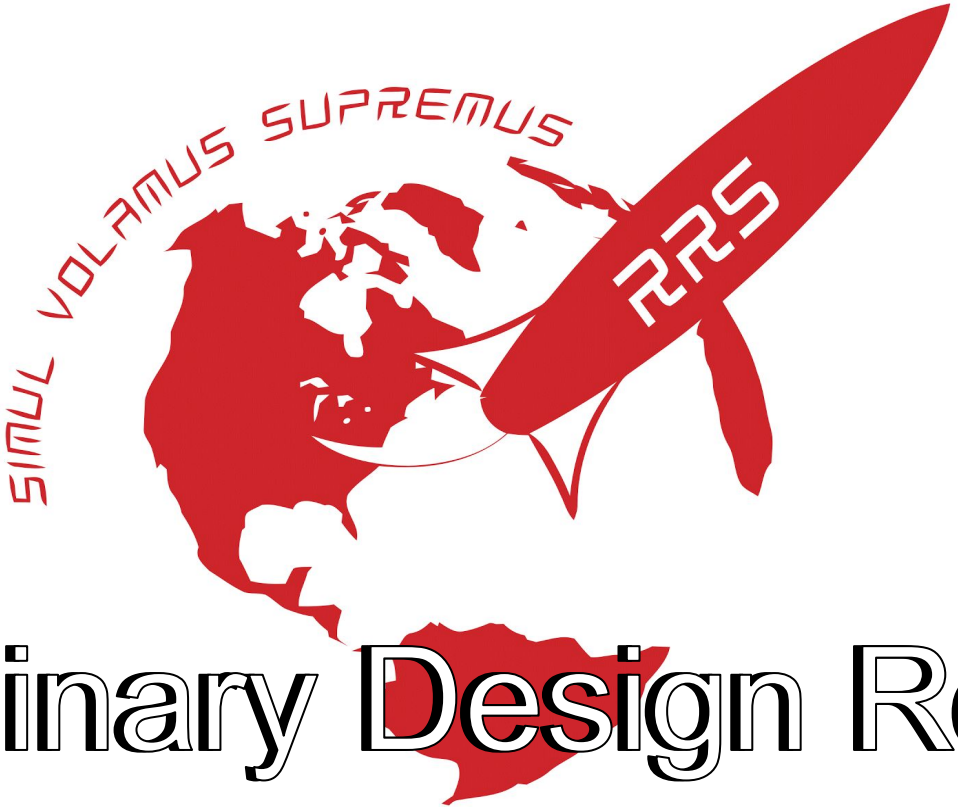



# Preliminary Design Review

## Rensselaer Rocket Society (RRS)
## Project Red Gemini

# System Level Design

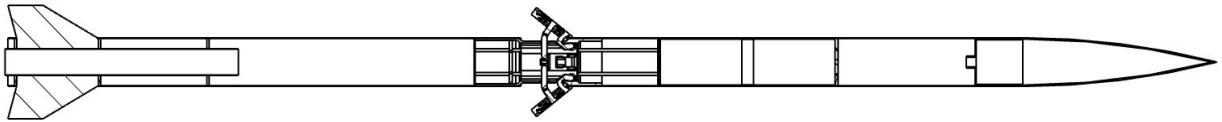
**Tasks:** Aerodynamic Analysis, Atmospheric Measurements

**Three Subsystems:**

- Recovery
- Structural
- Aerodynamics and Flight Stability

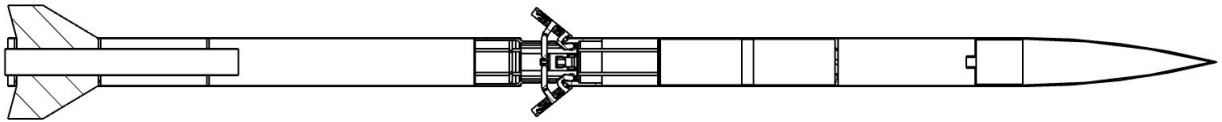
**Significant Features:**

- Drag flap control system



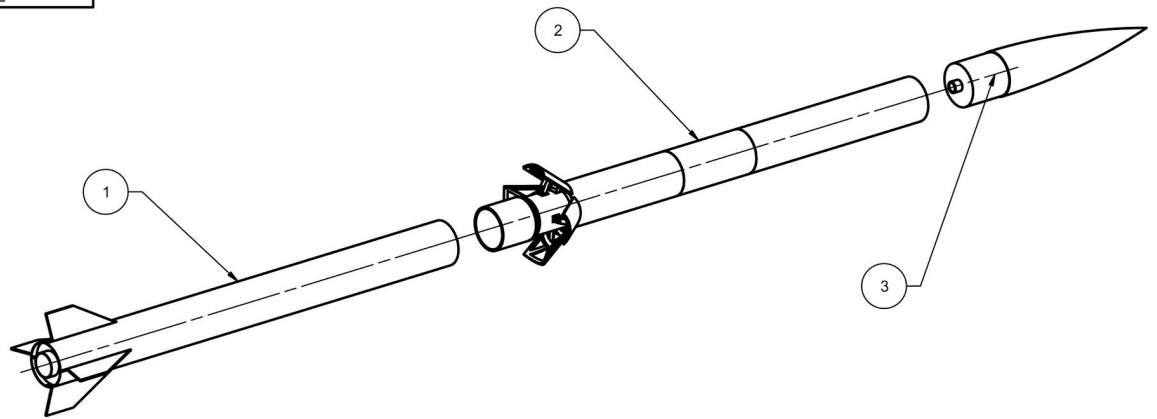
# Vehicle Dimensions, Materials, and Justifications

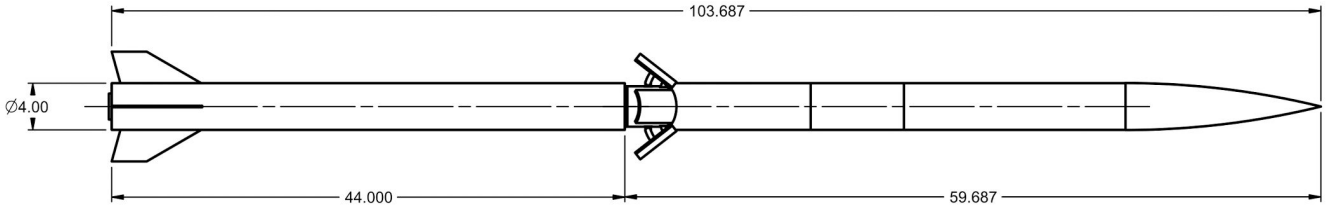
- No base model (previously Liberty 4 from Giant Leap Rocketry)
- Final Height: 104 inches
- Final Diameter: 4.02 inches
- Mass: 14.903 lbm
- Body tube material: phenolic resin tubing
- Fin material: G-10 fiberglass (Public Missiles Ltd.)



| PC NO | PART NAME |
|---|---|
| 1 | LOWER AIRFRAME |
| 2 | MAIN AIRFRAME |
| 3 | NOSE CONE |

| MODEL REV | SHEET REV | DESCRIPTION | DATE(YEAR-MO-DA) | APPROVED |
|---|---|---|---|---|
| | A | INITIAL_REVISION | | |



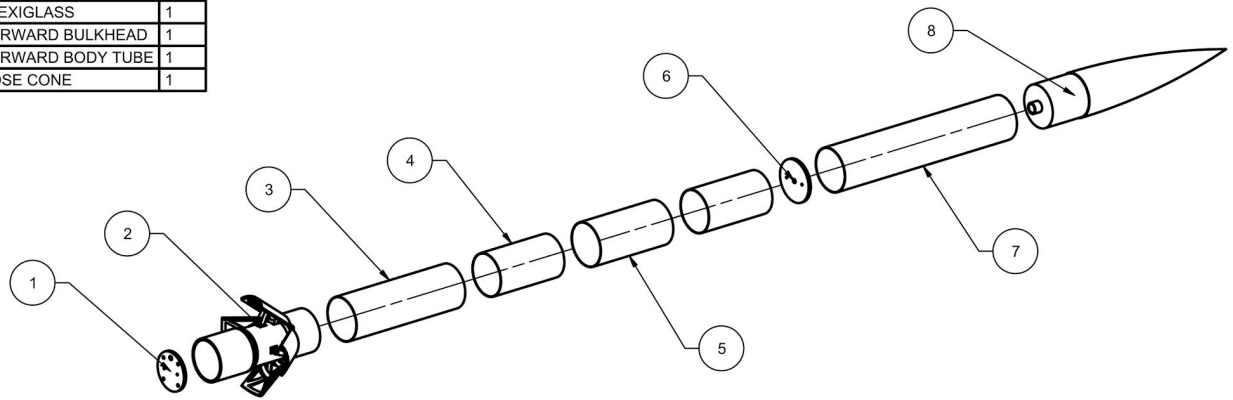

Rensselaer

| DRAWING NOTES (UNLESS OTHERWISE NOTED) | TOL. (UNLESS NOTED) | |
|---|---|---|
| 1. ALL DIMENSIONS IN INCHES | DECIMAL: | X.X: ± 0.015 |
| | | X.XX: ± 0.01 |
| | | X.XXX: ± 0.005 |
| | FRACT.: | ± 1/32 |

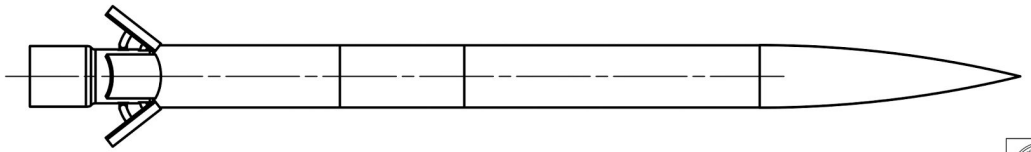
| TITLE | RED GEMINI FULL ASSY | | |
|---|---|---|---|
| MATERIAL | VARIOUS | | |
| AUTHOR | TUCKER BABCOCK | | |
| SIZE B | CAD FILE ____Rocket Full Assy_dwg1 | | QTY. REQUIRED |
| | SCALE 1:8 | SHEET 1 OF 13 | 1 |

| PC NO | PART NAME | QTY |
|---|---|---|
| 1 | AFT BULKHEAD | 1 |
| 2 | DRAG FLAPS ASSY | 1 |
| 3 | MIDDLE BODY TUBE | 1 |
| 4 | COUPLER | 2 |
| 5 | PLEXIGLASS | 1 |
| 6 | FORWARD BULKHEAD | 1 |
| 7 | FORWARD BODY TUBE | 1 |
| 8 | NOSE CONE | 1 |

| MODEL REV | SHEET REV | DESCRIPTION | DATE(YEAR-MO-DA) | APPROVED |
|---|---|---|---|---|
| | A | INITIAL_REVISION | | |




SCALE 1:8



| DRAWING NOTES (UNLESS OTHERWISE NOTED) |
|---|
| 1. ALL DIMENSIONS IN INCHES |
| 2. DRAG FLAPS DISCUSSED EXTENSIVELY IN SECTION 5.1 |
| 3. NOSE CONE IS PML PNC-3.9 WITH TANGENT OGIVE SHAPE |

| TOL. (UNLESS NOTED) | |
|---|---|
| DECIMAL: | X.X: ± 0.015 |
| | X.XX: ± 0.01 |
| | X.XXX: ± 0.005 |
| FRACT.: | ± 1/32 |

Rensselaer

TITLE: MAIN AIRFRAME ASSY

| | |
|---|---|
| MATERIAL | VARIOUS |
| AUTHOR | TUCKER BABCOCK |
| SIZE | B |
| CAD FILE | _Rocket Top Section_dwg1 |
| QTY. REQUIRED | 1 |
| SCALE | 1:6 |
| SHEET | 7 OF 13 |

# Mass Statement

**Lower Airframe:**

- Total: 8.3 lbm
- Motor: 54.42 ounces
- Body Tubing: 18.7 ounces

**Main Airframe:**

- Total: 6.603 lbm
- Tubing: 13.18 ounces
- Plexiglass Tubing (camera sub.): 16.01 ounces
- Drag Flap System: 16.79

**Total: 14.903 lbm**

# Material Justifications

**Phenolic Body Tubing:**

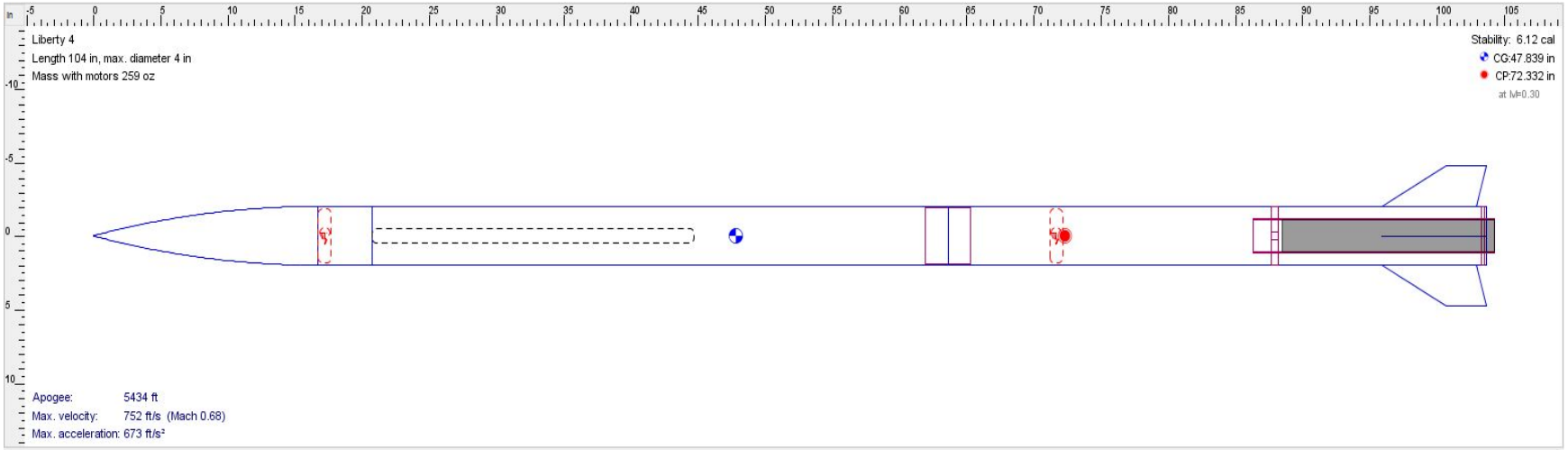
- Originally MagnaFrame (layers of vulcanized fiber and phenolic, moisture sealed)
- Now phenolic fiber tubing
- Both equally strong
- Phenolic has lower price point, more customizability, and compatibility with motor mount

**G-10 Fiberglass Fins:**

- Firm
- Machineable

# Static Stability Margin

- Margin: 6.1 cal with motor, 9.14 cal without motor
- Simulation: OpenRocket, drag flap models included
- CP and CG on diagram; 72 and 48 inches from nose tip respectively



# Plan for Vehicle Safety Verification and Testing

**Safety verification summary:**

- Risk analysis conducted, checklists created, testing plans drafted
- Launch failure modes and hazards identified and ranked for severity

**Testing plans:**

- Ground testing of flight avionics. Static load testing of drag flap system.
- Body separation testing for separation charges (parachute deployment failure, loss of vehicle)

**Safety Officer:** Chris Andre

# Plan for Launch Vehicle Verification and Testing

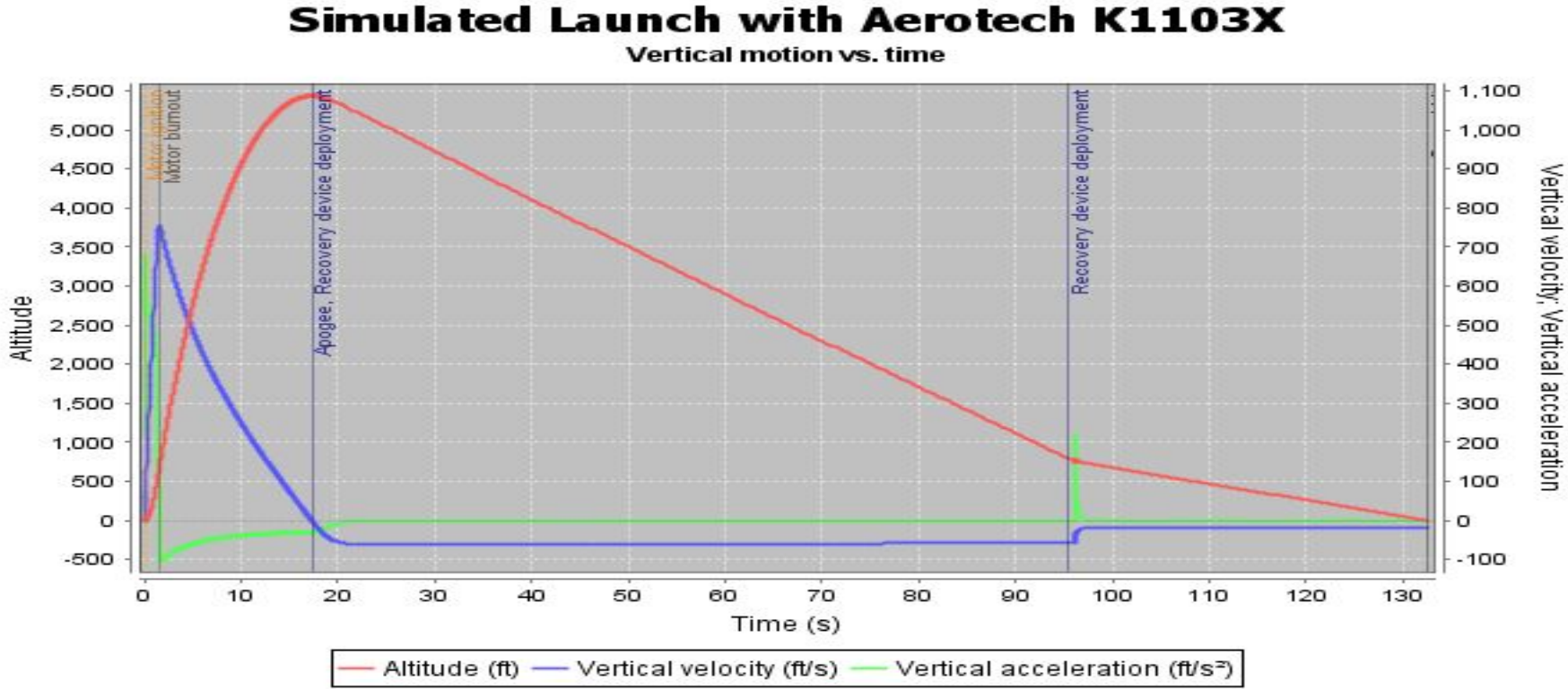
**Vehicle verification summary:**

- Several calculations performed to reinforce critical design points
- Simulations conducted during design phase to make informed decisions and models
- Designs and safety practices closely followed during the construction phase
- Modular construction and assembly of vehicle that allows for several verification checkpoints

**Testing plans:**

- Static load testing of major structural components
- Several scale and full test launches to verify all systems perform as expected

# Launch Vehicle Verification - Simulated Launch



# Kinetic Energies and Drift

## Kinetic Energies (all fall at ~20 ft/s):

- Nose cone: 3.78 ft-lb
- Upper body: 41.70 ft-lb
- Lower body: 25.58 ft-lb

## Drift:

| Wind Speed | Drift Value |
|---|---|
| 5 mph | 856 ft |
| 10 mph | 1712 ft |
| 15 mph | 2567 ft |
| 20 mph | 3423 ft |

# Plan for Payload Verification and Testing

**Payload verification summary:**

- Tasks: Aerodynamic Analysis, Atmospheric Measurements
- Radio relay of both pictures and data

**Test plan:**

- Static load testing on drag flaps
- CFD analysis of drag flaps
- Software testing of avionics relay
- Range testing of radio link
- Orientation testing of camera

# Verification Plan: Requirements Summary

**In accordance with the Statement of Work; 2016 SL Handbook:**

- Projected apogee: minimum 5280 feet, maximum 5600 feet unaltered
- Approved barometric altimeters with designated power supplies and arming switches, electronically separate from payload
- Launch vehicle separates into three independent sections, reusable after launch
- Single stage with commercially available motor (Aerotech K1103X, K-class)
- Recovery: electronic dual-deploy with drogue and main parachutes
- Independent sections fall with kinetic energy less than 75 ft-lbf

# Verification Plan

| Requirement | Design Feature | Verification | | |
|---|---|---|---|---|
| | | Design Phase | Construction Phase | Testing Phase |
| Apogee between 5,280 ft and 5,600 ft if left unaltered | Rocket Mass, Rocket Motor, Design | OpenRocket Simulations, Payload Mass, Rocket material selection, Motor Selection | Stay as close as possible to original Mass Estimates | Read apogee at several launches in different weather conditions |
| Reusable | Body Strength (fins, airframe, parachutes, etc.) | Stress Analysis of Vulnerable Components, Use of Large Factors of Safety in Critical Components | Use High-Strength Epoxies, Store all components Safely, Design Followed, Components inspected upon order arrival show no signs of damage | Launch in appropriate weather multiple times |

# Verification Plan (continued)

| Requirement | Design Feature | Verification | | |
|---|---|---|---|---|
| | | Design Phase | Construction Phase | Testing Phase |
| Four or fewer Independent Sections | General Design | Design fewer than four independent Sections (Nosecone section, Payload/Avionics Section, Lower Body Section) | Design Followed | Rocket is launched and recovered in less than four independent sections |
| Single Stage | General Design, Motor Design | Design only a single stage rocket | Design Followed | Rocket is launched with only a single stage motor |

# Verification Plan (continued)

| Requirement | Design Feature | Verification | | |
|---|---|---|---|---|
| | | Design Phase | Construction Phase | Testing Phase |
| Commercially available solid motor propulsion system under Class L | Motor | Ensure Mass and General Rocket Design allow for a motor well under Class L motor approved by the TRA and NAR | Design Followed, stay as close as possible to original mass estimates | Motor under Class L is used at several launches in different weather conditions |
| Capable of Launch by 12 V DC firing system | Motor, motor retainer | Select a motor retainer that allows for access to motor, select a motor able to be launched with 12V DC firing system | Design Followed, safely store motors | Launch rocket on standard 12 V DC firing system multiple times |

# Verification Plan (continued)

| Requirement | Design Feature | Verification | | |
|---|---|---|---|---|
| | | Design Phase | Construction Phase | Testing Phase |
| Electronic Dual Deploy | General Recovery Design (parachutes, shock cord, ejection charges, etc.) | General Design is Dual-Deploy, Use of a Drogue and Main Parachute, Design for Multiple Separation Points | Design Followed | Rocket launched with appropriate recovery system, Drogue and Main parachutes deploy at different points in flight |
| Drogue Deploys at Apogee, Main Parachute Deploys at much lower altitude | Parachutes, ejection charges, General Rocket Design, Altimeters | General Design has Drogue Parachute at First Separation Point and Main Parachute at another, Simulations run with required deployment locations | Design Followed, Set Altimeters to required ejection charge deployments (and keep track of which side is deployed when) | Rocket launched multiple times with parachute deployment at required times |

# Verification Plan (continued)

| Requirement | Design Feature | Verification | | |
|---|---|---|---|---|
| | | Design Phase | Construction Phase | Testing Phase |
| Shear Pins hold rocket sections together until Parachute Deployment | Shear Pins, Ejection Charges | Shear Pin Strength Accurately Calculated and inserted into Recovery Design, Ejection Charge Strength Accurately Calculated | Design Followed, Shear Pins show no signs of damage before install | Rocket launched multiple times with parachute deployment at required times |
| Independent Sections have less than 75 ft-lb of KE at Landing | General Rocket Design (Mass), Parachutes | Kinetic Energy of Each Independent Section Analyzed Accurately | Design Followed, stay as close as possible to original mass estimates, Parachutes and Recovery system components show no signs of damage upon order arrival | No damage or hard landing evident in any section after multiple test launches in varied flight conditions |

# Verification Plan (continued)

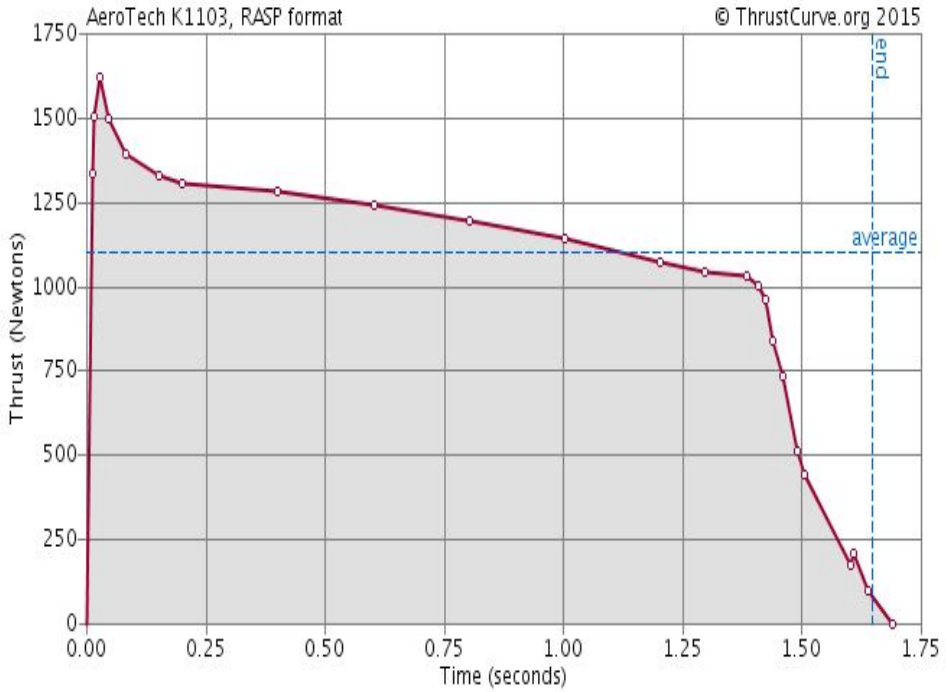
| Requirement | Design Feature | Verification | | |
|---|---|---|---|---|
| | | Design Phase | Construction Phase | Testing Phase |
| Redundant, Safe Altimeters | Altimeters, Supporting Recovery Electronics | Select at least 2 commercially available altimeters, Design has an independent power supply to each Altimeter | Design Followed, Altimeters stored safely, All components of supporting electronics and altimeters tested before installation | Recovery System Operates as Expected, Altimeters report similar apogees in all test launches |

# Baseline Motor Selection and Justification

- Selected Motor: Aerotech K1103X Motor
- Class: K
- Propellant: APCP
- Average Thrust: 1,044 N
- Maximum Thrust: 1620 N
- Total Impulse: 1763 N-s
- Thrust Duration: 1.688 s

**Rationale:**

- Apogee: 5431 feet without flaps



# Thrust-to-weight Ratio and Rail Exit Velocity

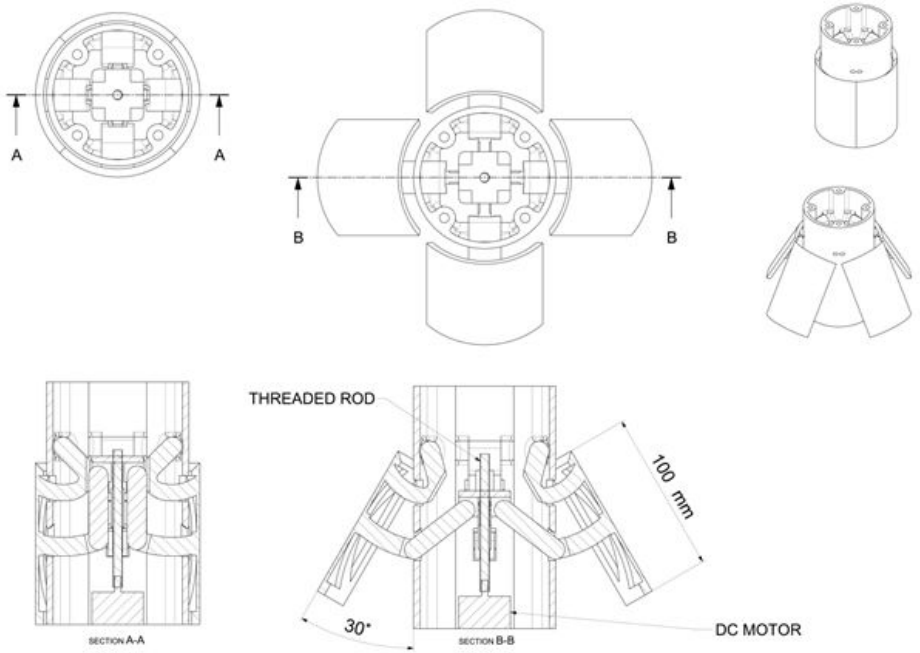
- TWR: **24.42 maximum**
- TWR: **15.74 average**

- Rail exit velocity: **63.6 ft/s**
- Rail length: **39.37 inches**

# Major Components and Subsystems

**Drag Flap Subsystem**

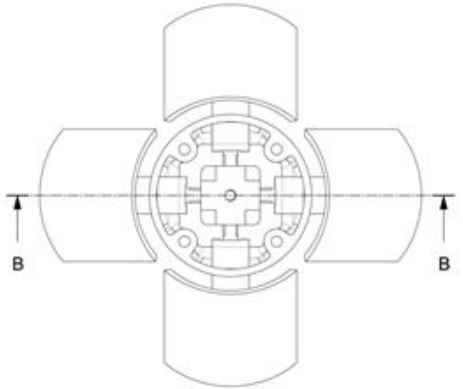
- Dynamically controlled to reduce vertical velocity to reach apogee of 5,280 feet
- Barometric pressure measured above and below flaps in order to fulfill payload requirement 3.1.6, “Aerodynamic Analysis of Structural Protuberances.”

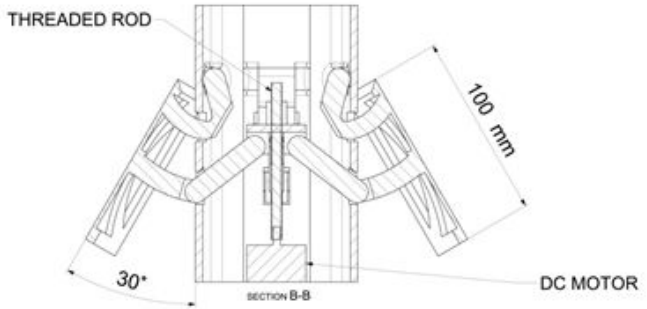


# Major Components and Subsystems

**Drag Flap Subsystem**

- Four quarter-cylinder elements fan out to create drag force
- Controlled simultaneously via threaded rod attached to single DC motor
- Ten 3D-printed plastic pieces



# Major Components and Subsystems

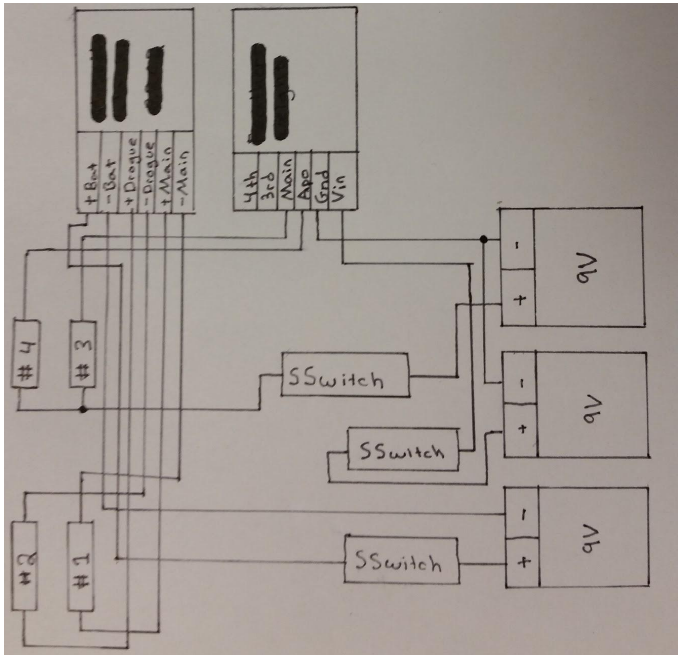
**Recovery System**

- Main parachute: SkyAngle Cert-3 Large
- Drogue parachute: SkyAngle Cert-3 Drogue
- Suspension lines for each rated at 2250 lbf, attached to swivel joint rated for 1500 lbf
- Descent velocity:
  - After dogue deployment: 50 ft/s
  - After main deployment: 14.5 ft/s
- Three body sections attached by 250’’ of Kevlar shock cord each

# Major Components and Subsystems

**Recovery System**

- Electronic Components
  - StratoLogger CF altimeter
  - Raven3 altimeter
- Two altimeters provide redundancy
- Ignite black powder charges mounted in aluminum blast caps
  - First charge (2.1 g): apogee
  - Second charge (1.7 g): 800 feet AGO

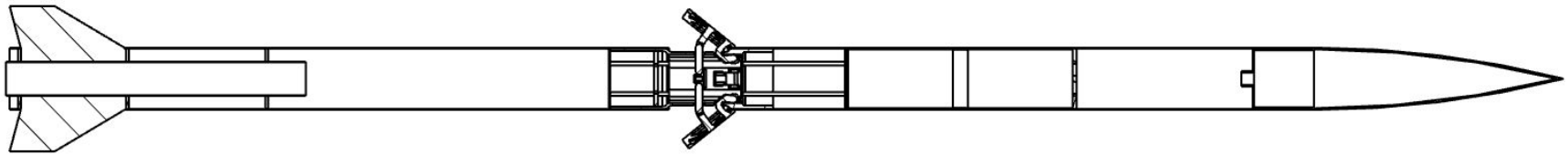



*Recovery system electronics*

# Major Components and Subsystems

**Structural**

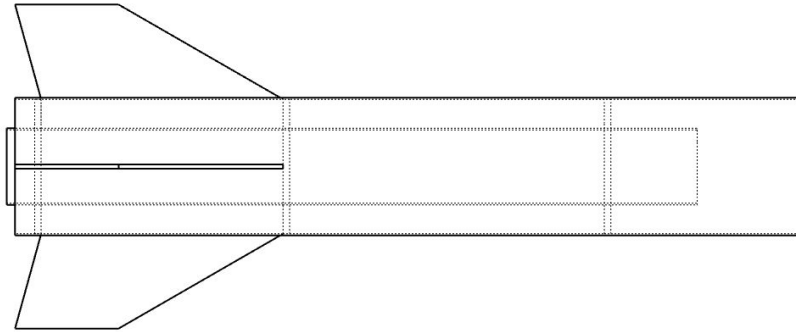
- 104 inches end to end, three separable sections
- 4 inch diameter
- Plastic nose cone
- Phenolic body
- Fiberglass fins



# Major Components and Subsystems

## Structural

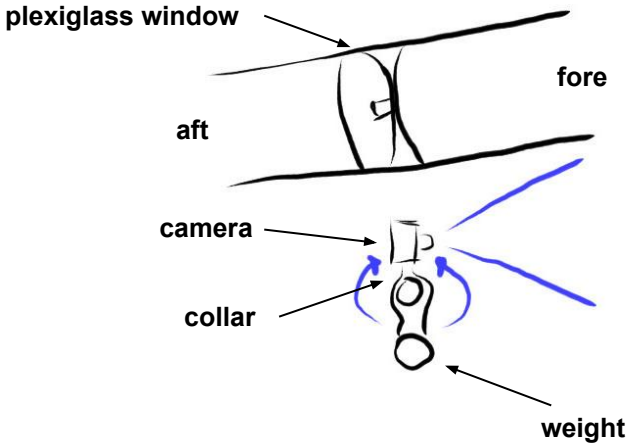
- Fin design selected for high apogee while preserving stability
- Four fins to be machined out of G-10 fiberglass for stiffness and strength



# Major Components and Subsystems

## Payload - Camera

- Body tube with transparent plexiglass section
- Camera system freely rotates about rocket vertical axis
- Camera system keeps image frame in proper orientation with counterweight



# Major Components and Subsystems

**Payload - Avionics and Science**

- Two Arduino microprocessors
- XBee radio data relay
- GPS / triple-axis accelerometer

**Science package:**

- Two barometers located above and below drag flaps to characterize flow
- UV and humidity sensors, solar irradiance measurement
- Camera system