
STAR

Presentation Map

1. **Airframe**
2. Payload
3. Recovery
4. Vehicle Interfaces
5. Flight Simulations
6. Full-Scale Flight
7. Project Plan
8. Full-Scale Reflight

Airframe

Vehicle Summary

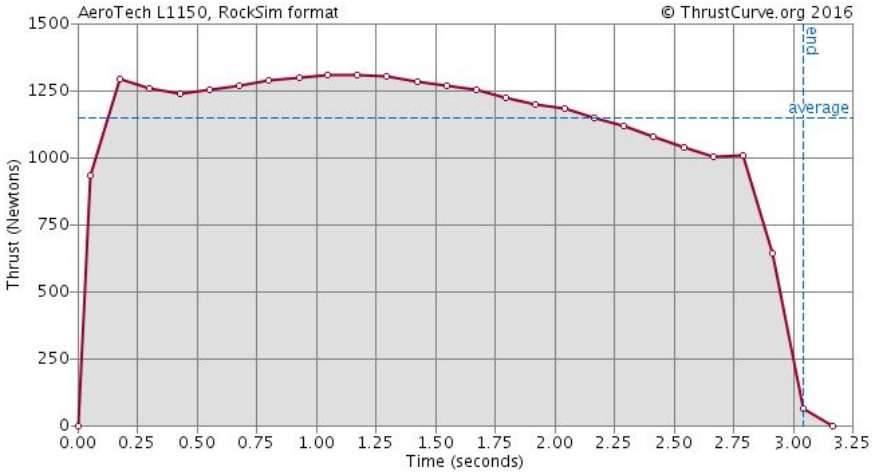
AirFrame

- Overall length: 8’ 7”
- Total Weight: 33.3 lbs
  - Total weight 25.18 lbs sans motor
  - Expected Weight Range: 30-34 lbs
- Diameter: 6”
- Nose cone length (ogive): 24”
- Payload section length: 18”
- Avionics section length: 15”
- Recovery section length: 18”
- Booster section length: 2’ 3”
- Motor type: Aerotech L1150 motor
- CG: 59.85” from nose cone tip
- CP: 76.56” from nose cone tip
- Stability margin: 2.78 calibers
- Thrust to weight ratio: 8.064
- Launch rod size: 12’ 1515 rail
- Rail exit velocity: 78.7 ft/s

Motor

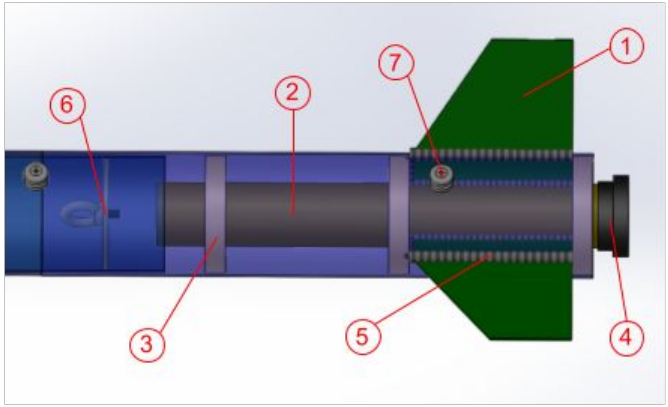
Motor type: Aerotech L1150 motor

- Total Weight: 3674g
- Propellant Weight: 1902g
- Diameter: 75mm
- Length: 53mm
- Average Thrust: 1150.0N
- Maximum Thrust: 1346.0N
- Total Impulse: 3157.0Ns
- Burn Time: 3.1s



Booster Section

1. G-10 Fiberglass Fins
2. Kraft Phenolic Motor Mount
3. Plywood Centering Rings
4. 75mm Motor Retainer
5. Carbon Fiber Fillets
6. Plywood Bulkhead
7. 1515 Rail Buttons



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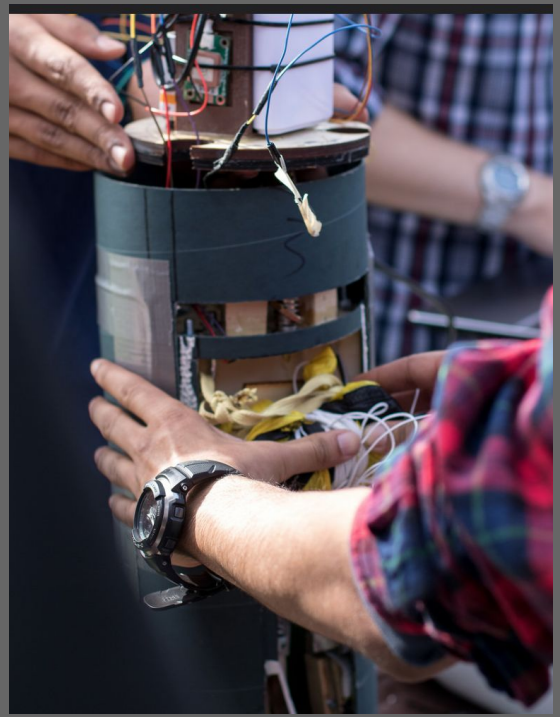
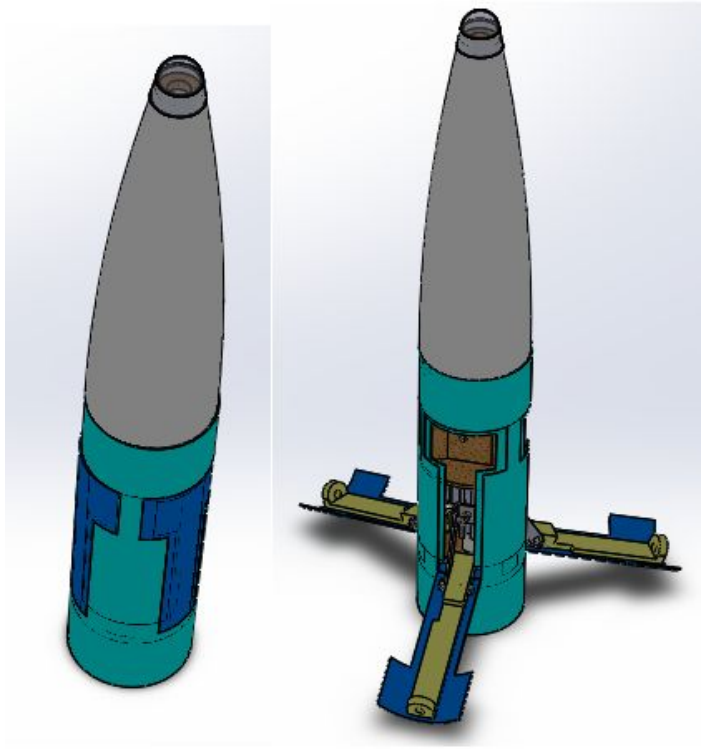
Payload



Payload

Target Detection and Upright Landing

- Detect and differentiate ground targets with camera mounted in nose cone
- Deploy three landing legs
  - Deploy three parachutes

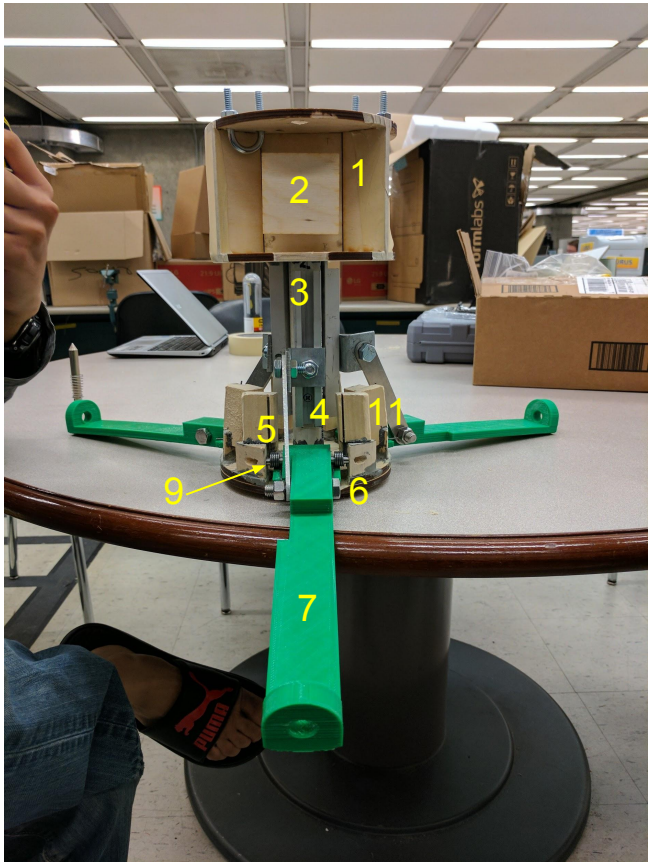


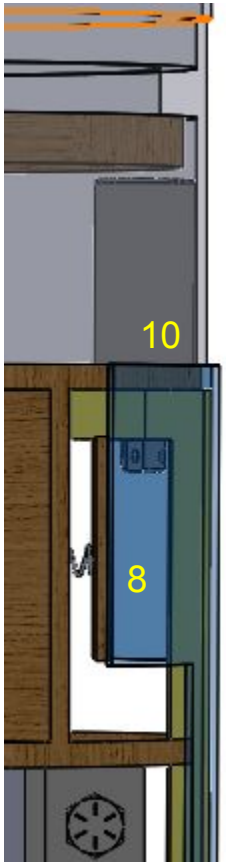
(A) (B)

Landing Leg Assembly

1) Parachute container
2) Parachute springboard
3) Rail
4) Rail carriage
5) Support leg
6) Lower bulkhead
7) Landing leg
8) Landing leg frame
9) Torsion springs*
10) Solenoid actuator
11) Hinge Posts *

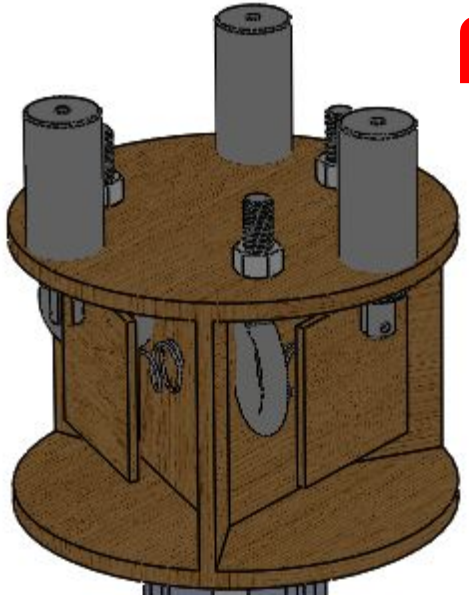
Design Change = *





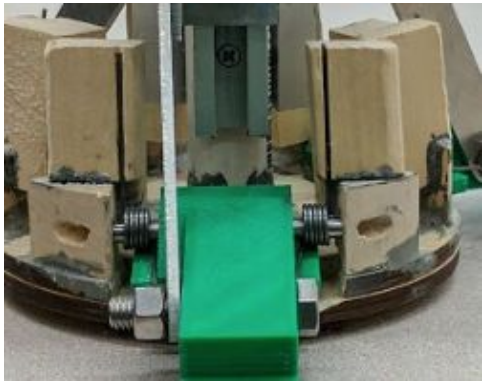
Payload Recovery System

- Parachute containers mounted to upper payload tube
- Spring boards deploy parachutes



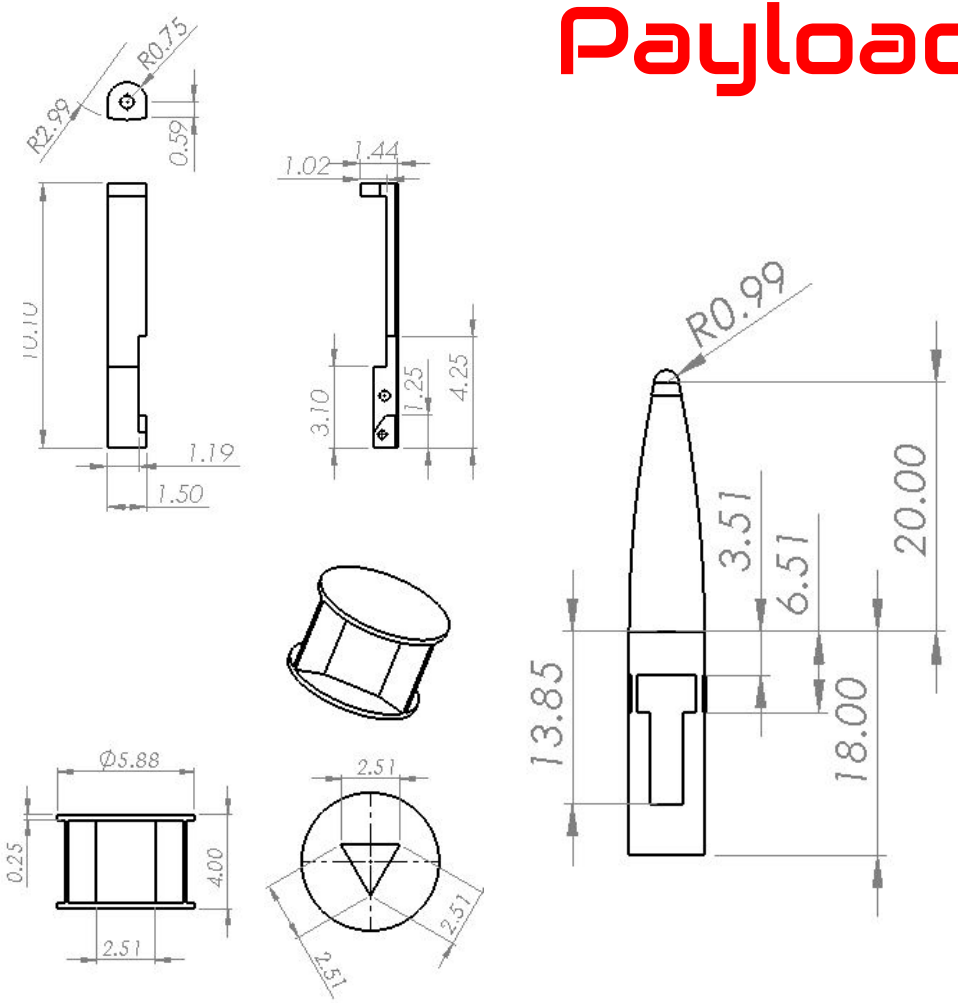
Torsion Spring Mechanism

- Original Design: one large torsion spring per leg situated between landing leg and sliding rail
- New Design: Two smaller springs around dowel pin situated on either side of the landing leg
    - Added hinge posts to accommodate new design



Payload Dimensions

- Three 8.75” aluminum rails, 120º apart
- Six 3” high posts
- Three steel dowels, ½” above bottom bulkhead
- Landing leg extends 3.5” below the payload bulkhead



Payload

Target Detection Procedure:

The algorithm will follow these steps for each image taken:

- Search the image captured for the three targets (regions of color in the image) using memory-efficient numpy operations in Python
  - PDR: numpy operations in Python
  - FRR report: Mathematica-based functions
  - Current: memory-efficient Python

- Images taken after main parachute deployment should be considered for target detection




Photos from subscale launch*

Payload

Target Detection Algorithm Sample

Image from altitude, taken by URSA Minor

- Two ground target sets in image with differing colors
- Identified correct set

Original Image

Processed Image

Payload

Target Detection Algorithm Sample

Image from altitude, taken by URSA Minor

- Two ground target sets in image with differing colors
- Identified correct set

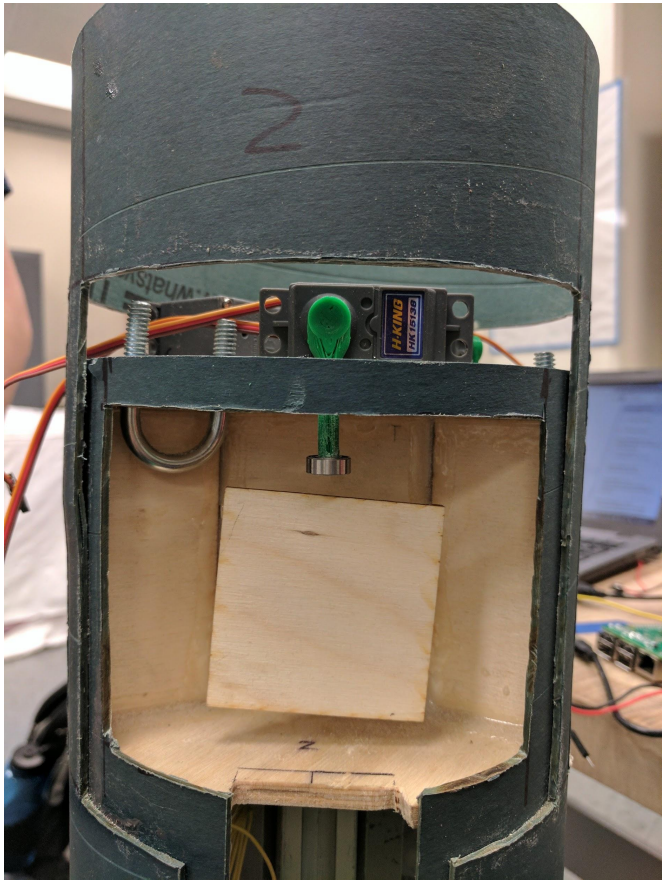
Detection, Partial False Positive

Processed Image

Design Changes since Full Scale Flight

Payload

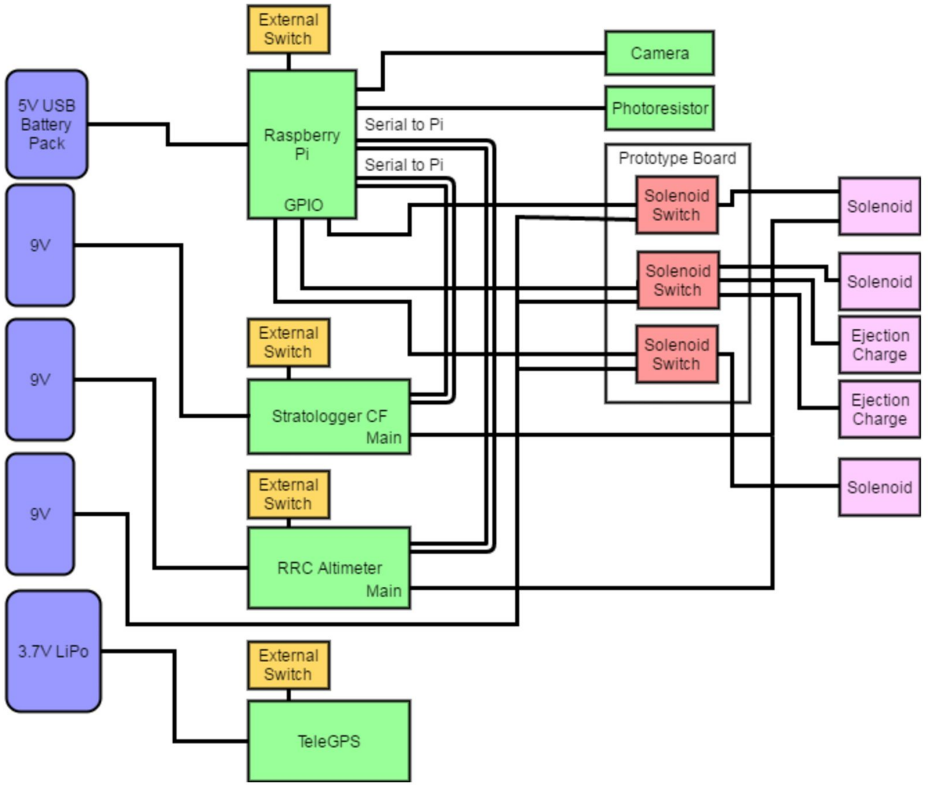
- Replacement of solenoids with servos
  - Increased reliability
  - Simplified electronics
- Removal of parachute springboard
  - Reduce force on closed leg



Full-Scale Payload Electronics

Components:

- Raspberry Pi
- Stratologger CF
- RRC3
- Camera
- Photoresistor
- TeleGPS
- Solenoid Switches
- Solenoids
- Batteries

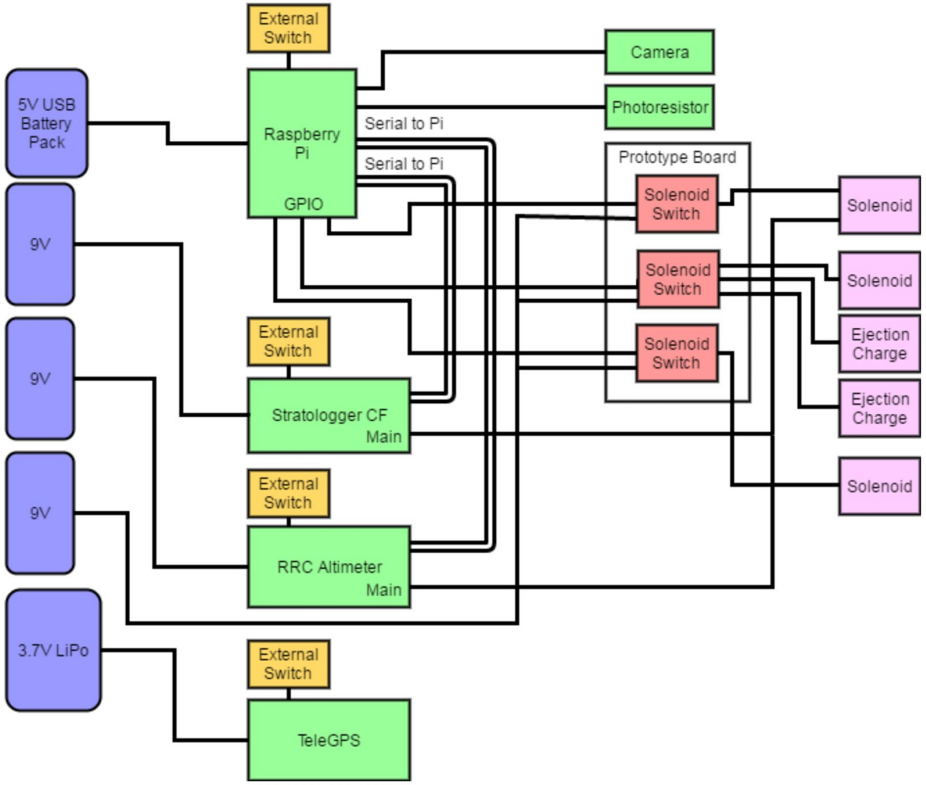


Full-Scale Payload Electronics

Raspberry Pi:

- Altitude data input serially from both altimeters.
- Camera input from camera port.
- Photoresistor input from GPIO.
- Solenoid signals as output via GPIO.

Contains launch program.

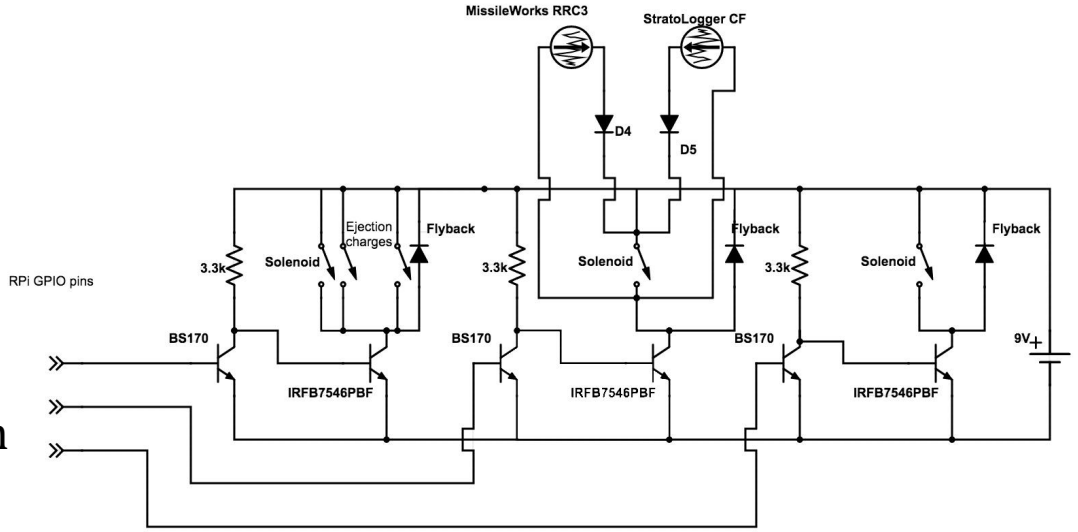


Full-Scale Payload Electronics

Prototype Board:

Contains three solenoid switches.

- Raspberry Pi signal via GPIO as input - one GPIO per switch.
- Altimeters' main ejection ports connected in parallel to first switch (the one activated first in normal operation).
- Ejection charges connected in parallel to second switch.

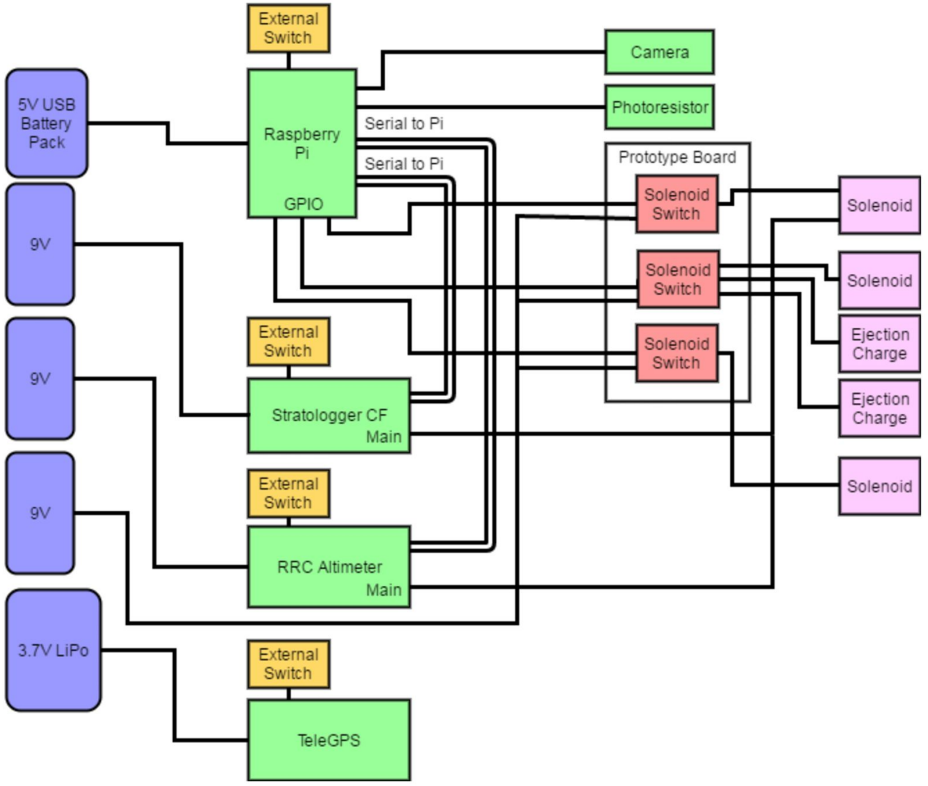


Full-Scale Payload Electronics

Batteries/Power:

- 5V USB power bank powered by 4 AA batteries for Raspberry Pi.
- 9V Duracell for Stratologger CF.
- 9V Duracell for RRC3.
- 9V Duracell for solenoids.
- 3.7V 2000mAh LiPo for GPS.

External switch for each power source.



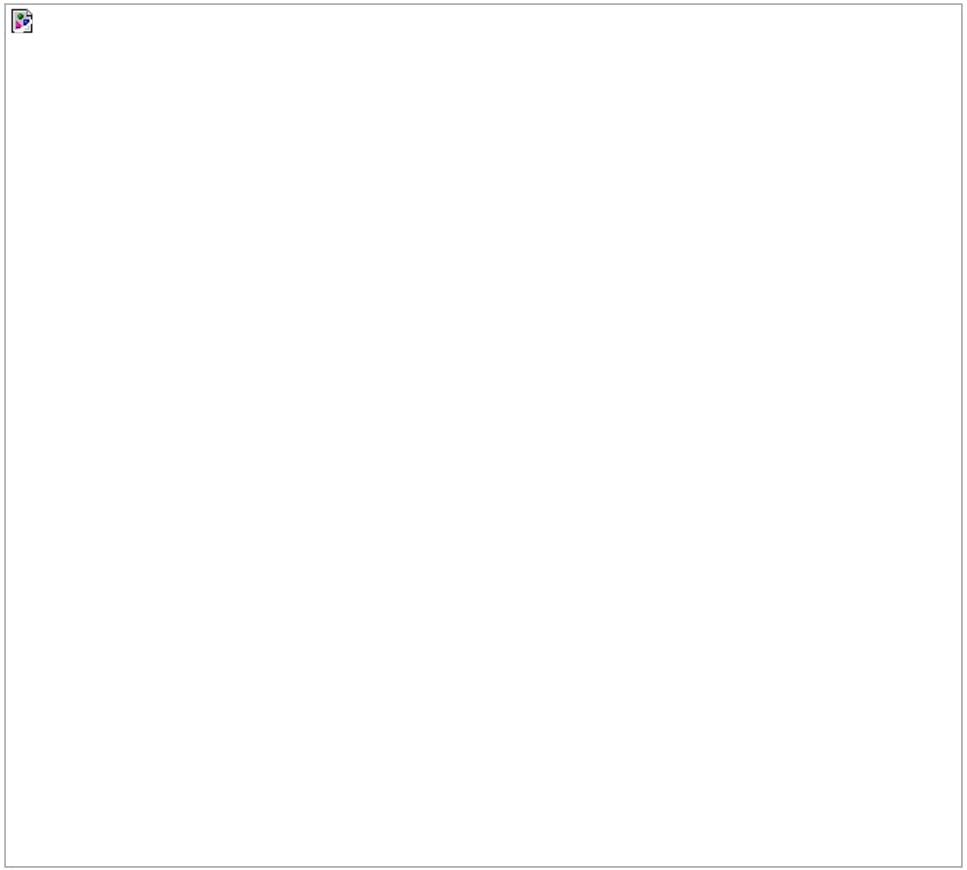
Full-Scale Reflight and Competition

Payload Electronics

Raspberry Pi:

- Altitude data input serially from both altimeters.
- Camera input from camera port.
- Photoresistor input from GPIO.
- Servo signals as output via GPIO.
- Ejection charge signal as output via GPIO.

Contains launch program.



Full-Scale Payload Electronics

Launch Program

No targets to detect, so use altitude instead.

- Confirm ascent at 200’ on the way up.
- Detect deployment at 700’ on the way down.
- Deploy first leg.
- For 15 seconds: check for light in the parachute box for the first leg.
- If no light: abort remaining deployment and ejection.
- If light: deploy second leg and eject payload section, then wait and deploy third leg.

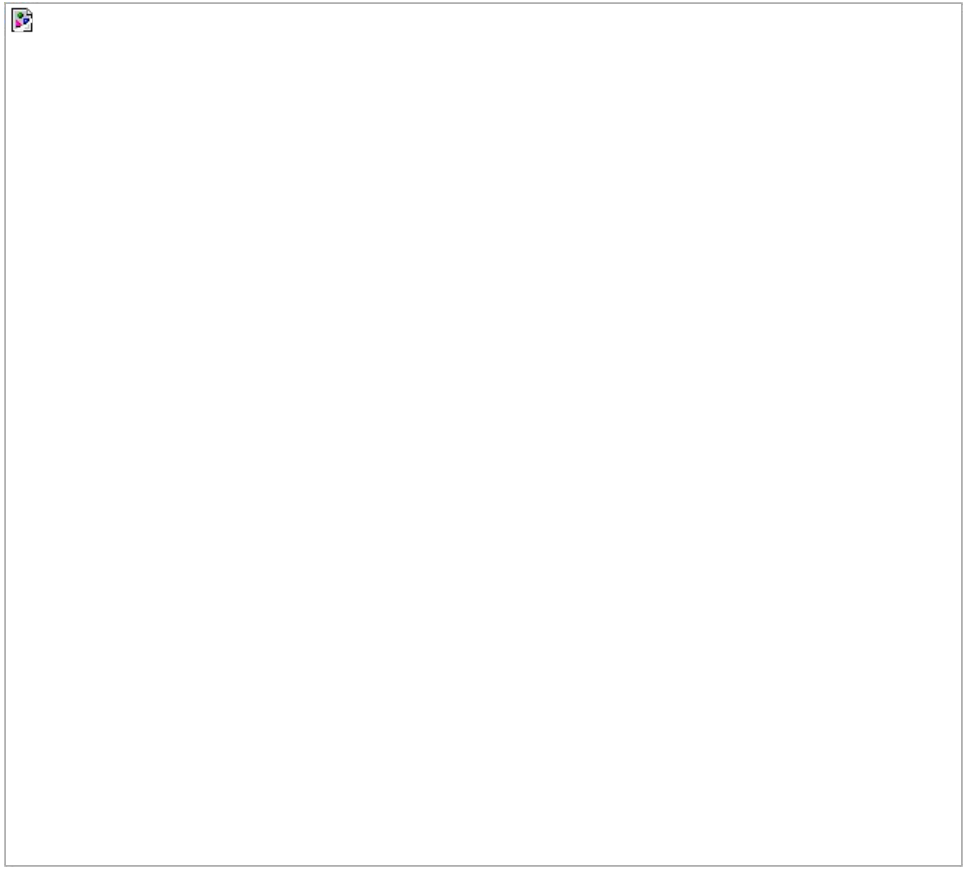
Full-Scale Reflight and Competition

Payload Electronics

Components:

- Raspberry Pi
- Stratologger CF
- RRC3
- Camera
- Photoresistor
- TeleGPS
- Ejection Charge Switch
- Servos

- Batteries



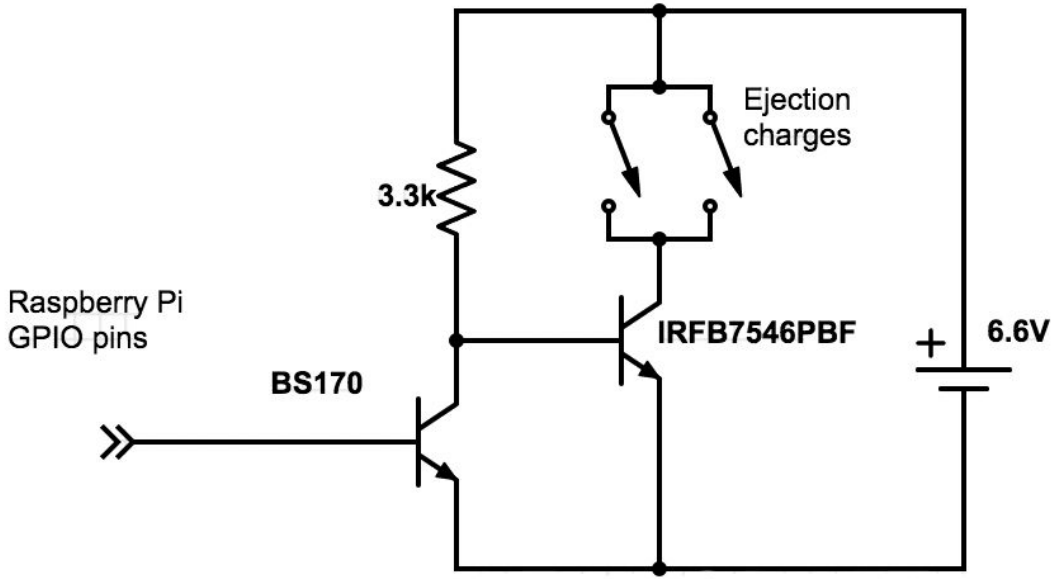
Full-Scale Reflight and Competition

Payload Electronics

Prototype Board:

Contains only the ejection charge switch.

- Raspberry Pi signal via GPIO as input.
- Ejection charges connected in parallel to the switch.



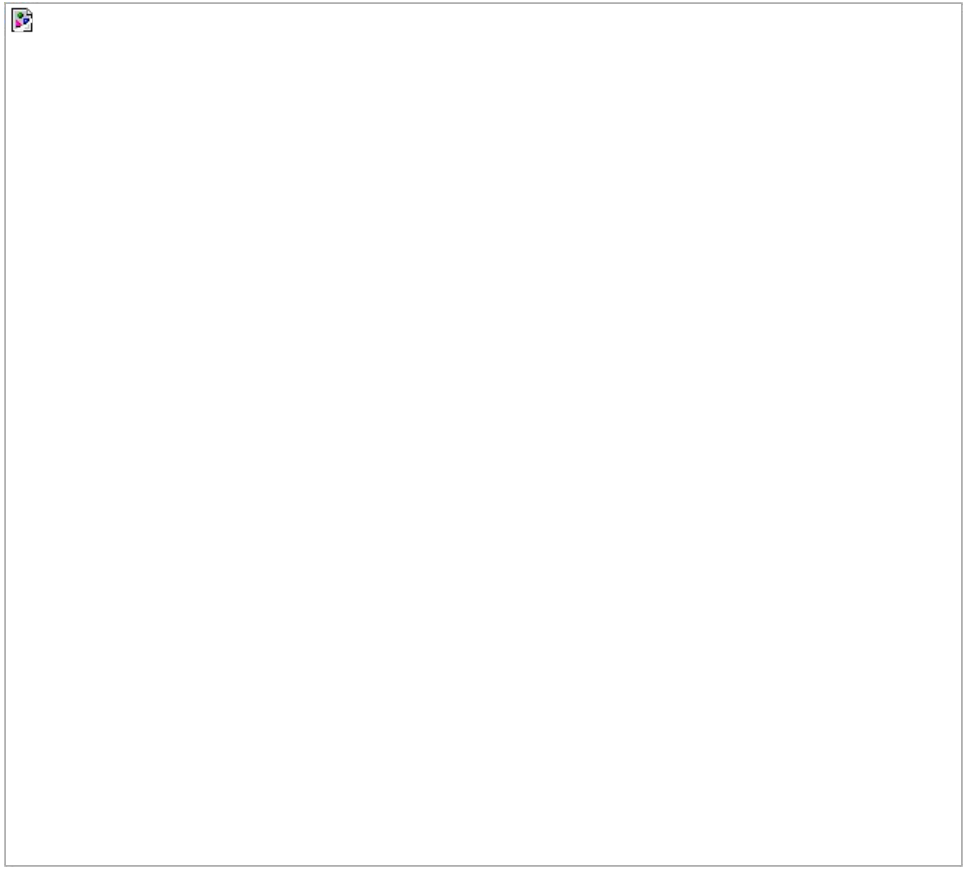
Full-Scale Reflight and Competition

Payload Electronics

Batteries/Power:

- 5V USB power bank powered by 4 AA batteries for Raspberry Pi.
- 9V Duracell for Stratologger CF.
- 9V Duracell for RRC3.
- 3.7V 2000mAh LiPo for GPS.
- 6.6V 2000mAh LiFe for servos and ejection charges.

External switch for each power source.



Payload Electronics

Launch Program

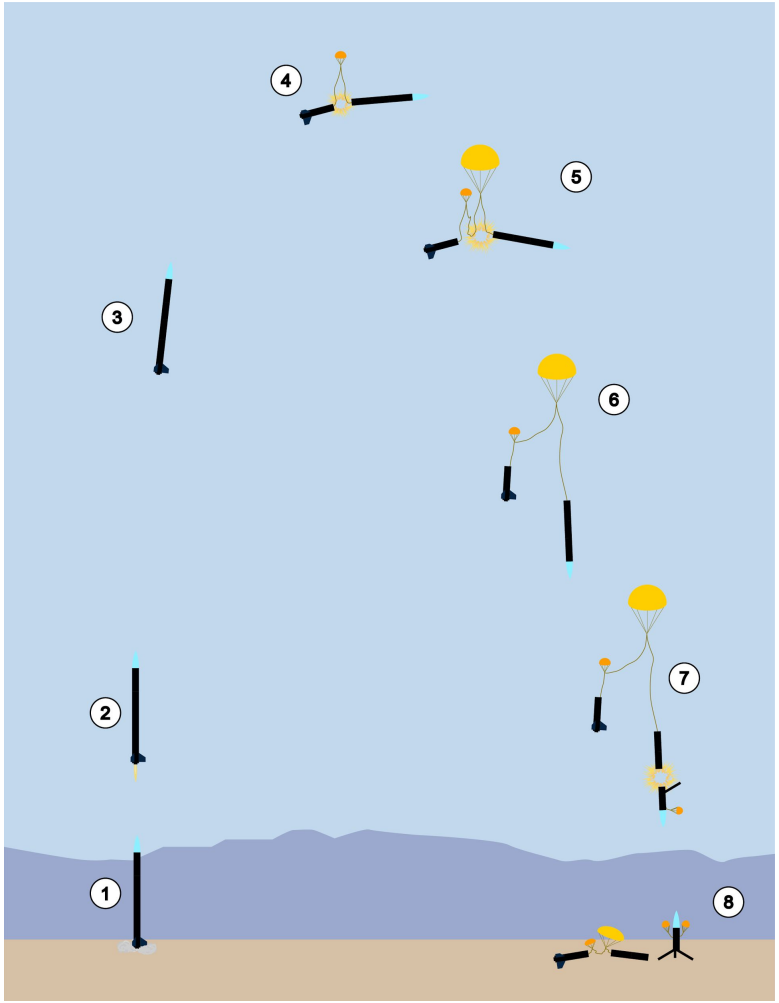
No targets to detect, so use altitude instead.

- Confirm ascent at 200’ on the way up.
- Detect deployment at 650’ on the way down.
- Deploy first leg..
- For 15 seconds: check for light in the parachute box for the first leg.
- If no light: abort remaining deployment and ejection.
- If light: eject payload section, then wait and deploy the second leg, then wait and deploy the third leg.

Competition Payload Electronics

Launch Program

- Confirm ascent at 200’ on the way up.
- Start camera/image analysis operation at 1000’ on the way down. Continue until the targets are found or deployment begins.
- At 650’ on the way down, deploy the first leg.
- For 15 seconds: check for light in the parachute box for the first leg.
- If no light: abort remaining deployment and ejection.
- If light: eject payload section, then wait and deploy the second leg, then wait and deploy the third leg.



Payload/Recovery

PHASE	EVENT
1	Ignition.
2	Powered flight.
3	Coasting.
4	Drogue parachute deployed at apogee (projected at 5,132 ft. AGL)
5	Main parachute deployed at an altitude of 1,000 ft. AGL.
6	Camera in the nosecone of the vehicle begins target spotting.
7	Payload section deploys itself from vehicle and deploys its legs and three parachutes.
8	All sections of the vehicle land with a KE under 75 ft-lbf.

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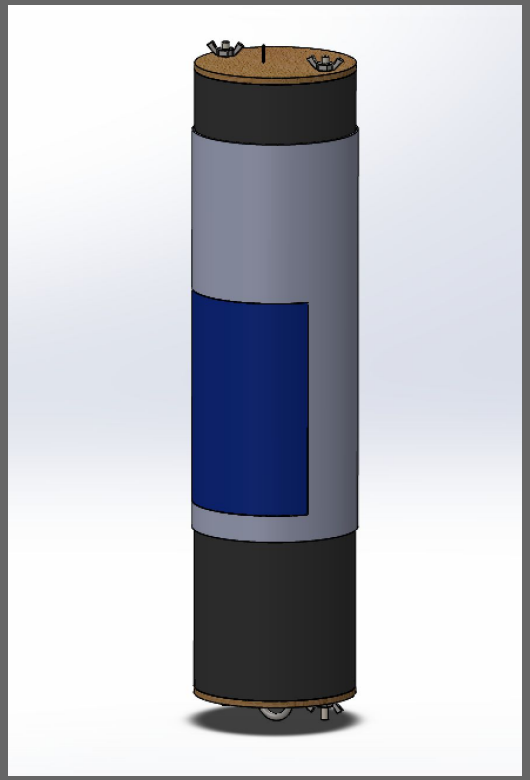
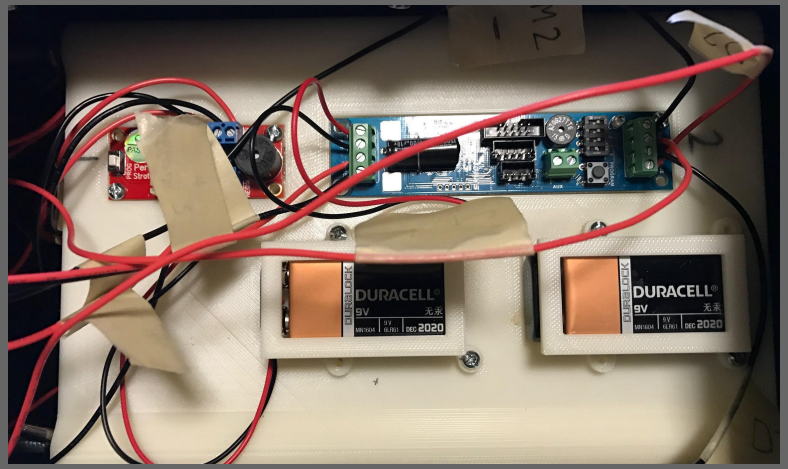
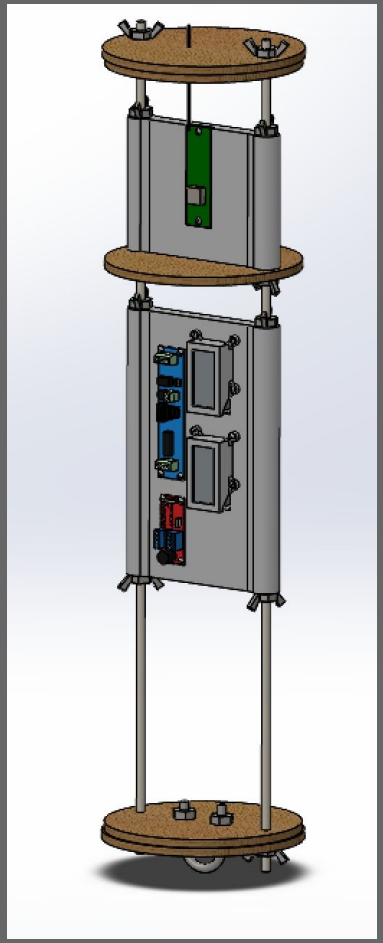
Recovery







Parachute Sizes

- *Drogue Parachute*
  - Optimally velocity 50 mph (or 73 ft/s)
  - **1x 24” diameter elliptical parachute with C_d = 1.5**
- *Main Parachute*
  - Payload will detach before vehicle lands
  - **1x 72” diameter toroidal parachute with C_d = 2.2**
- *Payload Parachute*
  - 3 parachutes for stabilization
  - **3x 36” diameter toroidal parachute with C_d = 2.2**

$$V_{Terminal} = \sqrt{\frac{(2m_{total}g)}{\rho C_1 A_1}}$$

$$m_{total(w/o\ payload)}g = \frac{1}{2}\rho v_{max}^2 C_1 A_1 + \frac{1}{2}\rho v_{max}^2 C_2 A_2$$

Descent Rates

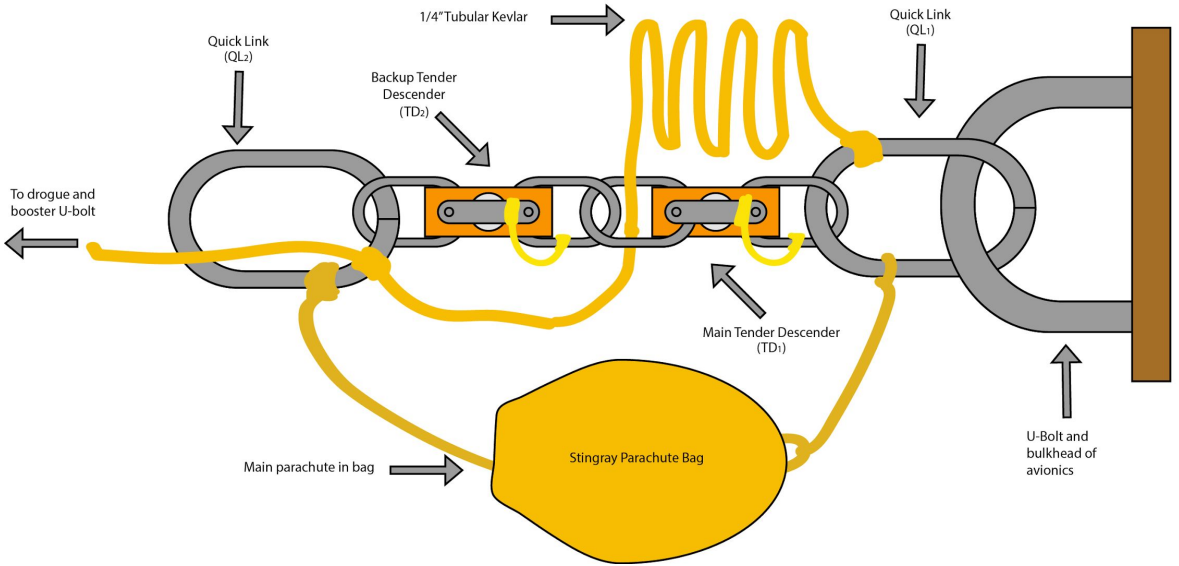
Section	Scenario	Phase	Descent Rate (ft/s)
All sections of vehicle	Drogue deployed	Descent under drogue	67.04
Avionics Bay	Payload Detaches	Landing	13.76
Booster	Payload Detaches	Landing	13.76
Payload	Payload detaches and 3 parachutes deploy	Landing	13.01
*Avionics and Payload (attached)	Payload does NOT detach	Landing	17.79
*Booster	Payload does NOT detach	Landing	17.79
*Payload	Payload detaches and 1 parachute deploys	Landing	22.50

Kinetic Energy

Section	Scenario	Phase	Kinetic Energy (ft-lbf)
All sections of vehicle	Rocket ascending	Ascent	Min: 2055.12 Max: 192518.47
Avionics and Payload (attached)	Drogue deployed	Descent under drogue	10032.34
Booster	Drogue deployed	Descent under drogue	549.00
Avionics Bay	Payload Detaches	Landing	13.79
Booster	Payload Detaches	Landing	23.15
Payload	Payload detaches and 3 parachutes deploy	Landing	24.76
*Avionics and Payload (attached)	Payload does NOT detach	Landing	72.70
*Booster	Payload does NOT detach	Landing	38.66
*Payload	Payload detaches and 1 parachute deploys	Landing	74.27

Tender Descender System

- Connected in series
- ¼” tubular kevlar
- Detachable wires
- Quicklinks



Recovery System Tests

Two major tests were performed for the recovery system, both of which were successful

- Tender descender tests
  - Tested tender descender release combinations
- Ground tests for black powder charge size verification
  - 1 4-40 shear pin
    - 4g for drogue
    - 0.5g for main
  - 2 4-40 shear pin
    - 2g for payload

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Vehicle Interfaces

Vehicle Interfaces

- Blue Tube couplers between booster - av-bay, and av-bay - payload.
- 3.5” shoulder at av-bay - payload interface; shear pinned
- 3.5” shoulder at payload - nose cone interface; screwed together
- Shock cord between booster and av-bay

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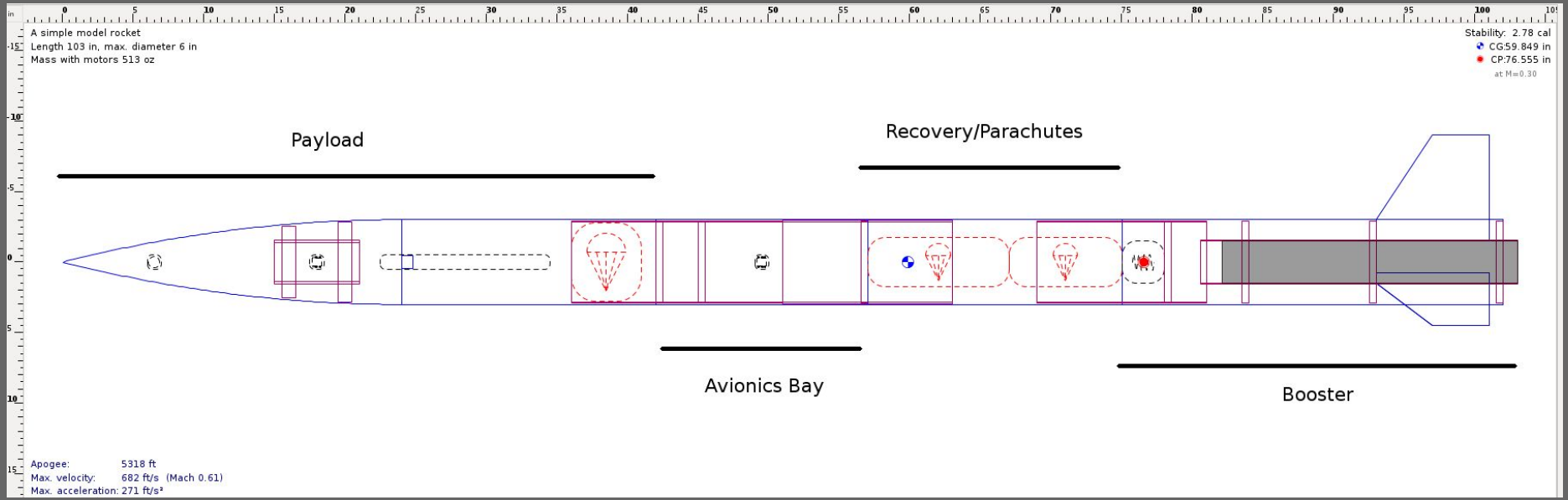
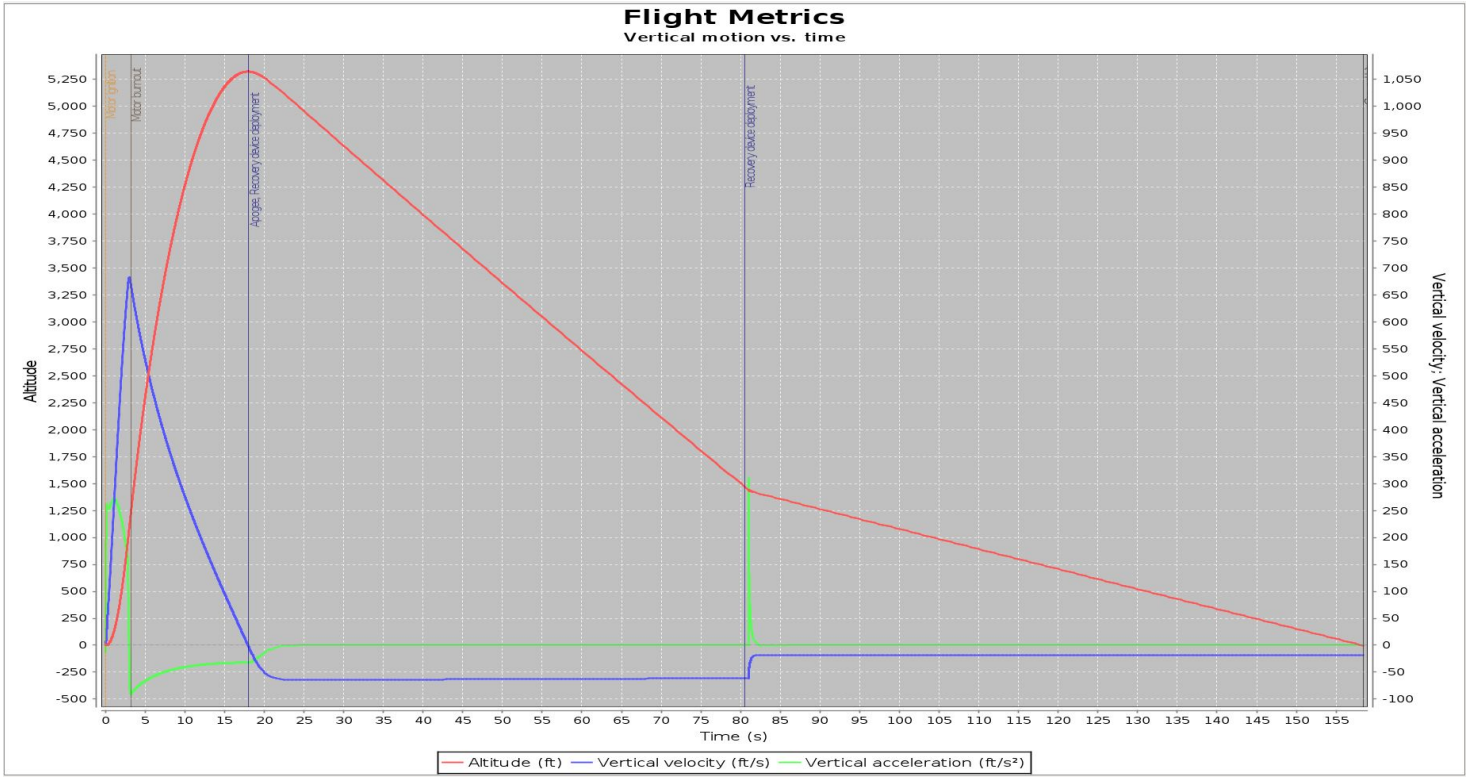
Flight Simulations



Simulated Flight Profile

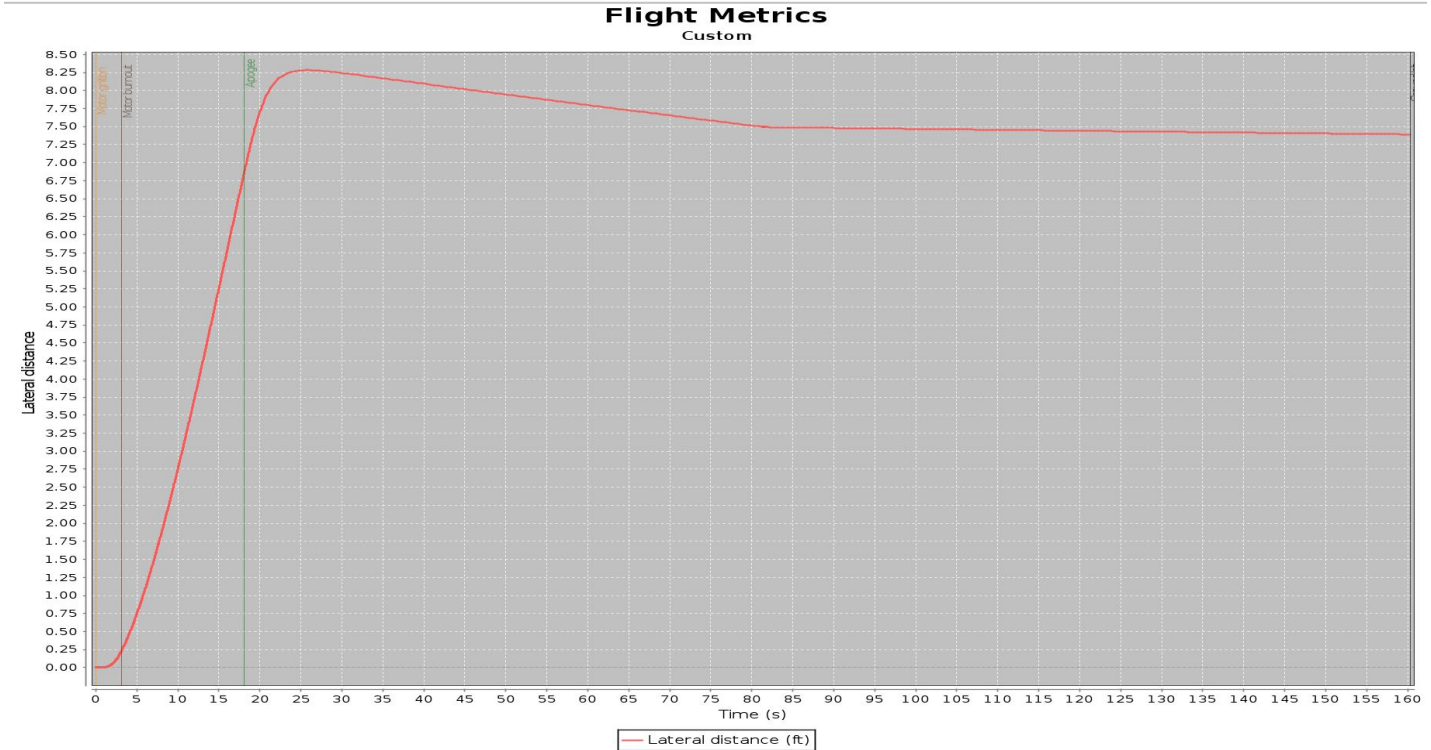
Flight Simulations



Drift Simulation (Zero Wind)

Flight Simulations

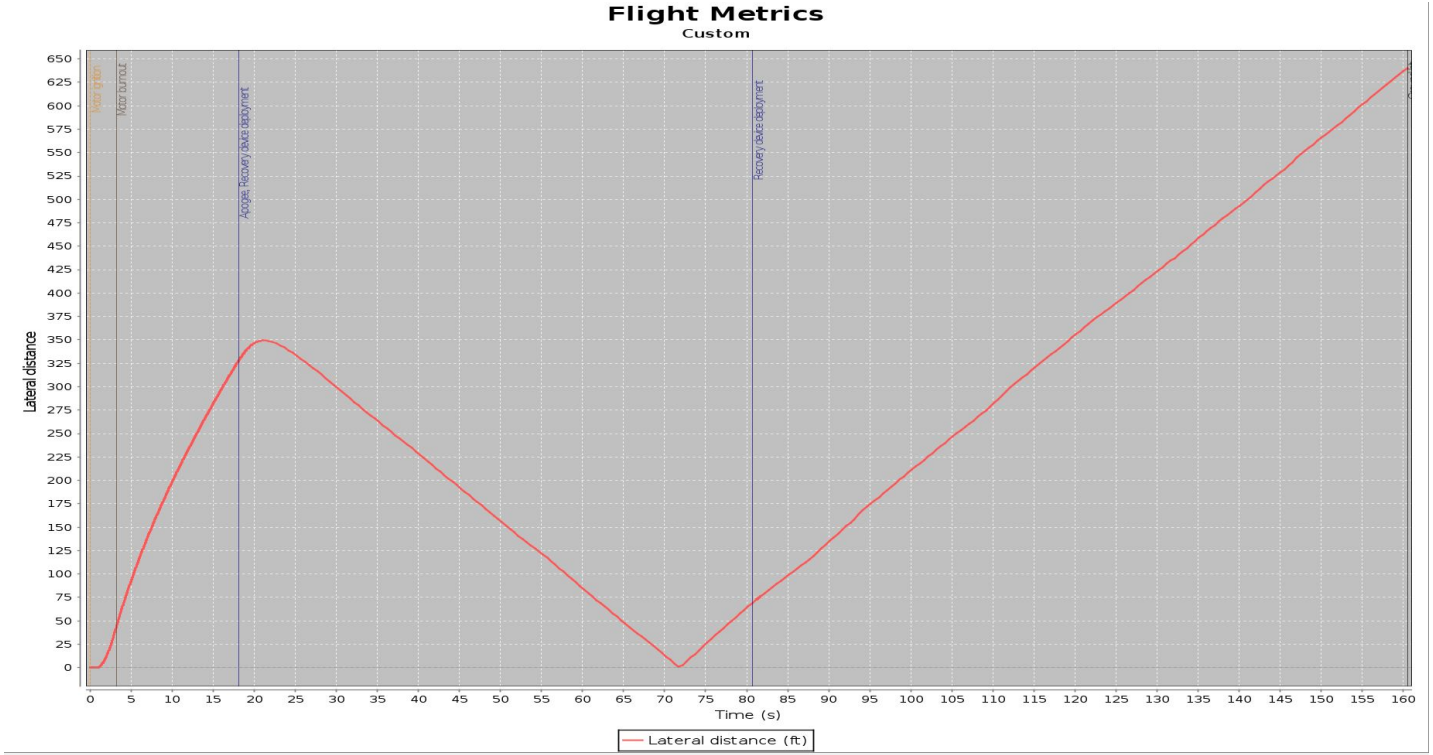
- Maximum Drift: ~7.50 ft



Drift Simulation (5 mph Wind)

Flight Simulations

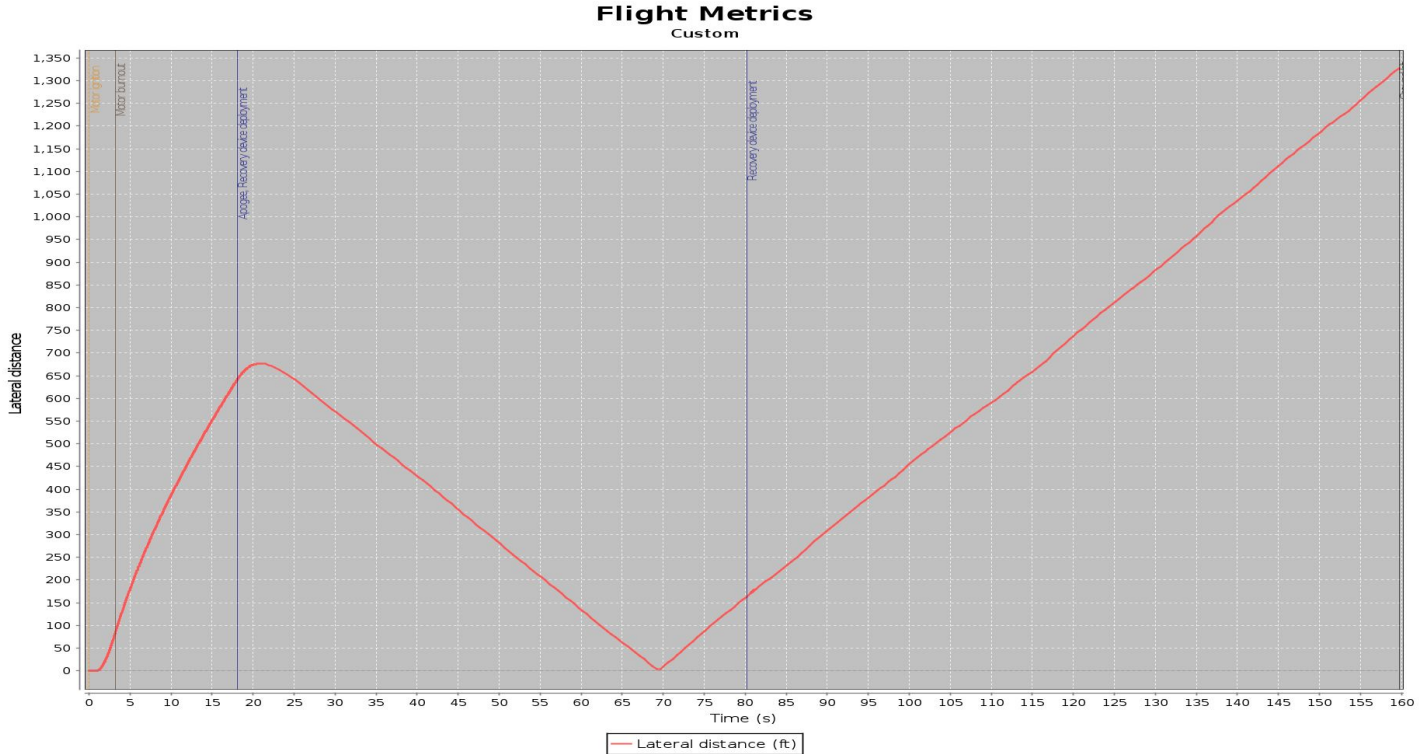
- Maximum Drift: ~640 ft



Drift Simulation (10 mph Wind)

Flight Simulations

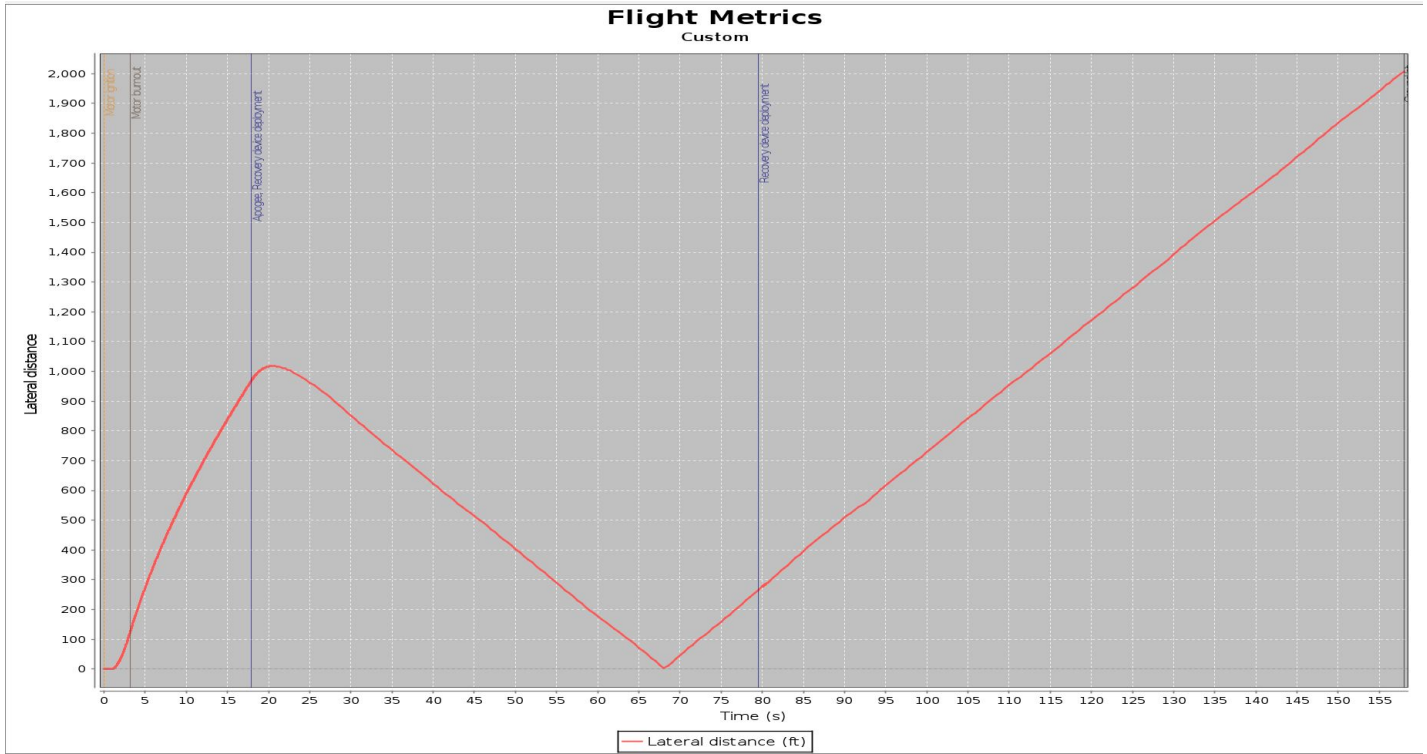
- Maximum Drift: ~1330 ft



Drift Simulation (15 mph Wind)

Flight Simulations

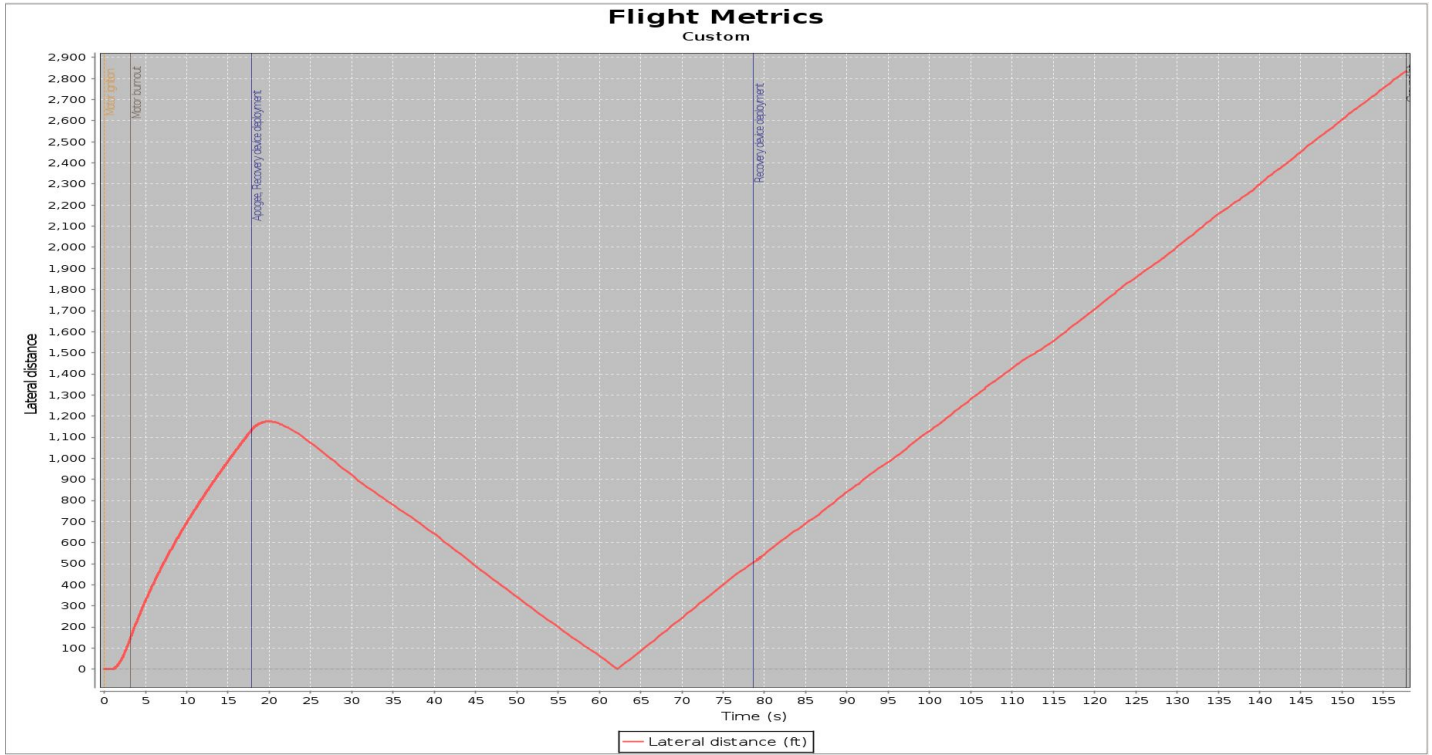
- Maximum Drift: ~2000 ft



Drift Simulation (20 mph Wind)

Flight Simulations

- Maximum Drift: ~2800 ft



Altitude and Drift Simulation Summary

Flight Simulations

Wind Speed (mph)	Predicted Drift (ft)	Predicted Apogee (ft)
5	640	5308
10	1330	5278
15	2000	5213
20	2800	5168

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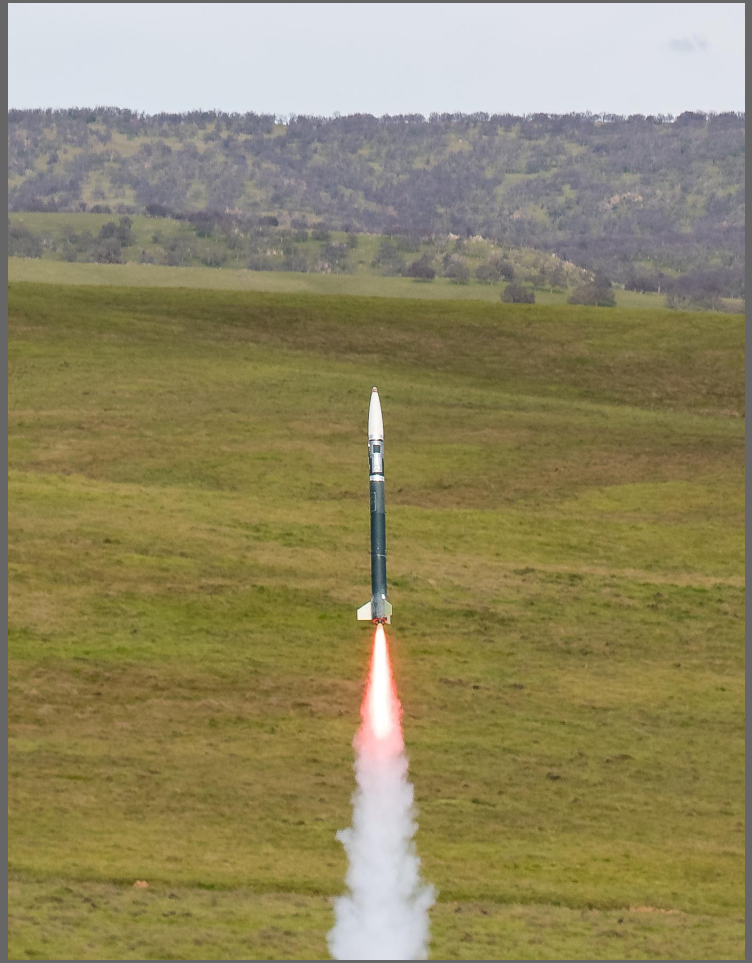
Full-Scale Flight

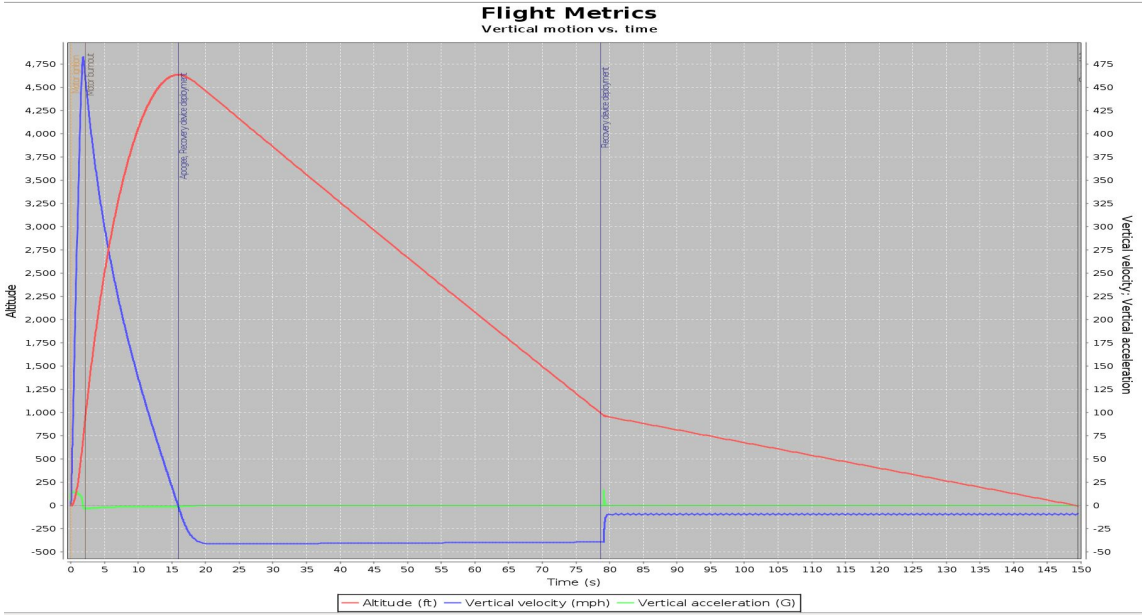


Launch Conditions/Flight Results

Full-Scale Flight

- March 4th, 2017
  - 3:05 P.M. PST
- Temperature: 60 deg F
- Air Pressure: 30.2 inHg
- Wind: 9 mph

- Simulated Apogee: 5131 ft
  - Actual Apogee: 4541 ft
- Velocity off Rail: 62.9 ft/s
- Maximum Velocity: Mach 0.59
- Maximum Acceleration: 15.3 G's



Flight Results

Full-Scale Flight

- Payload
  - Electronics failures
    - Camera
    - Switches
  - Leg deployment failed
- Airframe
  - Severe launch angle off the rail

Impact on Vehicle

Full-Scale Flight

- Payload system design
  - More reliable way to deploy legs
  - Ensure reliability of electronics components
- Airframe design
  - Reduce weight
  - Protect nose cone

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Project Plan

Test Plans and Procedures

Project Plan

Payload:

- Drop tests
- Landing Leg Deployment Tests
  - Led to many necessary design modifications
- Videos of both on our YouTube channel

Project Plan

Test Plans and Procedures

Electrical:

- Target Detection

Airframe:

- Durability Testing
  - Fins & Nosecone Tip
  - Water resilience

Requirement Verification: Vehicle

Project Plan

- All design requirements fulfilled
  - Full-scale rocket successfully flown and recovered
- Team Derived Requirements largely focused on quality of construction

Requirement Verification: Recovery

Project Plan

- All design requirements fulfilled
  - Full-scale rocket successfully flown and recovered
- Team Derived Requirements largely focused on safety and damage mitigation

Requirement Verification: Payload

Project Plan

- Some performance requirements are yet to be fulfilled
  - Full-scale payload to be flown again to fulfill these requirements
- Team Derived Requirements largely focused on robustness of ability to be recovered safely and land/remain upright

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4. Vehicle Interfaces
5. Flight Simulations
6. Full-Scale Flight
7. Project Plan
8. **Full-Scale Reflight**

Full Scale Reflight

Flight Results

Full-Scale Reflight

- Launch Rail Issue
  - Nose cone fell
  - Launch rail fell
  - Single payload leg opened leading to single parachute deployment

Impact on Vehicle

Full-Scale Reflight

- Airframe
  - Minor damage to booster section
    - Fixing with fiberglass
  - Minor damage to fillets

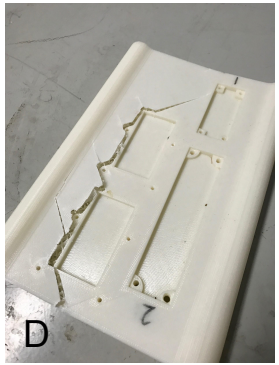
Impact on Vehicle

Full-Scale Reflight

- Recovery
  - Minor damage to door and airframe
    - Fixing with fiberglass
  - Sled cracked
    - Printing new sled
  - All avionics bay electronics are working properly and have experienced no damage
  - Main and drogue parachute in perfect condition
  - One payload parachute experienced burn damage
    - Purchasing new recovery parachute

Impact on Vehicle (Recovery)

Full-Scale Reflight



(Left: A, B, C) Minor Damage on Airframe

(Left: D) Sustained damage on altimeter sled

(Right) Overall Avionics Bay is in recoverable condition

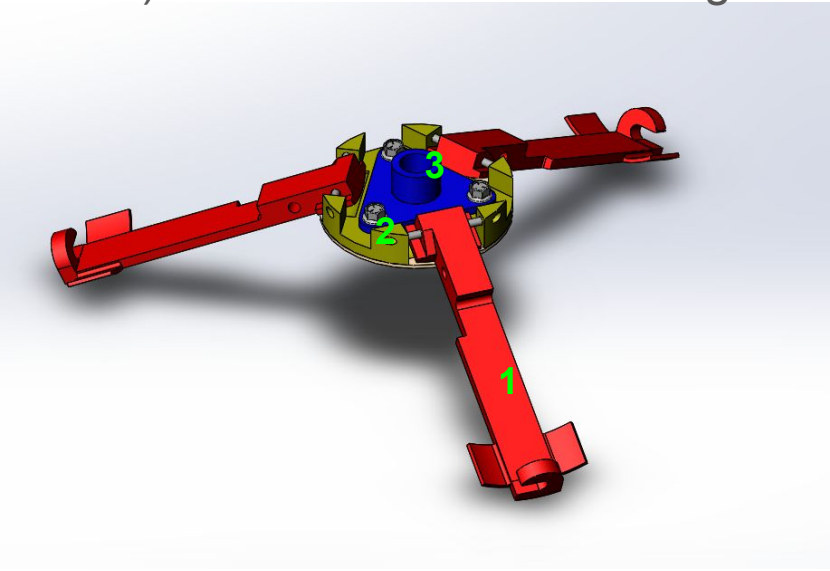
Impact on Vehicle

Full-Scale Reflight

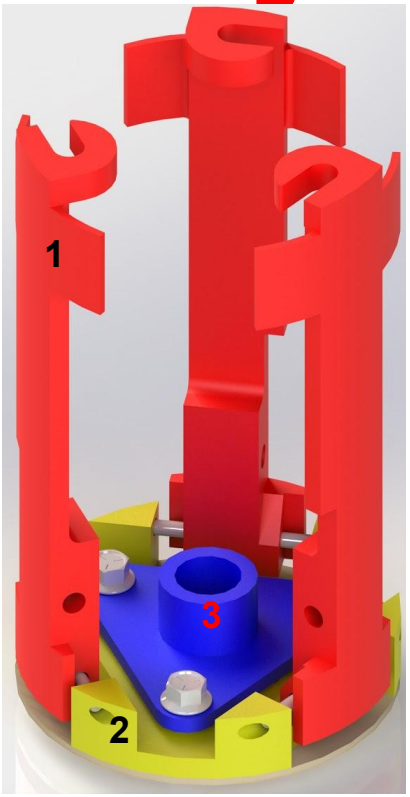
- Payload
  - Rebuild
    - Internal pvc + rail structure reusable
    - Reinforce walls with fiberglass
  - Improve tolerances
    - Manufacture more parts with computer assistance (3D printing, laser cutting)
  - Electronics
    - Make software more resilient to extraordinary conditions that turn off the Pi

Payload reconstruction

- Rebuilt parts
  - 1) Form fitting leg frame
  - 2) 3D Printed leg mount
  - 3) Central tube mount + weight



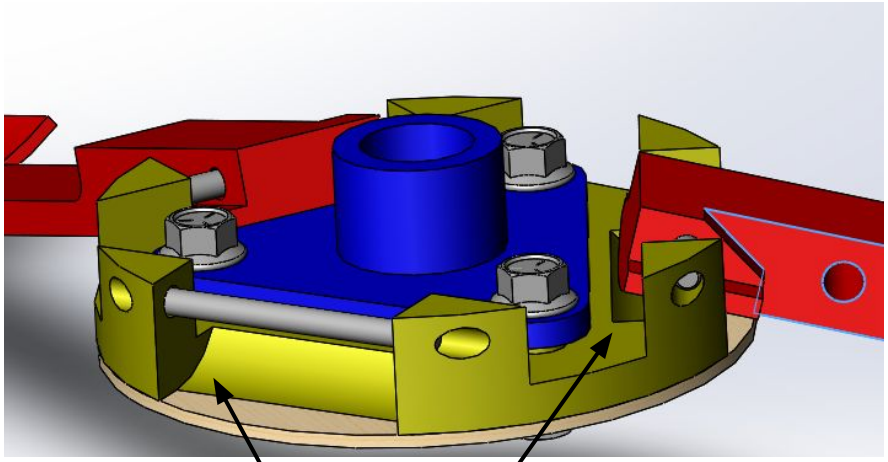
Full-Scale Reflight



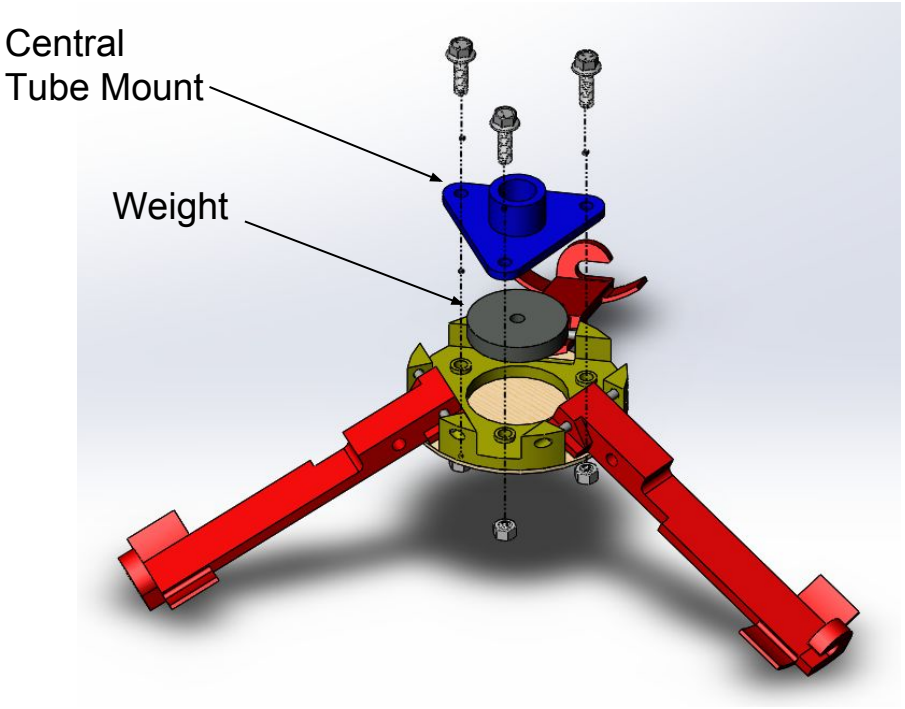
Payload reconstruction

Full-Scale Reflight

- Increased Quality



3D Printed Curve
for Clearance



Questions?

Thank You!