Modular Autonomous Launch Platform For A Martian Ascent Vehicle Analogue Mission

Critical Design Review
2015 NASA Student Launch

Icarus Rocketry
Arizona State University
School of Earth and Space Exploration

CDR OVERVIEW

- **SLP Mission**
- **Launch Vehicle**
  - Airframe Design
  - Motor Selection
  - Recovery and Electronics
  - Vehicle Performance
  - Verification and Testing Plan
- **Autonomous Ground Support Equipment**
  - Autonomous Retrieval Mechanism (ARM)
  - Modular Autonomous Launch Platform (MALP)
  - Motor Igniter Insertion System (MIIS)
  - Payload Bay Assembly
- **Subscale Test Flight**
- **Requirements Verification Status**
- **Budget & Schedule**
- **Educational Engagement Progress**

ABOUT ICARUS ROCKETRY

- **Newly founded team at Arizona State University in the School of Earth and Space Exploration**
- **Composed of graduate and undergraduate students**
  - 4 Ph.D. students
  - 3 M.S. students
  - 12 B.S. and B.S.E. students
  - Disciplines Studied: Astrophysics, Planetary Geology, Mechanical Engineering, Aerospace Engineering, Electrical Engineering

ICARUS MISSION STATEMENT

To engage students in the exploration, design, and development of High Power Rocketry launch vehicles to expand their knowledge of rocketry and engineering through competition, and ultimately build a launch system to fly beyond the von Karman line.

MISSION SUCCESS CRITERIA

1) **ARM successfully acquires payload and deposits it in rocket**
2) **MALP raises the launch vehicle to 5° off vertical**
3) **MIIS installs the igniter in the rocket**
4) **Successfully launch and maintain and stable flight trajectory to apogee**
5) **Attain an apogee between 2,800 and 3,200 ft AGL**
6) **Eject and deploy a drogue parachute within 1 to 2 seconds after reaching apogee**
7) **Eject and separate the nosecone/sample bay from the rest of the launch vehicle at 1,000 ft AGL and:**
    a) Deploy the nosecone/sample bay parachute
    b) Deploy the launch vehicle's main parachute
8) **Successfully recover the launch vehicle and sample bay**
9) **Minimal damage to the launch vehicle or sample bay post-flight**

SLP MISSION STATEMENT

To successfully launch a simulated Mars sample return mission payload to an altitude of 3000ft AGL, deploy the payload bay containing the payload at 1000ft AGL, and recover all launch vehicle components.

VEHICLE OVERVIEW

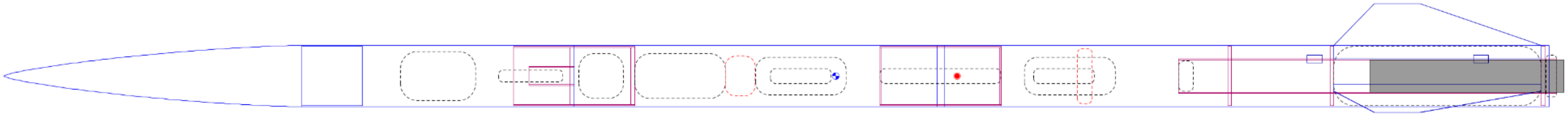
- **Length: 103 in**
- **Diameter: 4.02 in**
- **Mass: 11.0 lbs (empty)**

  13.8 lbs (w/ motor)

- **Stability Margin: 1.98**
- **CG: 55.057"**
- **CP: 63.088"**

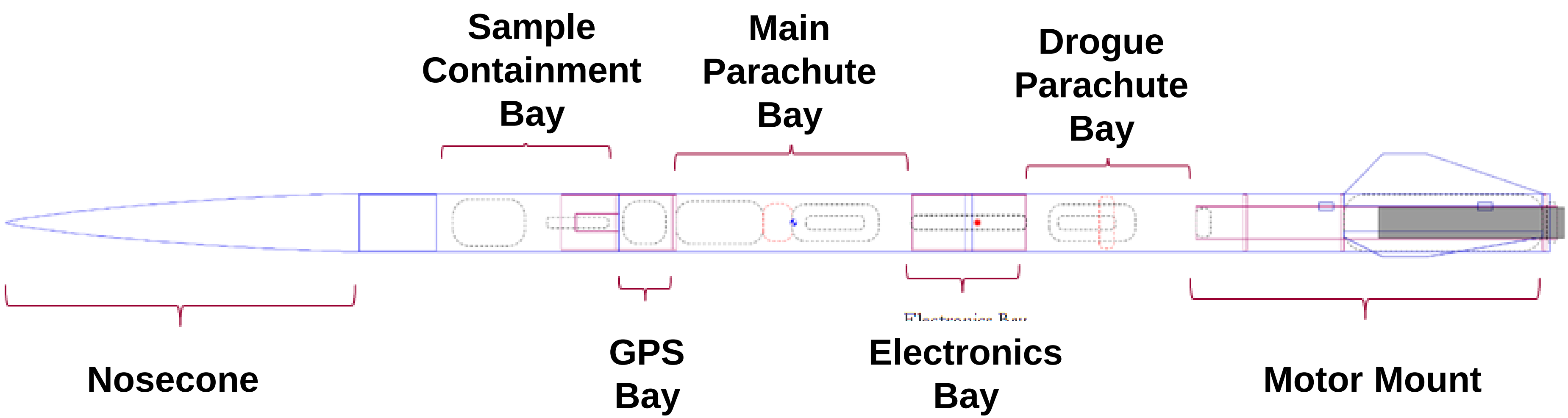
- **Materials**
  - Nosecone: Fiberglass
  - Airframe: BlueTube 2.0
  - Fins: Birch Plywood

- **Recovery System**
  - 18 in drogue parachute
  - 60 in main parachute



VEHICLE DESIGN

- Compartmentalized Construction
- Nosecone/Sample Containment Bay/GPS Bay
- Main Parachute Bay
- Electronics Bay
- Drogue Parachute Bay



VEHICLE MATERIALS

- **BlueTube 2.0 Airframe**
  - Strong, durable airframe material
  - Better impact resistance than non-composite airframes
  - Lighter than fiberglass and RF transparent
- **Fiberglass Nosecone**
  - Slighter heavier for more forward CG placement
  - Better durability and impact resistance
- **Birch Plywood Fins and Centering Rings**
  - Good strength-to-weight ratio
  - Easier and safer to machine and shape compared to composites

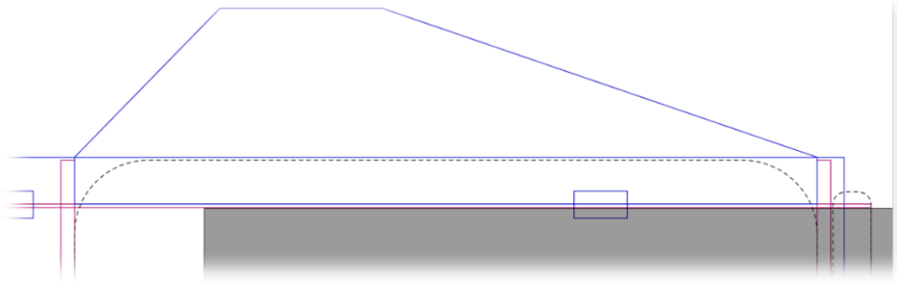
AIRFRAME

- BlueTube 2.0
- 4.02” Outer Diameter
- Electronics Bay: 8”
- Main Parachute Bay: 16”
- Drogue Parachute Bay: 11”
- Sample Payload/GPS Bay: 13”
- 2.15” ID BlueTube Motor Mount: 25”

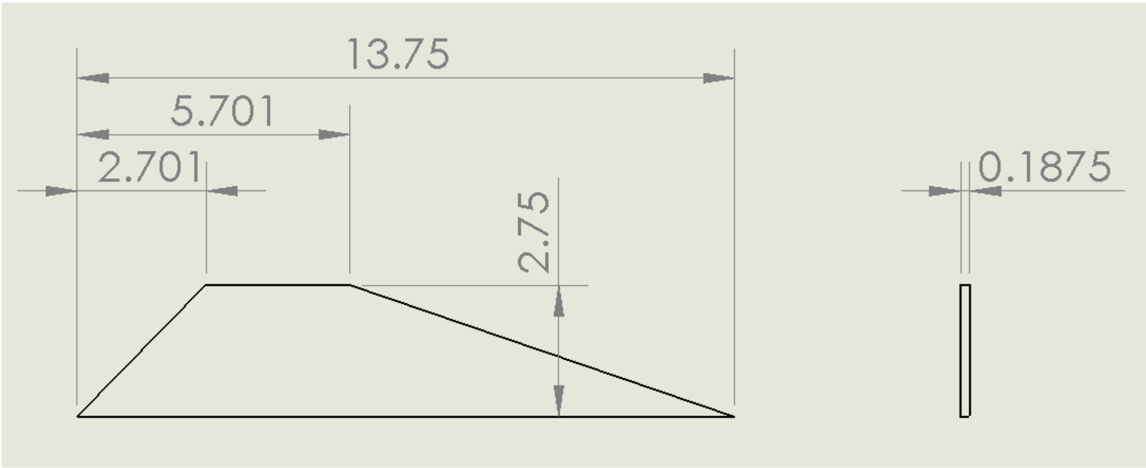
NOSECONE

- **Manufacturer: Wildman Rocketry**
- **4" Von Karman Fiberglass 5:1 Nosecone**
  - Replaced plans for Shockwave Rocketry 6:1 Nosecone due to business closure
- **Drag optimized, with hard-surface outer skin and fiberglass casing**
  - Screw-in aluminum tip
- **19.75" exposed, 5.375" shoulder, 0.824 lbs**

FIN DESIGN



- **“Aggressor” Fin Design**
  - Previously developed and used by the team
    - Forward-swept clipped delta
    - Low-aspect ratio
    - Sharp forward-swept trailing edge minimizes shearing and fin damage on impact
- **Through-the-wall fin mount**
  - Internal cavity filled with 4lb density closed-cell polyurethane expanding foam for increased support



MOTOR SELECTION

- **Aerotech J800T**
- **APCP motor with Blue Thunder formulation**
- **Rouse-Tech 54/2560 Motor Casing**
  - Aerotech 54mm Reload Adapter System
- **Thrust-to-weight ratio: 13.03**
- **Rail exit velocity: 108 ft/s**
- **Mass Margin: 0.217 (3lbs)**
- **OpenRocket simulations demonstrate that the motor best fits the mission requirements**
  - Several motors meet the altitude window for mission success criteria, but were ruled out for various reasons

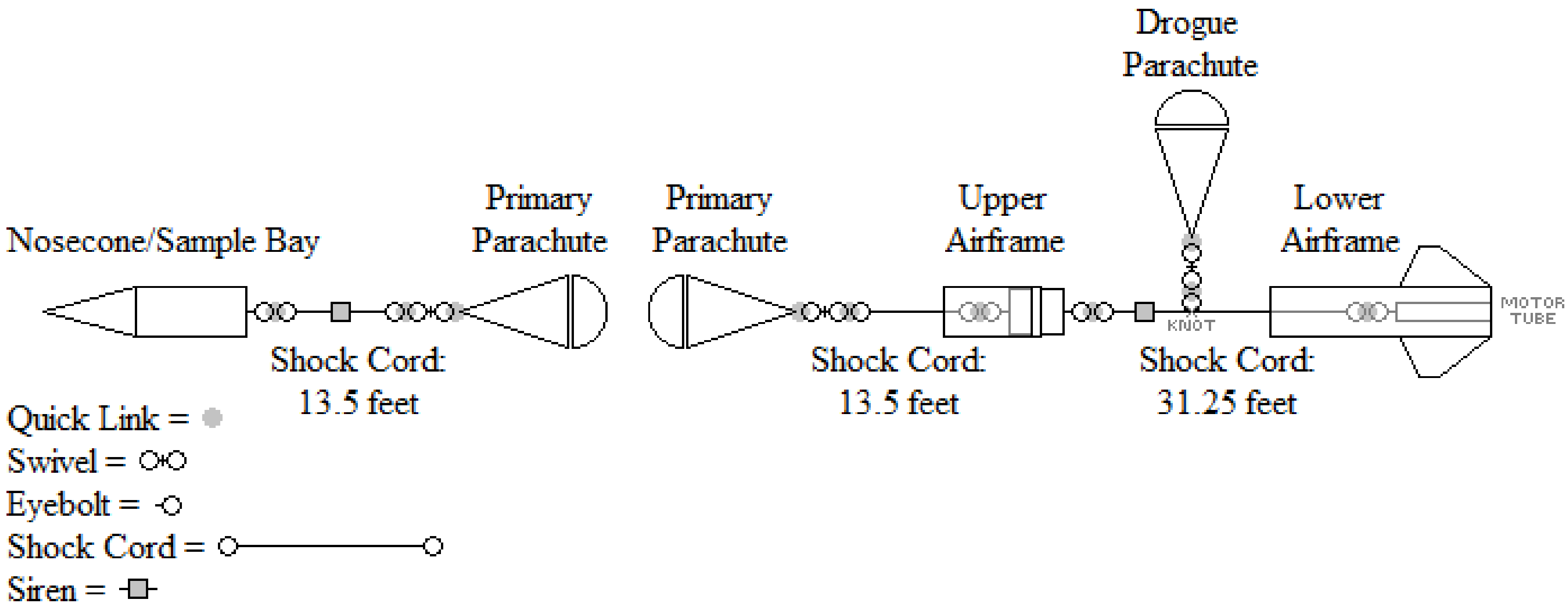
MOTOR MOUNT & RECOVERY

- Aeropack 54mm retainer
- Giant Leap Rocketry Hardpoint Anchor
- Shockcord: ¼” Tubular braided Kevlar, 3600lb test
- 2.25” swivels, 1500lb test
- ¼” quick links, 880lb test
- ¼” U-bolt, 2000lb test

RECOVERY SYSTEM

- **Drogue Parachute**
  - Public Missiles 18” parachute with 4” spill hole
  - $C_D = 0.80$
  - 1.9 oz urethane coated ripstop nylon
- **Main Parachute (x2)**
  - Fruity Chutes Classic Elliptical 60” parachute
  - $C_D = 1.6$
  - 1.1 oz Mil-spec calendared ripstop nylon
  - One parachute will be dedicated to the launch vehicle; a separate parachute will be dedicated to the payload bay

RECOVERY SYSTEM



IMPACT KINETIC ENERGY

- $KE_{SampleBay} = 0.7376\frac{ft \cdot lbf}{J}\left[1/2(5.452kg)\left(4.6\frac{m}{s}\right)^2\right]$

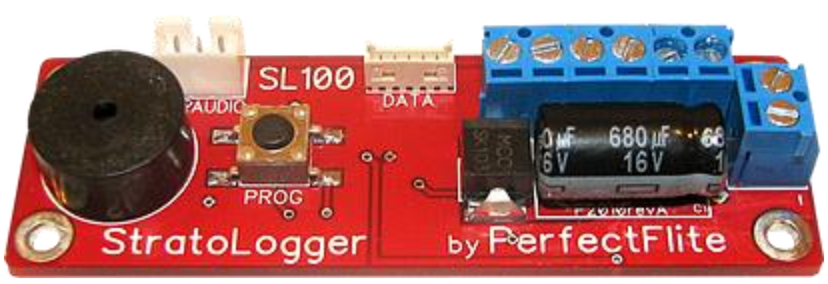
$$KE_{SampleBay} = 30.60\ ft \cdot lbf$$

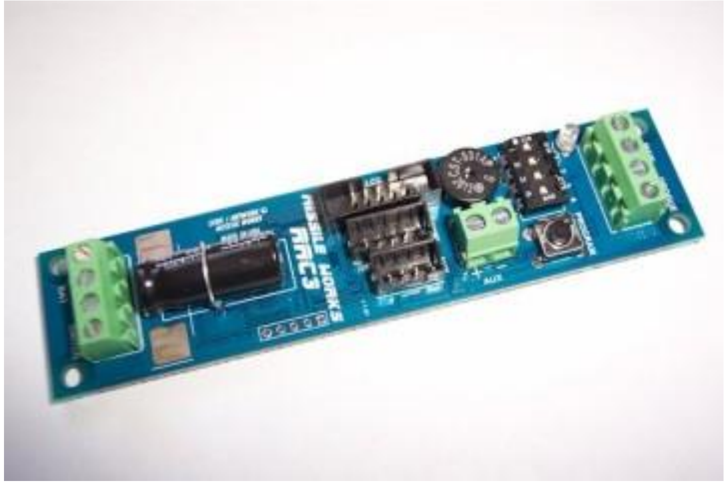
- $KE_{Airframe} = 0.7376\frac{ft \cdot lbf}{J}\left[1/2(0.609\ kg)\left(4.6\frac{m}{s}\right)^2\right]$

$$KE_{Airframe} = 4.75\ ft \cdot lbf$$

ELECTRONICS - RECOVERY

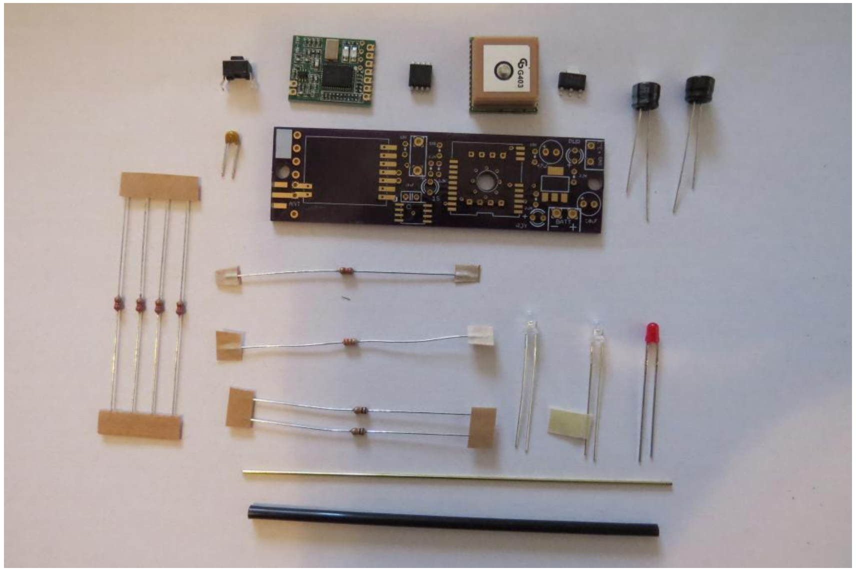
- **Dual-redundant, independent altimeters for recovery**
  - PerfectFlite Stratologger
    - Supports up to 100 Kft, Mach capable, brownout protection, wind and sunlight resistant sensor
  - MissileWorks RRC3
    - Supports up to 100 Kft, Mach capable, brownout protection, velocity and temperature telemetry

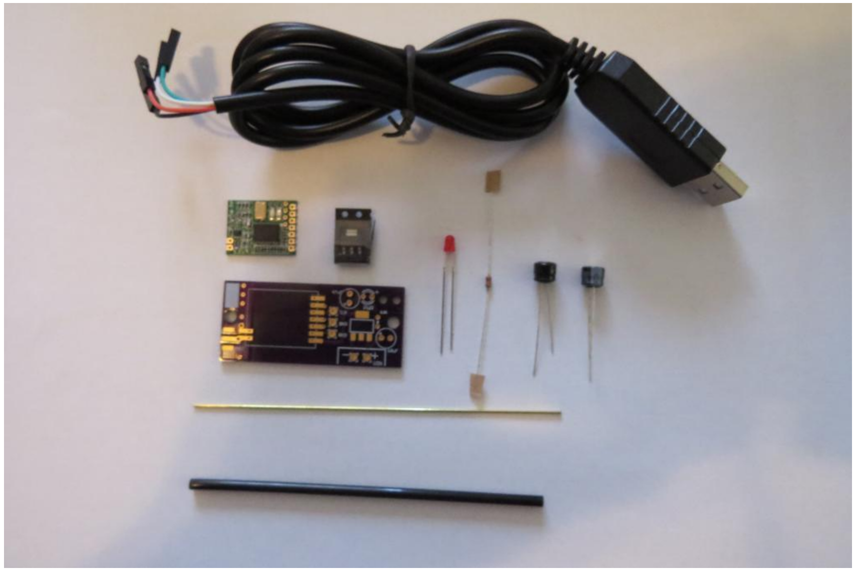




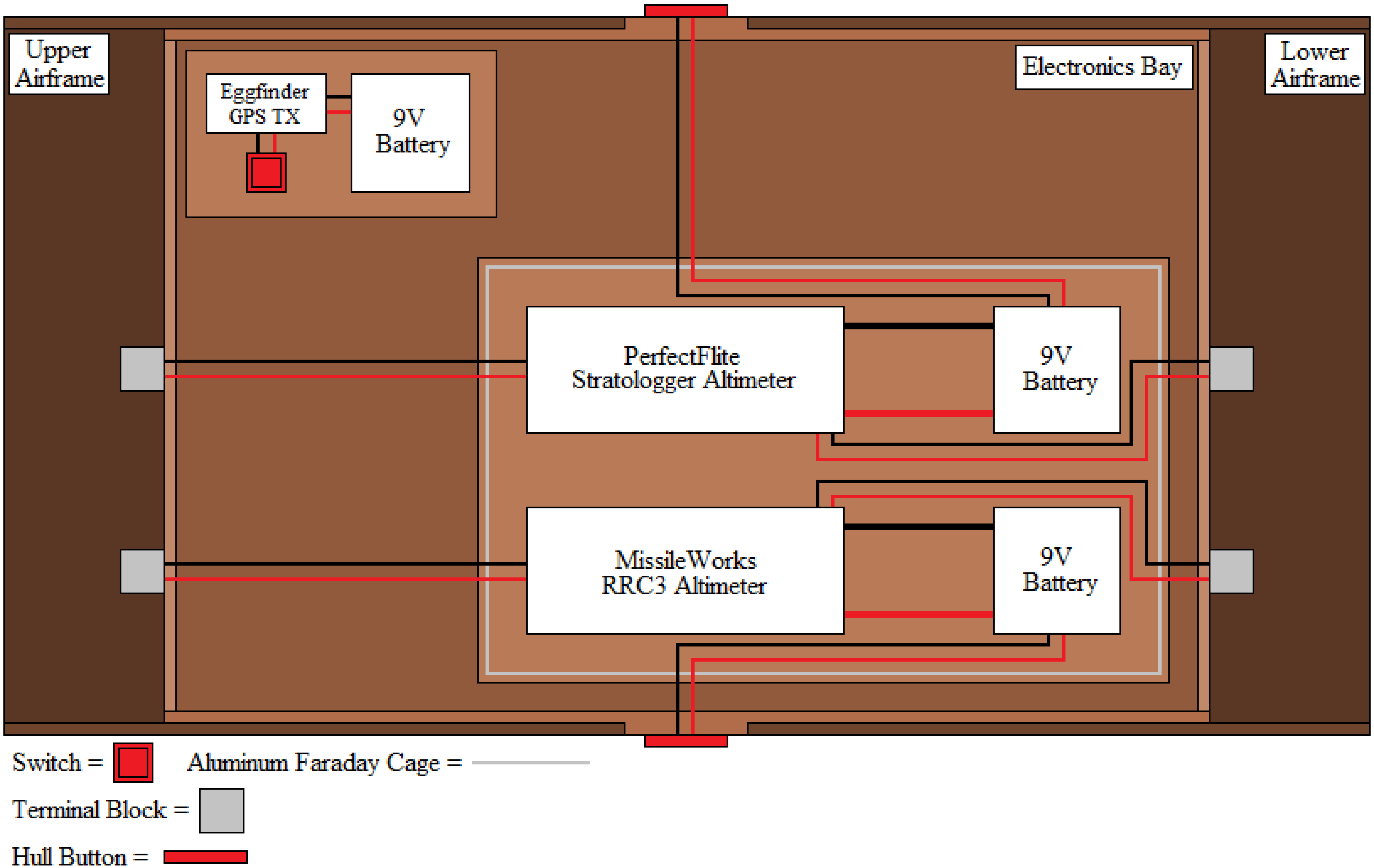
ELECTRONICS – GPS BAY

- **GPS Telemetry for Payload Sample Bay & Electronics Bay provided by Eggfinder GPS**
- **Kits require assembly, but much cheaper**
  - Similar performance to original BRB9000 selected
- **100mW, 900 Mhz spread spectrum transmitter**
- **Matching receiver with USB interface for computer integration**

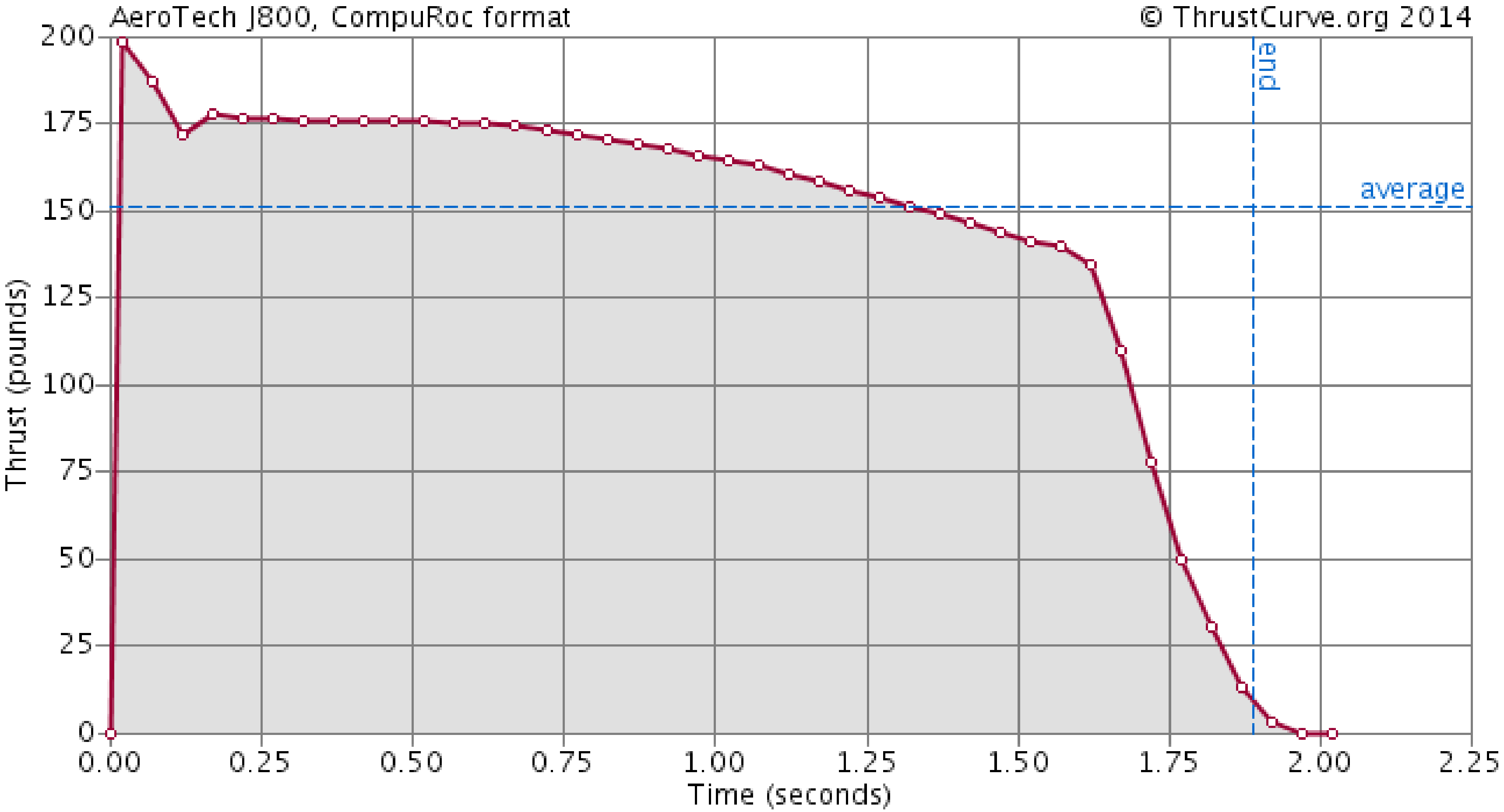




ELECTRONICS BAY SCHEMATIC



MOTOR THRUST CURVE



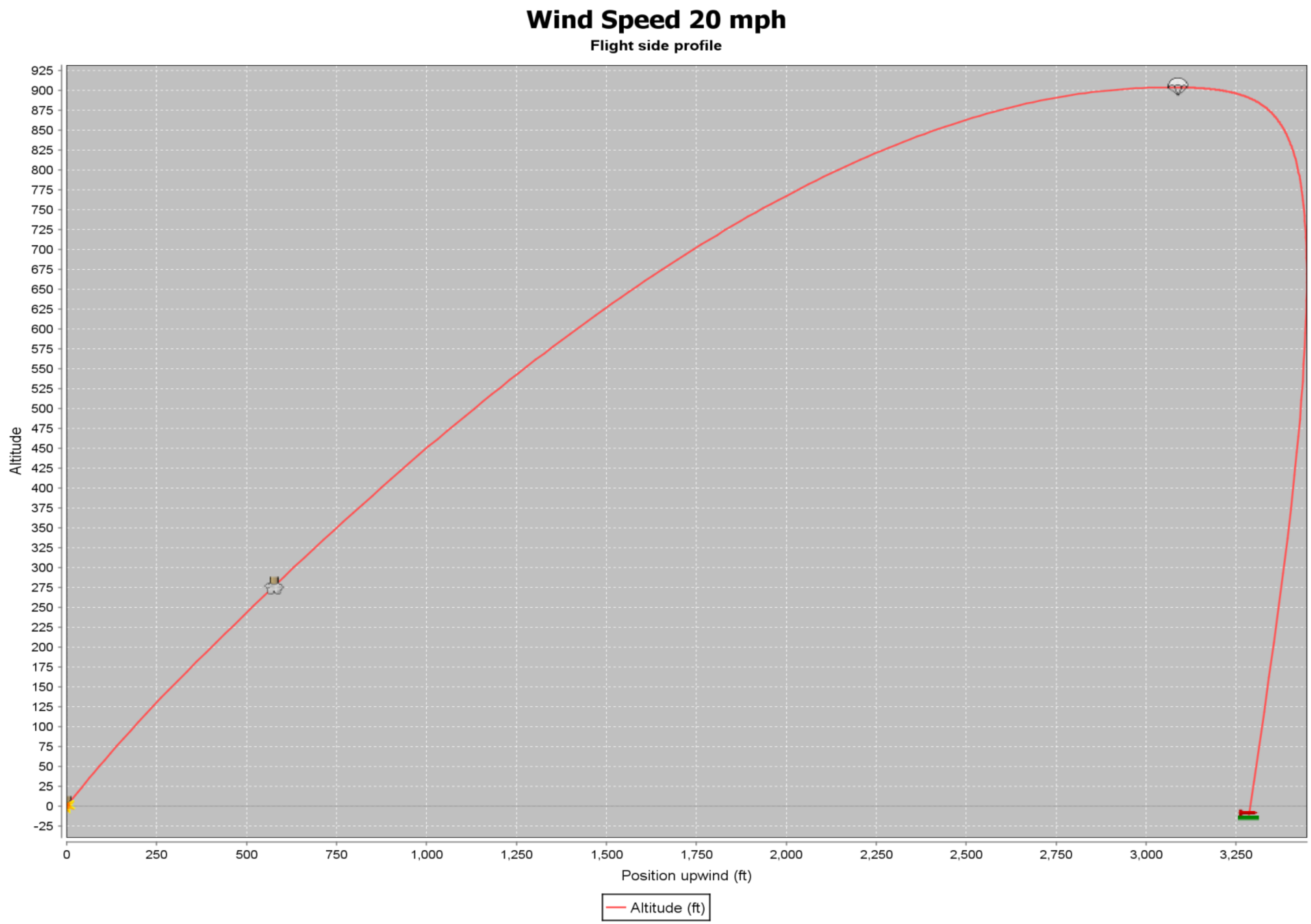
FLIGHT DYNAMICS

- **Predicted Altitude: 3,201ft**
- **Max Acceleration: 16.8G**
- **Max Velocity: 525 ft/s**
- **Airframe Drift (worst cases)**

Wind Speed (mph)	Drift (ft)
0	701
5	1316
10	-1941
15	-2531
20	-3120

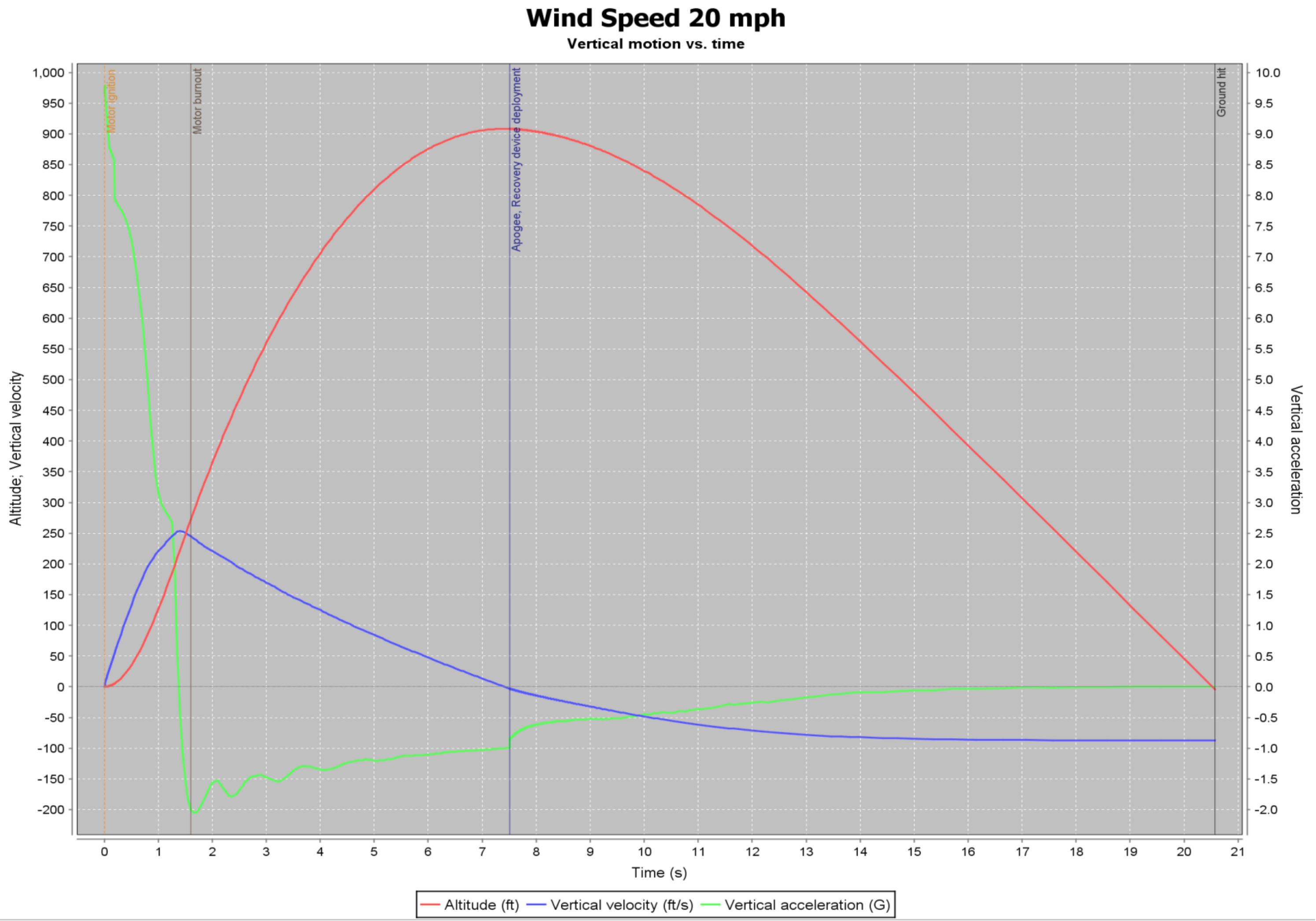
FLIGHT DYNAMICS

- **Worst-case scenario airframe drift**



FLIGHT DYNAMICS

- **Worst-case scenario airframe drift velocity**



LAUNCH VEHICLE VERIFICATION AND TESTING PLAN

- **Launch Vehicle Requirement Verification Plan**
  - Verification plan for each SOW requirement
    - relevant design features
    - verification method (design, testing, inspection, schedule)
    - status of verifications (as of CDR)
- **Risk Assessment**
  - Major risks to project success
  - Specific potential impacts to project
  - Mitigation plan for each risk
- **Hazard Assessment**
  - Major hazards to team members during construction and operation of the vehicle
  - Mitigation plan for each hazard
    - Safety Briefing (NAR Safety Code, FAA Regulations, Tool Use, etc)
    - Specialized Safety Training (Machine Shop Tools, etc)

LAUNCH VEHICLE VERIFICATION AND TESTING PLAN

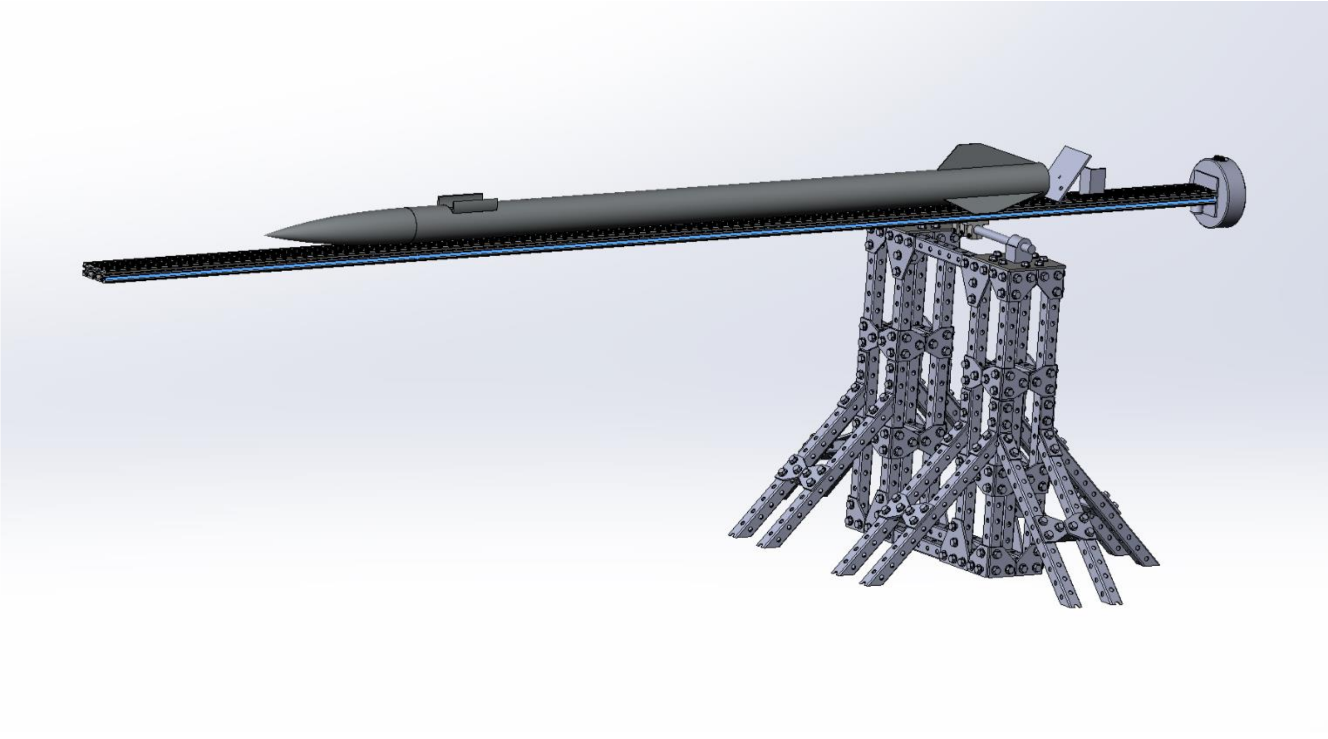
- **Failure Mode Analysis**
  - Identification of Failure Modes
    - Vehicle/AGSE Design and Construction
    - AGSE Operations
    - Autonomous Launch Operations
  - Mitigation plan for each failure mode
- **Mentor-Supervised Testing and Operations**
  - Tests Involving Prohibited Items
    - Ground testing of parachute deployment (ejection charge)
    - Full-scale test flight (ejection charge and ACPC motor)

LAUNCH VEHICLE VERIFICATION AND TESTING PLAN

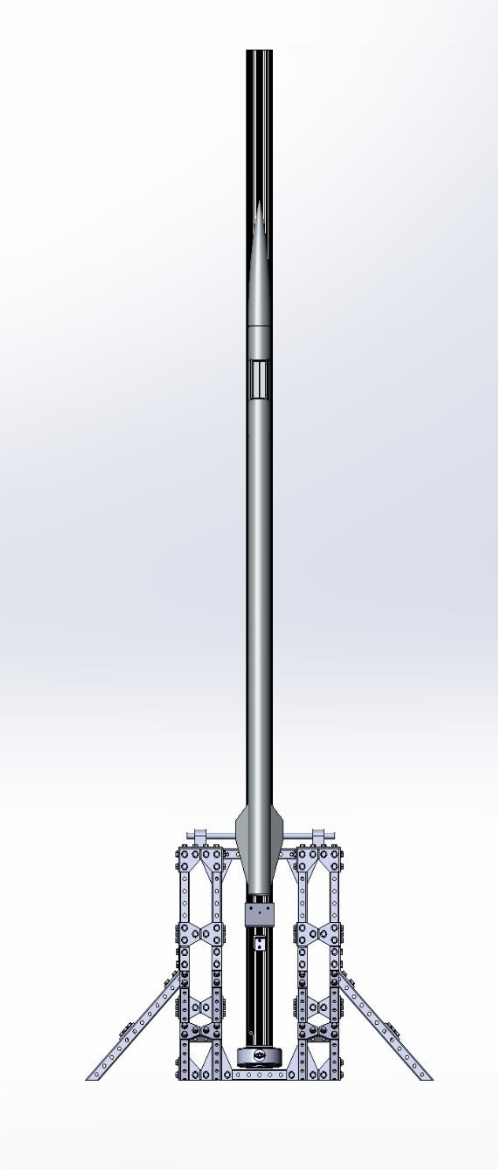
- **OpenRocket simulations to establish baseline performance characteristics**
  - Verify required altitude can be reached
  - Verify safe recovery of all sections can be achieved
- **Ground testing of Electronic Systems**
  - Verify electrical components are free of interference
  - Verify system can meet on-pad time requirements
- **Ground Testing of Recovery System Deployment**
  - Conducted under the supervision of the team's mentor
- **Multiple Test Flights**
  - Sub-Scale: Verify performance prediction methods, assembly techniques, electronics designs, etc
  - Full-Scale: Verify performance of all vehicle and AGSE systems

AGSE OVERVIEW - MALP

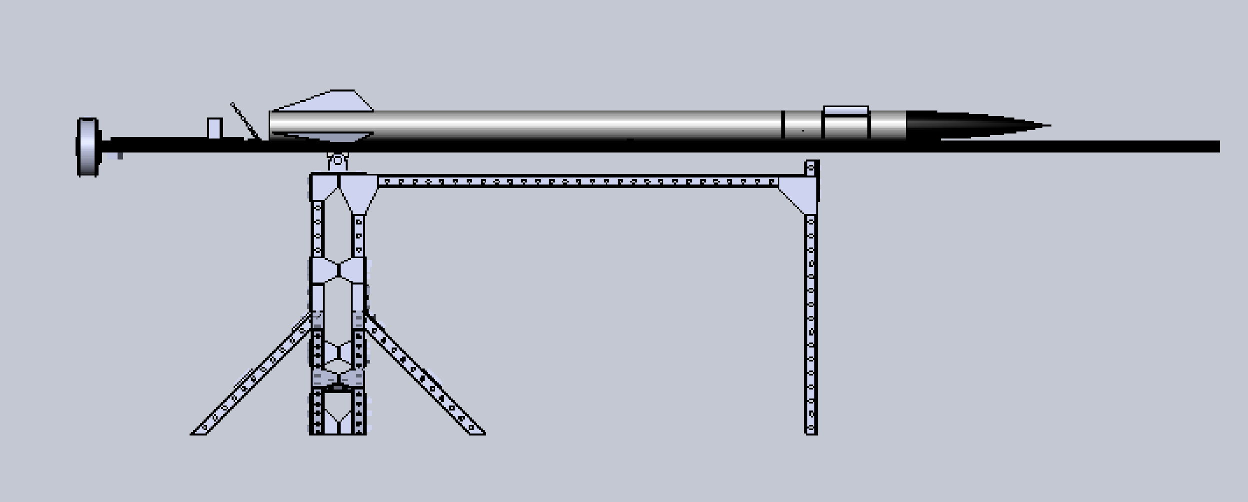
- **Support Towers**
  - Height: 38.5”
  - Footprint: 25.6”x40”
  - Total Footprint: 61.04”x40”
- **Launch Rail**
  - Length: 12.75’

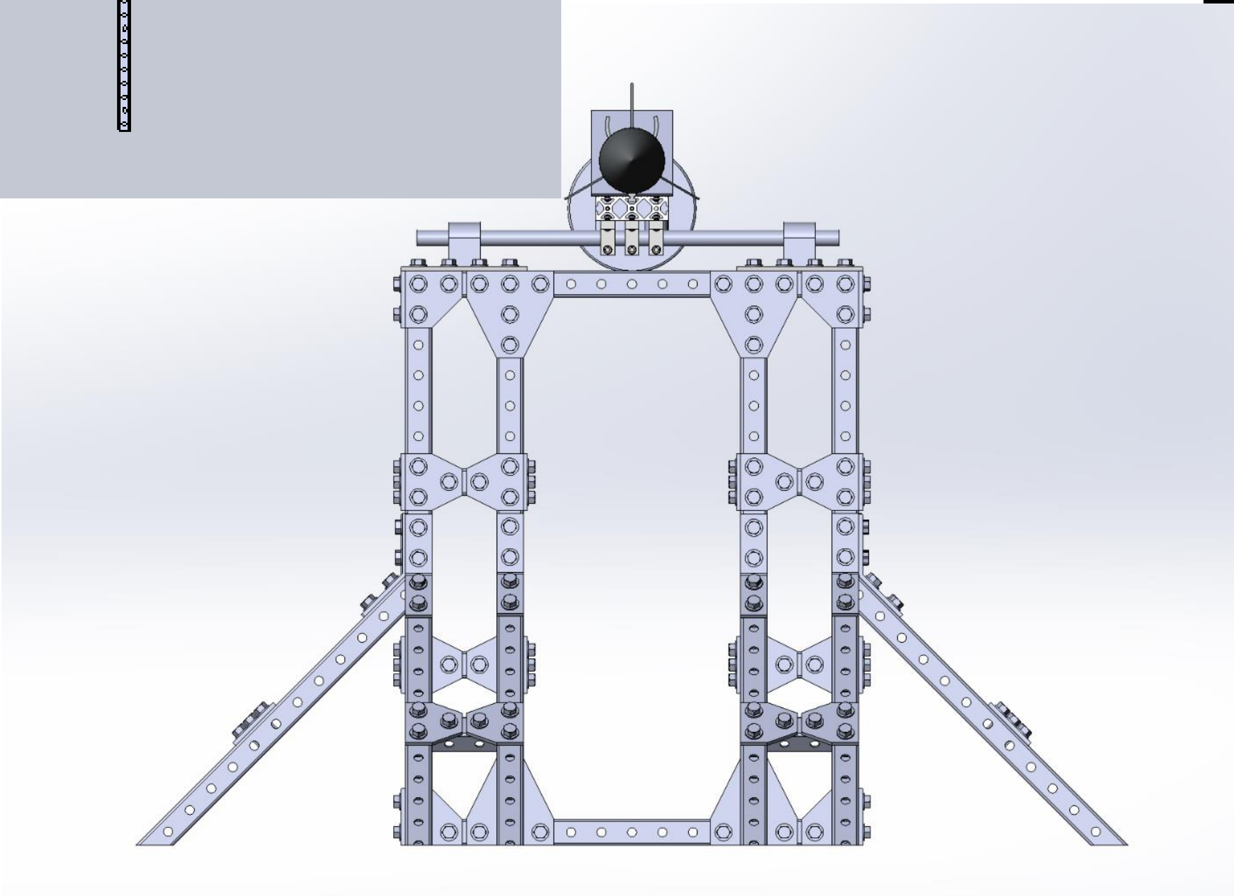


AGSE OVERVIEW - MALP

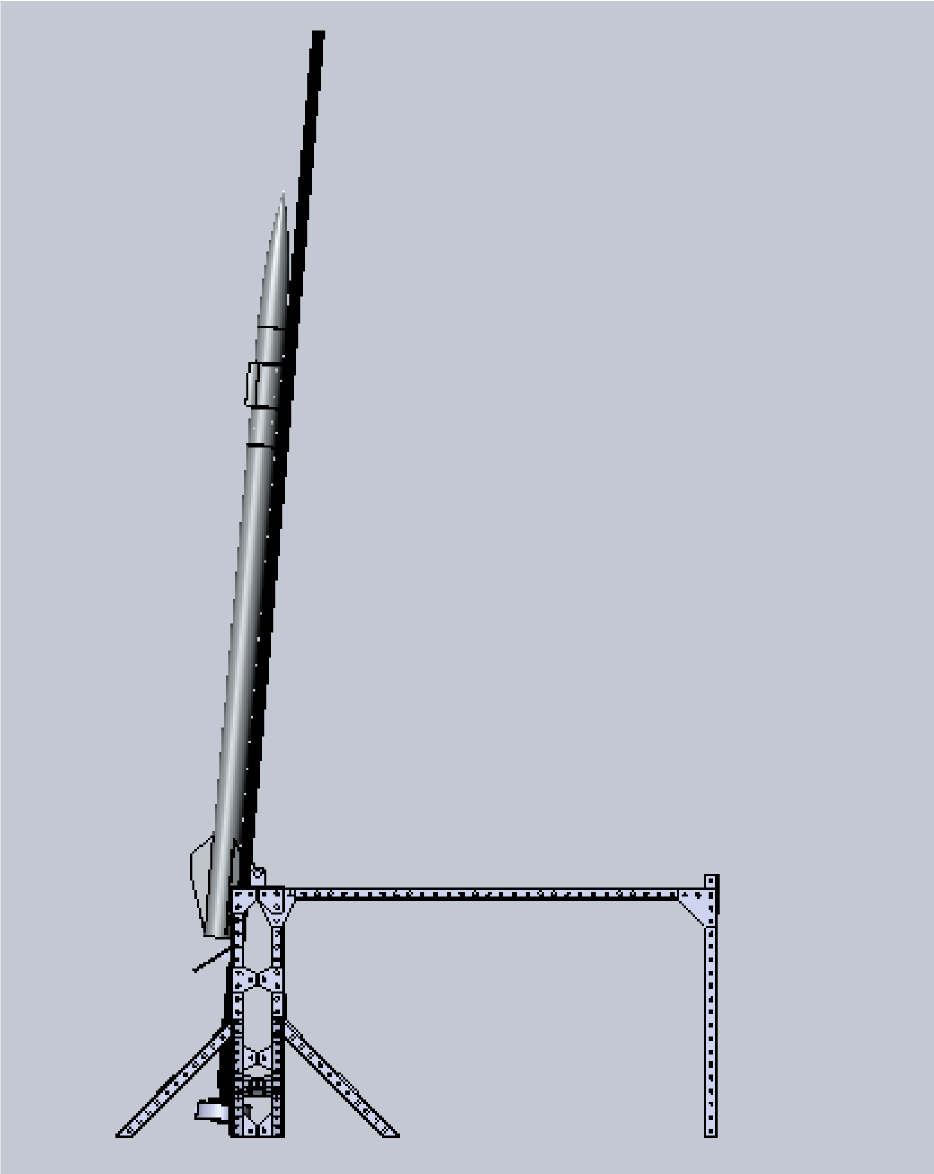


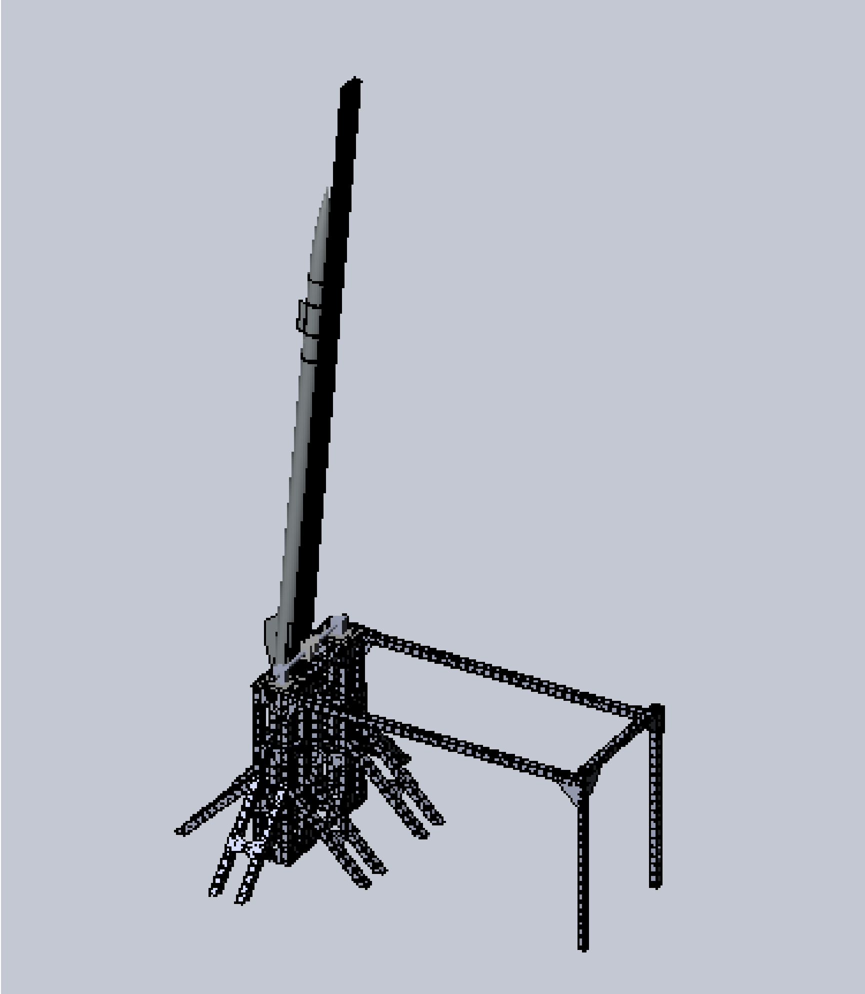
AGSE OVERVIEW - MALP



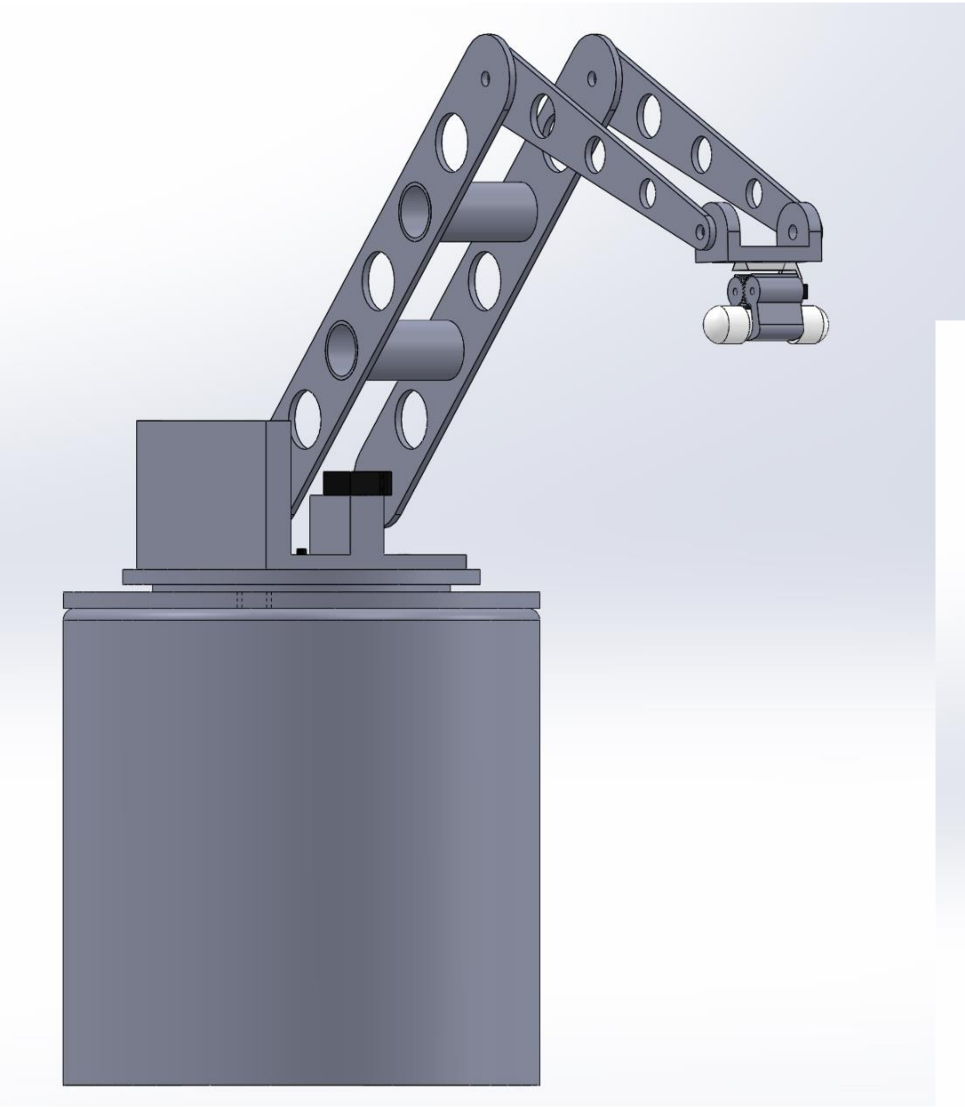


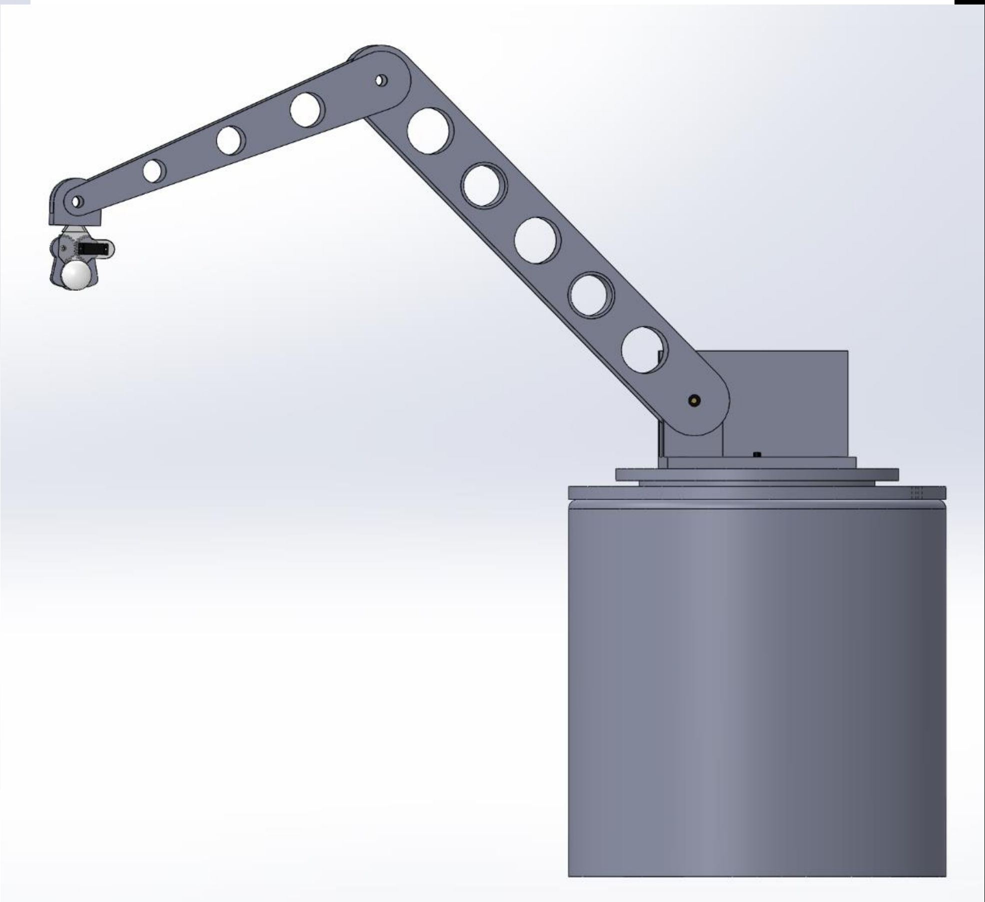
AGSE OVERVIEW - MALP



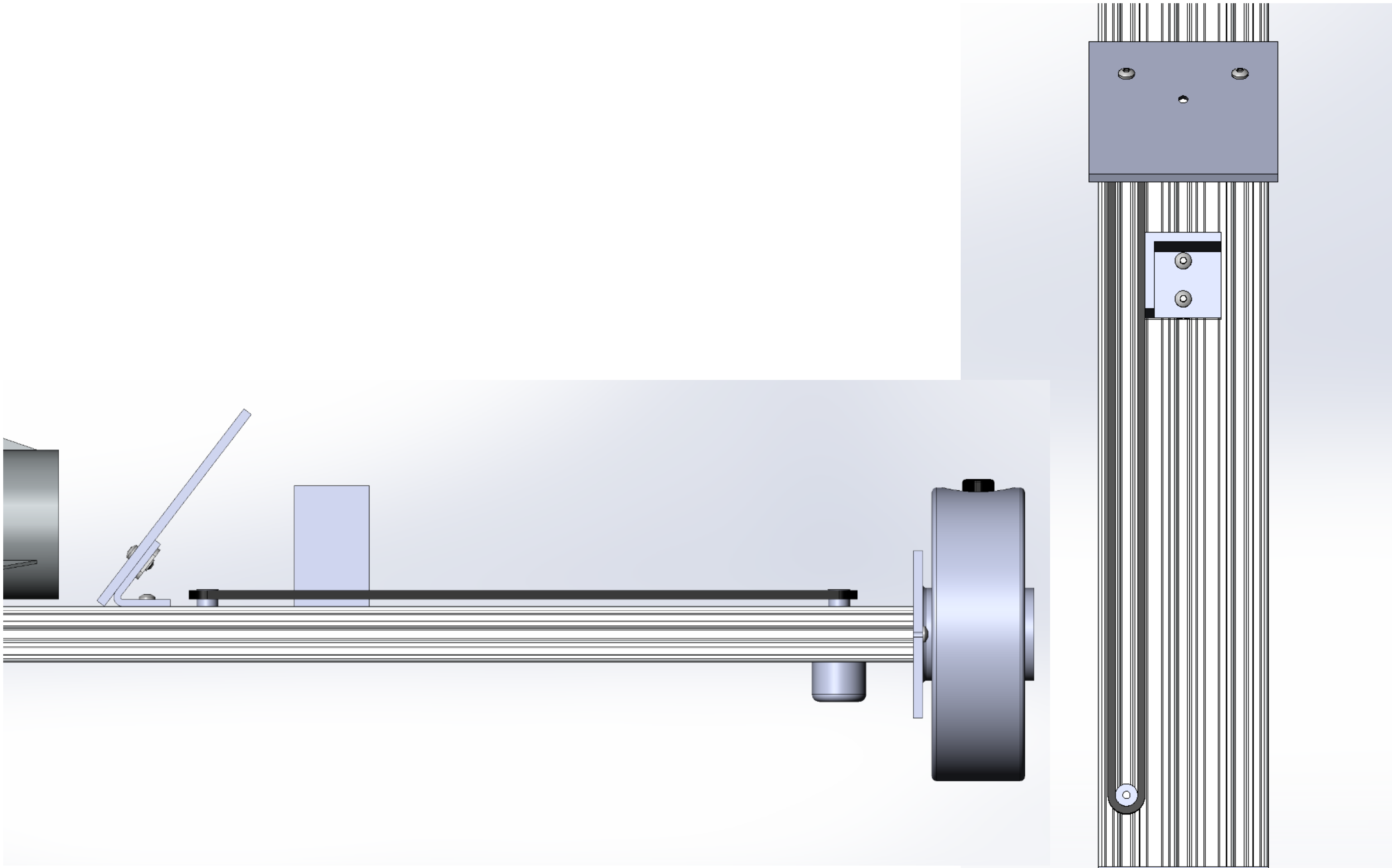


AGSE OVERVIEW - ARM



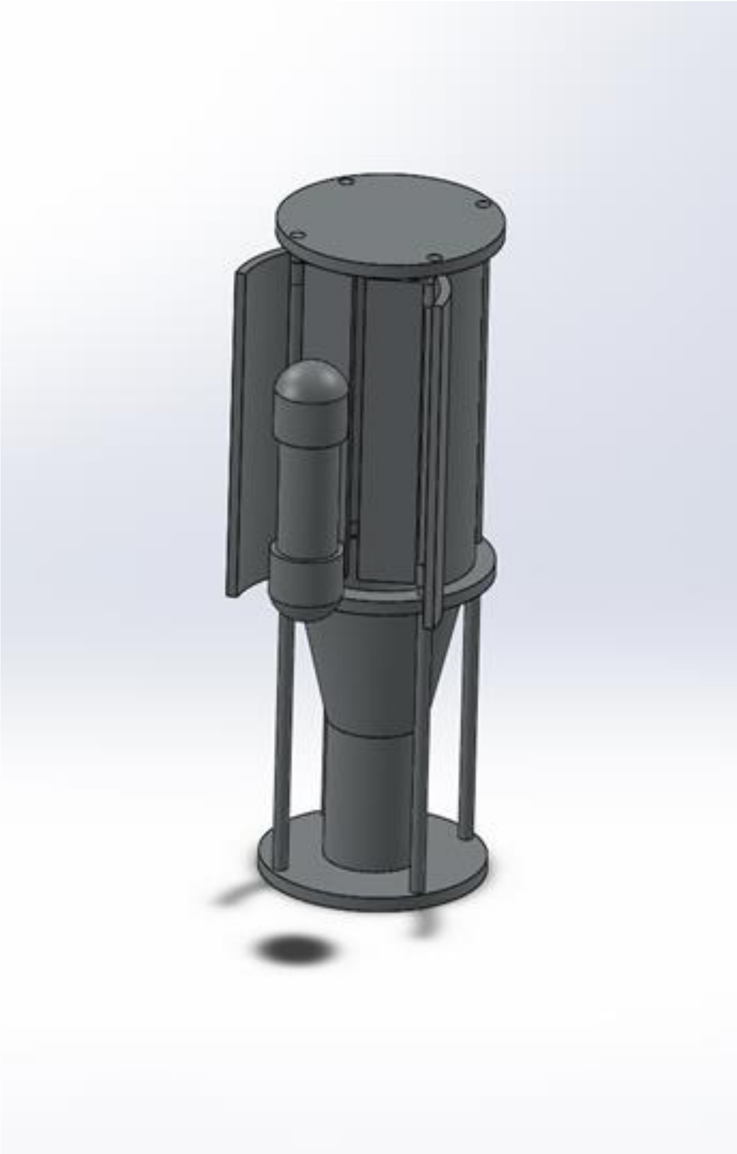


AGSE OVERVIEW - MIIS



AGSE OVERVIEW - PAYLOAD BAY

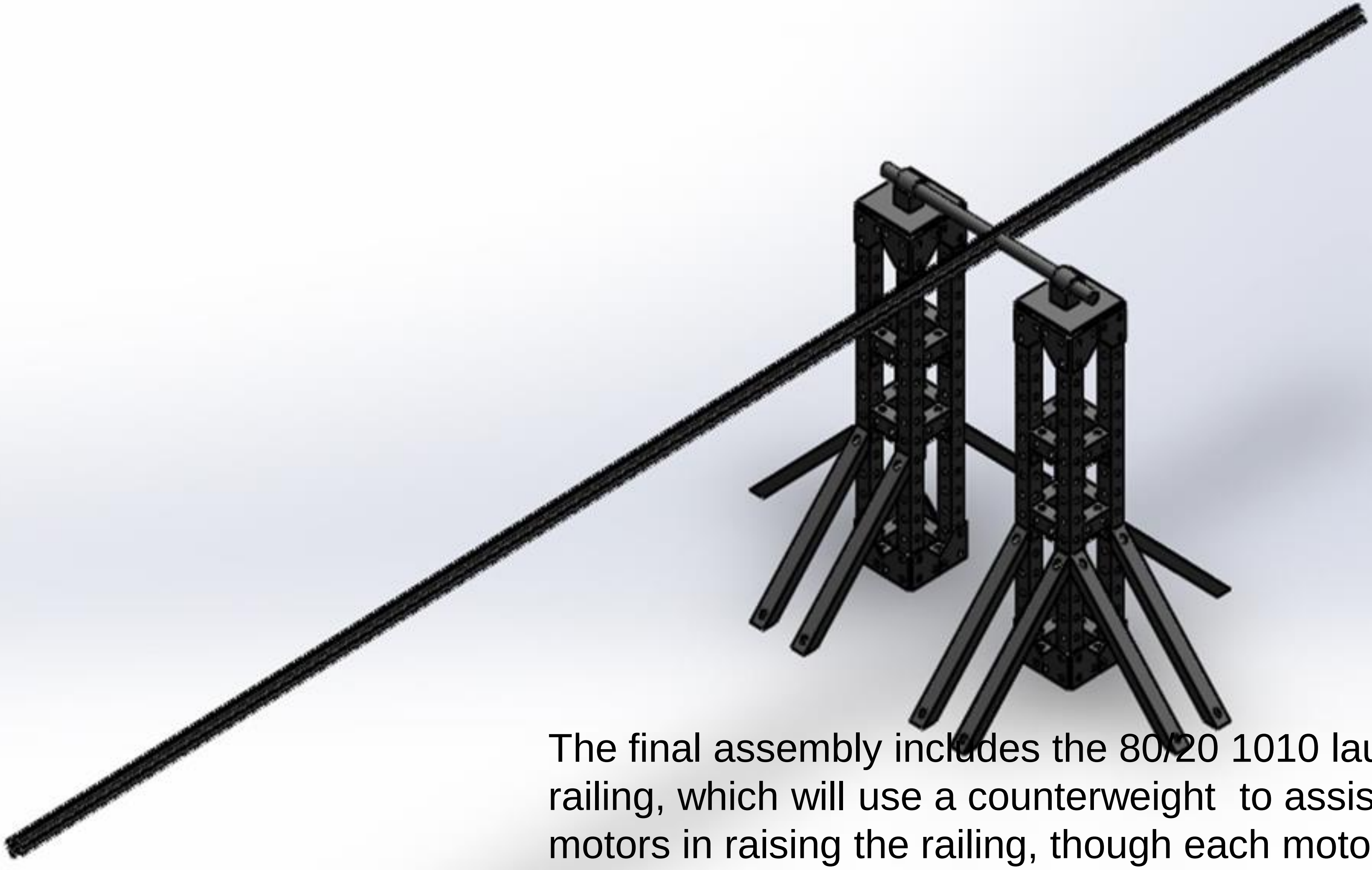
- **Secured in launch vehicle airframe**
- **Diameter: 3.9in**
- **Mass: 609g**
- **Materials**
  - Aluminum 6061
  - Cardboard



AGSE/PAYLOAD DESIGN

- **The AGSE will be responsible for:**
  - autonomously loading the payload into the vehicle's payload bay
  - raising the vehicle into a near-vertical launch position
  - inserting the motor igniter in preparation for launch.
- **Begins with vehicle secured to the launch rail in a horizontal position with the payload bay door opening upward.**
- **Pick up the sample capsule, raise it above the vehicle, and drop it into the payload bay**
- **Payload bay doors will automatically close once capsule has been placed inside and will lock shut**
- **Uses servo motors to raise the launch rail into a near-vertical position in preparation for launch**
- **Motor Igniter Insertion System will autonomously insert the igniter into the motor.**
- **The AGSE will then activate a "Ready to Launch" light, after which the hard-wired remote launch button will be used to ignite the motor and begin the flight.**

MODULAR AUTONOMOUS LAUNCH PLATFORM (MALP)



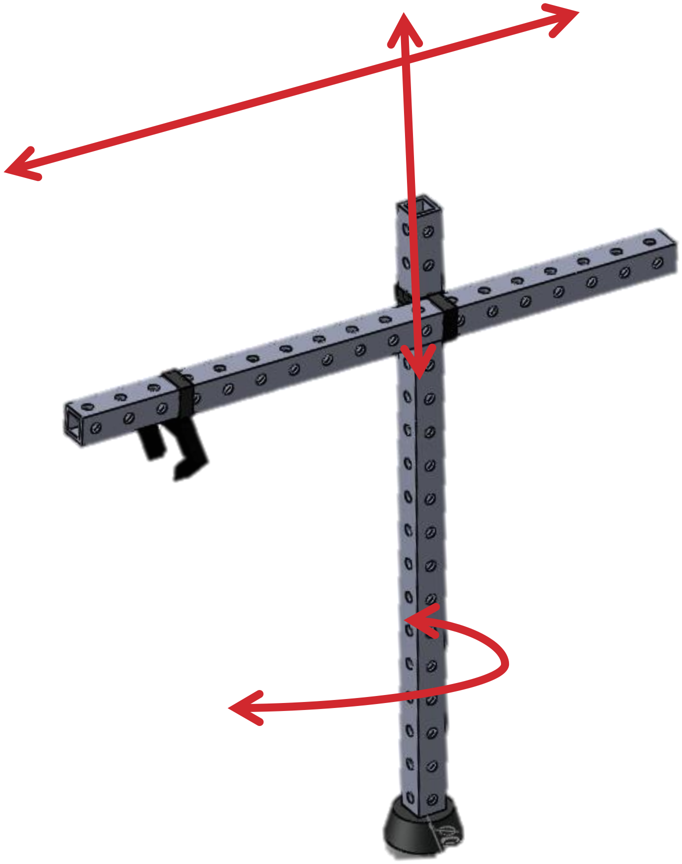
The final assembly includes the 80/20 1010 launch railing, which will use a counterweight to assist the motors in raising the railing, though each motor will be able to raise the railing on its own.

MALP TOWERS WITH STRUTS

- Bullet point descriptions

AUTONOMOUS RETRIEVAL MECHANISM (ARM)

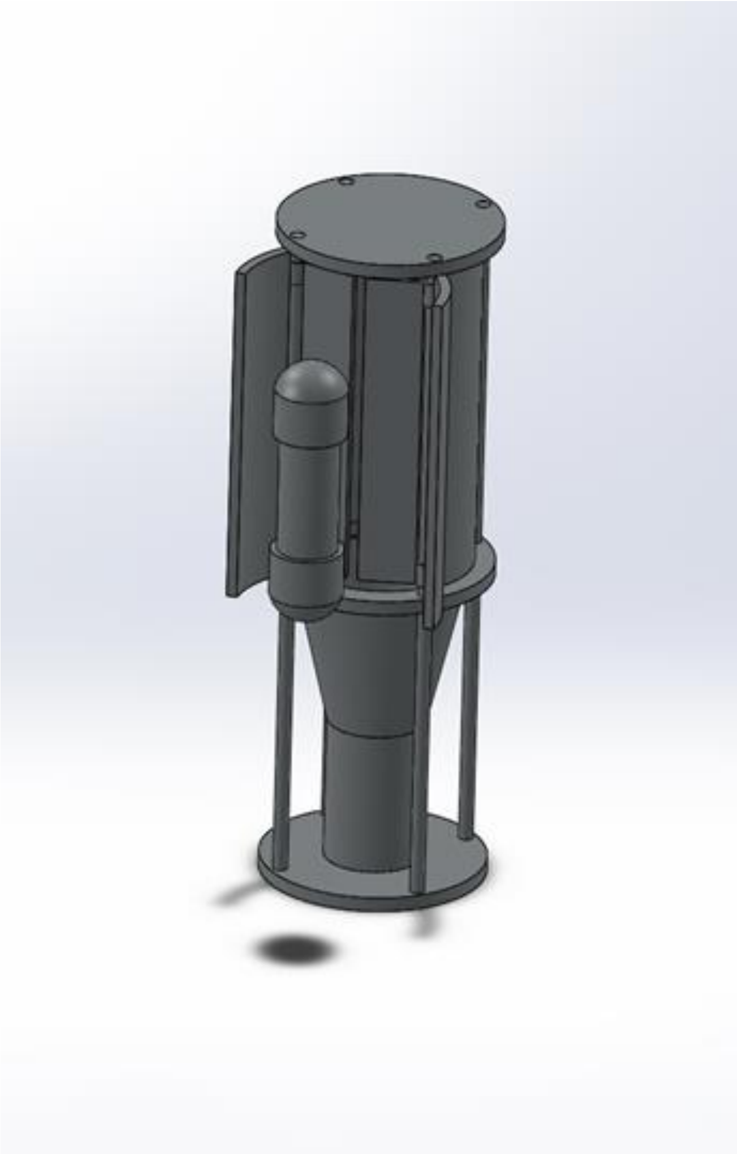
- Bullet point descriptions



MOTOR IGNITER INSERTION SYSTEM (MIIS)

PAYLOAD BAY ASSEMBLY

- **Secured inside airframe**
- **Doors open upward when vehicle is in horizontal position**
- **ARM will drop payload onto inner bay doors**
- **Mass of payload will rotate outer doors into closed position**
- **Magnets will lock the doors closed for launch**



AGSE/PAYLOAD VERIFICATION AND TESTING PLAN

- **Pre-Launch Testing of Major AGSE Systems**
  - Electronics (“Start” and “Pause” buttons, status lights)
  - Payload retrieval system
  - Payload encapsulation system
  - Moving vehicle to launch-ready position
  - Igniter insertion (using motor mock-up)
- **Full AGSE SystemsTest**
  - Verify all subsystems work together
  - Verify all operations are completed within time limit
- **Full-Scale Test Flight**
  - Verify AGSE performs all required functions

SUBSCALE TEST FLIGHT

- **Date: Dec 13th, 2014**
- **Aerotech K456DM**
- **Rouse-Tech 54/2560 casing**
- **Altitude**
  - Expected: 6,020 ft AGL
  - Actual: 5,977 ft AGL
- **Stability Margin: 2.314**

<u>**Successful Test Flight!**</u>

REQUIREMENTS VERIFICATION

- **Vehicle Requirements**

Requirement	Status
1.1	In-Process
1.2	Verified
1.3	In-Process
1.4	Verified
1.5	Verified
1.6	In-Process
1.7	In-Process
1.8	In-Process
1.9	Verified
1.10	In-Process

Requirement	Status
1.11	In-Process
1.12	Verified
1.13	Verified
1.14	In-Process
1.15	In-Process
1.16	Verified

* See Tables 1-5 in the CDR Report for Detailed Verification Plan and Status

REQUIREMENTS VERIFICATION

- **Recovery Requirements**

Requirement	Status
2.1	Verified
2.2	Verified
2.3	In-Process
2.4	Verified
2.5	Verified
2.6	Verified
2.7	Verified
2.8	Verified
2.9	Verified
2.10	In-Process

Requirement	Status
2.11	In-Process

* See Tables 1-5 in the CDR Report for Detailed Verification Plan and Status

REQUIREMENTS VERIFICATION

- **Maxi-MAV Competition Requirements**

Requirement	Status
3.2.1.1	Verified
3.2.1.2	In-Process
3.2.1.3	In-Process
3.2.1.4	In-Process
3.2.1.5	In-Process
3.2.1.6	In-Process
3.2.1.7	In-Process
3.2.1.8	In-Process
3.2.1.9	In-Process
3.2.1.10	In-Process

Requirement	Status
3.2.1.11	In-Process
3.2.1.12	In-Process

* See Tables 1-5 in the CDR Report for Detailed Verification Plan and Status

REQUIREMENTS VERIFICATION

- **Safety Requirements**

Requirement	Status
4.1	In-Process
4.2	In-Process
4.3	In-Process
4.4	In-Process
4.5	In-Process
4.6	In-Process

Requirement	Status

* See Tables 1-5 in the CDR Report for Detailed Verification Plan and Status

REQUIREMENTS VERIFICATION

- **Recovery Requirements**

Requirement	Status
5.1	In-Process
5.2	In-Process
5.3	In-Process
5.4	Verified
5.5	Verified
5.6	In-Process
5.7	In-Process
5.8	In-Process
5.9	In-Process
5.10	In-Process

Requirement	Status
5.11	In-Process
5.12	In-Process

* See Tables 1-5 in the CDR Report for Detailed Verification Plan and Status

BUDGET

Budget Item	Cost
Electronics	$589.16
MALP	$1645.92
Build Materials	$849.0
Propulsion	$224.97
Sample Containment Bay	$44.98
MIIS	$693.51
Recovery	$720.65
Tools	$400.00
Outreach	$2,492.94
Travel	$3,368.78

SCHEDULE

Event	Dates
Design Period	11/17-1/16
Corporate Funding Campaign	11/17-3/1
Subscale Work	11/17-12/12
Pitchfunder Campaign Setup	11/17-12/8
Subscale Model Launch at SARA Club Launch	12/13/14
Ejection charge test	12/13/14
Fullscale Work	12/14-2/15
MALP/MIIS/Payload Bay Manufacturing	12/15-2/15
Pitchfunder Campaign	1/5-2/5
Critical Design Review	1/16
MALP/MIIS/Payload Bay Testing Complete	
Fullscale Model Launch	2/15

EDUCATIONAL ENGAGEMENT

- **Reached over 300 students through informal engagement**
  - Earth and Space Exploration Day (Oct 25th, 2014)
- **Reached over 50 students through informal engagement**
  - Akimel A-al Middle School (Dec 9th, 2014)
- **Upcoming engagement in February and March 2015!**

QUESTIONS?