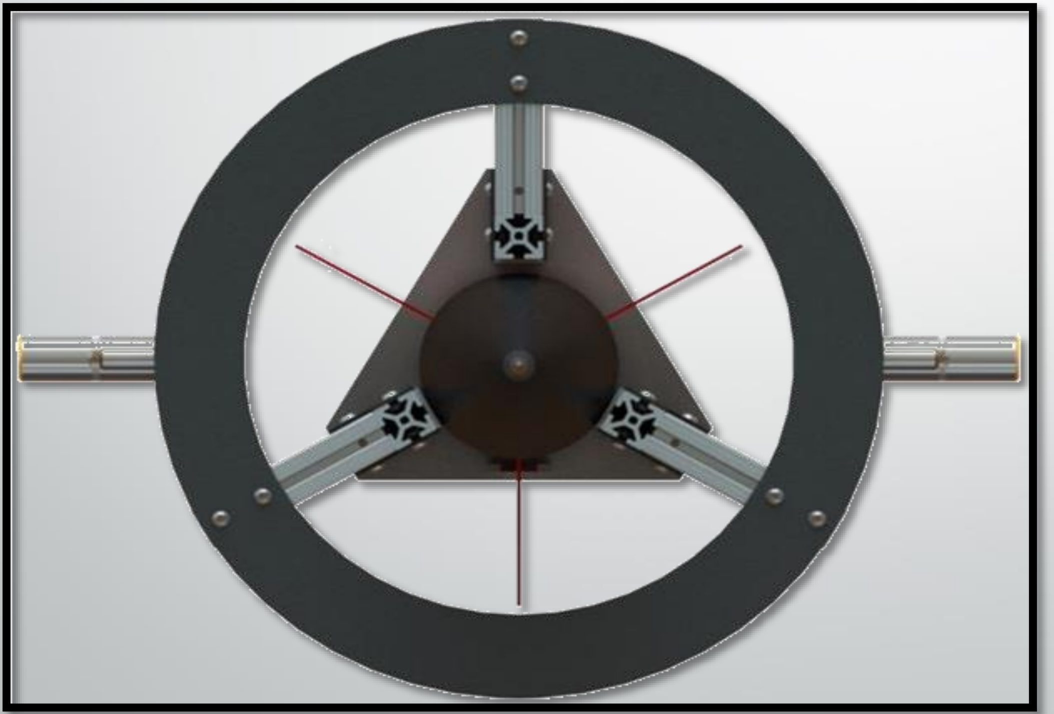
Preliminary Design Review Presentation

University of Louisville
River City Rocketry
November 19, 2014

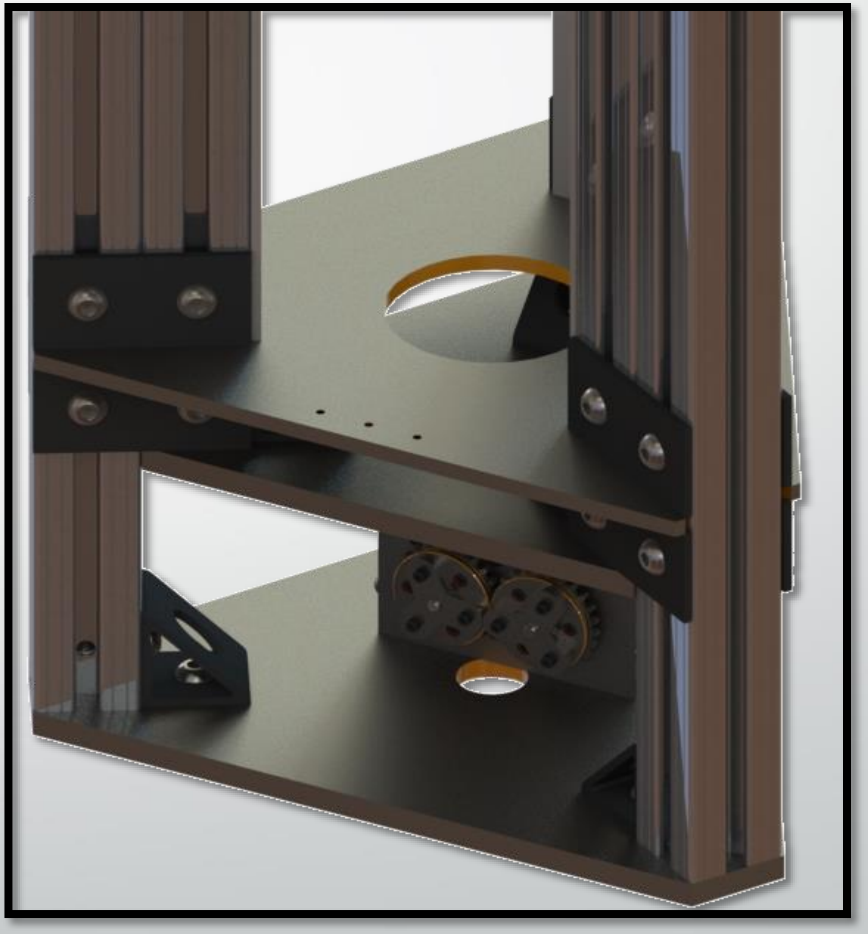
Launch Platform

Overall Height (in)	Guided Height (in)	Overall Mass (lb_m)
126.78	120.36	106.17



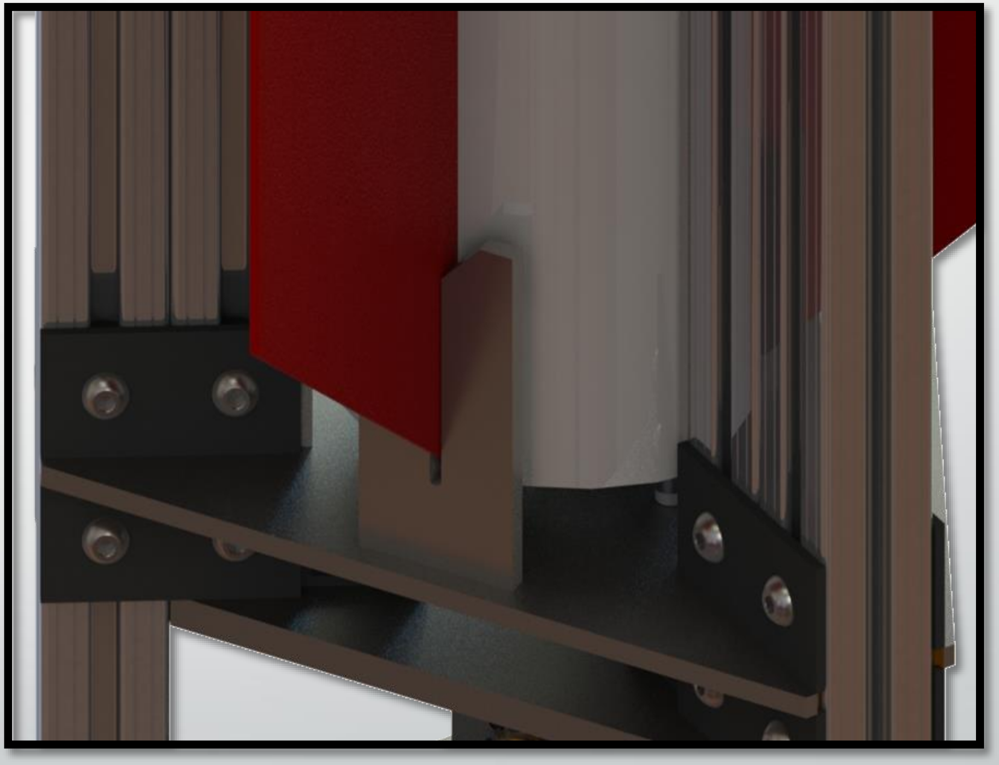
Base and Ignition Station

- The ignition station is fastened to the base of the launch platform.
- Three support rails support the guide rails.



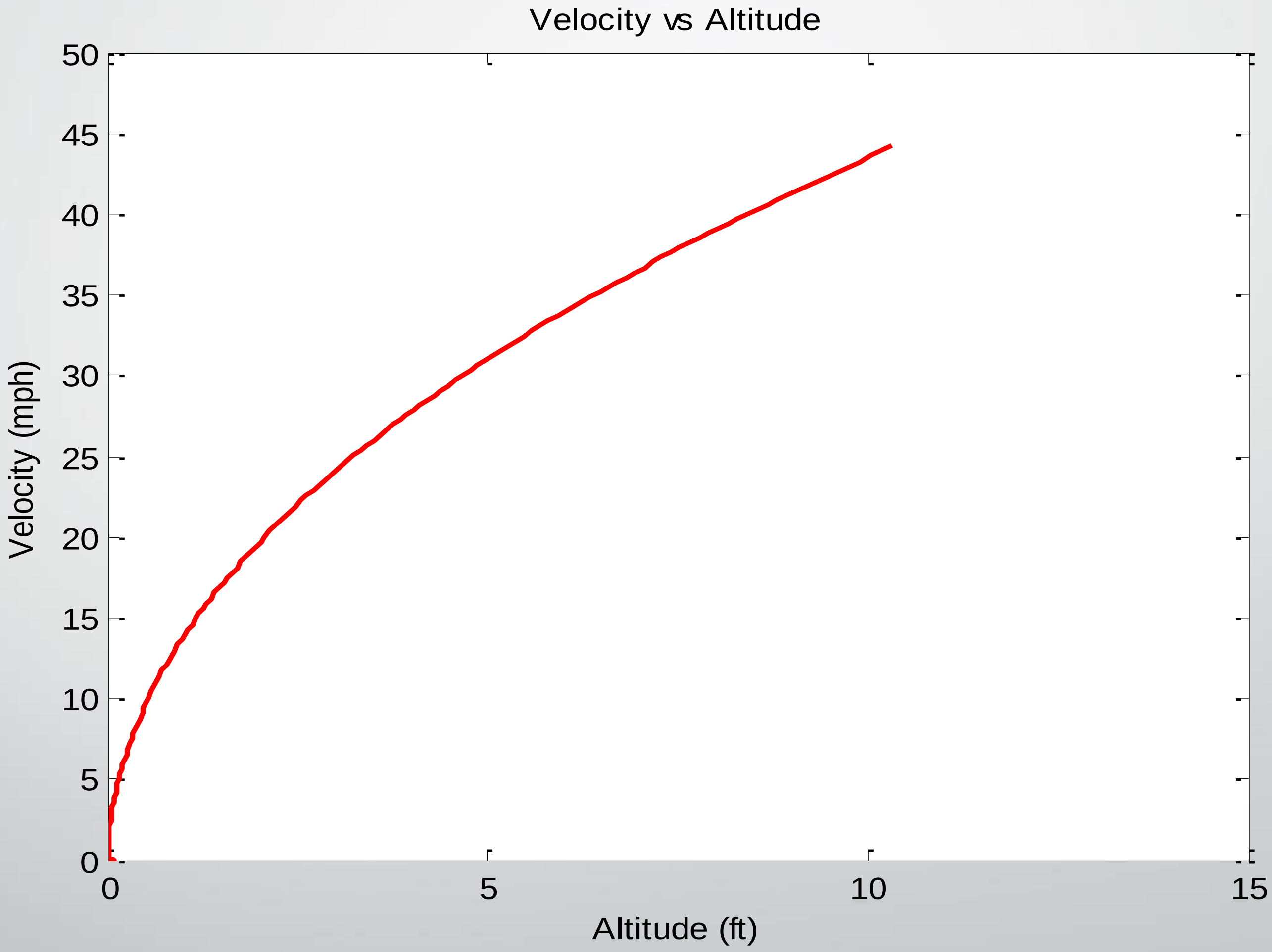
Vehicle Position and Orientation

- The vehicle will be held in the proper orientation by alignment plate shown here.

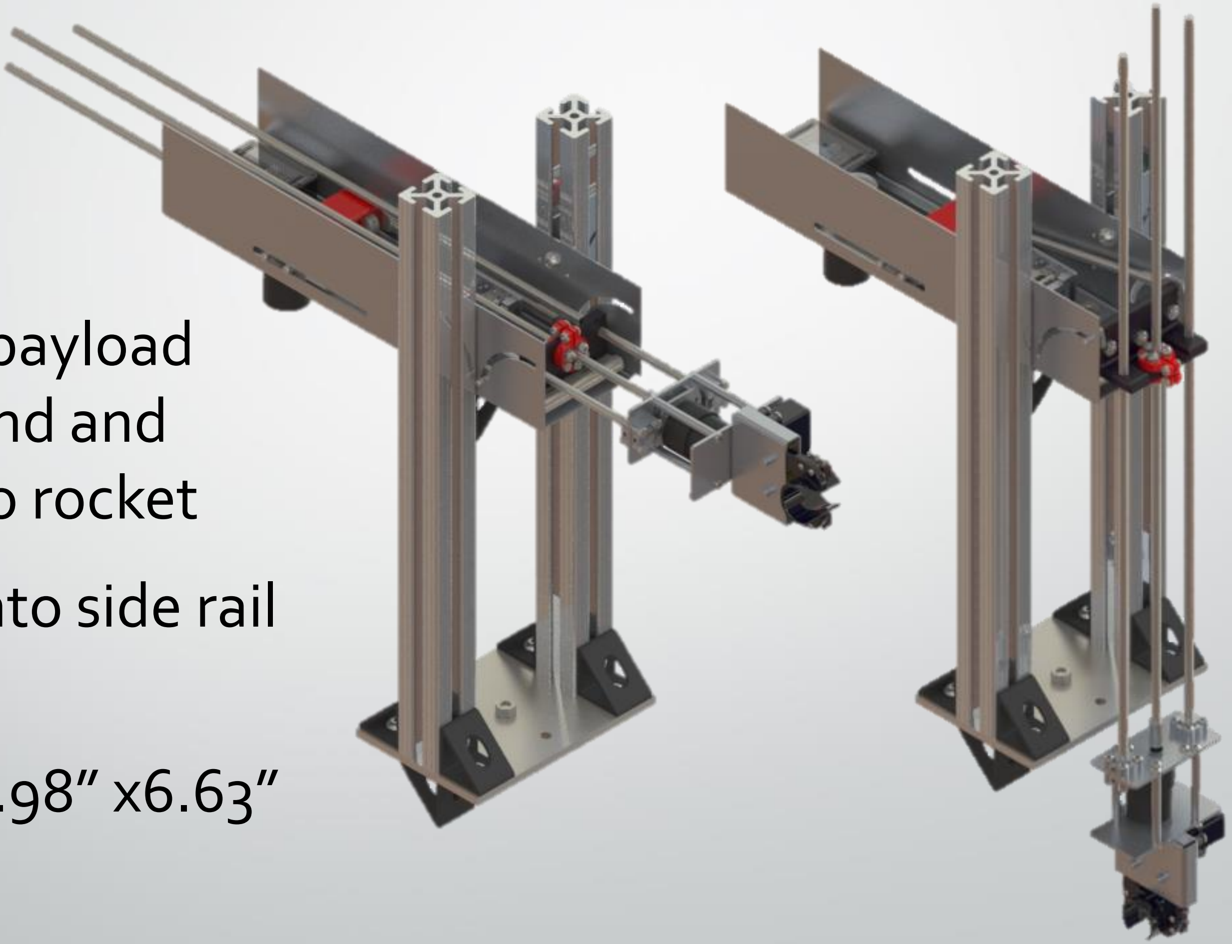


Exit Velocity

Exit Velocity (mph)
45.4



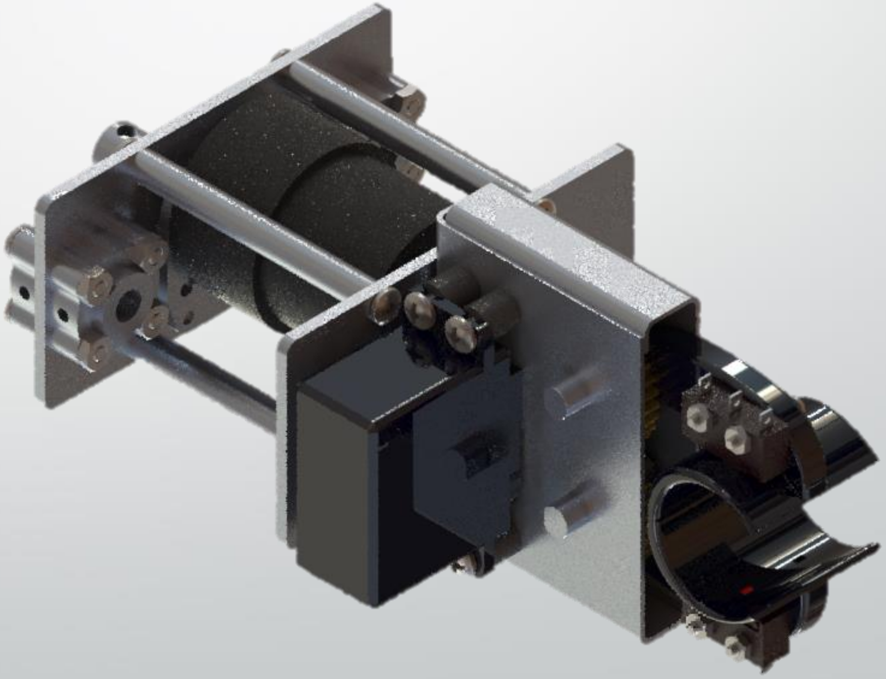
Payload Capture System



- Retrieves payload from ground and inserts into rocket
- Mounts onto side rail of AGSE
- 18.25" x15.98" x6.63"

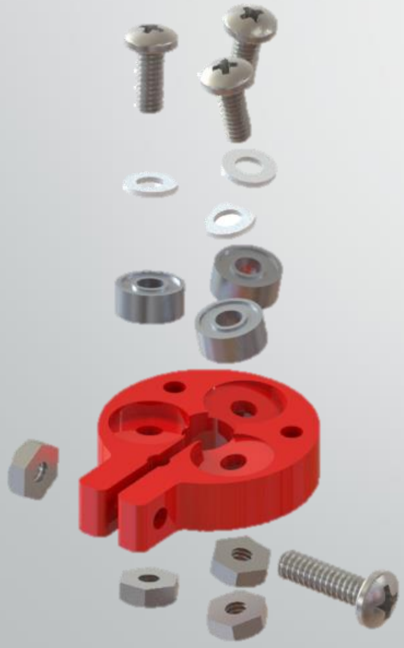
Gripper Assembly

- Three gears driven by servo
- Touch sensor on each arm to detect payload
- 12VDC motor to move assembly vertically & horizontally



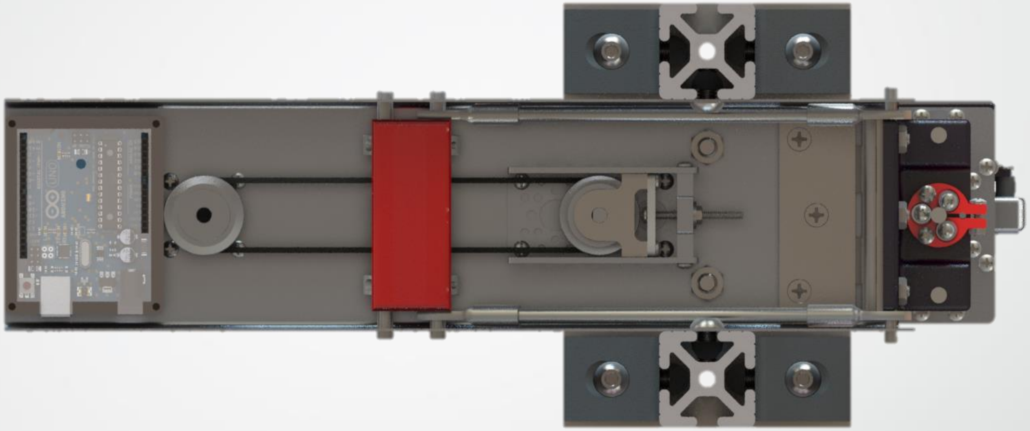
Threadless Ball Screw

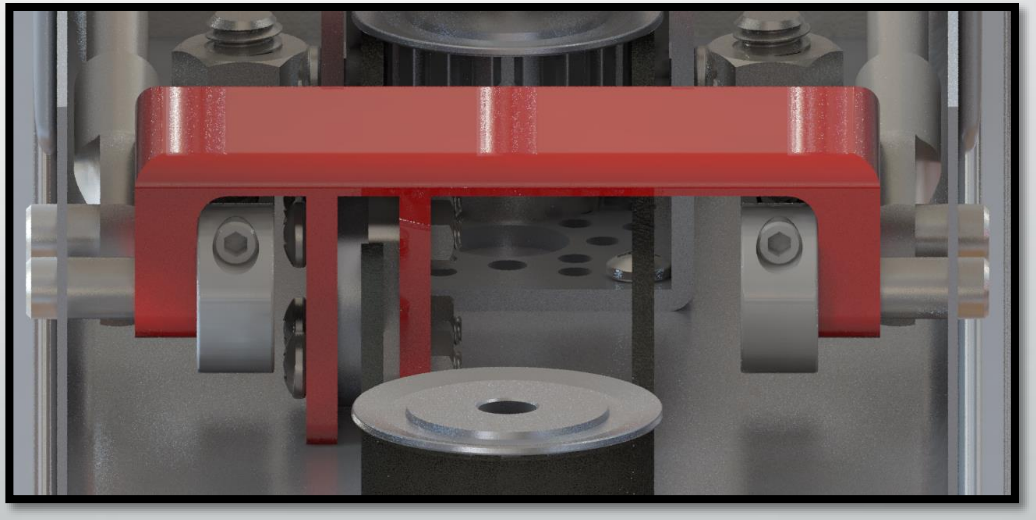
- Low Cost
- Height from ground could vary from 18-48in
- Bearings are angled to simulate a thread pitch



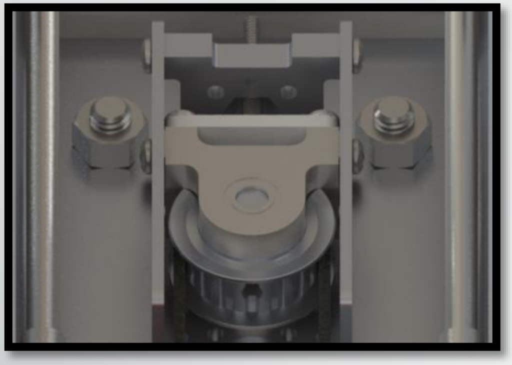
Belt System

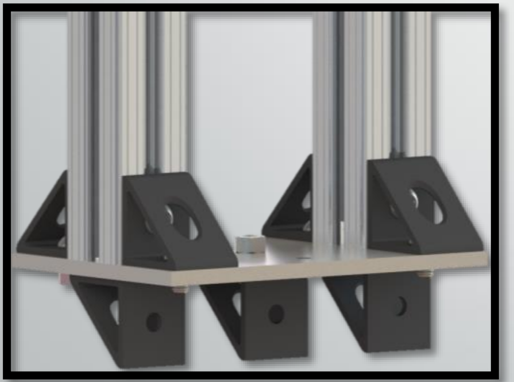
- Push rods connect slider and threadless ball screw assembly
- Slider attached to timing belt
- Motor drives slider backwards
- Gripper Assembly rotates 90 degrees





Flow Chart





System is Activated

Close Gripper Arms

Have touch sensors been activated

No

Yes

Move Payload Upwards

Has Gripper Assembly Reached Z Distance

No

Yes

Rotate Gripper Assembly Horizontally

Is the Payload Parallel to the Rocket

No

Yes

Move Payload Horizontally Towards Rocket

Has Payload Reached Clips in the Rocket

No

Yes

Stop and Open Gripper Arms

Retract Arm Horizontally

Pause Switch is Activated

Stop System and Save Current Step

Is Pause Switch Deactivated

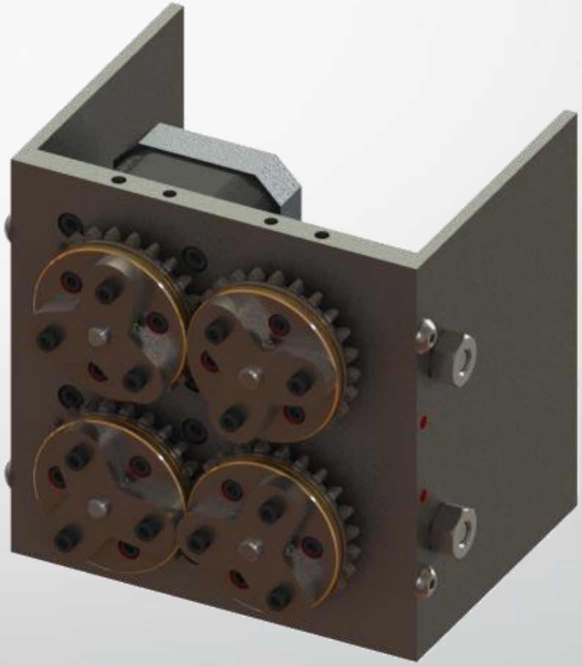
No

Yes

Resume System from Last Saved Step

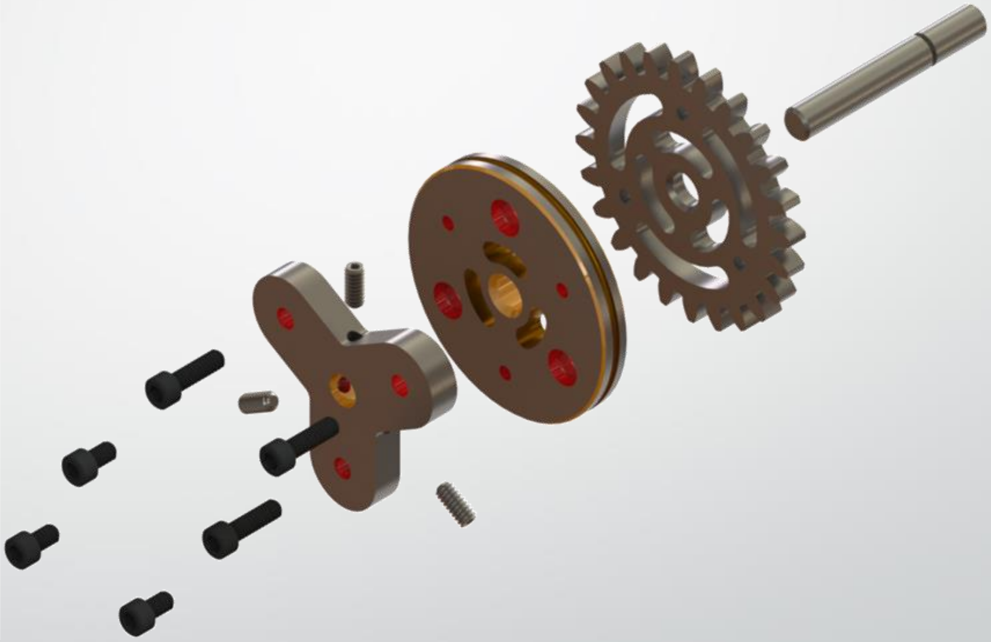
Ignition Station

Overall Height (in)	Overall Thickness (in)	Overall Width (in)	Overall Mass (lb_m)
4.00	3.00	4.20	4.17



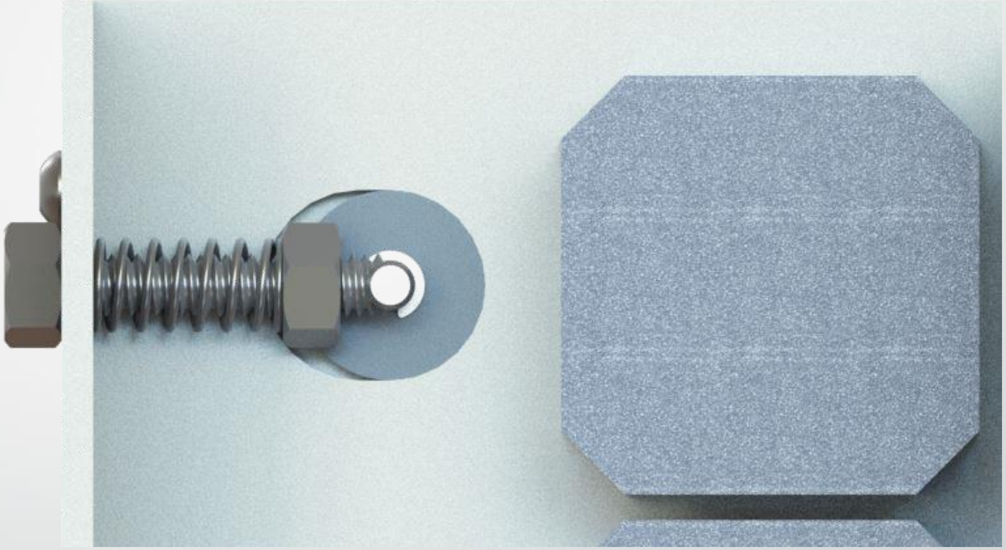
Extrusion Wheel

- 4 Wheel assemblies.
- 1.5 inch diameter.

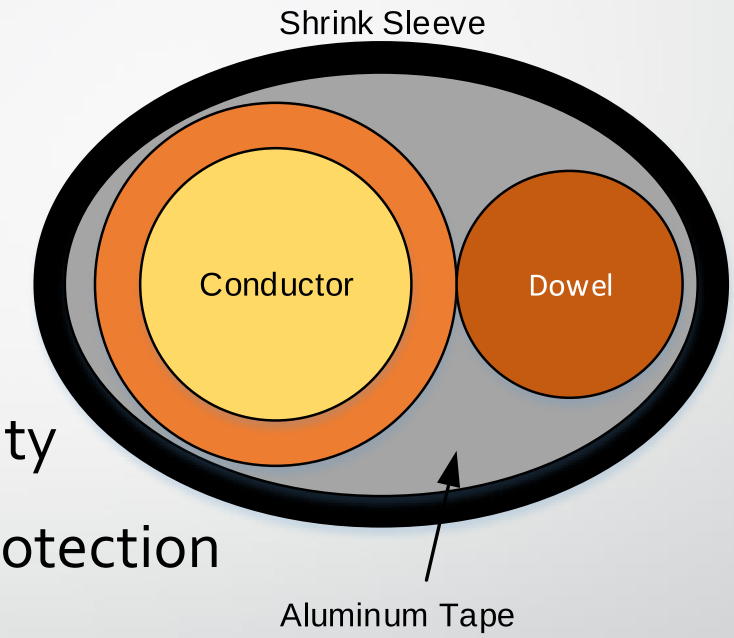


Spring Tensioner

- Keep constant tension on secondary drive wheels.
- Removable in case of damage

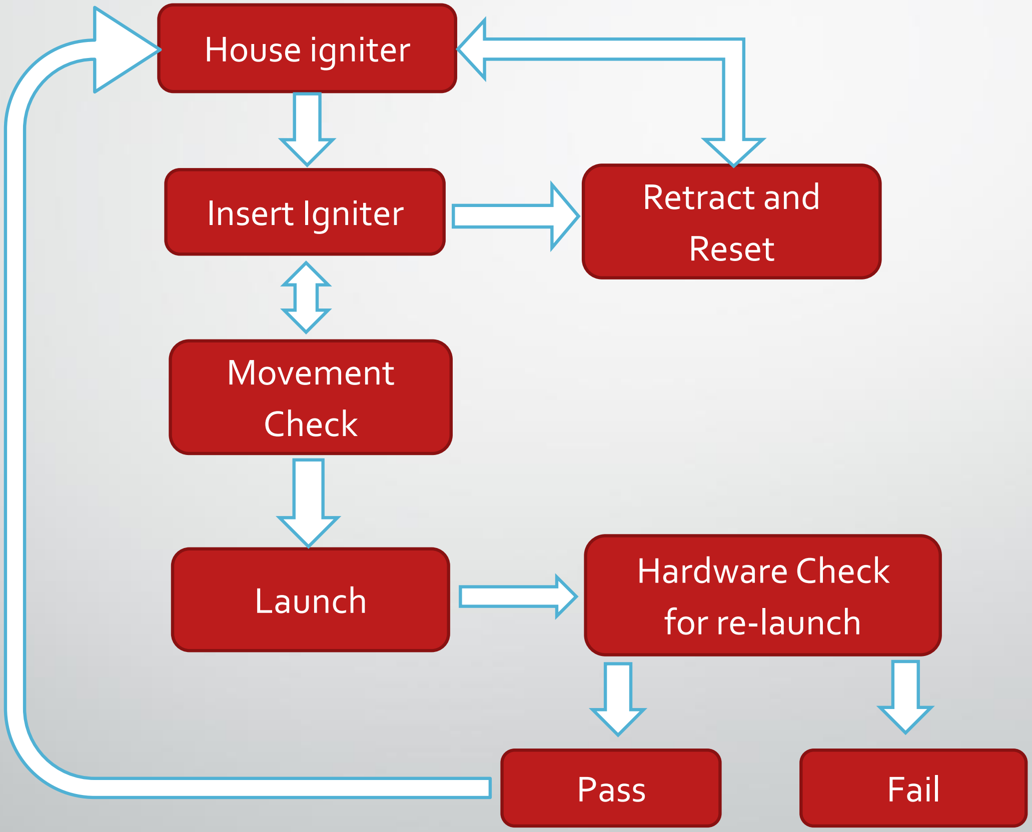


Igniter Augmentation



- Augmented with dowel - rigidity
- Aluminum tape – electronic protection
- Shrink Sleeve - grip

Overview



House igniter

Insert Igniter

Retract and Reset

Movement Check

Launch

Hardware Check for re-launch

Pass

Fail

Requirements

Requirements	Performance Characteristics	Validation Method
Accurately place igniter into the top portion of the rocket motor	Control of igniter within an inch	Resolution of stepper motor movement during testing
Stay within specified time constraints	Control speed allowing installation of igniter within a minute	RPM of stepper motor during testing
No movement of Igniter until liftoff has been achieved	Igniter will not move until given logic HIGH	Inspection of Arduino code
Hardware remains fully functional post liftoff	Reliability of stepper motor and electronics to withstand heat	Inspection of Arduino/Shield data sheet

Design Challenges

- Controlling both steppers simultaneously
  - Arduino can only step one stepper at a time
  - Use object oriented programming to allow alternating stepping at an imperceptible rate
  - With the given clock cycle of 16MHz the time between steps is approximately 0.1 microseconds.
    - $2 * \frac{1}{16MHz} = 2 * 0.065\mu\text{s} \approx 0.1\mu\text{s}$

Design Challenges

Design Challenge	Solution
Accurate guidance of the igniter into the motor.	Dowel rod sections will be attached to the igniter. The stepper motors will be used for movement of the igniter into the rocket.
Disable Ignition of motor until approved by safety officer.	Power supply to igniter will be isolated by toggle switch
Knowing when the igniter is in the proper position	Validation testing to be performed to measure true travel distance of the igniter installer.
Keeping the igniter in the station during V.E.S. actuation.	The wheels that guide the igniter into the vehicle has grooves that will keep the wire in place.
Components are able to withstand ignition	The motors will be behind the mounting plate. Tests to be performed to determine the amount of heat the motors will experience.

Performance Characteristics

- **Precision** - The stepper motors can place the igniter within 0.047 inches:
  - Circumference = $2\pi * 1.5\ in = 9.4\ in$
  - % of circumference per step = $\left(\frac{1.8}{360}\right) * 100\% \approx 0.5\%$
  - Distance of 1 step = $0.5\% * 9.4 = 0.047\ inches$
- **Accuracy** - The stepper motors can move the igniter 10 inches per second:
  - RPM of stepper $= \ 60\ RPM \ = \ 1\ RPS$
  - Circumference = $9.4\ in * 1\ RPS \approx \frac{10in}{s}$

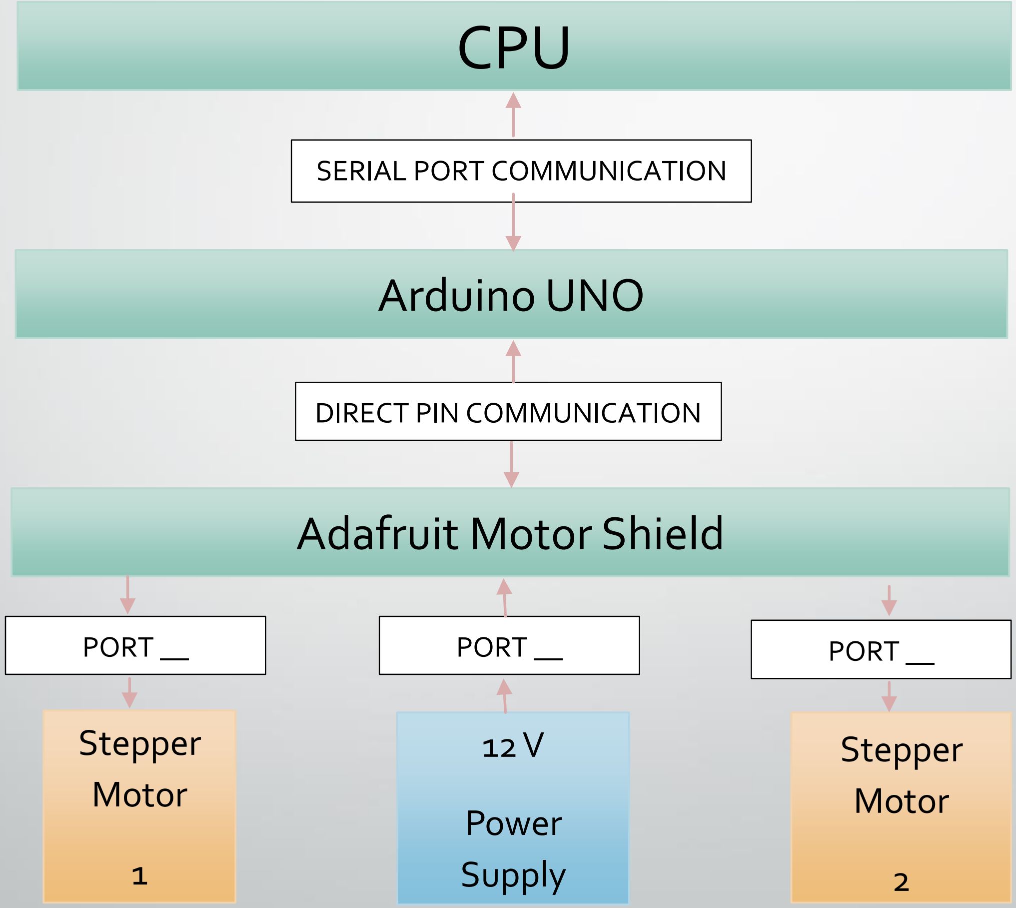
Verification Plan

Requirements	Performance Characteristics	Validation Method
House Igniter	Static in housing	Physical Validation
Insert Igniter	Igniter flush at upper interior of motor	Depth Markings on igniter housing
Post launch function check	Fully operational housing and retracted ignition housing at start position	Visual inspection

Controls

Number of Items	Description	Specs.
1	Arduino Uno	Microcontroller
1	Adafruit Motor Shield (Driver)	V2.0, 2-3 A,12 V port
2	Adafruit Stepper Motor	NEMA – 17, 350 mA, 12 V Size: 200 steps/rev Coil #1 Red & Yellow Wire Coil #2 Green & Gray
1	Power Supply	12 Volt

Controls



CPU

SERIAL PORT COMMUNICATION

Arduino UNO

DIRECT PIN COMMUNICATION

Adafruit Motor Shield

PORT __

PORT __

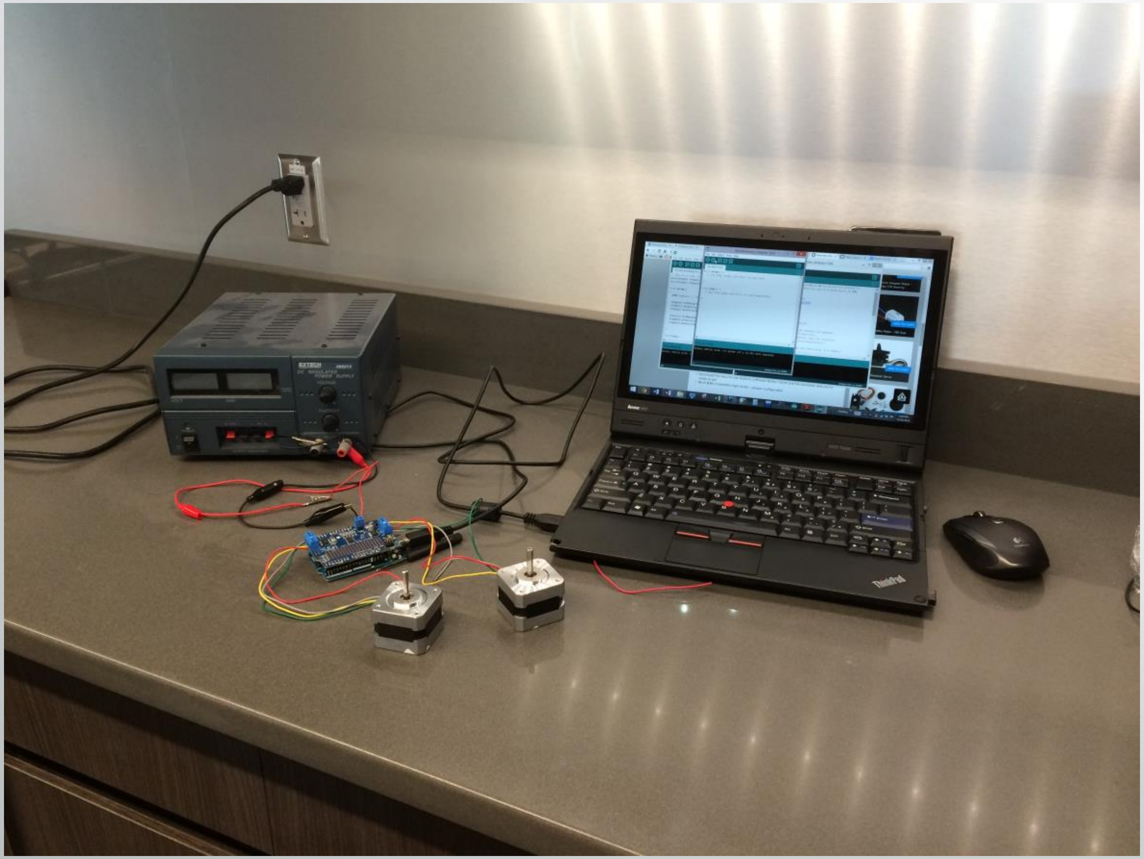
PORT __

Stepper Motor 1

12 V Power Supply

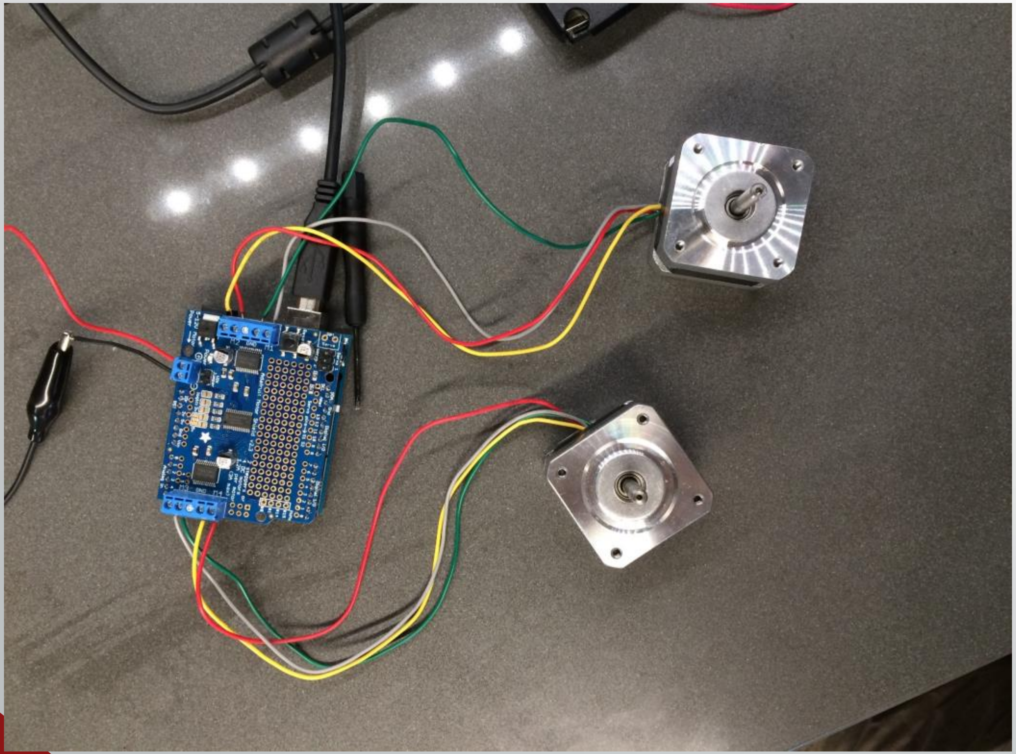
Stepper Motor 2

Test Setup



- 12 Volt Power Supply
- Arduino Uno
- Adafruit Motorshield
- 2x Stepper Motor
- PC running Arduino Software

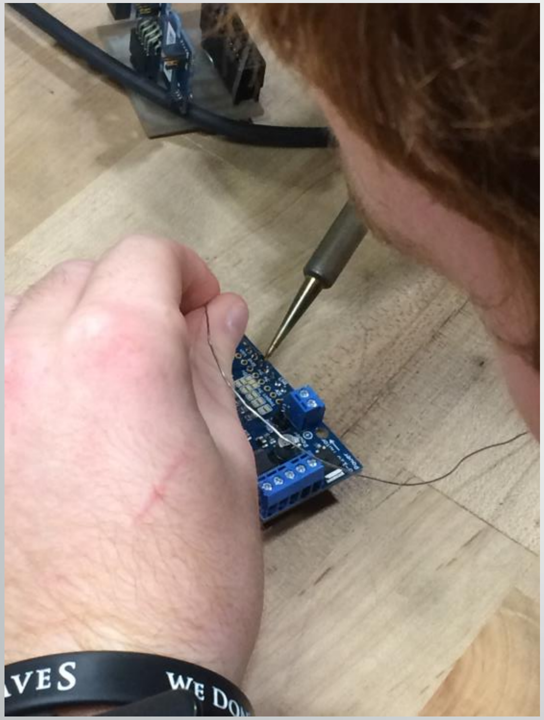
Connections

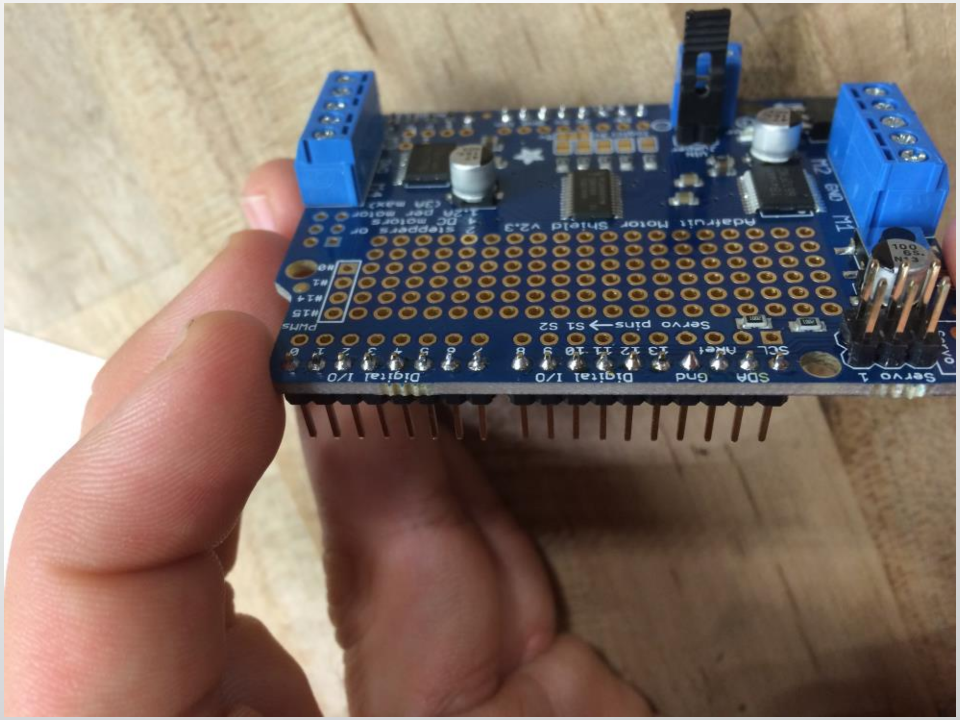


- Left – Red and Black wire is 12 volt power supply
- Top - USB plug is to computer running Arduino Software
- Right - 2 Stepper motors.

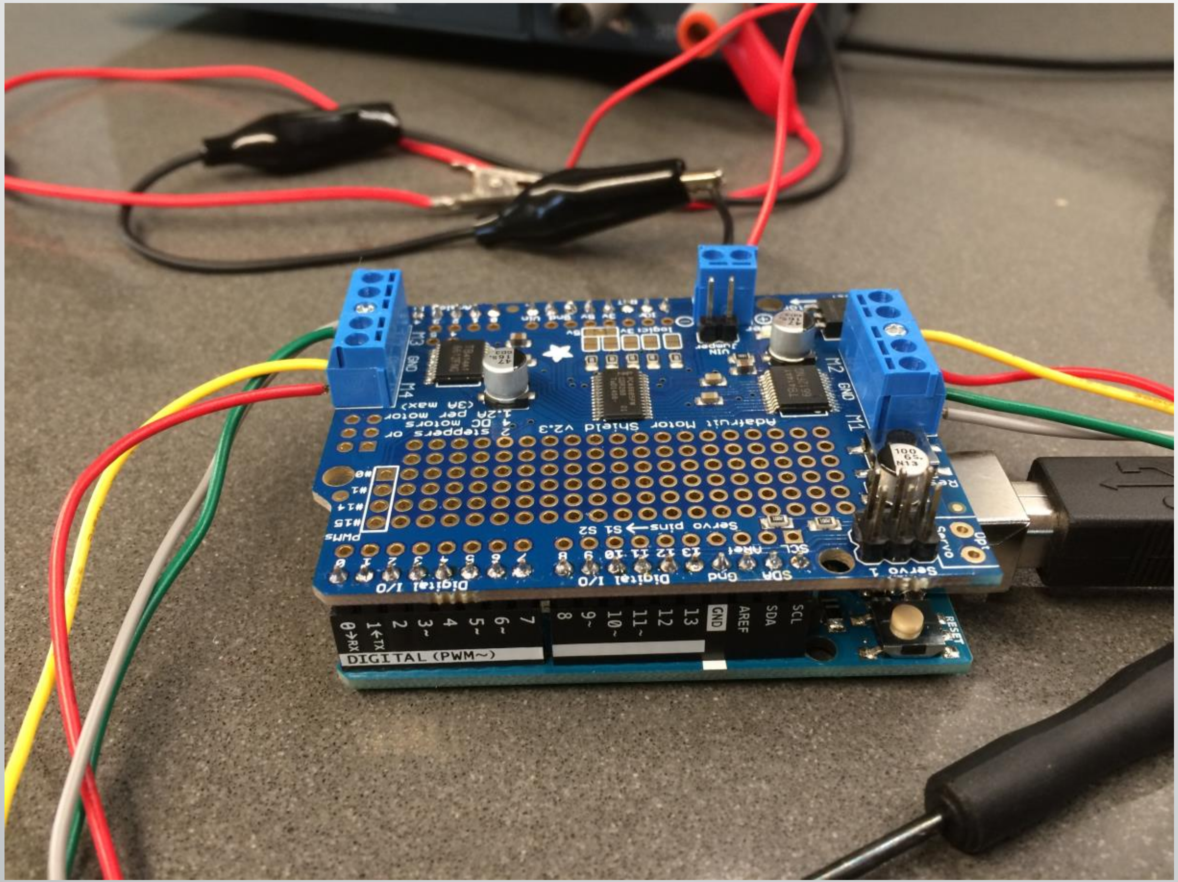
Electromagnet:
Coil #1 – Grey and Green
Coil #2 – Red and Yellow

Soldering the Motor Shield





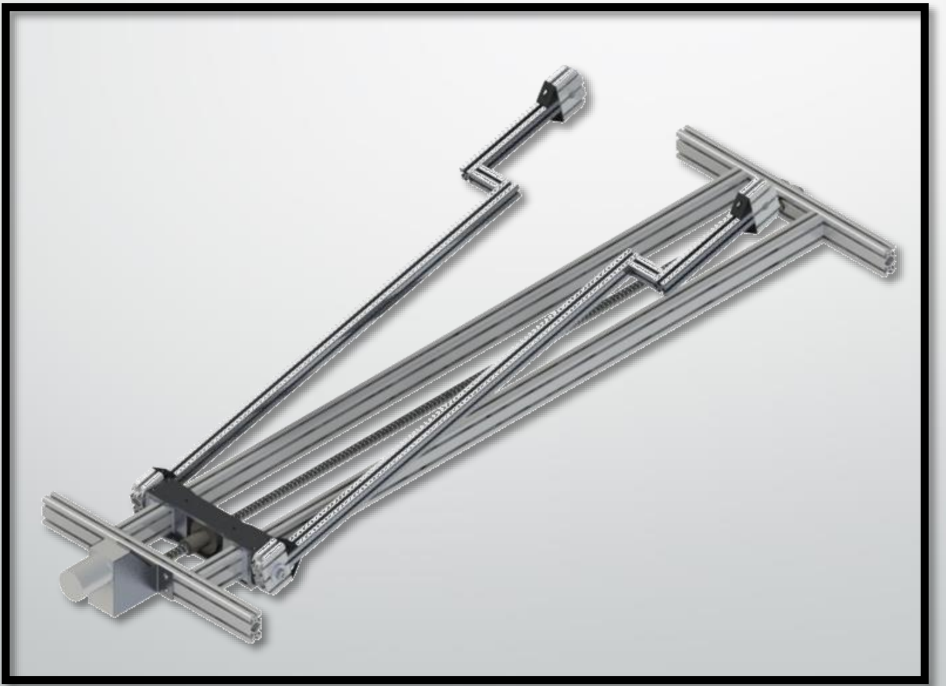
Connections



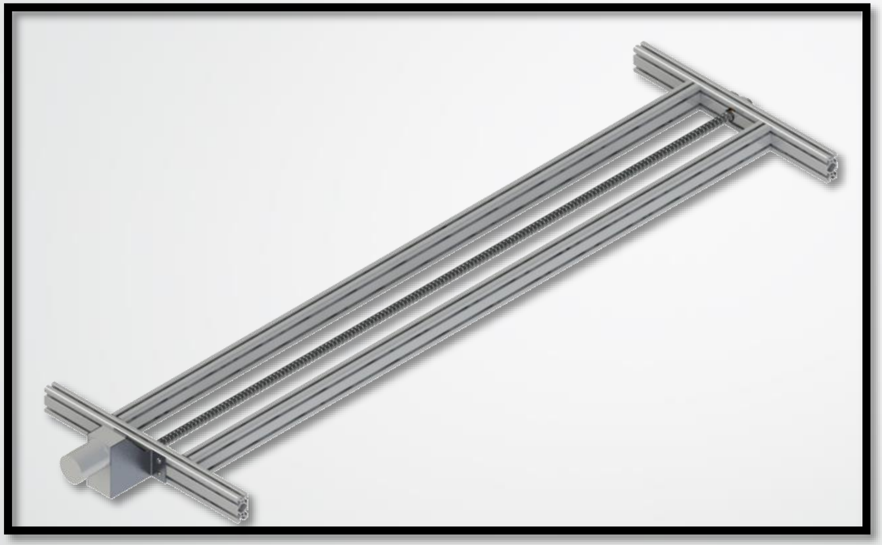
Arduino Uno on bottom with Adafruit Motor Shield soldered on top.

Vehicle Erection System

Length (in)	Width (in)	Overall Mass (lb_m)
91.52	26	74.45



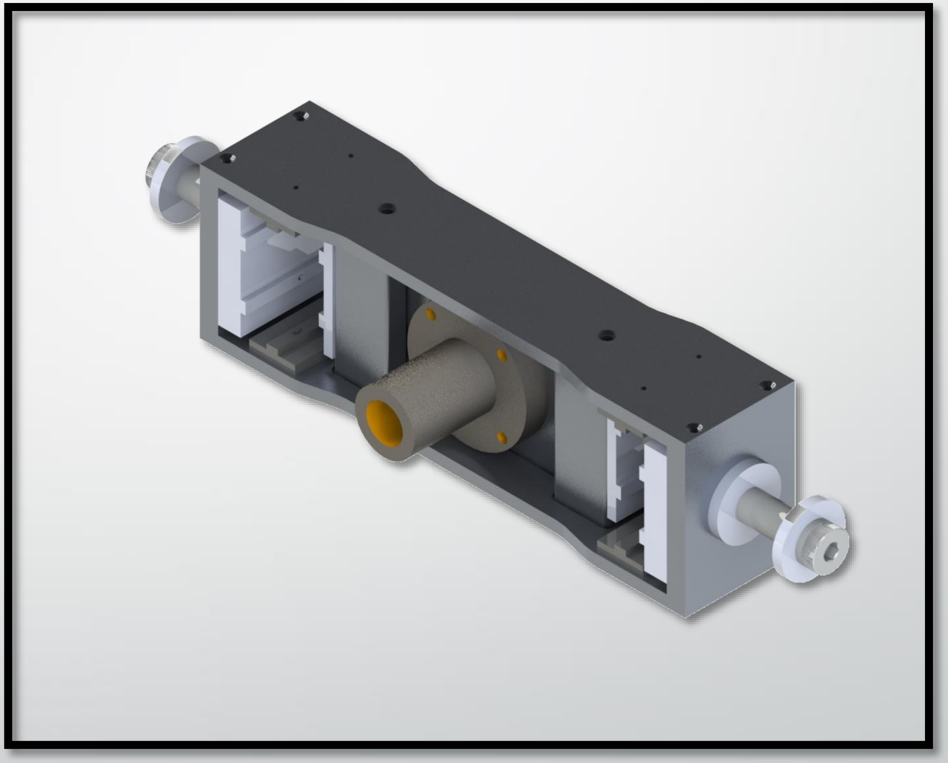
VES - Track



- Ball screw used for linear actuation.
- Two t-slotted aluminum extrusions provide linear guides.

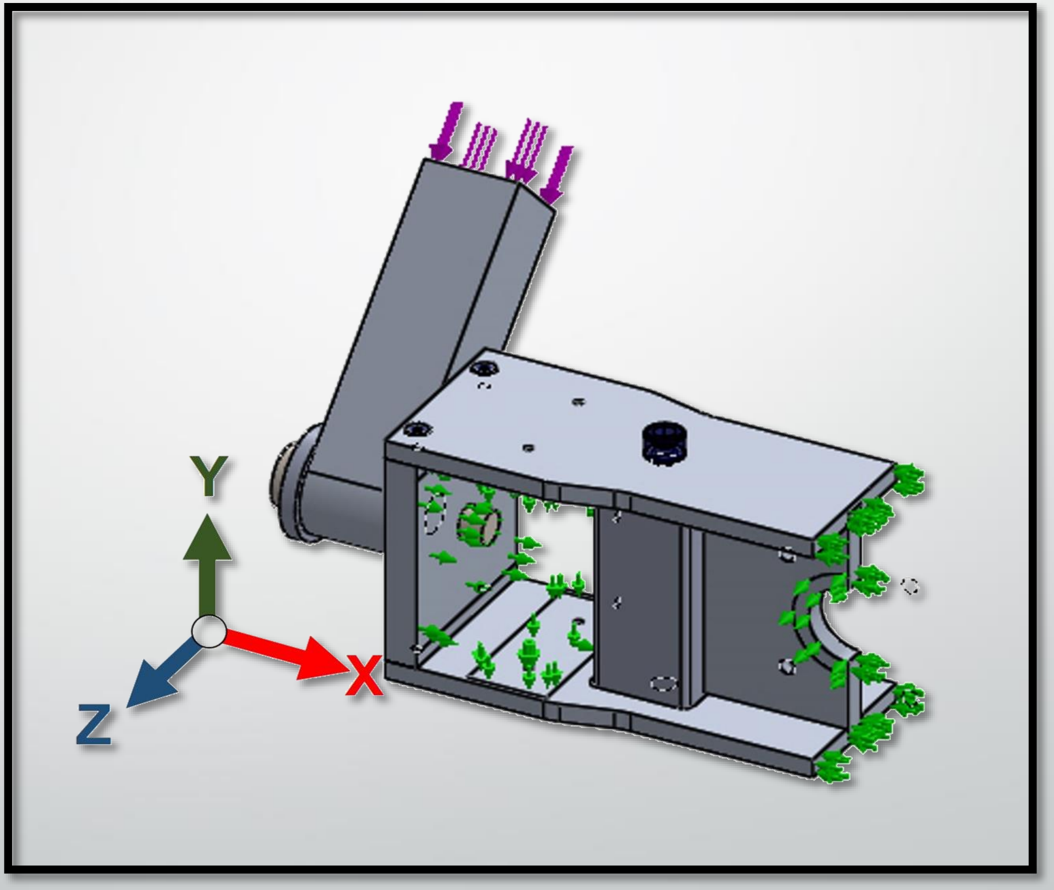
VES - Carriage

- Nylon guides to reduce friction
- Wide spacing between load attachment points
- Loads centered on neutral axis

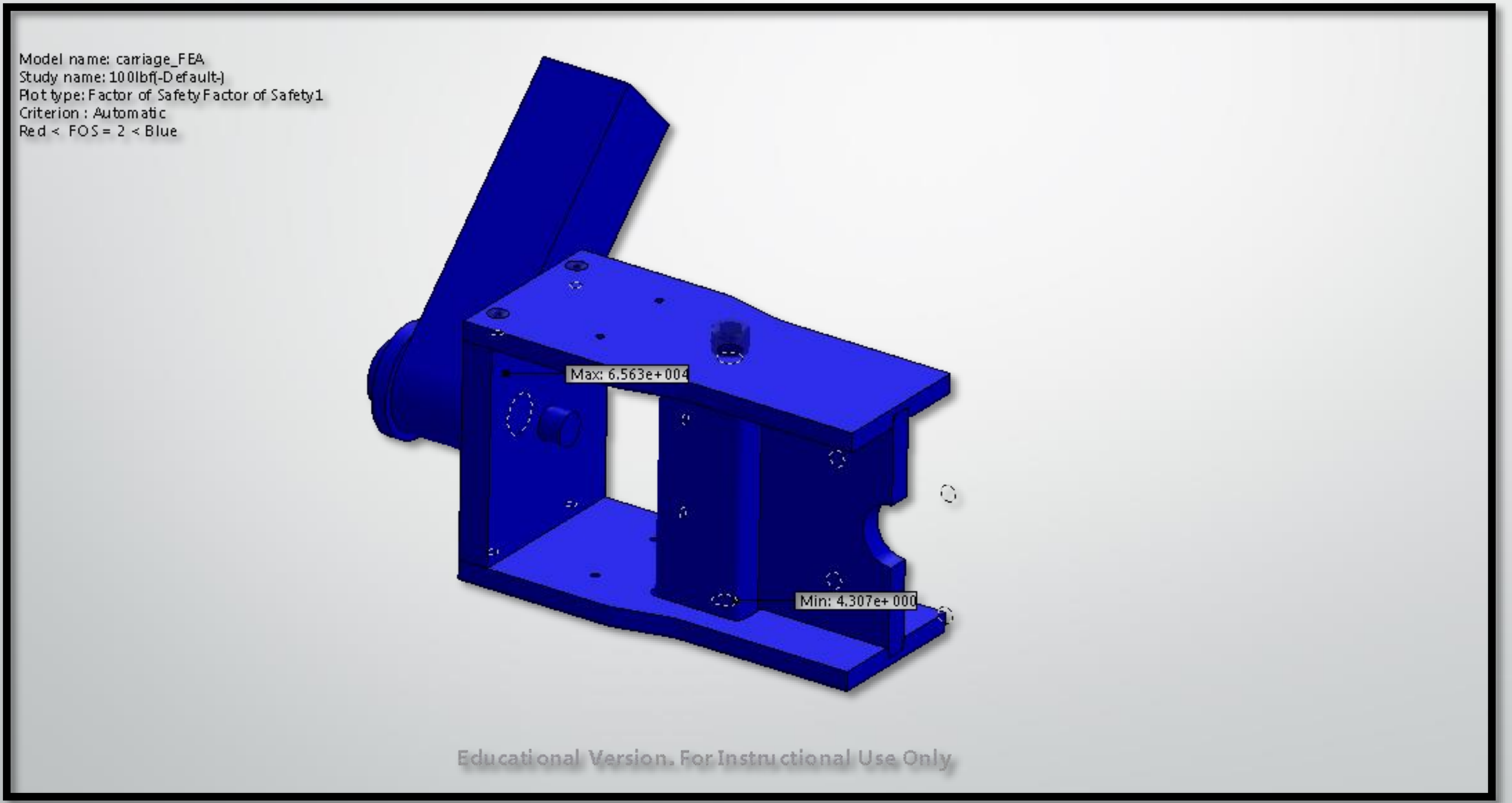


VES – Carriage Analysis

Load (lb_f)
100



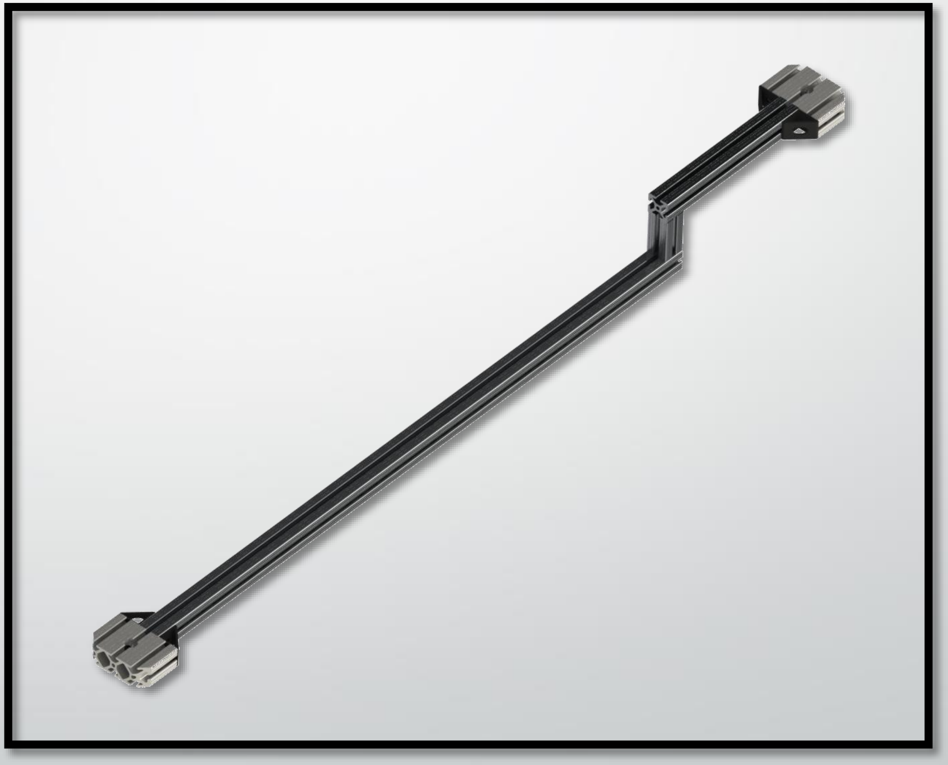
VES – Carriage Analysis



Model name: carriage_FEA
Study name: 100lbf(-Default-)
Plot type: Factor of Safety Factor of Safety1
Criterion : Automatic
Red < FOS = 2 < Blue

VES – Articulating Arms

- Connects carriage to launch platform
- Two arms are used in complete assembly

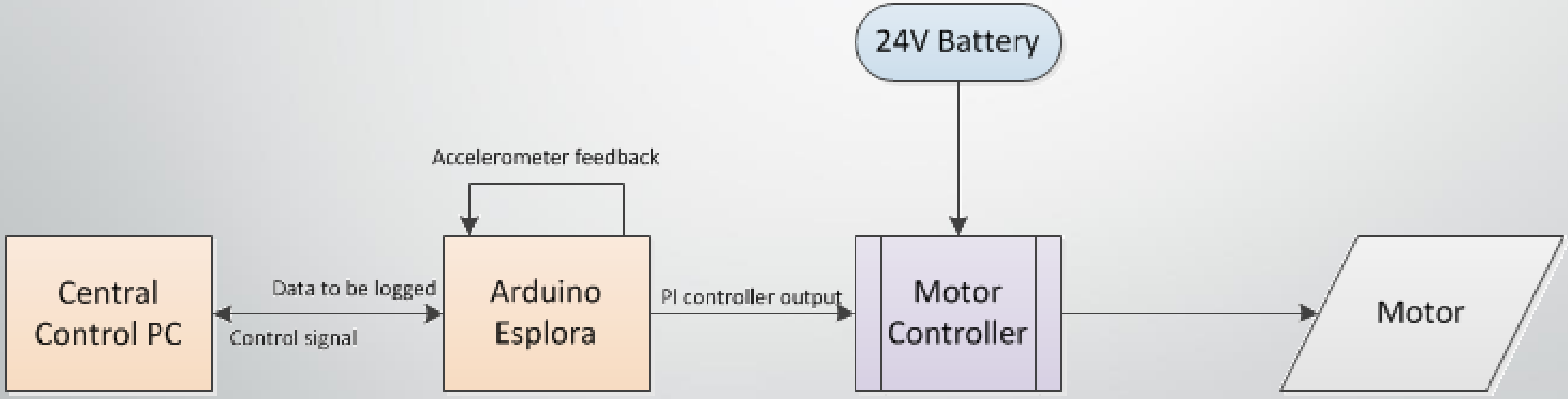


Vehicle Erection System (V.E.S.)

- The ground station will contain all the elements of the V.E.S.
- The Esplora will implement a PI control algorithm to erect the system through the motors
- An accelerometer on the Esplora will monitor the tilt of the system, which will be used in a feedback loop to the PI controller

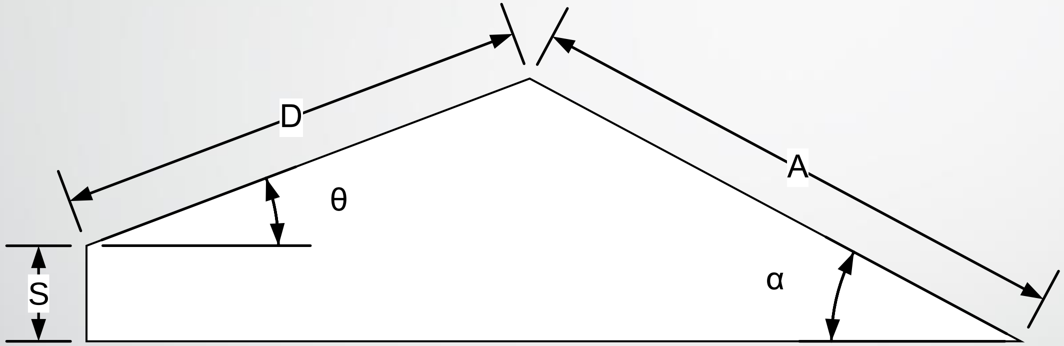
Vehicle Erection System (V.E.S.)

V.E.S. Flow Diagram



System’s dynamical equations

- The erector diagram:



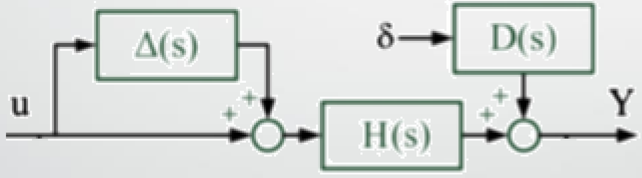
- Lagrange equation of motion based on kinetic and potential energy (K and P)

$$\tau_i = \frac{d}{dt}\frac{\partial K}{\partial \dot{\theta}_i} - \frac{\partial K}{\partial \theta_i} - \frac{d}{dt}\frac{\partial P}{\partial \dot{\theta}_i} + \frac{\partial P}{\partial \theta_i}$$

- Linearization:

$$M\ddot{\theta} + B\dot{\theta} - \Pi = \tau.$$

- Laplace transform (system schematics including uncertainty Δ and disturbance δ):

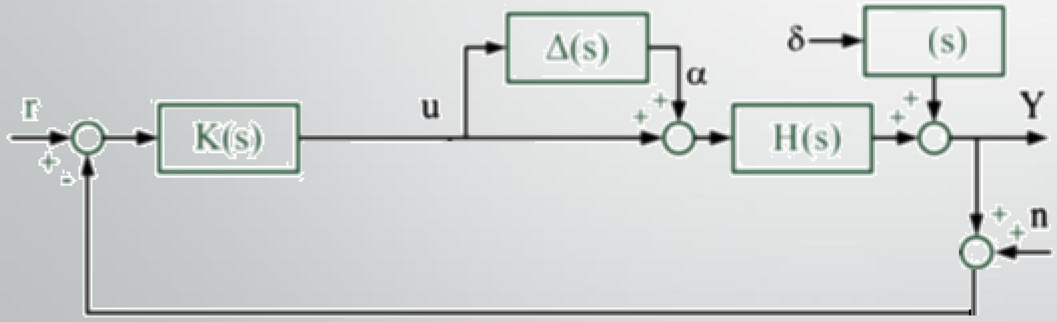


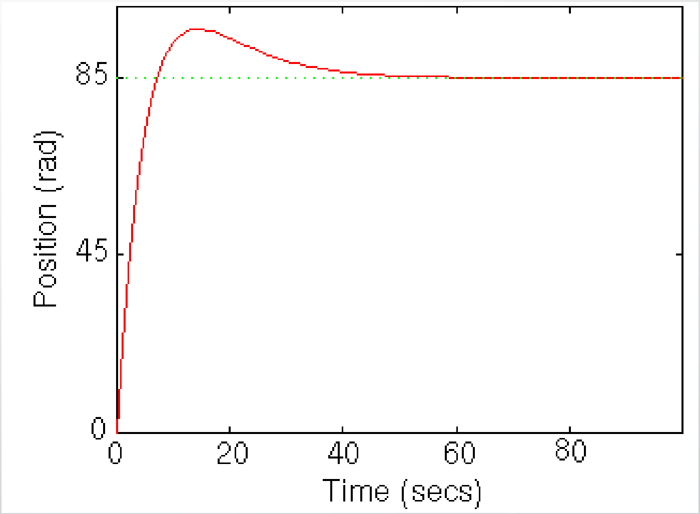
- System identification

$$H = \frac{0.47*10^{-3}(1+0.04s)}{(1+1.03s)(1+0.07s)} \qquad \Delta = \frac{2.11*10^{-2}}{(1+0.71s)} \qquad \mathrm{D} = \frac{(1+1.28s)}{(1+1.43s)}$$

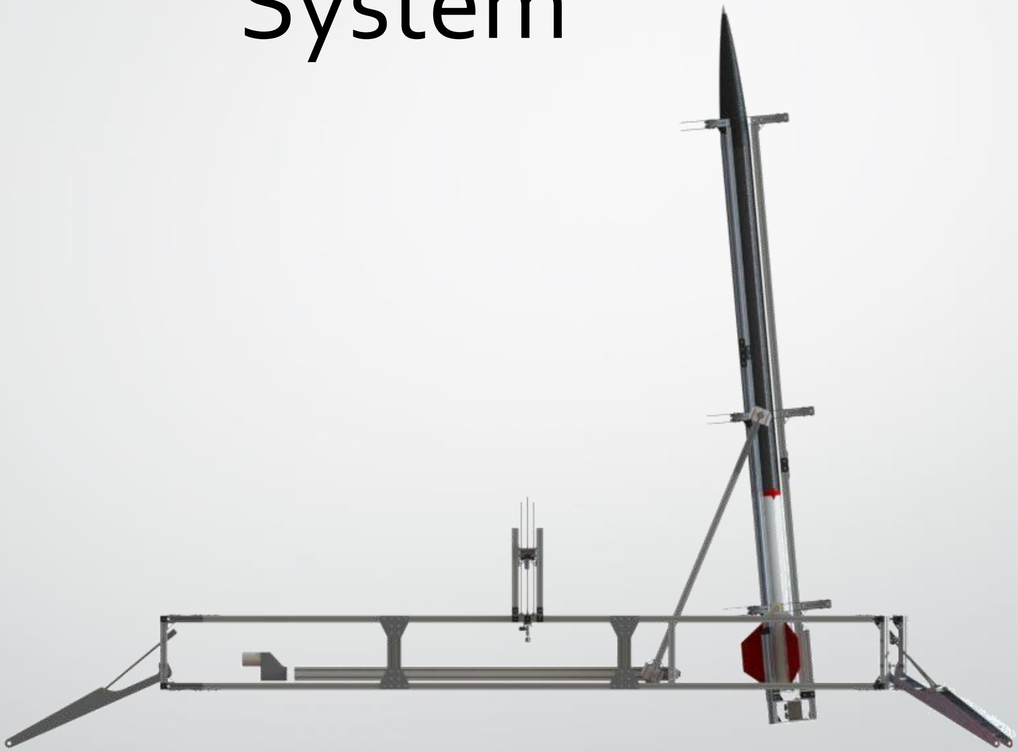
Compensator

- Based on the required characteristics (settling time, overshoot, noise reduction, disturbance rejection, etc.)



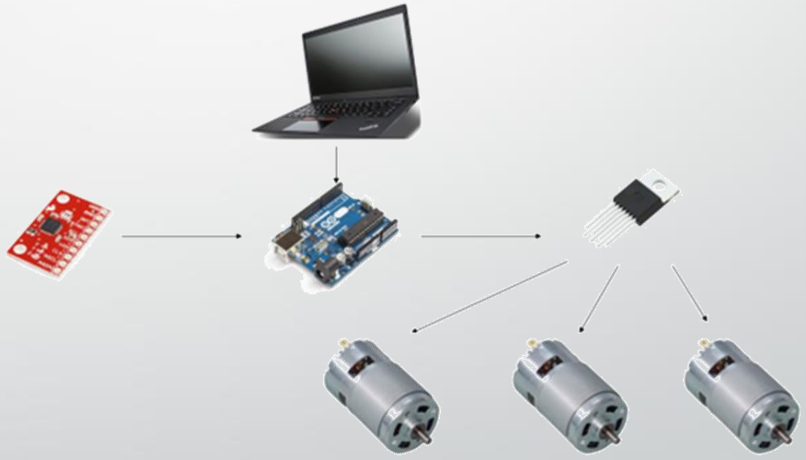


Automatic Platform Leveling System

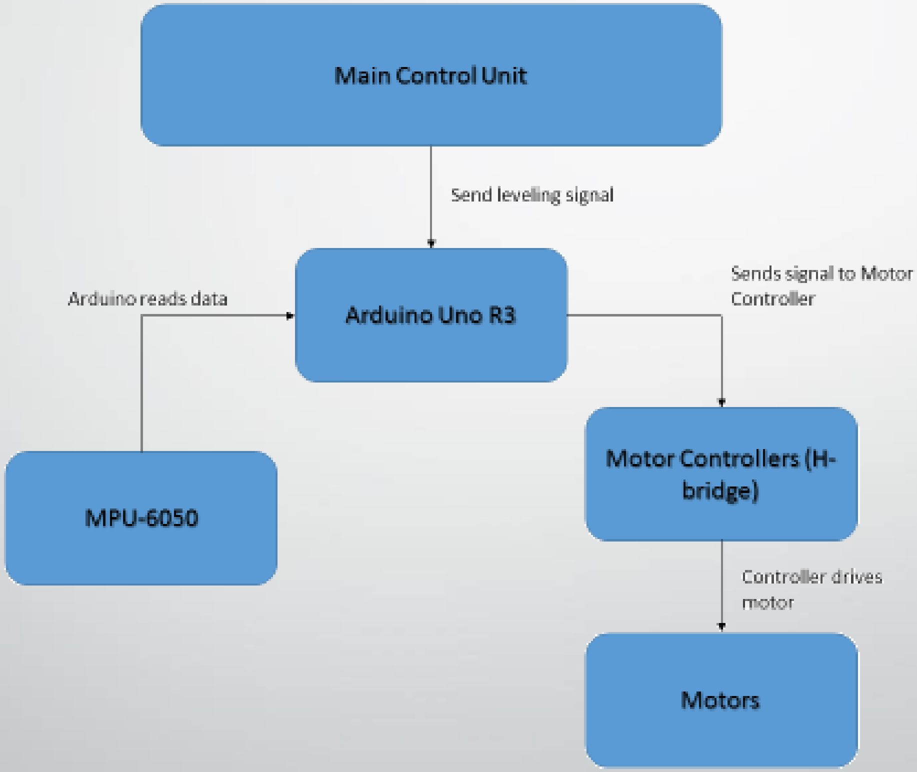


Purpose

- Autonomously level the ASGE to allow the optimal angle for the rocket launch
- Decrease human involvement and error
- Optimize rocket launch and efficiency

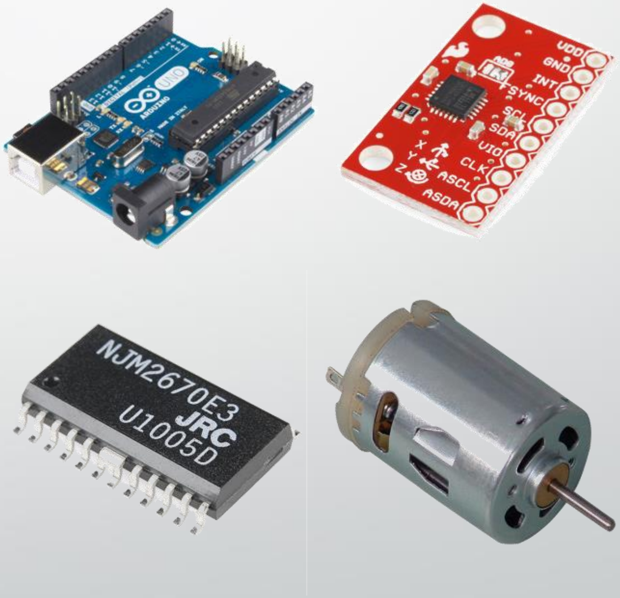


Overview

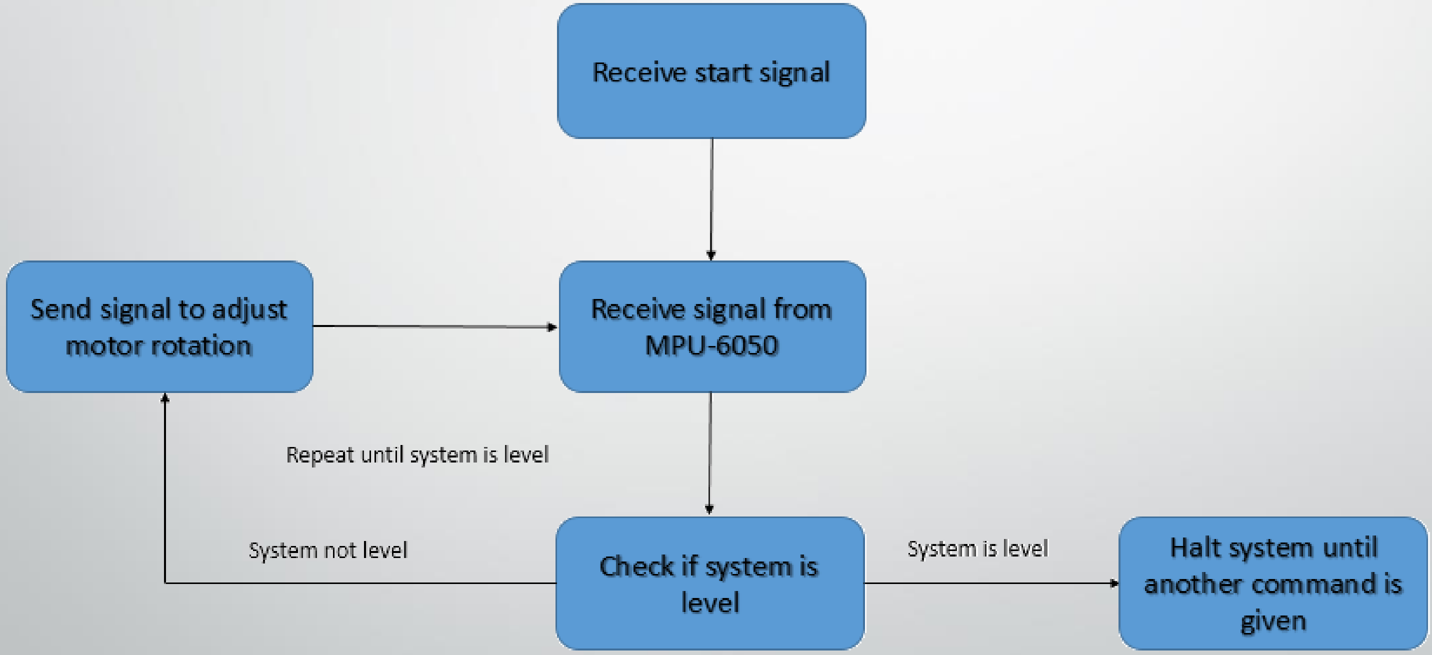

Main Control Unit
Send leveling signal
Arduino reads data
Arduino Uno R3
Sends signal to Motor Controller
MPU-6050
Motor Controllers (H-bridge)
Controller drives motor
Motors

Hardware

- Arduino Uno
- MPU 6050 Gyroscope
- H-Bridge Circuit
- Three DC Motors



Process



Receive start signal

Receive signal from MPU-6050

Send signal to adjust motor rotation

Repeat until system is level

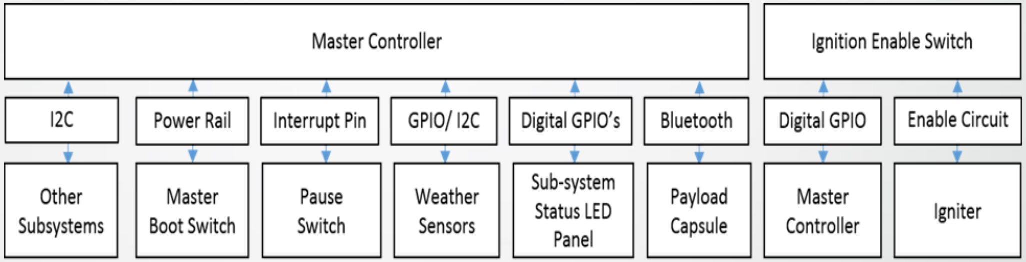
System not level

Check if system is level

System is level

Halt system until another command is given

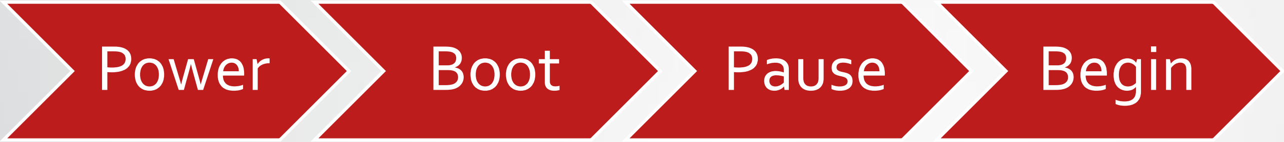
Ground Station Electronics



Master Controller						Ignition Enable Switch	
I2C	Power Rail	Interrupt Pin	GPIO/ I2C	Digital GPIO's	Bluetooth	Digital GPIO	Enable Circuit
Other Subsystems	Master Boot Switch	Pause Switch	Weather Sensors	Sub-system Status LED Panel	Payload Capsule	Master Controller	Igniter

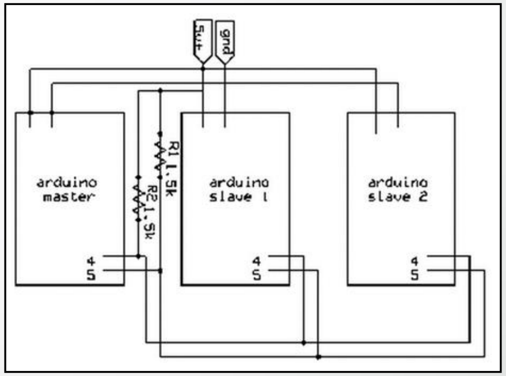
- Initiate start-up
- Integrate sub-systems
- Distribute electrical power
- Provide user interface

Starting Up


Power
Boot
Pause
Begin

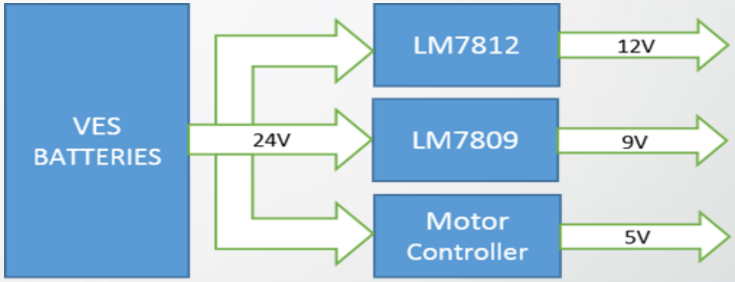
- Master Boot switch energizes station
  - Begin internal communication
  - Boot to pause
- Limit autonomy with “Go No-Go” decisions
- Process begins after pause deactivation

System Integration



- Main connection path over I2C bus
- Custom wiring harnesses for signals and power
- Master controller directs sub-system operation

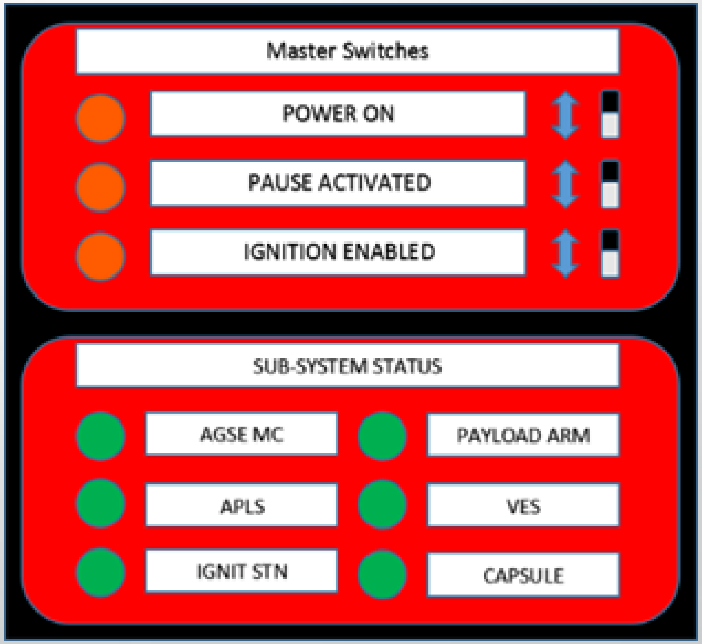
Power Distribution



- Reliable power regulation
- 24V Main Supply
- 5V regulated from VES motor controller
- 9V/12V provided through 78xx IC's

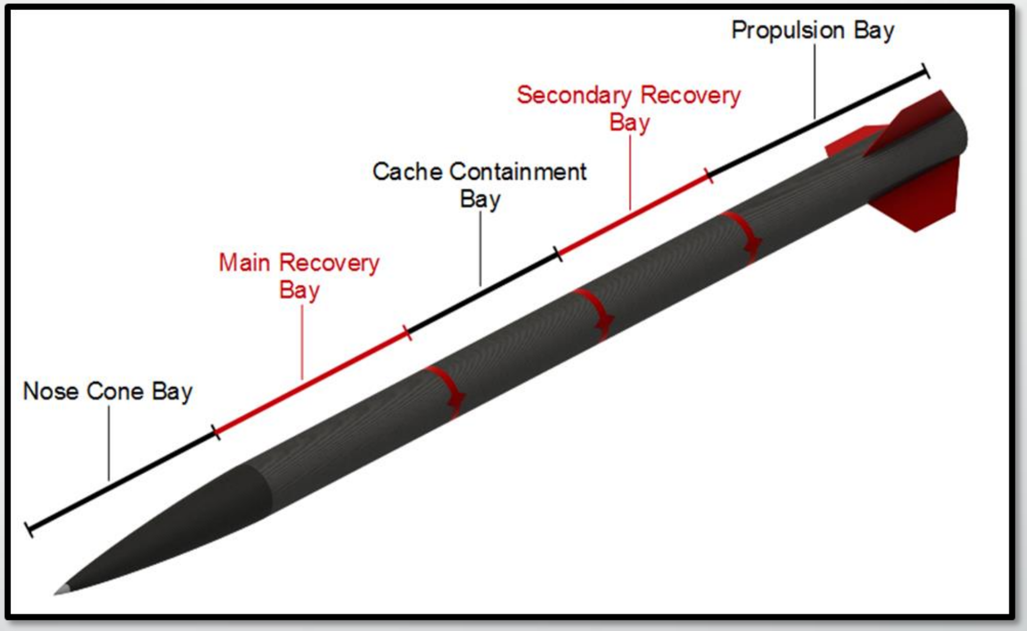
User Interface

- Master switch accessibility
- System status indication
- User friendly



Overall Vehicle Design

- 6” Diameter Carbon Fiber Launch Vehicle
- Adjustable Ballast System
- Removable Fin System
- Retractable Door Assembly



Overall Vehicle Design (cont.)

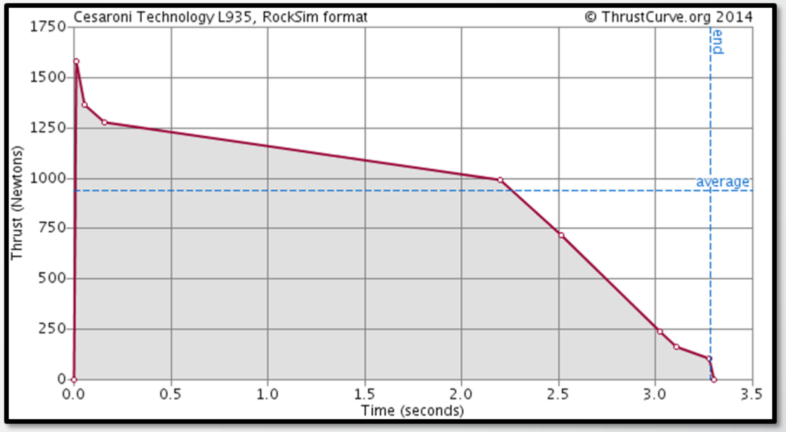
Primary Component Materials

- Carbon fiber
- Fiberglass
- Aluminum
- Stainless Steel
- Titanium
- ABS Plastic
- Plywood

Section of Launch Vehicle	Length of Section (in)	Mass (lbs)
Nose Cone	30.85	5.335
Main Recovery Bay	27.5	5.905
Cache Containment Bay	21.5	7.83
Secondary Recovery Bay	28	4.977
Propulsion Bay	32	8.466
Witness Rings	2	0.201
Motor	N/A	5.604
	Total Mass	**38.318**

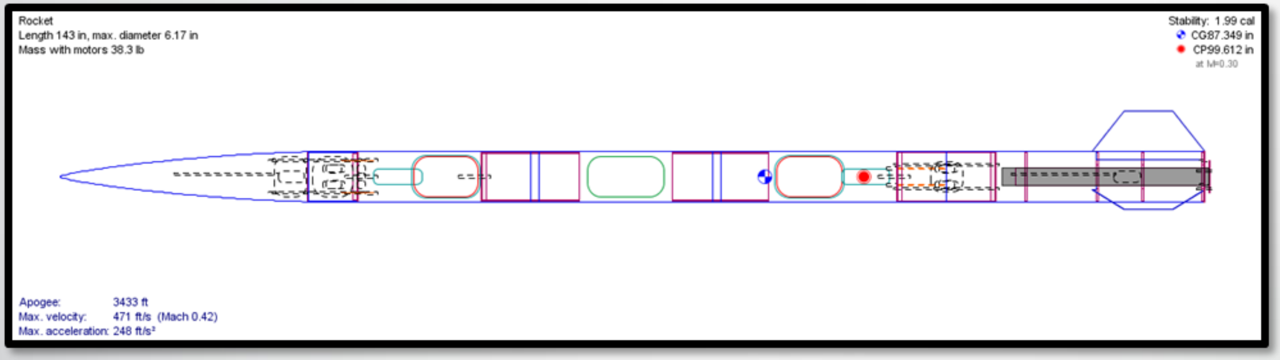
Vehicle Motor Selection

- Cesaroni L935-IM
- Obtained motor selection through various OpenRocket simulations trials



Thrust-to-Weight Ratio	5.48
Rail Exit Velocity	66.2 ft/s
Projected Altitude	3,422 ft
Maximum Acceleration	248 ft/s^2
Motor Burn Time	3.4 sec
Maximum Motor Thrust	1585.6 N
Average Motor Thrust	933.8 N
Total Motor Impulse	3146.8 N-sec

Stability Margin



Rocket
Length 143 in, max. diameter 6.17 in
Mass with motors 38.3 lb

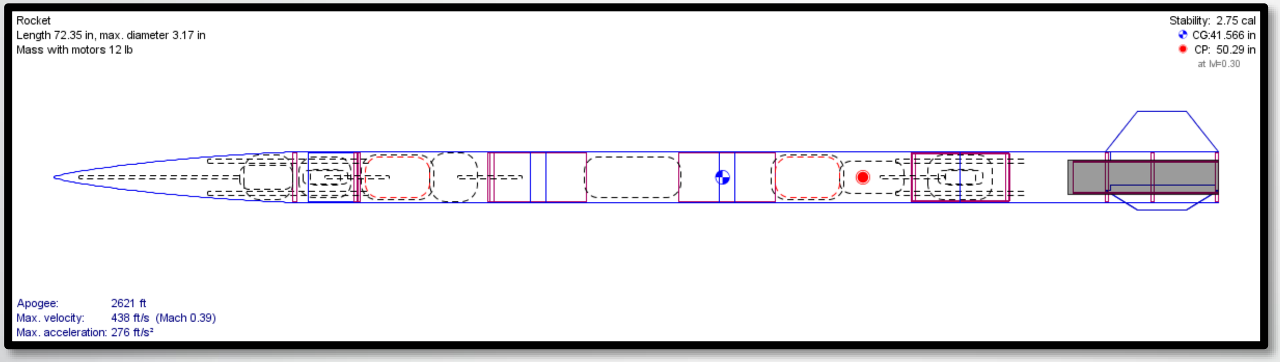
Stability: 1.99 cal
CG87.349 in
CP99.612 in
at M=0.30

Apogee: 3433 ft
Max. velocity: 471 ft/s (Mach 0.42)
Max. acceleration: 248 ft/s²

- Overall Length: 143 in
- Overall Diameter: 6.17"
- Overall Mass: 38.3 lbs

- Stability Margin: 1.99
- CG Location (from tip): 87.35 in
- CP Location (from tip): 99.61 in

Subscale Verification



Rocket
Length 72.35 in, max. diameter 3.17 in
Mass with motors 12 lb

Stability: 2.75 cal
CG:41.566 in
CP: 50.29 in
at M=0.30

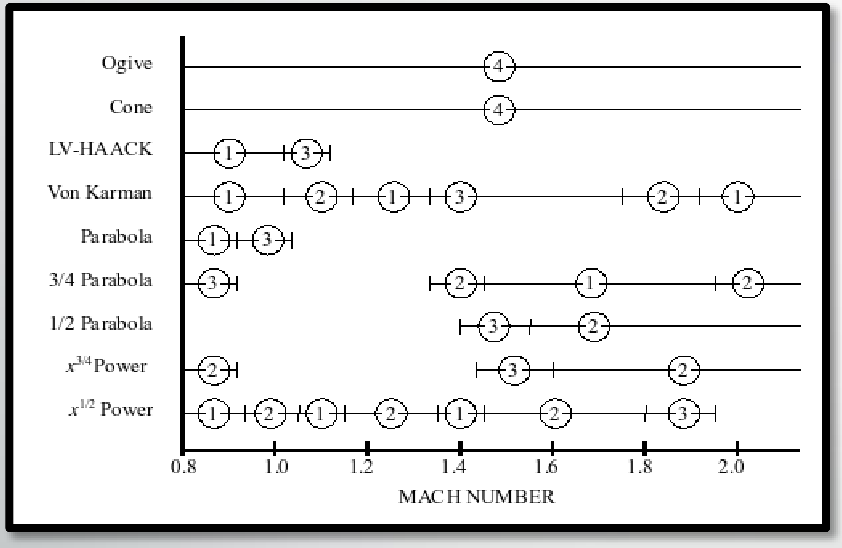
Apogee: 2621 ft
Max. velocity: 438 ft/s (Mach 0.39)
Max. acceleration: 276 ft/s²

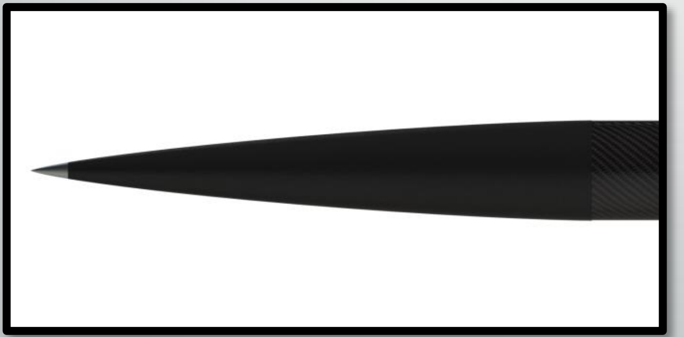
- A half scale model will be launched to verify aerodynamic properties of the rockets design.
- Will verify:
  - Aerodynamic properties and stability of the launch vehicle.
  - Custom vortex parachute design, and other recovery devices.
  - Range of on-board live Bluetooth feed from the launch vehicle to the ground station.

Subscale Verification (cont.)

Property	**Full Scale**	**Subscale**
Diameter (in)	6	3
Length (in)	143	72.35
Mass (lbs)	38.3	12
Motor Selection	CTI 3147-L935-IM-P	CTI 821-J430-WT-18A
Stability Caliber	1.99	2.75
Maximum Velocity (ft/s)	471 (Mach 0.42)	438 (Mach 0.39)
Maximum Acceleration (ft/s^2)	248	276

Nose Cone Design

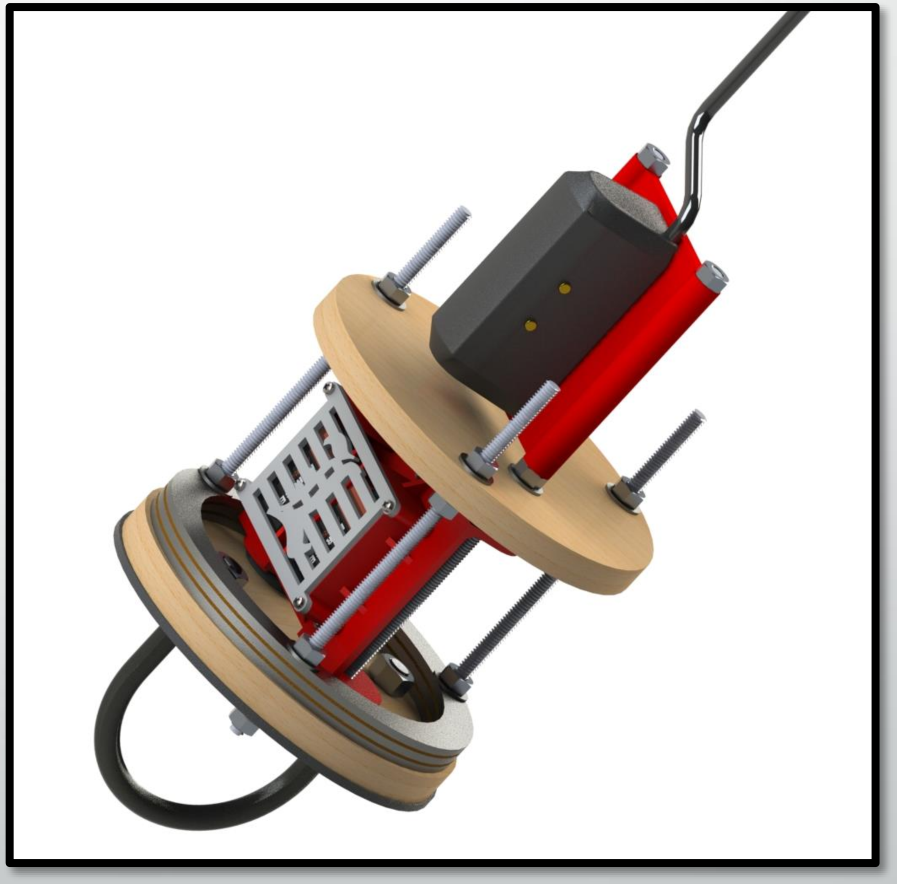




- The equation used to model the nose cone was the Von Karman equation, otherwise known as the LD-Haack.
- Optimal usage in ranges of Mach 0.8-1.2.
- $y = \frac{R}{\sqrt{\pi}}\sqrt{\theta - \frac{\sin(2\theta)}{2} + C sin^3\theta}$
- $C = 0\ for\ LD - Haack$

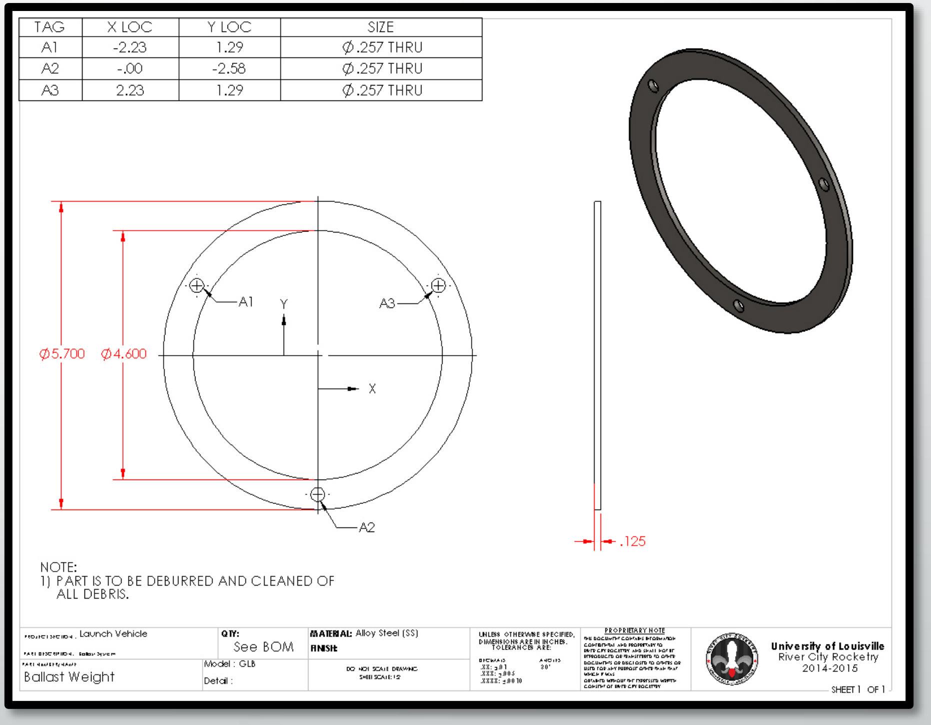
Adjustable Ballast System

- Designed to not interfere with avionics bay
- Adjustability of 0.33 lb increments



Adjustable Ballast System (cont.)

- AISI 1080 low carbon steel ballast
- 0.05" thick silicone spacer to reduce vibration during flight
- Allows for versatile manipulation of CG



TAG	X LOC	Y LOC	SIZE
A1	-2.23	1.29	∅.257 THRU
A2	-.00	-2.58	∅.257 THRU
A3	2.23	1.29	∅.257 THRU

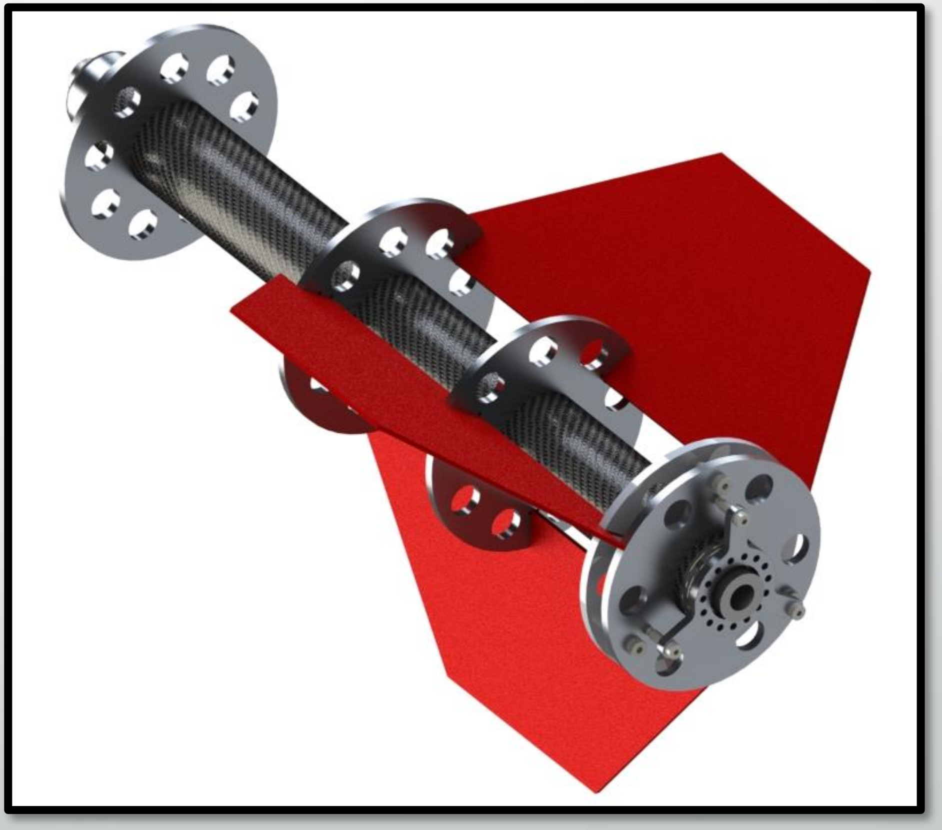
NOTE:
1) PART IS TO BE DEBURRED AND CLEANED OF ALL DEBRIS.

PROJECT SECTION: Launch Vehicle
PART DESCRIPTION: Ballast System
PART NUMBER/NAME: Ballast Weight
QTY: See BOM
Model : GLB
Detail :
MATERIAL: Alloy Steel (SS)
FINISH:
DO NOT SCALE DRAWING
SHEET SCALE: 1:2
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES. TOLERANCES ARE:
DECIMALS .XX: ±.01 .XXX: ±.005 .XXXX: ±.0010
ANGLES 30'
PROPRIETARY NOTE

University of Louisville
River City Rocketry
2014-2015
SHEET 1 OF 1

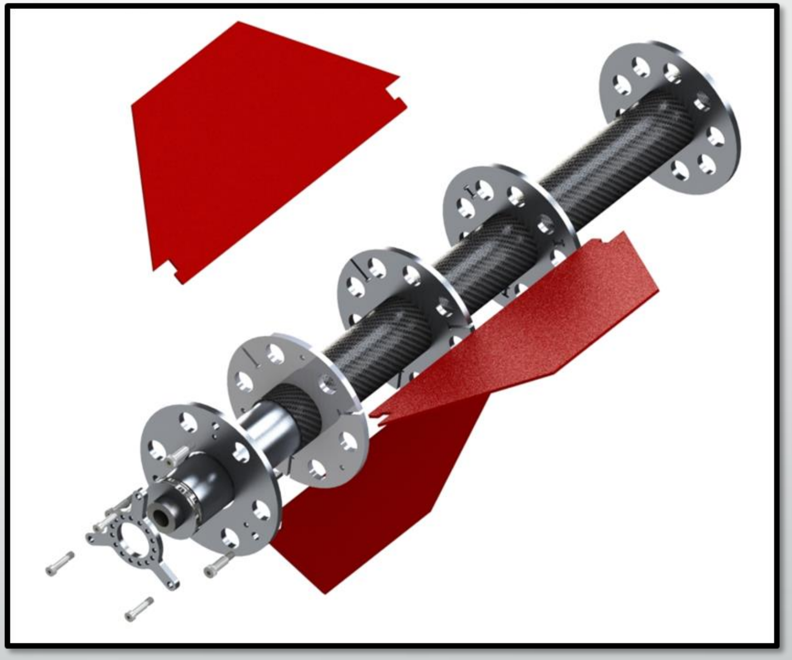
Removable Fin System

- Designed for quick and easy removal and installation of fins
- Advantages:
  - Fins are immediately replaceable in the event of breakage
  - Accurate mounting allows for predictably stable flight
  - Test various fin designs
  - Easier transportation

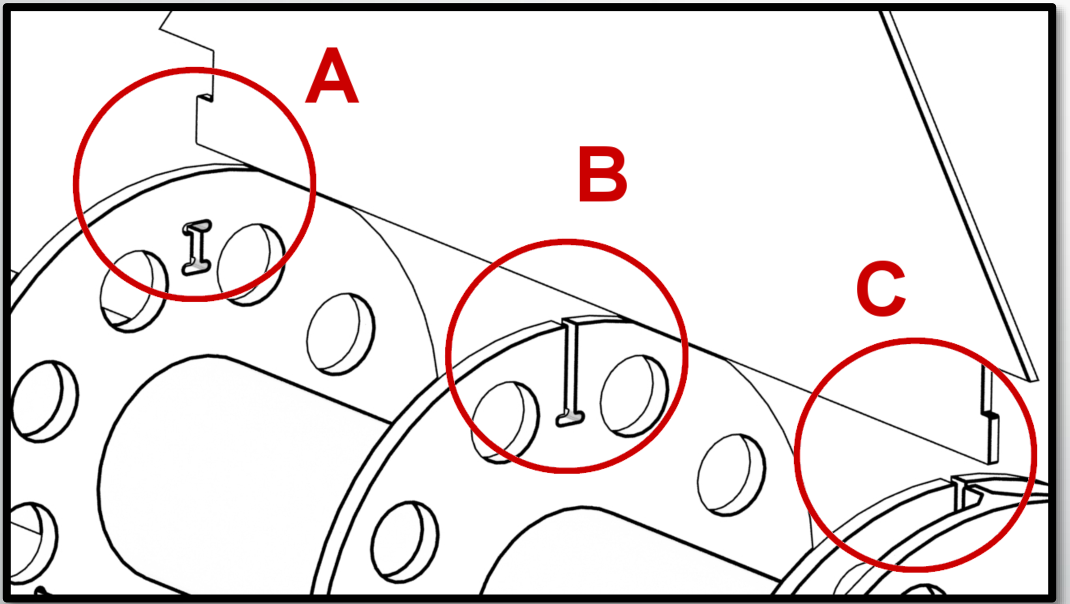


Removable Fin System (cont.)

- Components:
  - Fore, middle, and aft fin centering rings
  - Rear fin retainer
  - Motor Casing Retainer
- All components machined from 6061-T6-Aluminum
- Centering rings are epoxied in place



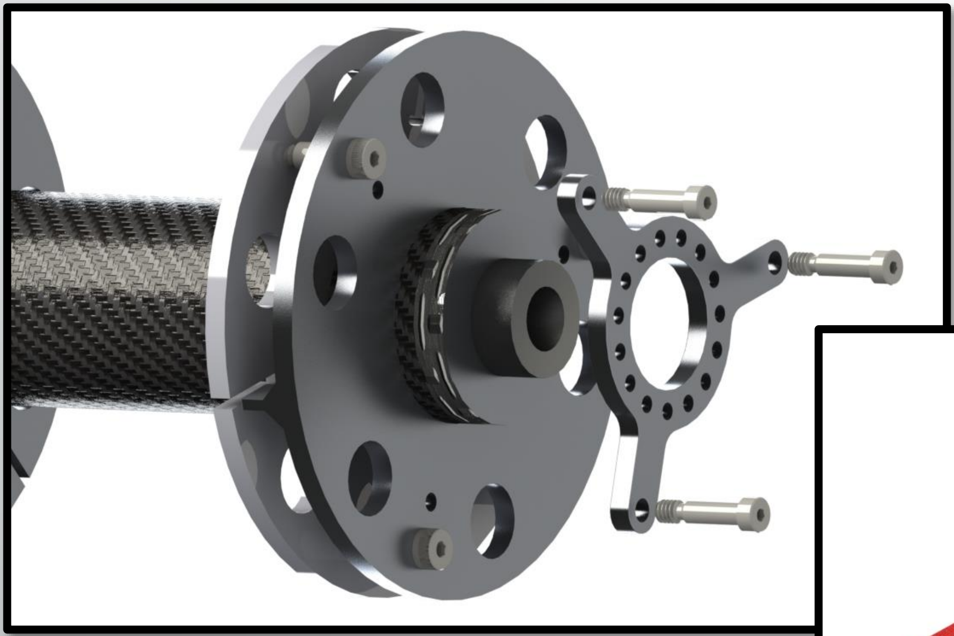
Removable Fin System (cont.)

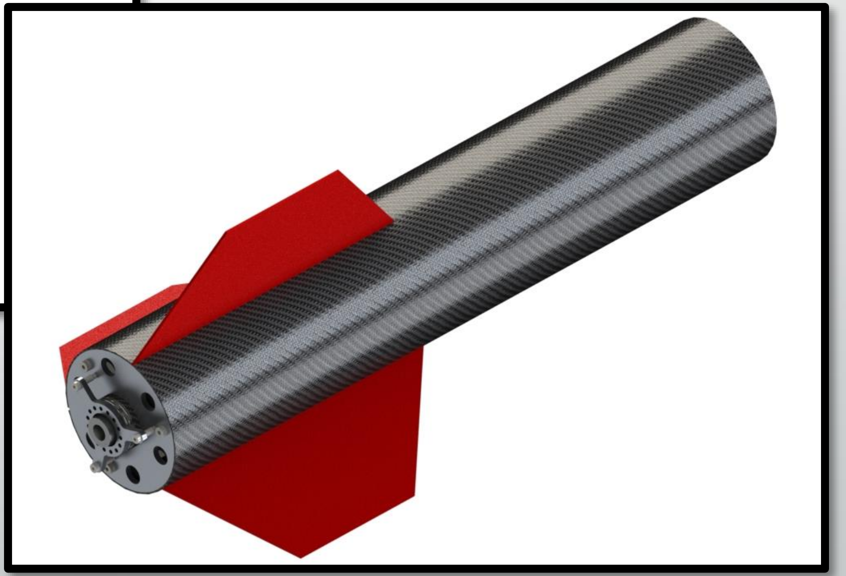


- Fin is inserted through airframe into slots at B and C
- Fin tab is pushed forward through slot A
- Rear fin retainer is installed onto aft fin centering ring (see next slide)

Removable Fin System (cont.)

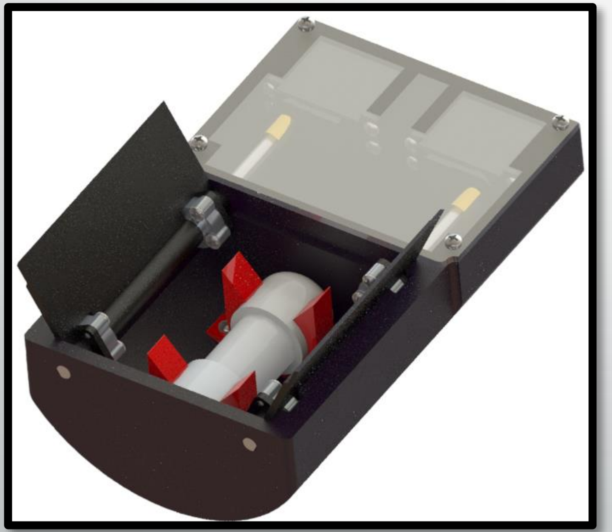
- Motor casing is installed into the motor tube
- Motor casing retainer is installed onto the rear fin retainer





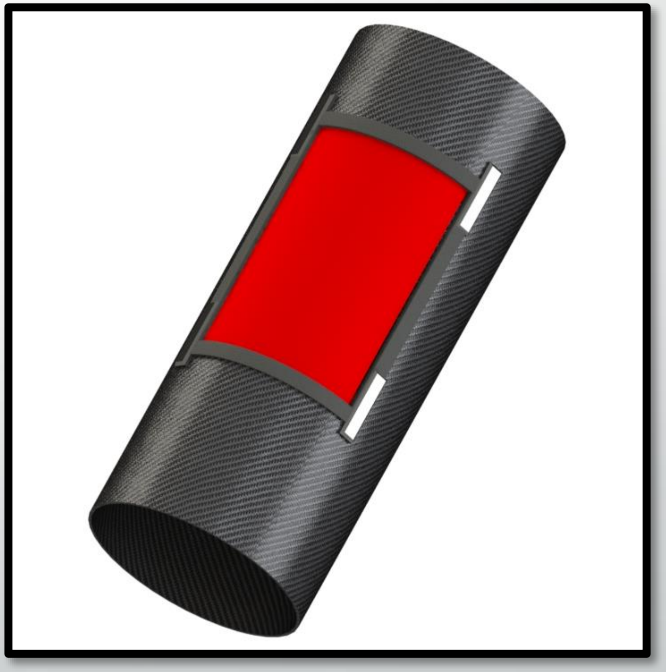
Cache Containment

- Cache loaded into containment housing via autonomous arm
- 3D printed clips retain cache payload
- Servo motor controls door movement to seal cache from environment



Retractable Door Assembly

- A rotating 3D printed door was designed to allow for access to load payload into cache containment bay
- Door is to be sealed from the environment

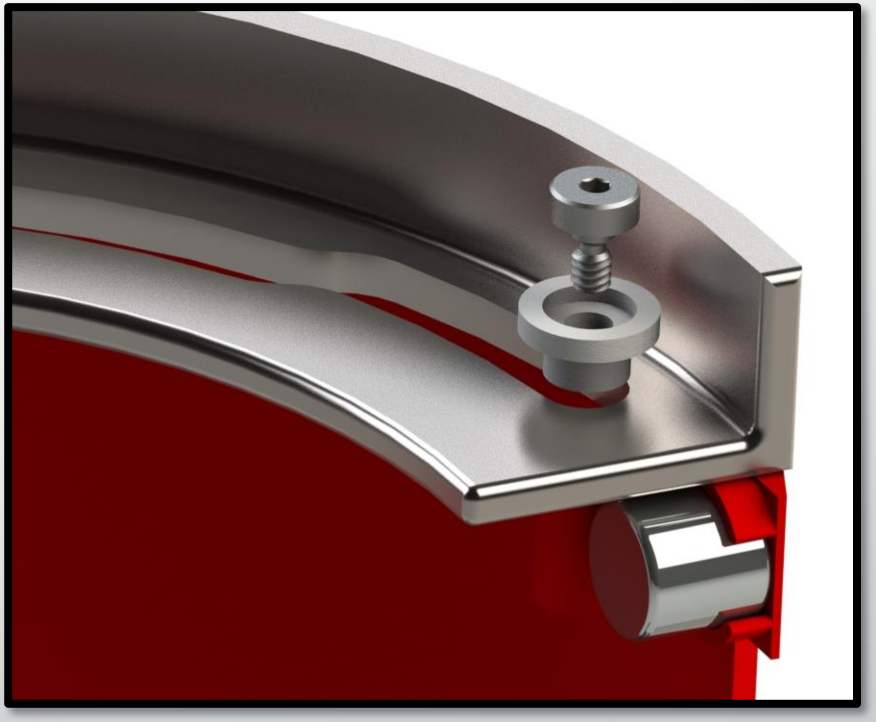


Retractable Door Assembly (cont.)

- Rotational movement eliminates wasted space from linear movement
- Door is driven by a servo motor connected to a rack and pinion gear system

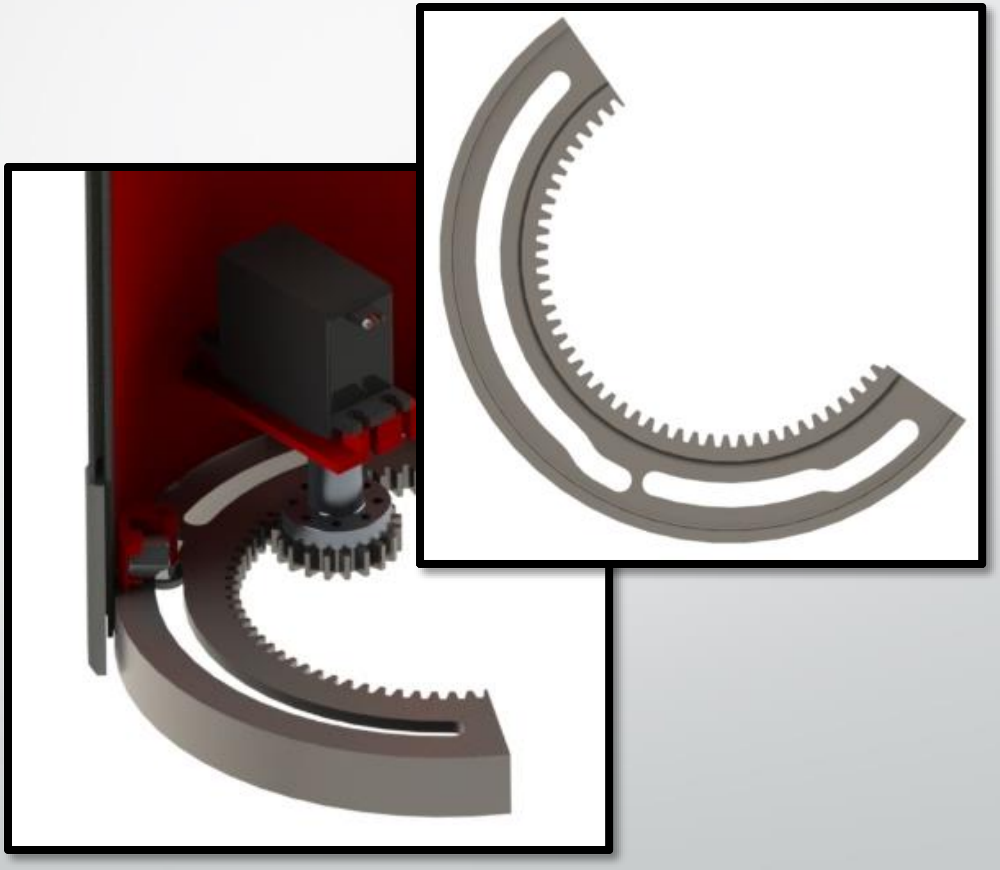
Retractable Door Assembly (cont.)

- Polyethylene track wheels are installed via steel should screws
- Polyethylene was chosen for its low static coefficient of friction against titanium (0.175)



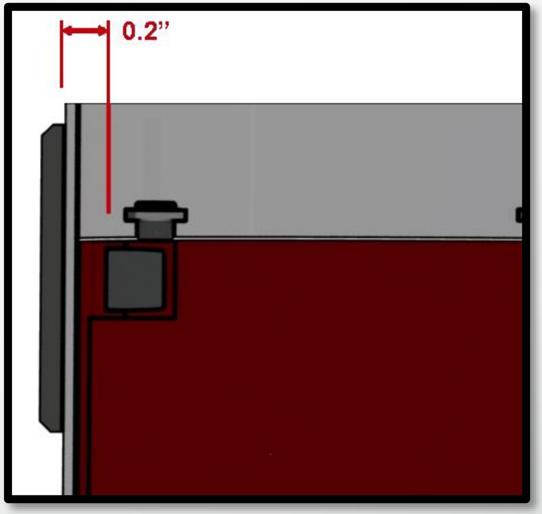
Retractable Door Assembly (cont.)

- Two separate paths for track wheels on each guide
- Lower guide acts as the rack for pinion to run against



Retractable Door Assembly (cont.)

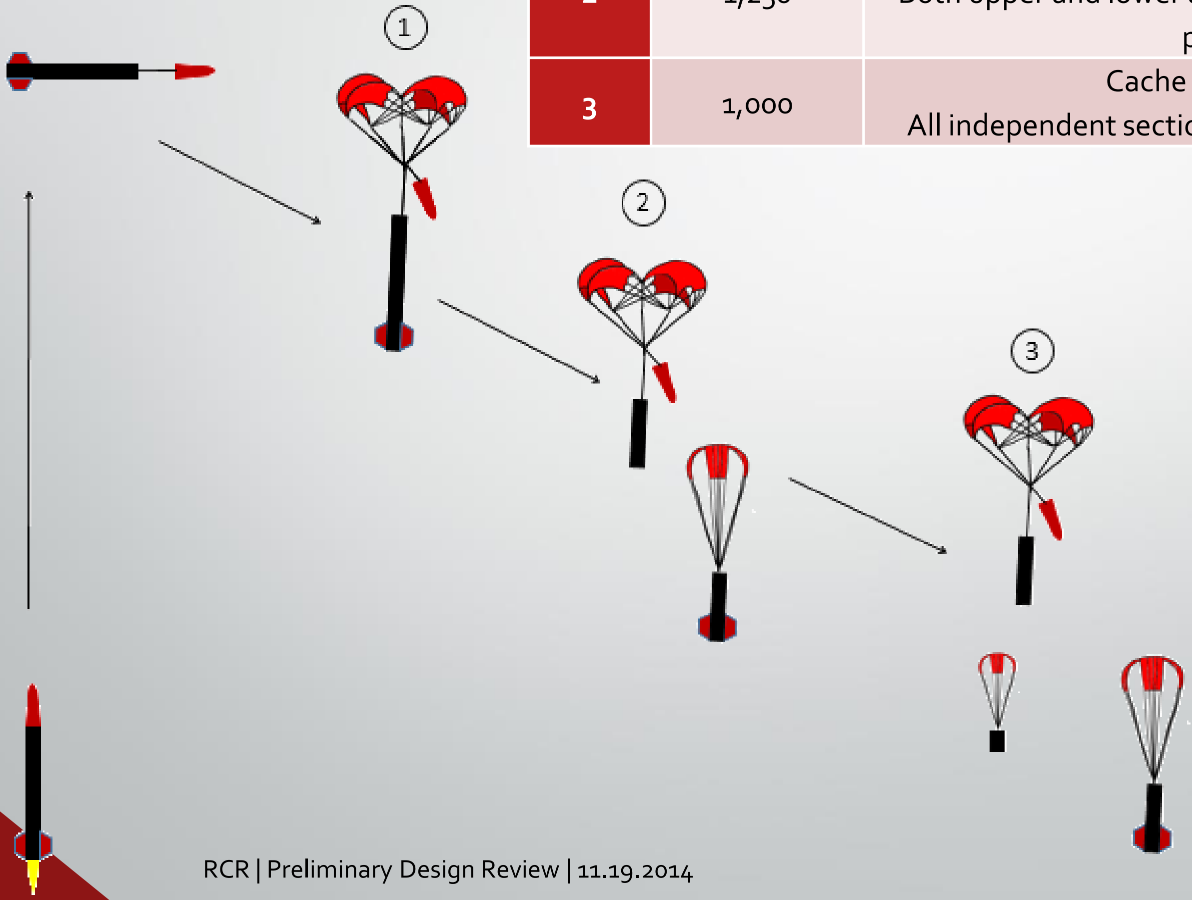
- N52 neodymium magnet holds door in place
- Pull force between magnet and ferrous target seals door against silicone gasket



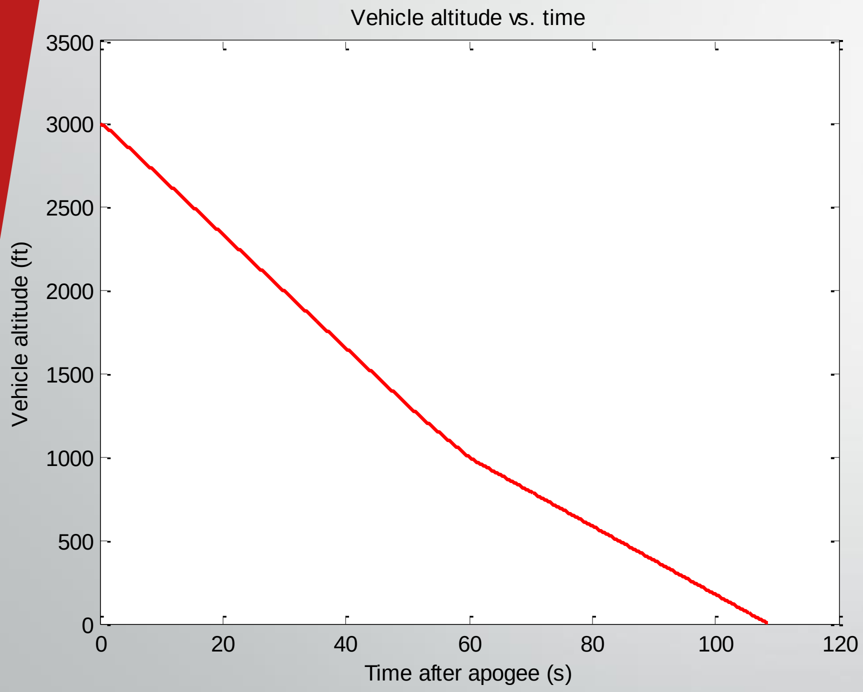
Neodymium Magnet Grade	N52
Diameter (in)	0.4
Thickness (in)	0.375
Distance from Target (in)	0.2
Pull Force (lbs)	0.59
Number of Magnets/Target	4
Combined Pull Force on Door (lbs)	2.36

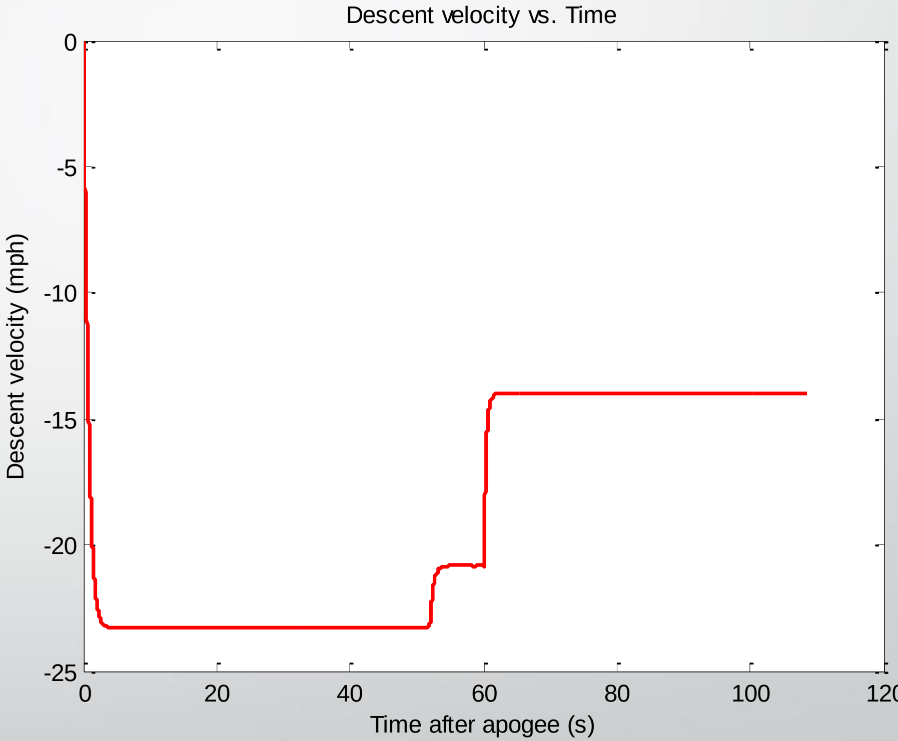
Vehicle Flight Path

Event	Altitude (ft.)	Description
1	3,000	Apogee. Nose cone ejection. Entire rocket under main parachute acting as drogue.
2	1,250	Eject lower airframe. Both upper and lower airframes now falling under main parachutes.
3	1,000	Cache capsule ejection. All independent sections now under main parachutes.



Recovery Plots



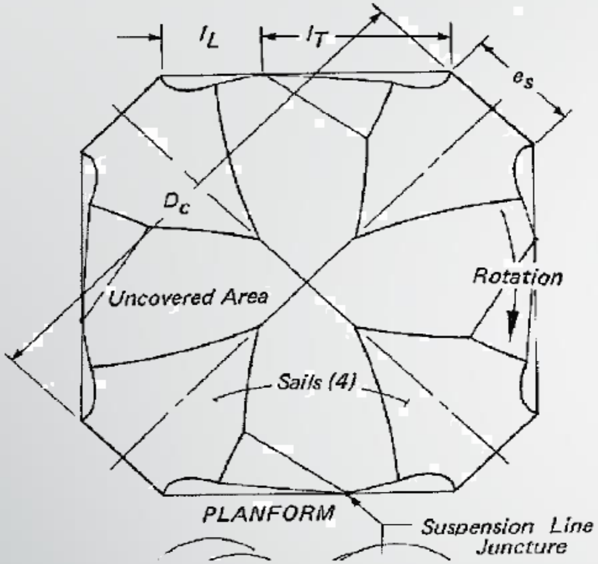


Kinetic Energy and Drift Calculations

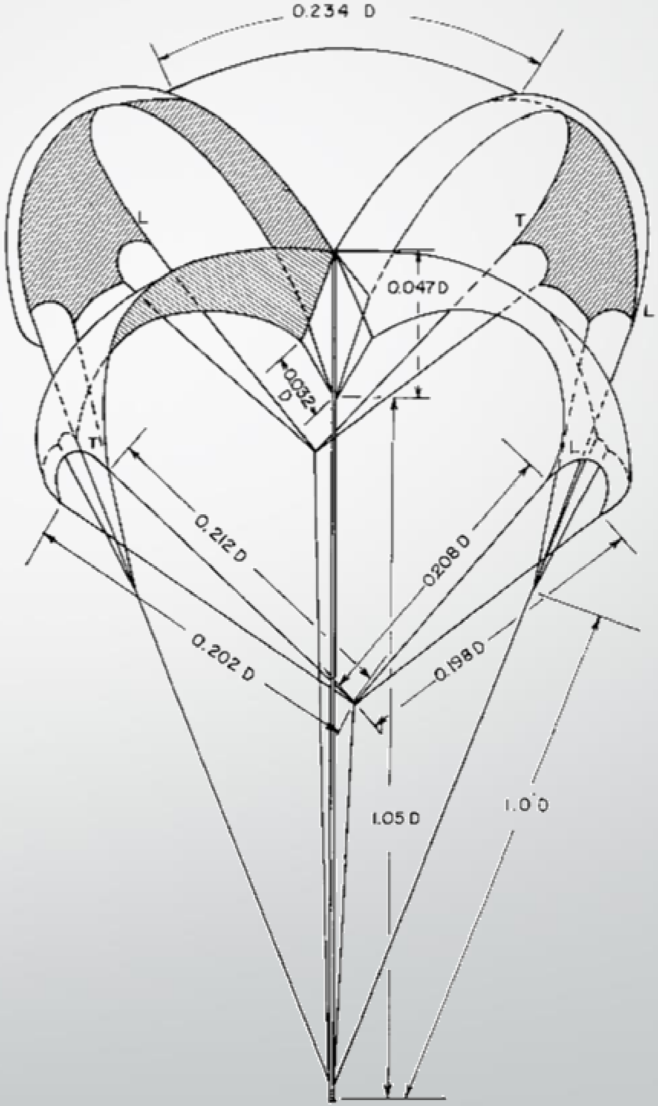
Section of rocket	Mass (lb_m)	Area (ft^2)	Diameter (ft)	Velocity (ft/s)	E (lb_f-ft)
Upper airframe	11.4	17.5	4.7	18.40	60
Lower airframe	13.8	58.4	8.6	16.73	60
Cache capsule	6.28	24.2	5.6	17.53	30

Wind speed (mph)	Distance drift from launch pad (ft)
0	0
5	242.9
10	485.7
15	728.6
20	971.4

Vortex Ring Schematic

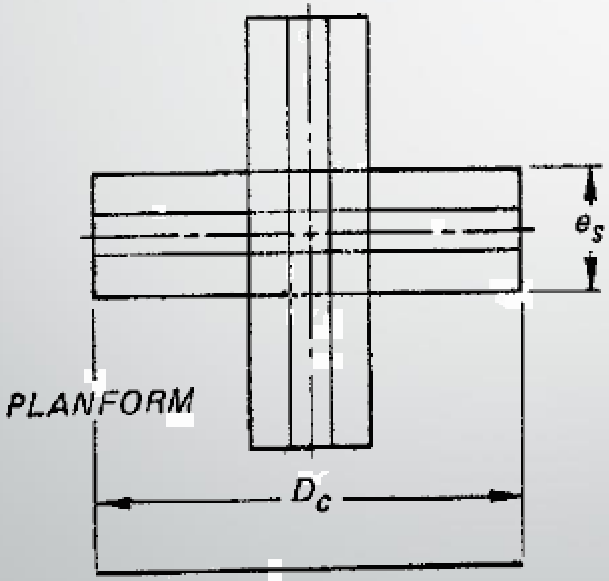


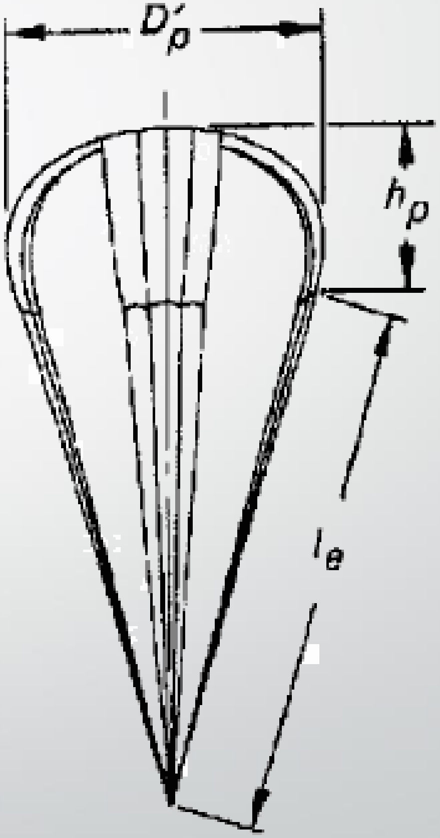
Dimension	Length [ft]
D_C	4.5
l_C	4.5
l_E	4.5
l_T	1.5
l_L	0.9
e_s	1.0



Cruciform Parachute Schematic

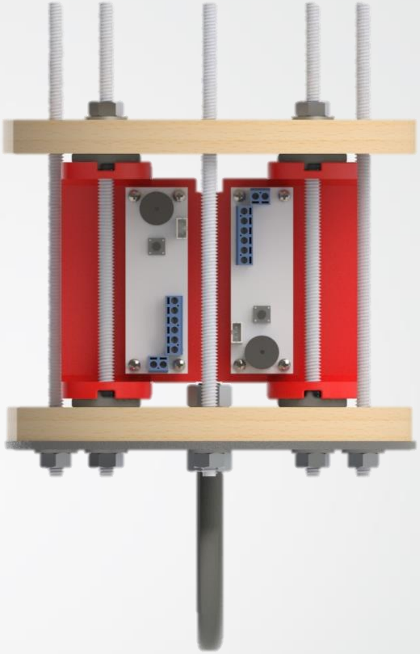
Section of rocket	e_s (ft)	D_c (ft)	l_e (ft)
Lower airframe	1.5	5.1	17.3
Cache capsule	1.0	3.3	11.1

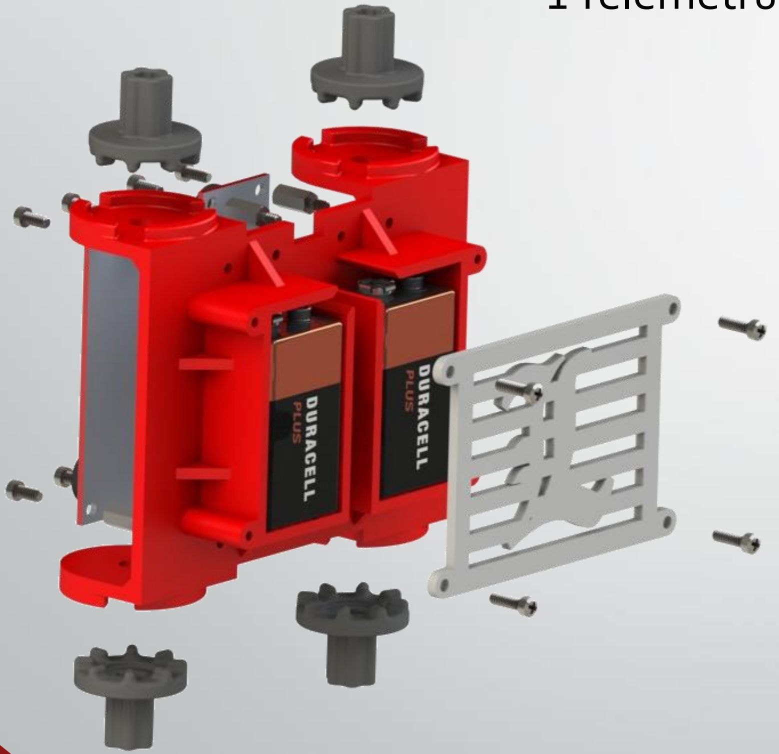


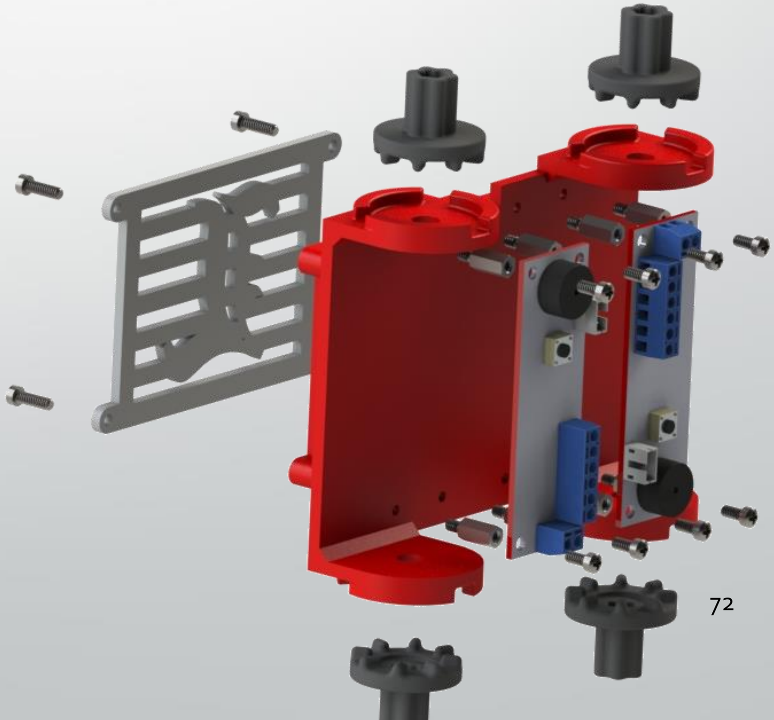


Avionics

- Nosecone: 2 StratoLoggers
- Lower Airframe: 2 StratoLoggers
- Cache Capsule: 1 StratoLogger
  1 Telemetrum



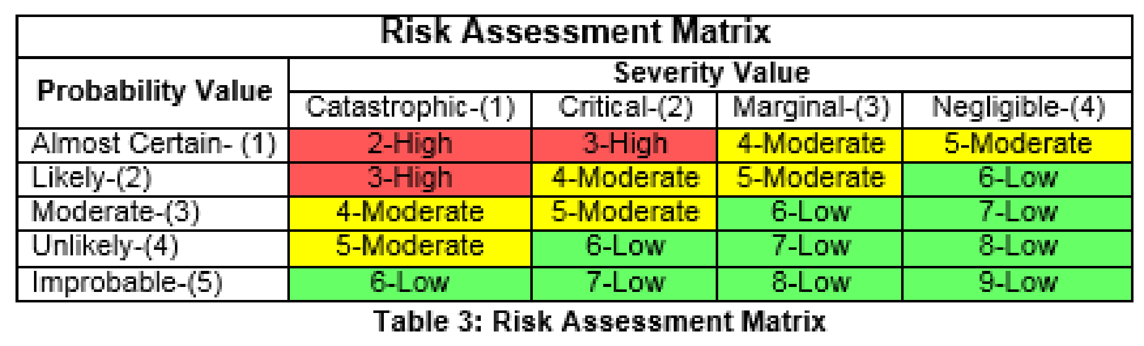




Safety Features

Safety Manual

- Lab workshop safety
- Launch safety
- EE safety
- MSDS
- Energetics safety



Risk Assessment Matrix				
Probability Value	**Severity Value**			
	Catastrophic-(1)	Critical-(2)	Marginal-(3)	Negligible-(4)
Almost Certain- (1)	2-High	3-High	4-Moderate	5-Moderate
Likely-(2)	3-High	4-Moderate	5-Moderate	6-Low
Moderate-(3)	4-Moderate	5-Moderate	6-Low	7-Low
Unlikely-(4)	5-Moderate	6-Low	7-Low	8-Low
Improbable-(5)	6-Low	7-Low	8-Low	9-Low

Table 3: Risk Assessment Matrix

Comprehensive launch procedure:

- Required tools
- Assembly instructions
- PPE
- Warning, Caution and Danger icons

⚠WARNING ⚠CAUTION

⚠ DANGER

Risk Assessment Matrix:

- Lab and machine shop
- AGSE
- Electronics
- Recovery
- Vehicle
- Environmental

Educational Engagement

New programming!

- Robotics
- Programming through games
- Electronics
- Satellites

E-Expo

- Paper rockets
- Water rocket competition

Big Brothers Big Sisters

2014-2015 Overall Budget

Overall Tentative Budget

Budget	Total Cost
Full Scale Vehicle	$4,321.66
Recovery	$1,322.21
Subscale Vehicle	$946.08
Payload "Arm" Budget	$243.99
Educational Engagement	$778.79
Travel Expenses	$5,750.00
Promotional Materials	$975.00
Safety Materials / Miscellaneous	$1,739.75
Ground Station	$3,742.03
Overall Cost	**$19,819.51**