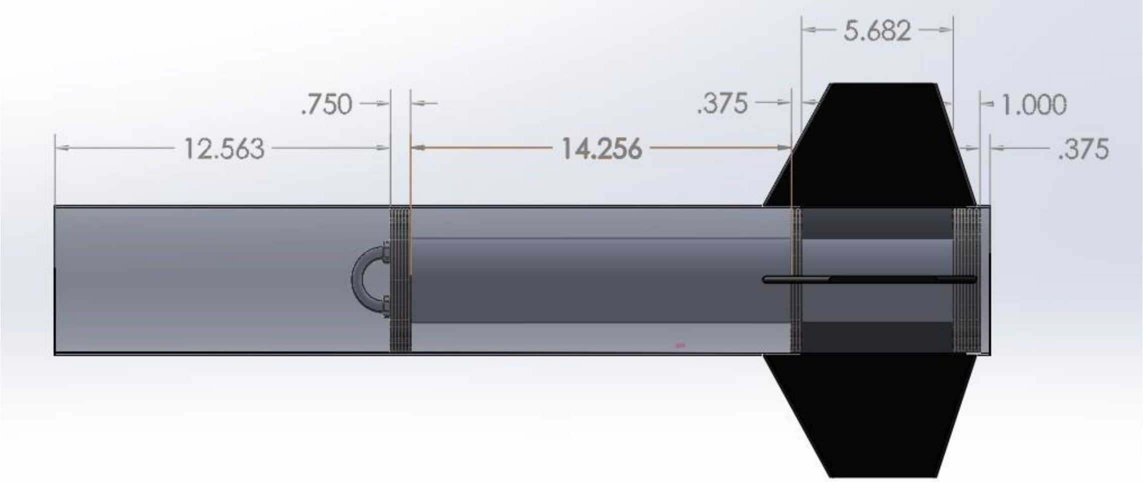
AV Bay

- 10.25 inch coupler section with 2 inch body tube section
- Bulkheads have 3 layers matching body ID and 3 layers matching coupler ID
  - Each have a U-bolt securing either the main or drogue parachute
- Two ¼ inch threaded rods secure bulkheads and AV sled
- Weight: 4.1 lb



Fin Can

- Total length of 35 inches
- 12.563 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
- U-bolt in bulkhead that is secured to drogue parachute
- Weight: 9.8 lb



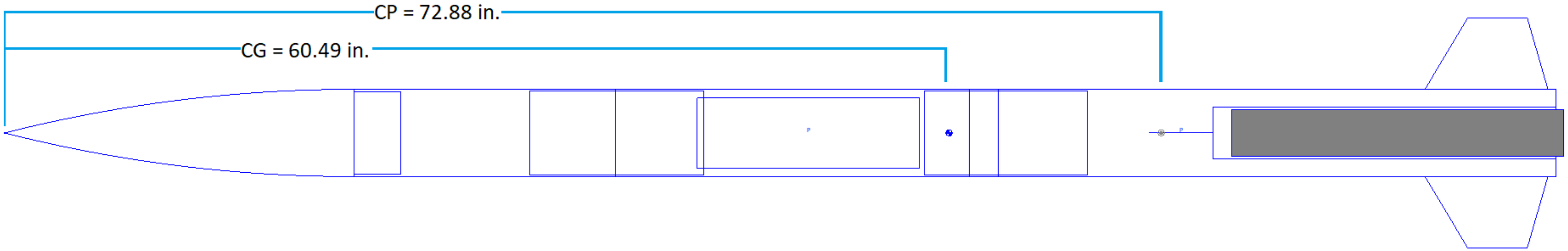
T-Nut Inserts

- T-nuts secured in 1/8 inch thick plywood
- Epoxied to interior of coupler section
- Secures permanently attached sections during flight
- Four at each attachment point

Stability and Mass Margin

- CP: 72.88 inch
- CG: 60.49 inch
- Stability margin on launch rail: 2.25

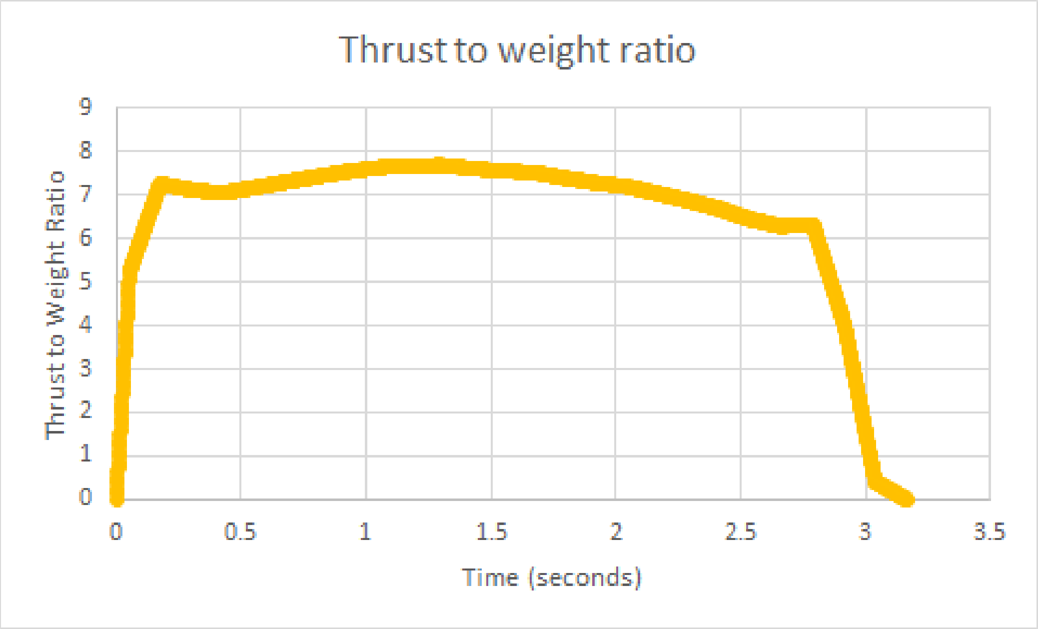
- Mass Margin expanded as a result of VDF
- Mass Margin is now 39.0-43.5 lb



Propulsion

Motor Selection

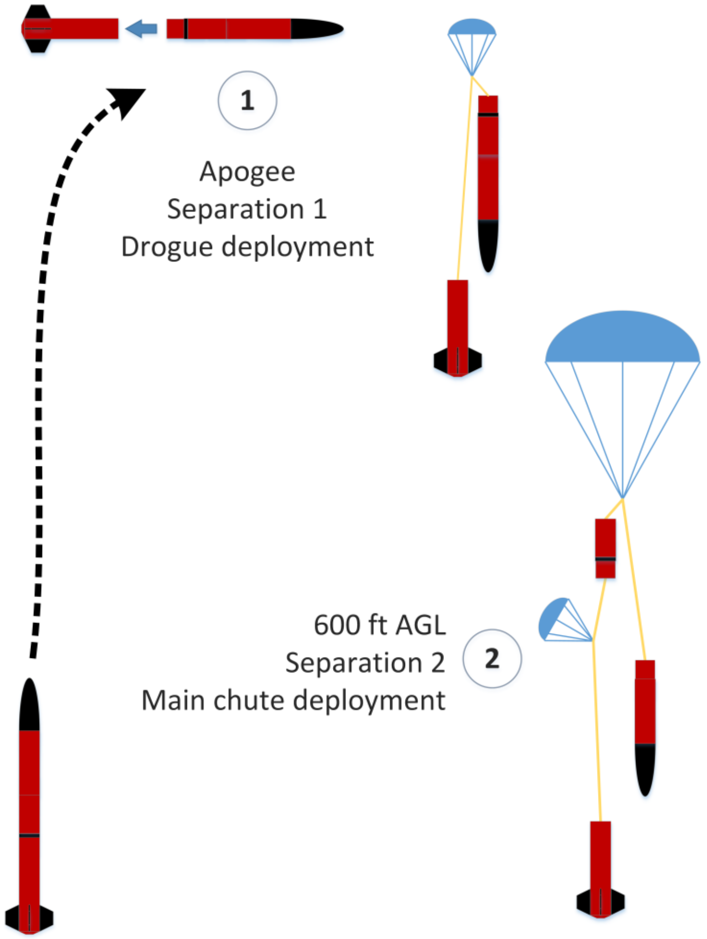
- The Motor for the Full-Scale Launch Vehicle is the Aerotech L1150R
- Provides a Thrust to Weight ratio of 7.22 at launch
- Provides a launch rail exit velocity of 69.45 fps



Recovery and Avionics

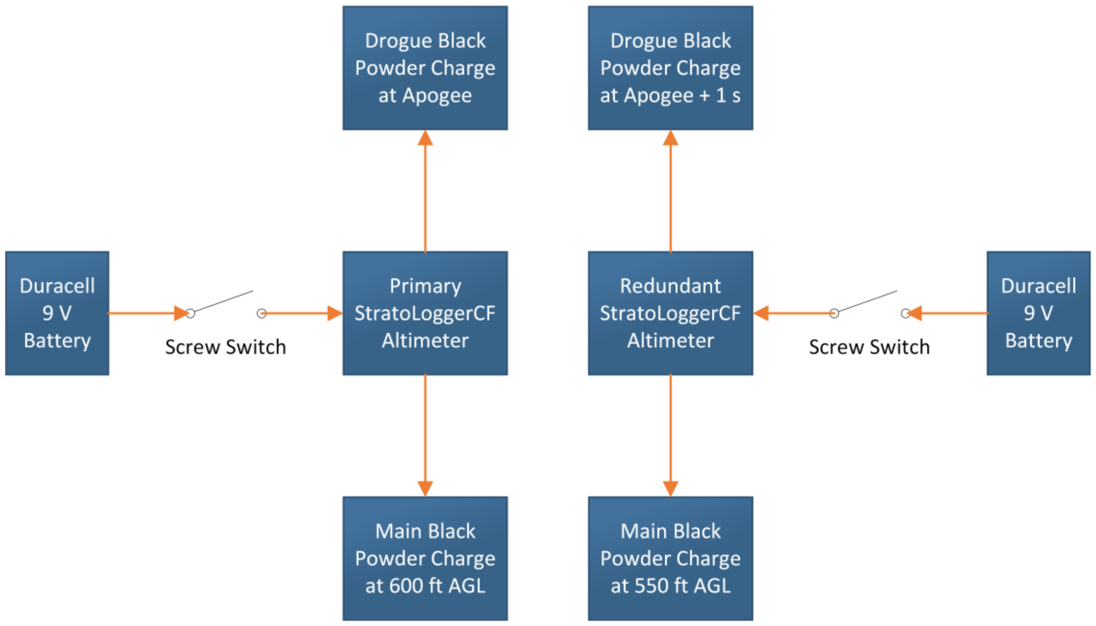
Recovery Overview

- 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

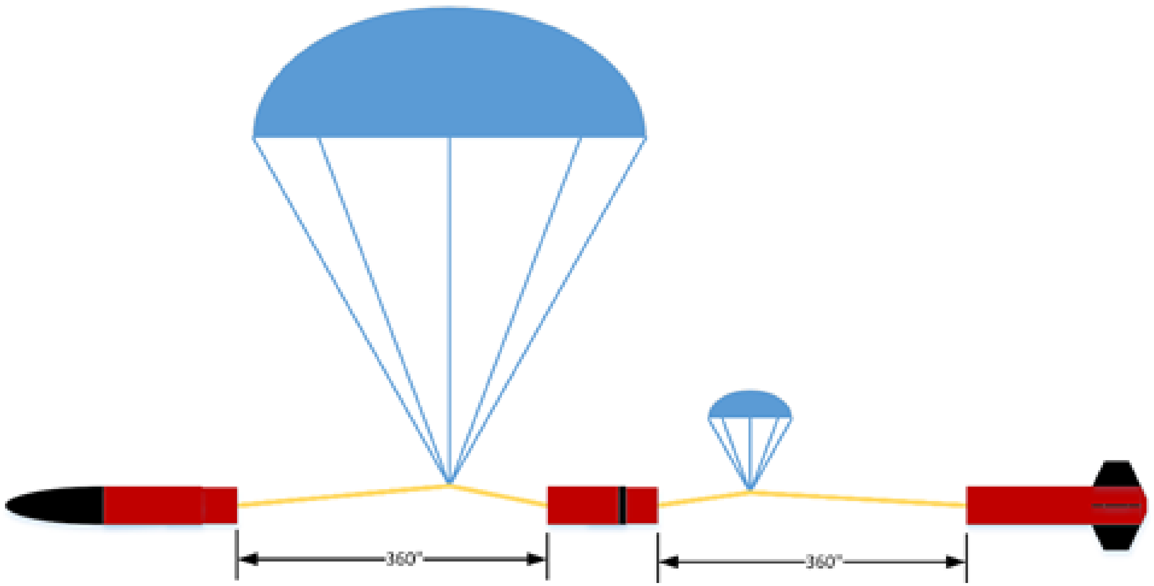


Parachutes

- **Drogue:** 24 inch Fruity Chutes Compact Elliptical
  - Diameter: 24 inches
  - Drag coefficient: 1.47
  - Descent velocity: 71.539 ft/s
- **Main Parachute:** 84 inch Fruity Chutes Iris UltraCompact
  - Diameter: 84 inches
  - Drag coefficient: 2.10
  - Descent velocity: 16.979 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	4272 ft AGL	87 s	0 ft
5 mph	4220 ft AGL	86 s	630 ft
10 mph	4143 ft AGL	85 s	1245 ft
15 mph	4043 ft AGL	83 s	1836 ft
20 mph	3922 ft AGL	82 s	2399 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 71.539 ft/s under the 24-inch Classic Elliptical drogue.

Section	Mass	Kinetic Energy
Nosecone	0.3512 slugs	898.7 ft-lb
Midsection	0.2191 slugs	560.7 ft-lb
Fin Can	0.3046 slugs	779.4 ft-lb

Kinetic Energy at Landing

- The launch vehicle descends at a velocity of 16.979 ft/s with the 84-inch Iris UltraCompact Parachute

Section	Mass	Kinetic Energy
Nosecone	0.3512 slugs	50.6 ft-lb
Midsection	0.2191 slugs	31.6 ft-lb
Fin Can	0.3046 slugs	43.9 ft-lb

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

Payload

"The Eagle and the Egg"

Payload UAV

- Payload UAV is a QAVR-220 carbon fiber quadcopter frame
- Utilizes folding arm design
- Battery protection with sled-style legs
- Custom camera mount
- Switch-activated solenoid beacon deployment system

Folding Hinge

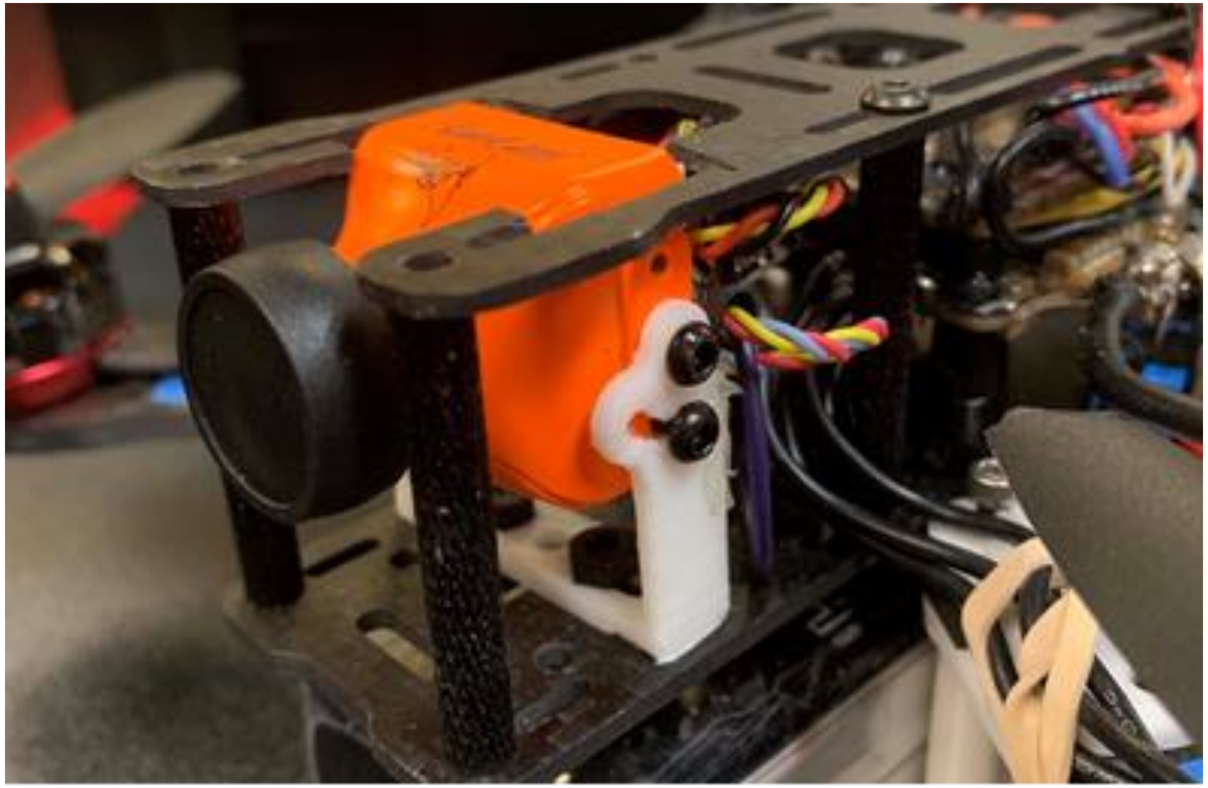
- Hinge mechanism is 3D printed for rapid manufacturing and ease of replacement
- Two hinges sandwich each quadcopter arm, creating a pivot joint close to the body
- Arms fold slightly further than parallel to UAV center section
- Two-blade propellers will be used as they can sit parallel to rocket body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

Power Cell Protection

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

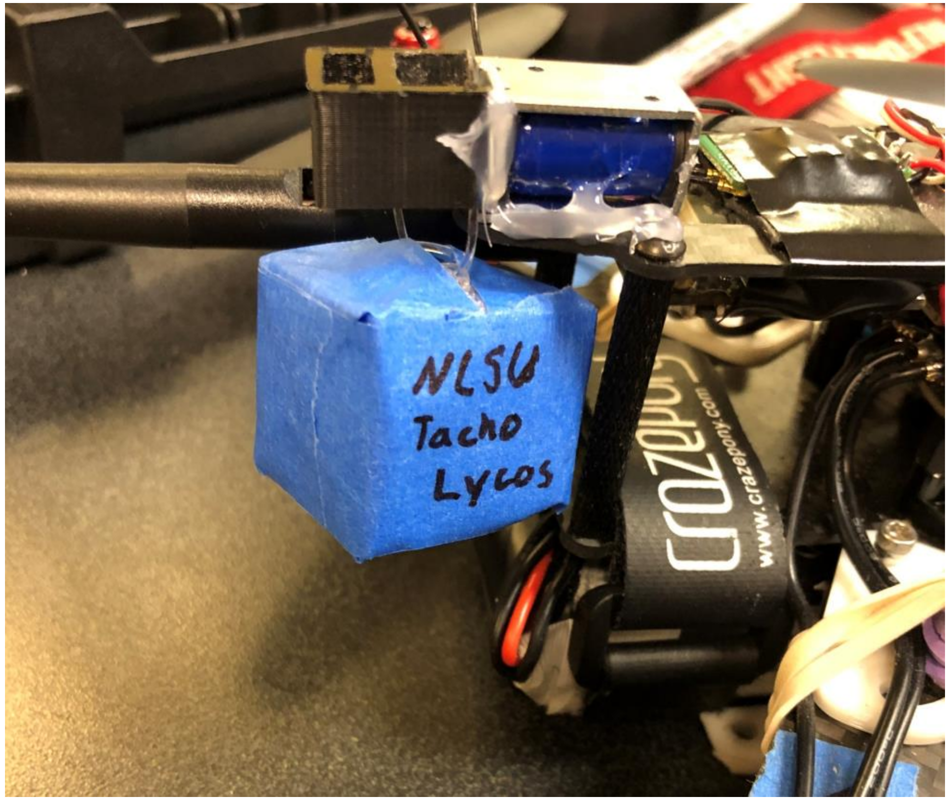
Custom Camera Mount

- To allow for carbon fiber rod clearance
- New raised camera position meant a slot must be cut from ceiling

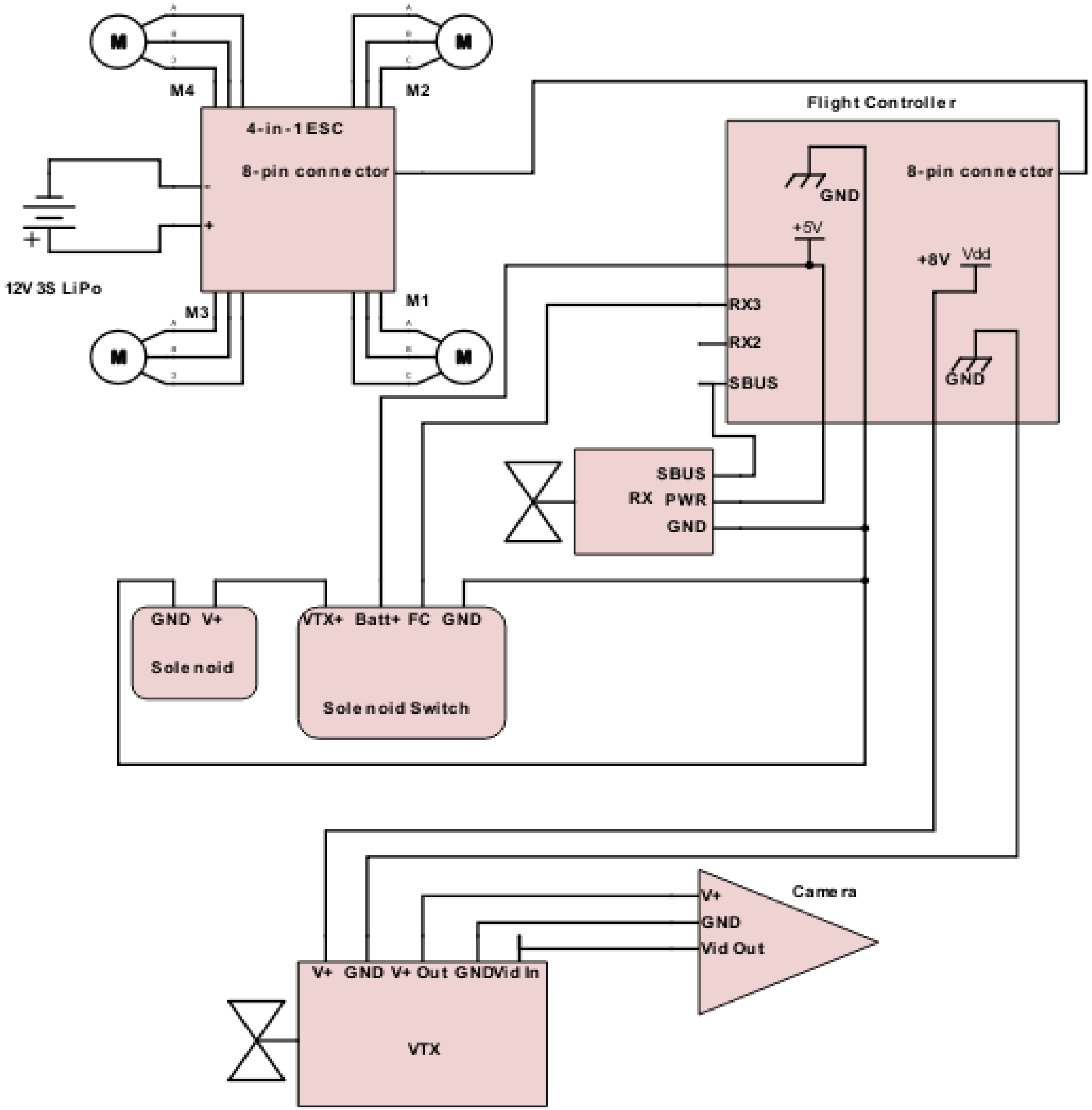


Beacon Delivery System

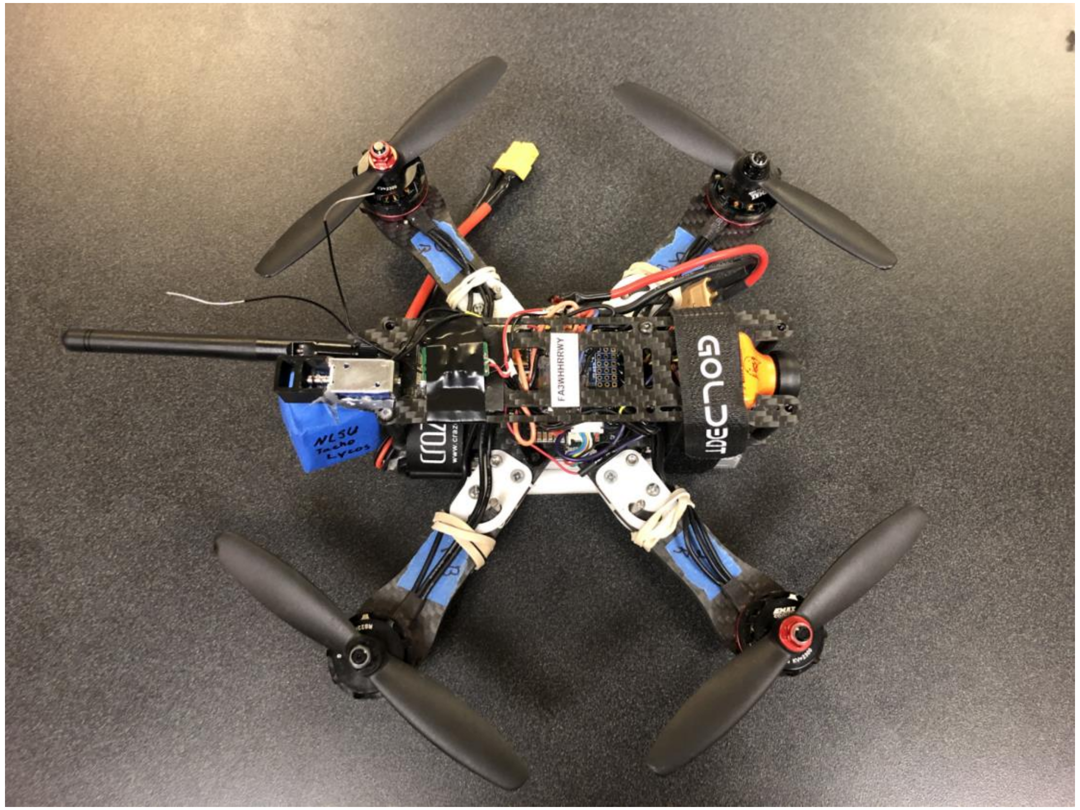
- The Navigational Beacon will be suspended from a 5V solenoid actuator
- Solenoid activated via a switch on the radio transmitter, utilizing a "RealPit VTX" switch.

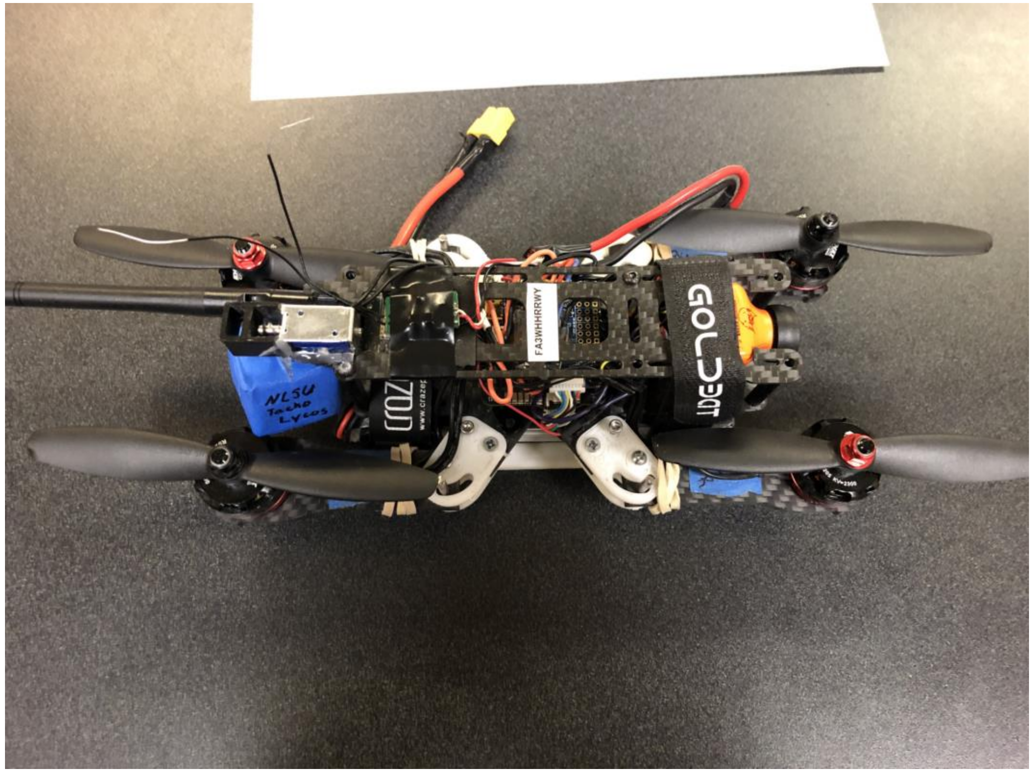


UAV Electrical Schematics



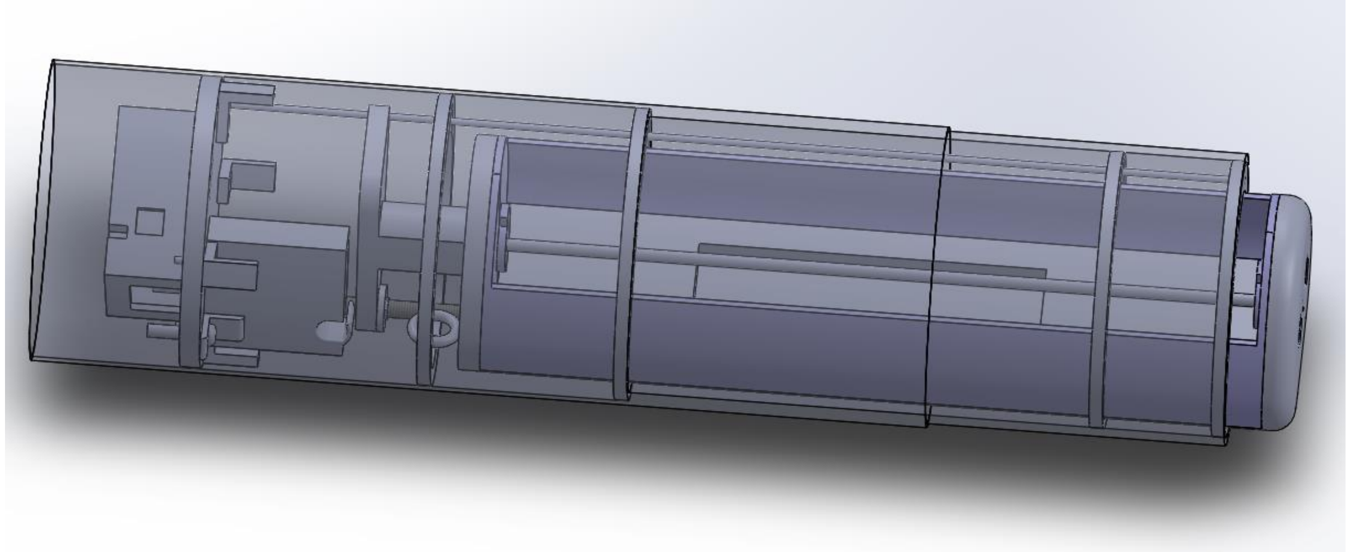
Total UAV System





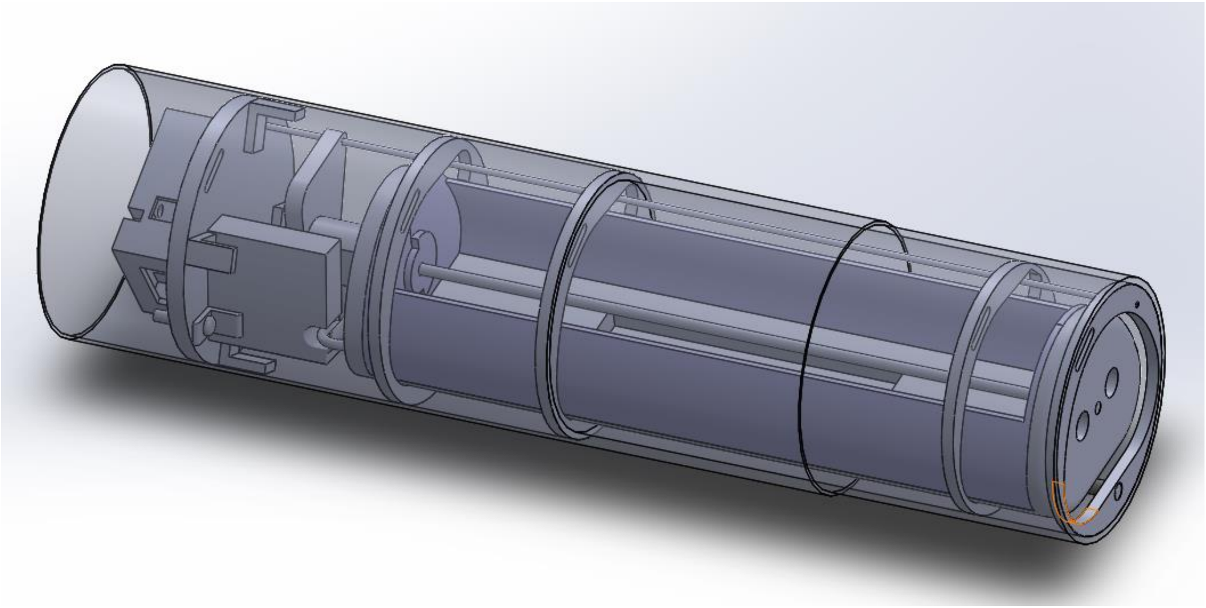
Payload Deployment

- Components:
  - Removable Bulkhead
    - L-brackets, latch, stepper motor, Arduino Uno, and motor driver
  - Lead Screw with Gears
  - Auxiliary Rod
  - "Pusher"
    - Cantilevered Rod
  - Payload Pod



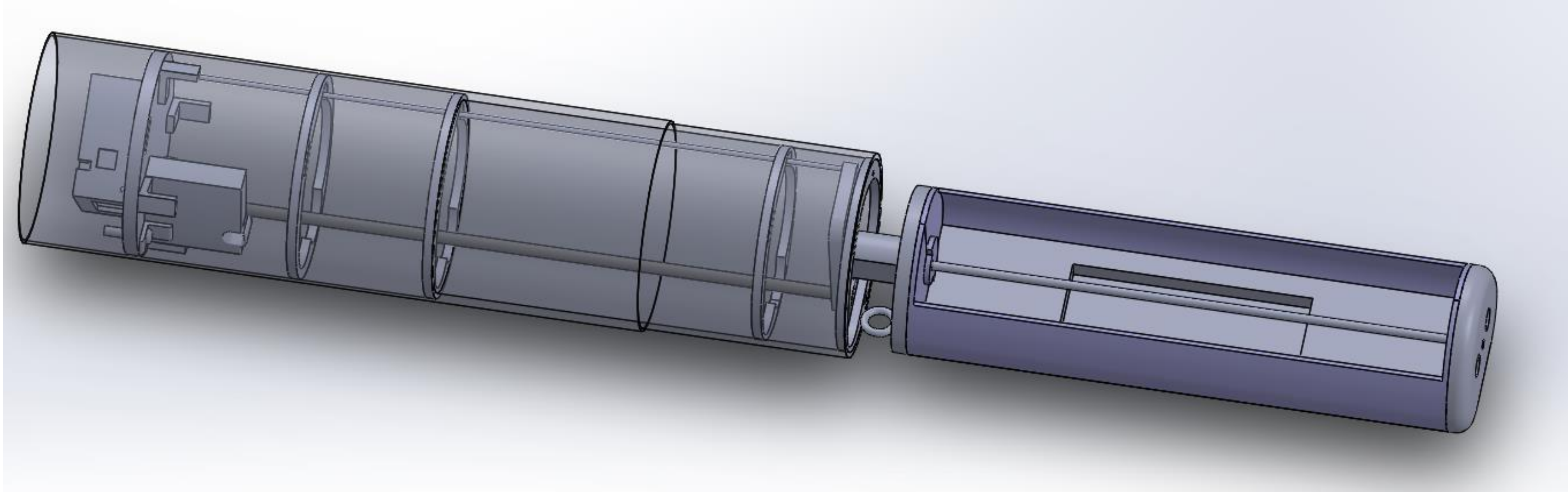
Steps 1 to 3: Landing, Latch, and Signal

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



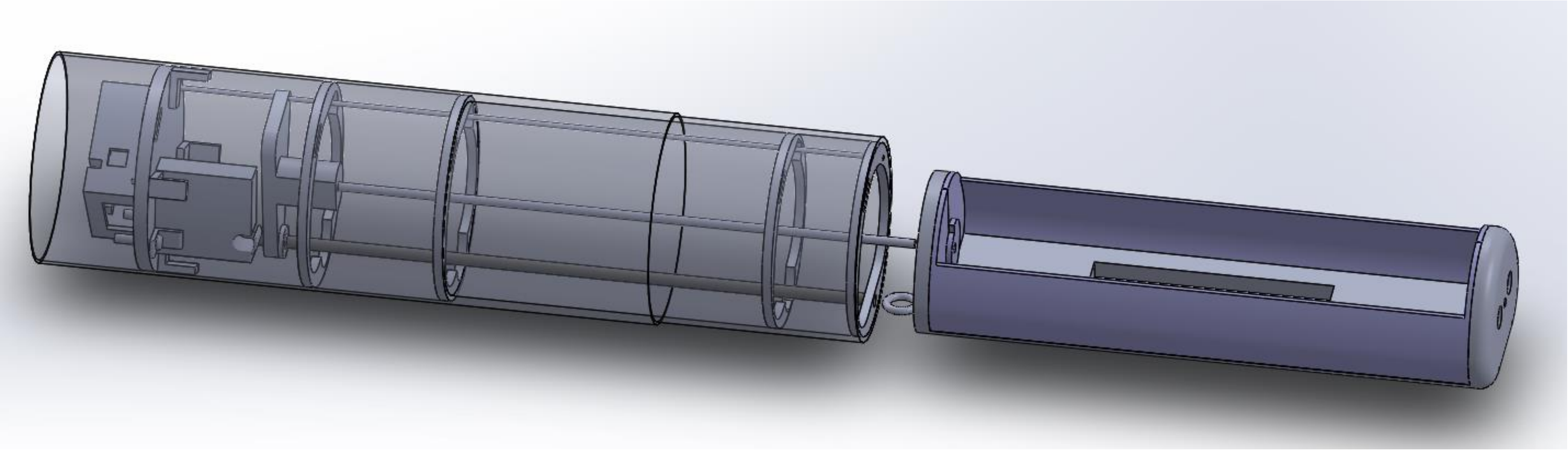
Step 4: Suspended Pod

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.



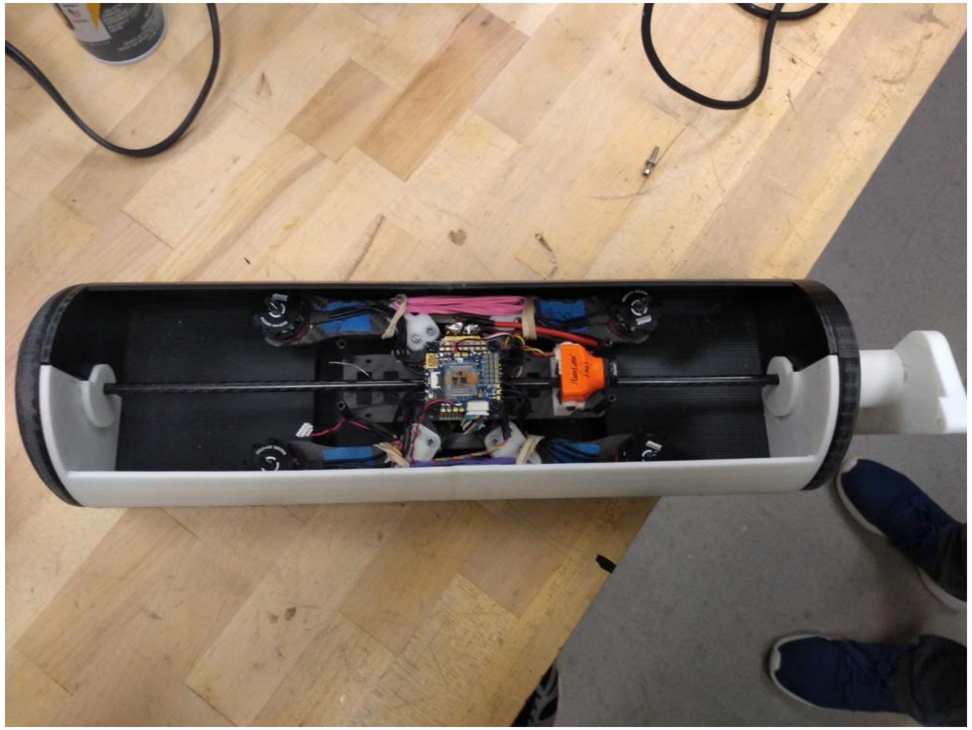
Step 5: Pusher Retracts

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



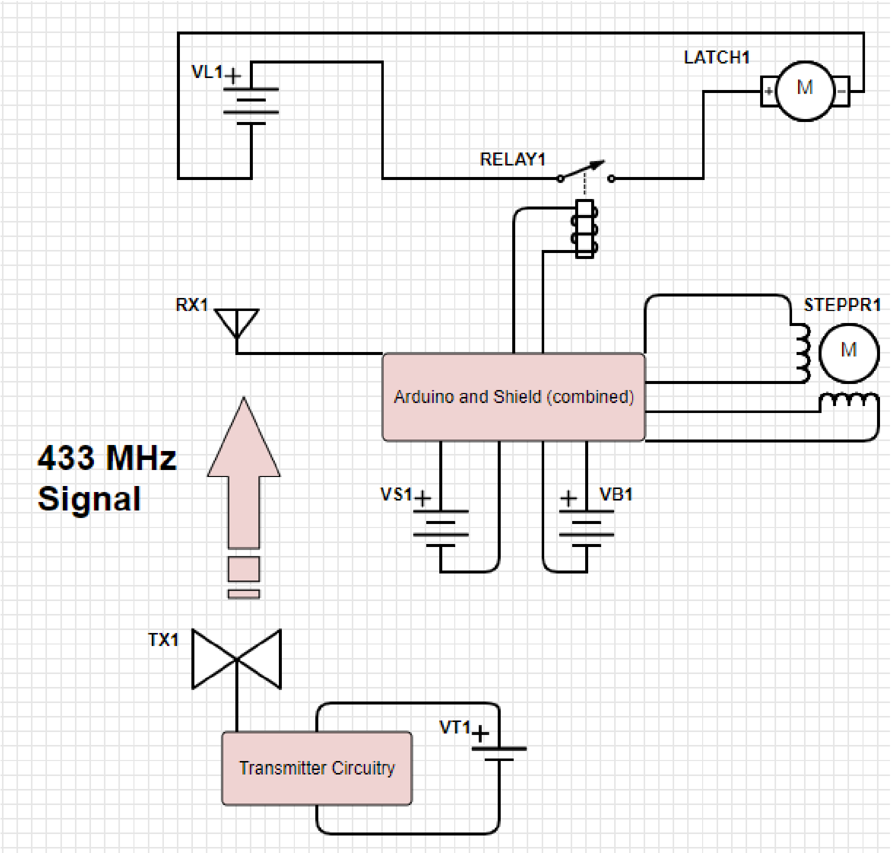
Step 6: Pod Drops and Opens

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

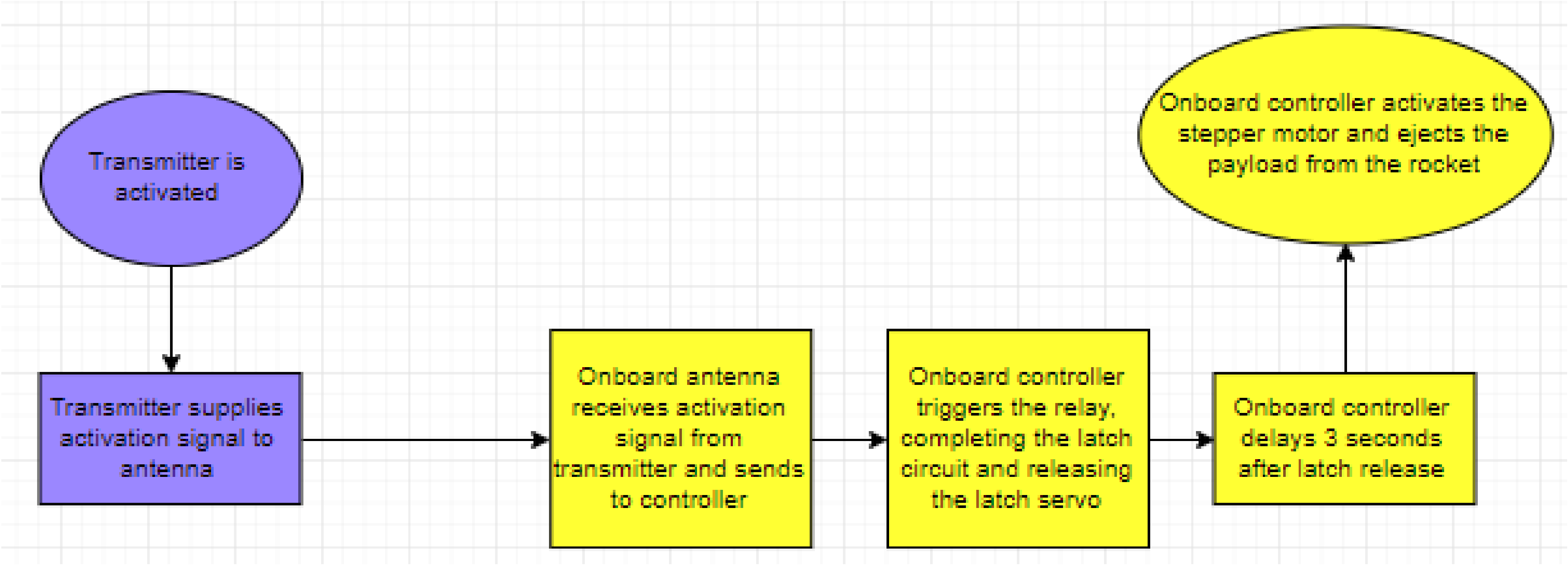


Payload Deployment Electronics

- Deployment system will utilize a 433 MHz transmission frequency
- Retention latch release will be controlled via electrical relay
- Locking quick disconnects and hot melt adhesive will ensure solid connections during flight

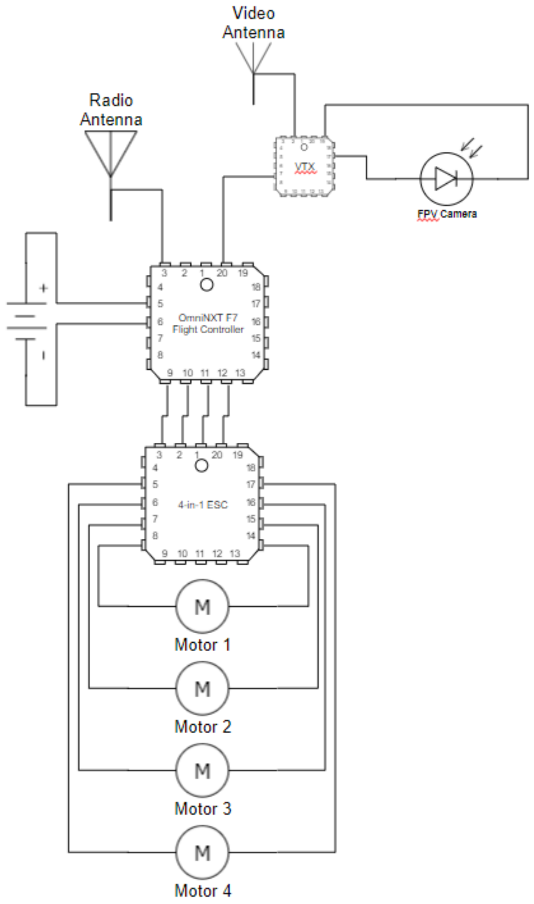


Payload Deployment Electronics



Payload Control

- UAV arming 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

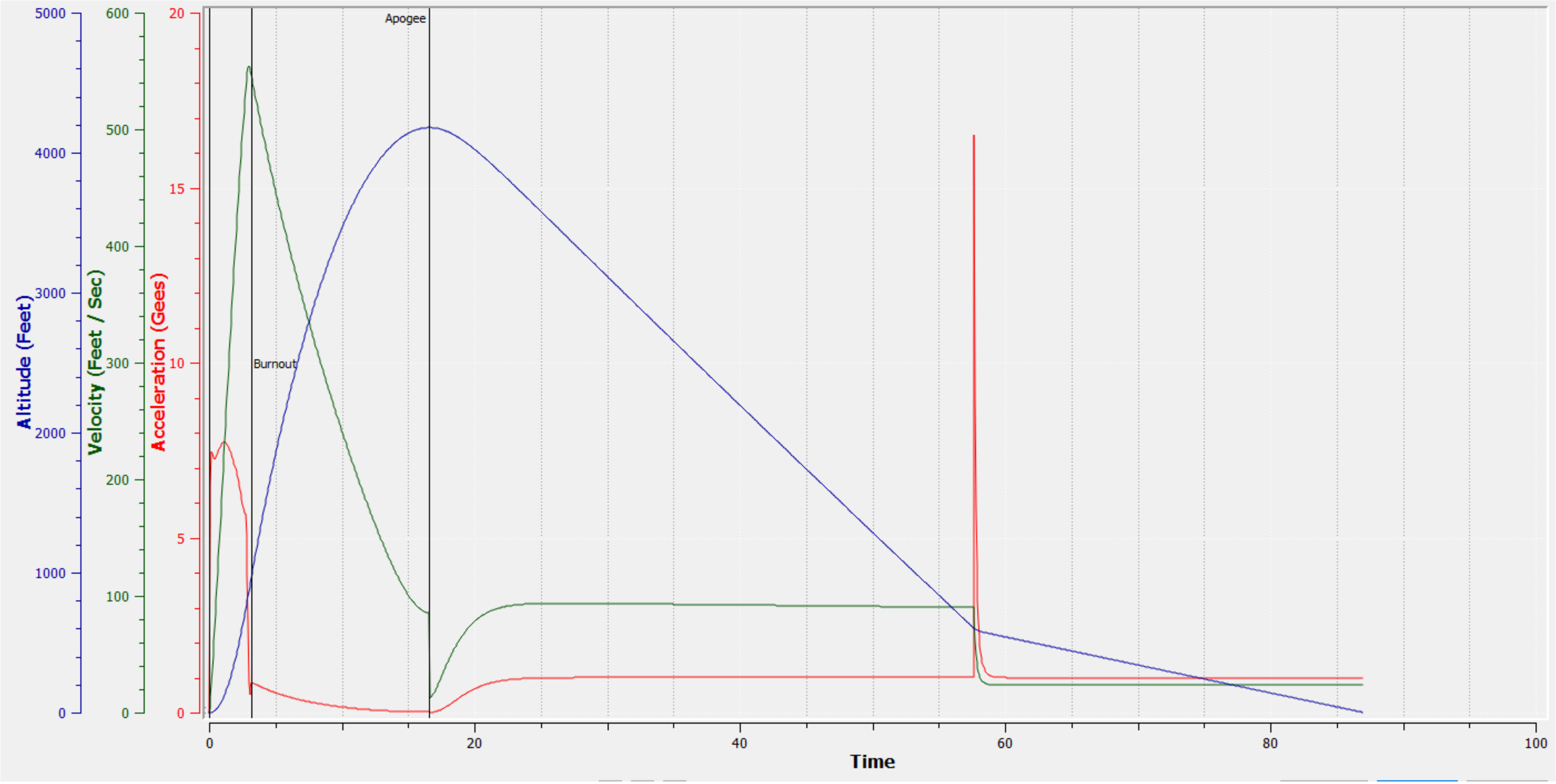


Launch Vehicle Demonstration Flight Results

Launch Overview

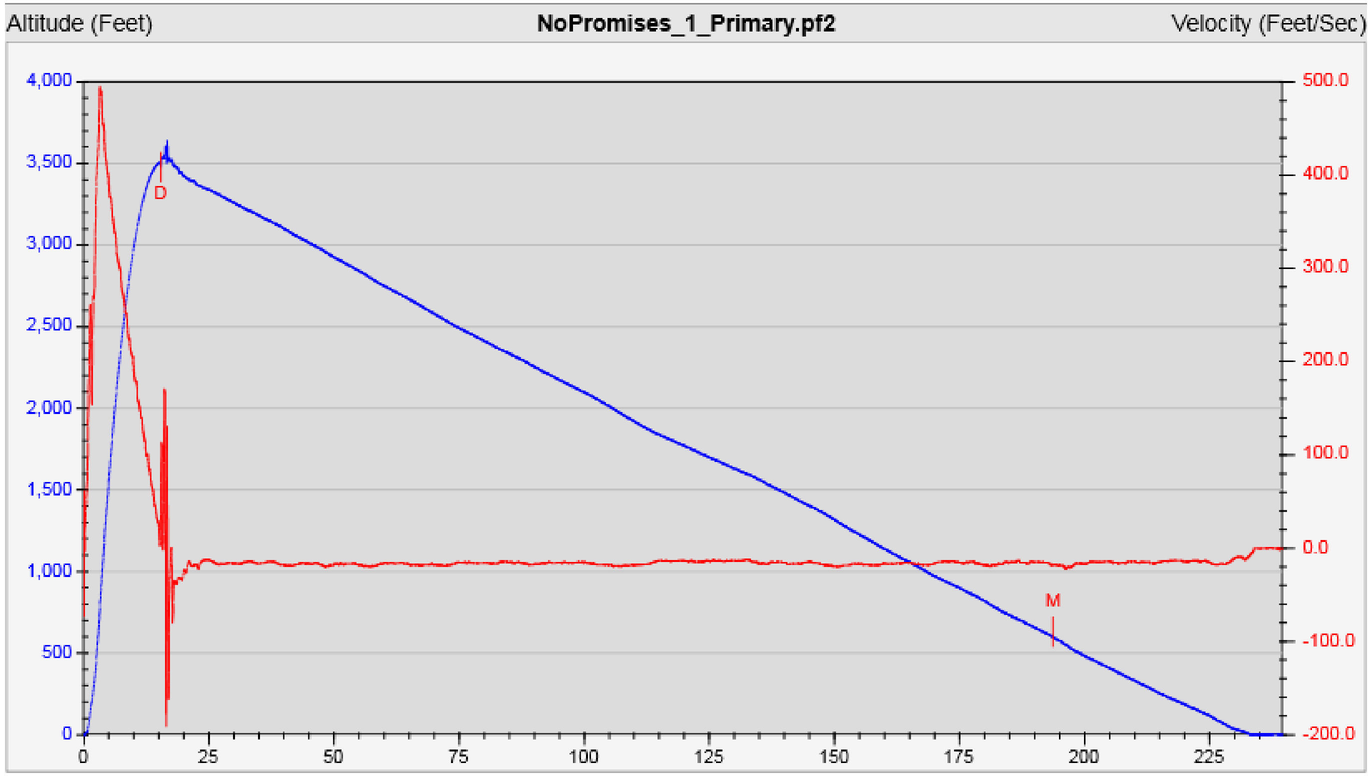
- Full-Scale Launch Vehicle built to the specifications of the CDR
- Body diameter of 5.5 inches
- Launched Feb 9 in Bayboro, NC with windspeeds of 8-12 mph
- Used an 8 ft 1515 rail
- RockSim predicted apogee of 4173 ft, max velocity of 554 fps, drogue parachute descent rate of 71.5 fps, and main parachute descent rate of 17 fps

RockSim Simulation



Flight Results

- Apogee: 3506 ft
- Max velocity: 500 fps
- Drogue descent rate: N/A
- Main descent rate: 17 fps
- Apogee difference of ~19%



Issues

- 2 second delay of motor ignition
- ~15° of weathercocking upon rail exit
- Main parachute deployment at apogee

Changes for Future Launches

- 10 ft launch rail
- Reinforced launch pad
- Dowel to insert Ignitor
- Increase number of shear pins at main separation point
- Team is requesting an extension for launch vehicle demonstration flight

Payload Demonstration Flight Results

Results

- Same flight as Vehicle Demonstration Flight
- Payload retention system worked as intended but was not a complete demonstration
- Payload deployment system did not work
- As a result, the UAV was not deployed and tested

Issues

- Main parachute deployed at apogee thus reducing the load on the payload retention system.
- After landing sequence, the deployment system was triggered remotely but failed to unlatch the payload pod which was determined to be a result of a wire that broke during the flight
- Additionally, the stepper motor was not providing sufficient torque to drive the payload pod out of the payload bay body tube after the latch was manually opened

Changes for Future Launches

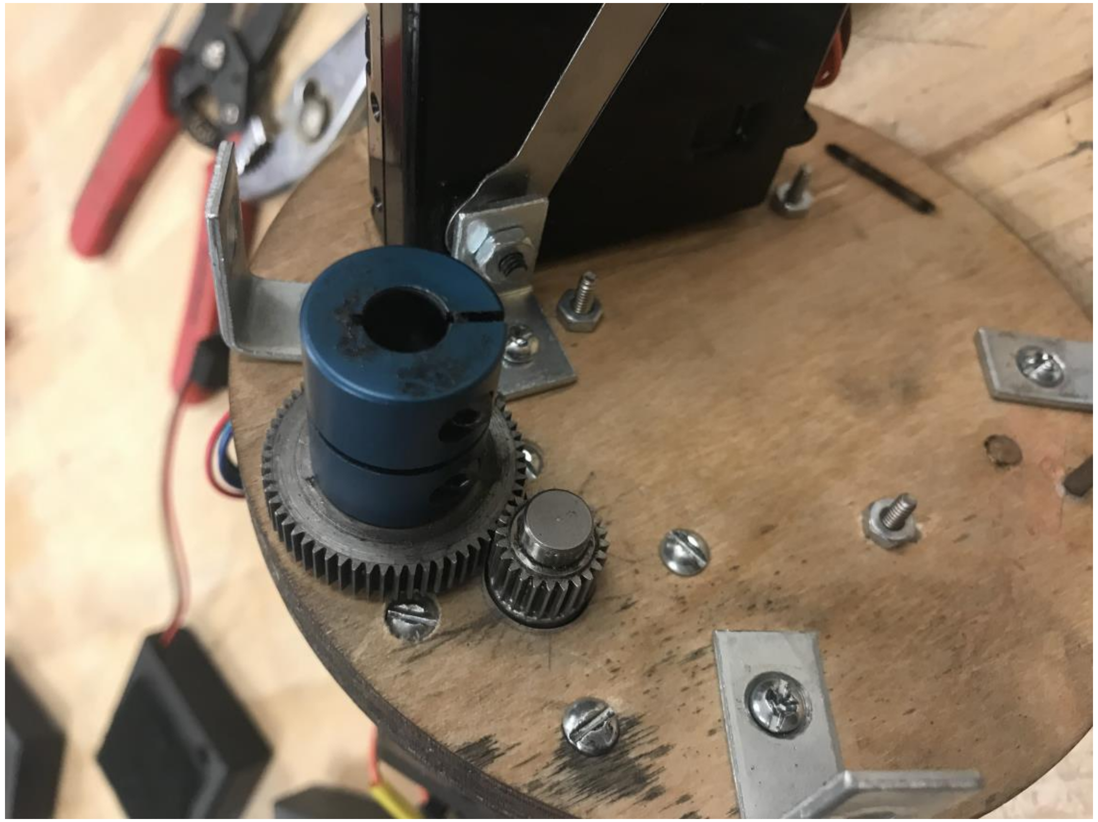
- Wiring for the payload system is now zip tied and secured to the bulkheads
- Battery packs are now attached via Velcro to the inside of the nosecone
- Wires connecting to individual payload deployment components and power supply has quick connects
- Wires have been secured to bulkheads and ziptied together

Changes Since CDR

- Added Gears and Lowered Lead Screw Pitch
  - Increase Torque and Robustness to friction
- Added Pins to the payload pod
  - Provides smoother UAV liftoff with less risk of tipping
- Changes Flap Shape
  - Ensures clear space for UAV blades even with ground debris

Changes for Future Launches

- Lead screw has a reduced screw threading in order to increase the magnitude of torque
- Lead screw is geared with the stepper motor to further increase the torque output
- Stepper motor and other electronics are encased in 3D printed mounts



Plans for Future Launches

- At this present time, the team is exploring various future launch opportunities that will enable the team to perform a successful payload demonstration flight prior to the FRR Addendum deadline of March 25th

Requirements Verification

Requirements Verification – Launch Vehicle

- The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit
  - Verified by analysis
  - RockSim simulations show a rail exit velocity of 69.45 fps
  - 10 ft launch rail will be used at next launch to ensure higher rail exit velocity
- At landing, each independent section of the launch vehicle will have a maximum kinetic energy of 75 ft-lb
  - Verified by analysis
  - Calculations show that this requirement will be satisfied even at 20 mph winds

Requirements Verification - Payload

- Any UAV weighing more than 0.55 lb will be registered with the FAA and the registration number marked on the vehicle
  - Verified by inspection
  - The UAV is registered with the FAA and proper paperwork will be brought to competition
- Teams will ensure the UAV's batteries are sufficiently protected from impact with the ground
  - Verified by inspection
  - The UAV's battery retention system ensures that the battery will not impact the ground upon landing

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 weathercocking 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

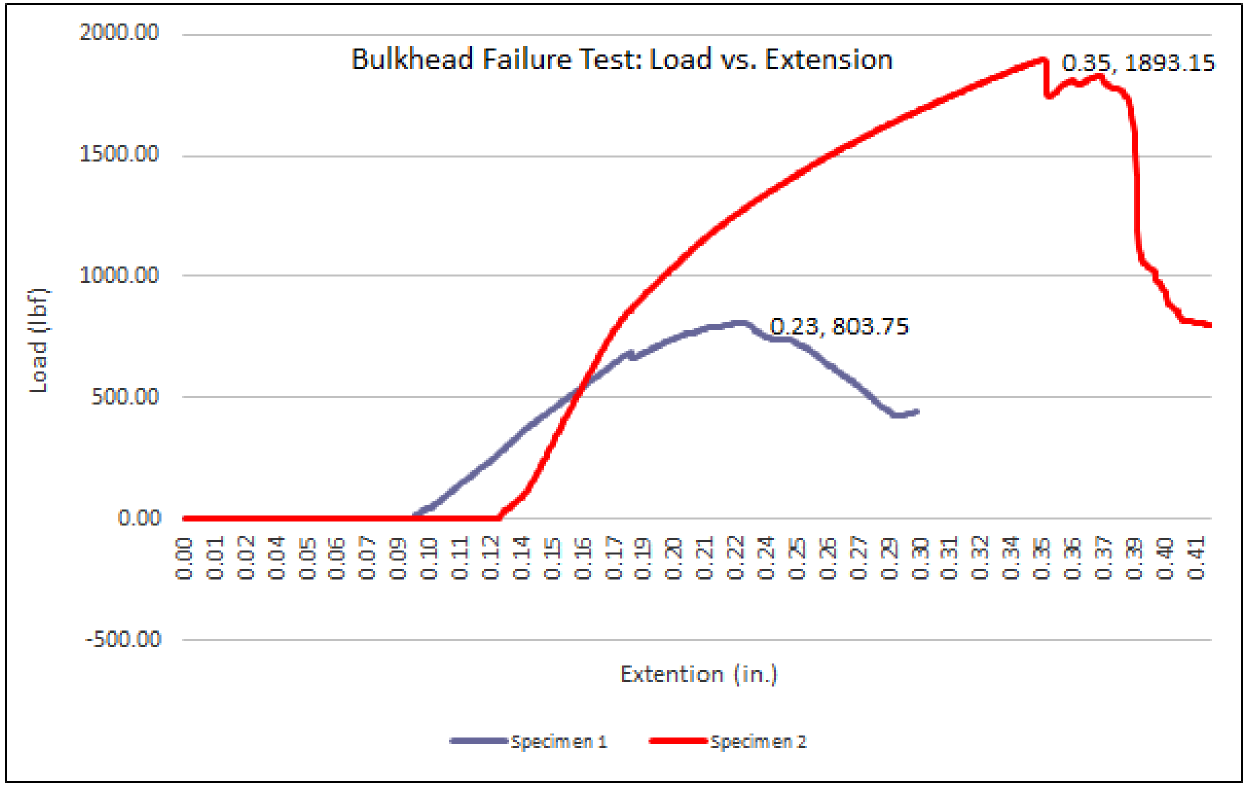
- The UAV shall be capable of flying 0.5 miles in unfavorable wind conditions
  - Ensures that the UAV will be able to reach the FEA in poor conditions
  - Prepares for the worst-case scenario
- Flight time of at least 5 minutes
  - Maximum necessary flight time to reach the FEA
- The UAV and retention system shall weigh less than 5 lb
  - Keeps stability within the chosen range

Bulkhead Failure Testing

- The purpose of this test was to test adherence between plywood bulkheads and fiberglass tubing
- Procedure:
  - A bulkhead was constructed of 6 layers of 1/8 inch plywood and a U-bolt was attached
  - The bulkhead was 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

Bulkhead Failure Testing

- Failure in fiberglass, not bulkhead
- Bulkhead withstood sufficient loading



Black Powder Ejection Demonstration

- This demonstration verified the functionality and sizing of black powder charges prior to launch
- Procedure:
  - The launch vehicle was assembled following launch day procedures with mass simulators replacing avionics and payload
  - Black powder charges were installed by following the e-match and black powder installation checklists
  - The launch vehicle was taken outside and set against a wall horizontally
  - The ejection testing switch was connected to one e-match via alligator clips
  - Power was applied and the switch was flipped after a five second countdown
  - A single black powder charge went 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

Black Powder Ejection Demonstration

- Ejection demonstration was performed prior to February 9 launch
  - This testing was successful with two shear pins at each separation point
  - 2.0 g of black powder at drogue and 3.0 g at main
- Ejection demonstration was performed again after addition of shear pins at main parachute separation point
  - First attempt was unsuccessful with 2.1 g of black powder
  - Successful separation with 3.8 g

Shear Pin Testing

- The purpose of this test was to measure the strength of the shear pins
- Procedure:
  - A shear pin was placed in the hole of two tensile test specimens
  - A nut is attached to the shear pin in order to secure the pin and only load the shear pin in the shearing direction
  - The ends of the tensile test specimens are placed into the top and bottom of a tensile testing machine
  - The tensile testing machine is then run until the shear pin fails and the force is recorded at which it breaks
  - Repeat test until shear pin failure points are consistent
- The strength of the shear pins is to be determined through this testing

Shear Pin Testing

- Shear pins were determined to fail in a range between 30 and 35 lb
- This value is significantly less than the previously thought 70-75 lb
- As a result, the number of shear pins has been increased to six per section from two

Payload Retention Testing

- This tested the functionality of the payload latch under sample loads between 25 and 35 lb
- Procedure:
  - A cord was attached to the payload latch to hold the weights
  - The weight was released on the cord slowly
  - After 1 second, the weight was removed
  - This was repeated for weights between 25 and 35 lb in 5 lb increments.
- Neither the SouthCo latch nor the payload pod eyebolt showed any signs of damage - success

Adverse Conditions UAV Flight Test

- This test simulated a more realistic flight environment for the UAV and tested UAV performance in realistic conditions
- Procedure:
  - An anemometer was used to measure wind speed and wind speed must be greater than 10 mph to proceed
  - A quarter mile was measured and marked in a large open field
  - The battery was connected to the UAV and all system's functionality was verified
  - The UAV was flown in loops across the quarter mile track
  - The number of loops and time of flight were recorded when the battery reaches 85% discharge
  - Repeated for three fully charged batteries
- UAV maintained stable flight for 10 min in winds exceeding 10 mph and performed a controlled landing - success

Questions?