Georgia Tech

GIT LIT

2017-2018 NASA STUDENT LAUNCH

CRITICAL DESIGN REVIEW

JANUARY 24TH, 2017

CREATING THE NEXT®

AGENDA

1. Project Plan Update (5 Min)
2. Launch Vehicle (10 min)
3. Payload - ATS (5 Min)
4. Payload - Rover (5 Min)
5. Flight Systems (10 Min)
6. Test Plans and Procedures (2 Min)
7. Requirements and Verifications (3 Min)
8. Sub-scale Flight (10 Min)
9. Questions (15 Min)

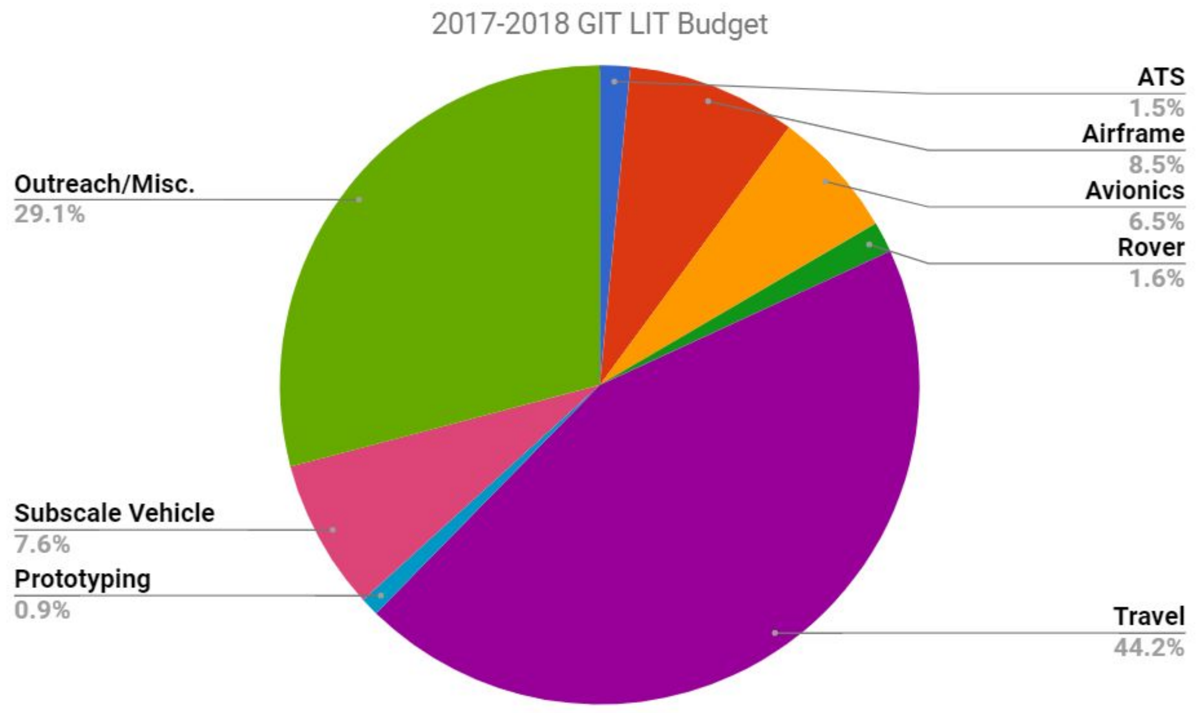
Project Plan Update

Educational Outreach

1. Peachtree Charter Middle School
2. Boy Scout Merit Badge: **Robotics!**
3. CEISMC GT (Center for Education Integrating Science, Mathematics and Computing)
4. Atlanta Science Festival

Project Budget Summary

Category	Cost
ATS	$113.10
Airframe	$632.19
Avionics	$479.95
Rover	$115.00
Travel	$3,268.00
Prototyping	$69.74
Subscale Vehicle	563.67
Outreach/Misc.	$2,152.71
Total	**$7,394.36**



Project Funding

Sponsor	*Contribution*	*Date*
2016-2017 Unused Funds	$1,775.23	--
Georgia Space Grant Consortium	$4,000	November 2017
Alumni Donations	$200 (est.)	December 2017
Georgia Tech School of Aerospace Engineering	$2,500 (est.)	January 2018
Corporate Donations	$1,000 (est.)	January 2018
Orbital ATK Travel Stipend	$400 (est.)	April 2018
Total	**$9,875.23 (est.)**	

New Emphasis in Documentation

- Emphasis on safety
  - Not just hazards, but mitigation strategies and how they pose a risk to our team/launch vehicle
  - Specific procedures for manufacturing and testing
- Team-derived requirements, and SMART verification goals and plans for these requirements

Hazard	Causes	Impacts	Risk	Mitigation Strategy
Rover deployment actuates during flight	Signal interference	Creates highly unstable flight leading to loss of vehicle, Challenge incomplete	1C	Rover deployment system does not actuate unless sensors indicate that the rocket has landed
	Coding error			
	Improper wiring			
	Component failure in a non safe mode			
Rover deployment mechanism structural failure	Pre-existing crack propogation	Slight imbalance affecting flight path, Premature rover deployment, Rover unable to deploy, Challenge incomplete	2D	Deployment mechanism components will undergo structural testing to ensure they can withstand all loads with a factor of safety of 2
	Delamination of printed material			
	Adhesive improperly mixed and set			
	Hard impact with ground			

PDR Action Items

- Air brakes must be aft of CG
    - They already were, we went back and re-confirmed that they are ~9in apart

Launch Vehicle

Final Launch Vehicle Dimensions

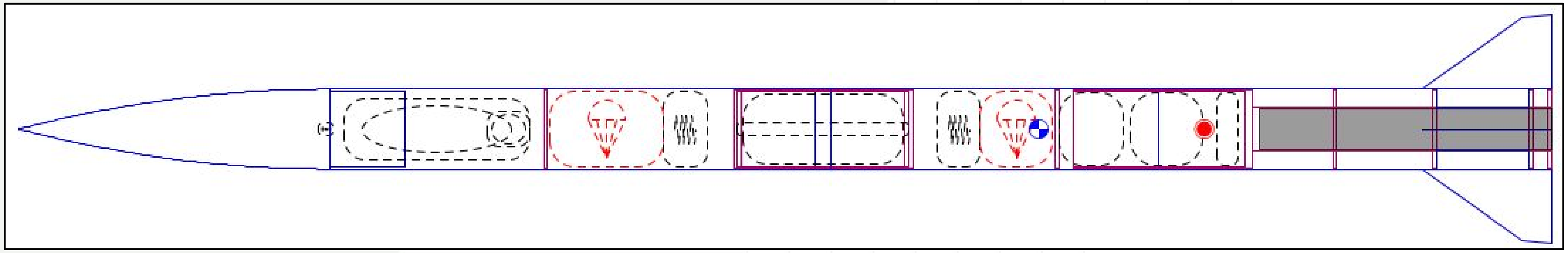
Overall Specifications

Overall Specs	Value
Overall Length	107 in
Launch Vehicle Diameter	5.562 in
Overall Mass	37.38 lb
Center of Gravity (measured from nose cone)	71.336 in
Center of Pressure (measured from nose cone)	82.897 in

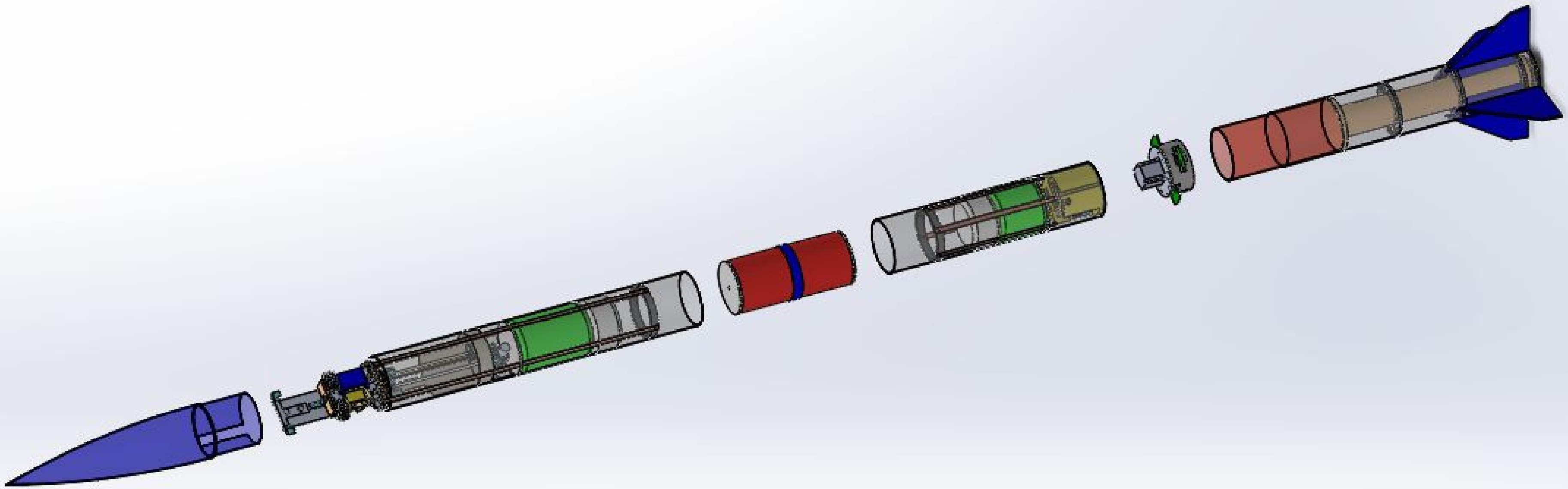
Mass Breakdown

Section	Mass (lb)	Length (in)
Nose cone	1.06	21.75
Rover housing section	8.69	34.00
Avionics bay	4.00	12.50
ATS section	7.13	23.00
Booster section	16.50	27.40

Final OpenRocket model



Launch Vehicle Exploded View

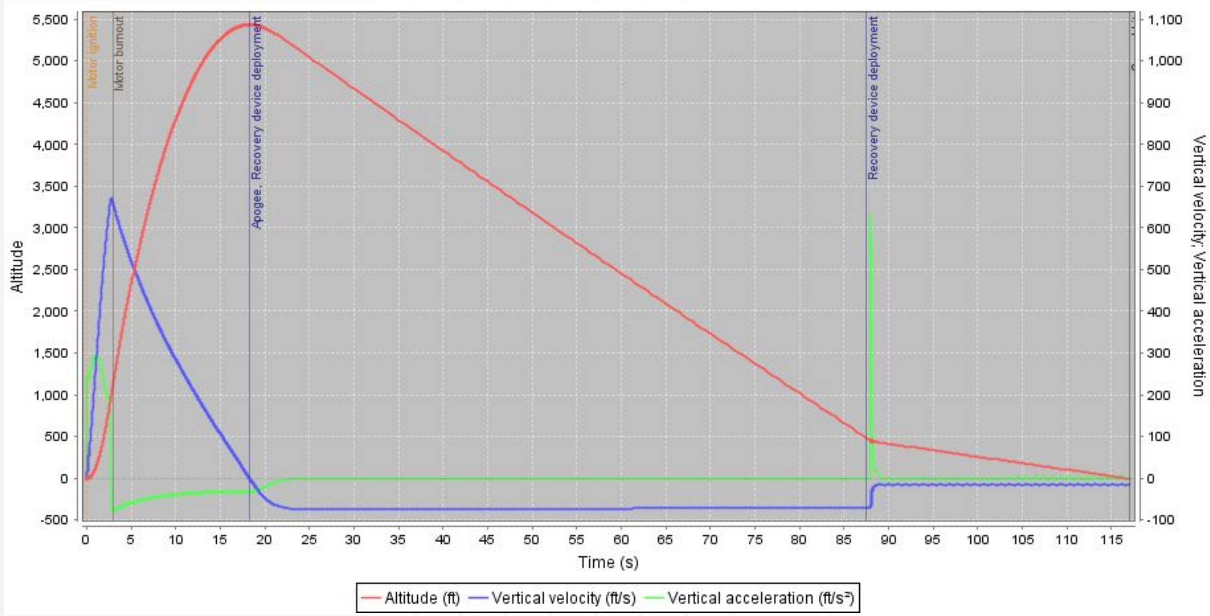


Location	Separation Mode	Separation Event
Nose Cone + Rover Tube	Supporting beams from rover tube	Rover deployment
Rover Tube - Avionics Bay	Shear Pins	Main parachute deployment
Avionics Bay - ATS Tube	Shear Pins	Drogue parachute deployment
ATS Tube + Booster Stage	Rivets	Not applicable

Flight Ascent Performance

Flight Performance

Property	Value
Center of Gravity	71.336 in
Center of Pressure	82.897 in
Apogee altitude	5434 ft
Maximum velocity	669 ft/s
Maximum acceleration	294 ft/s^2
Rail exit velocity	71.7 ft/s
Thrust-to-weight ratio	8.26
Ground hit velocity	16.3 ft/s

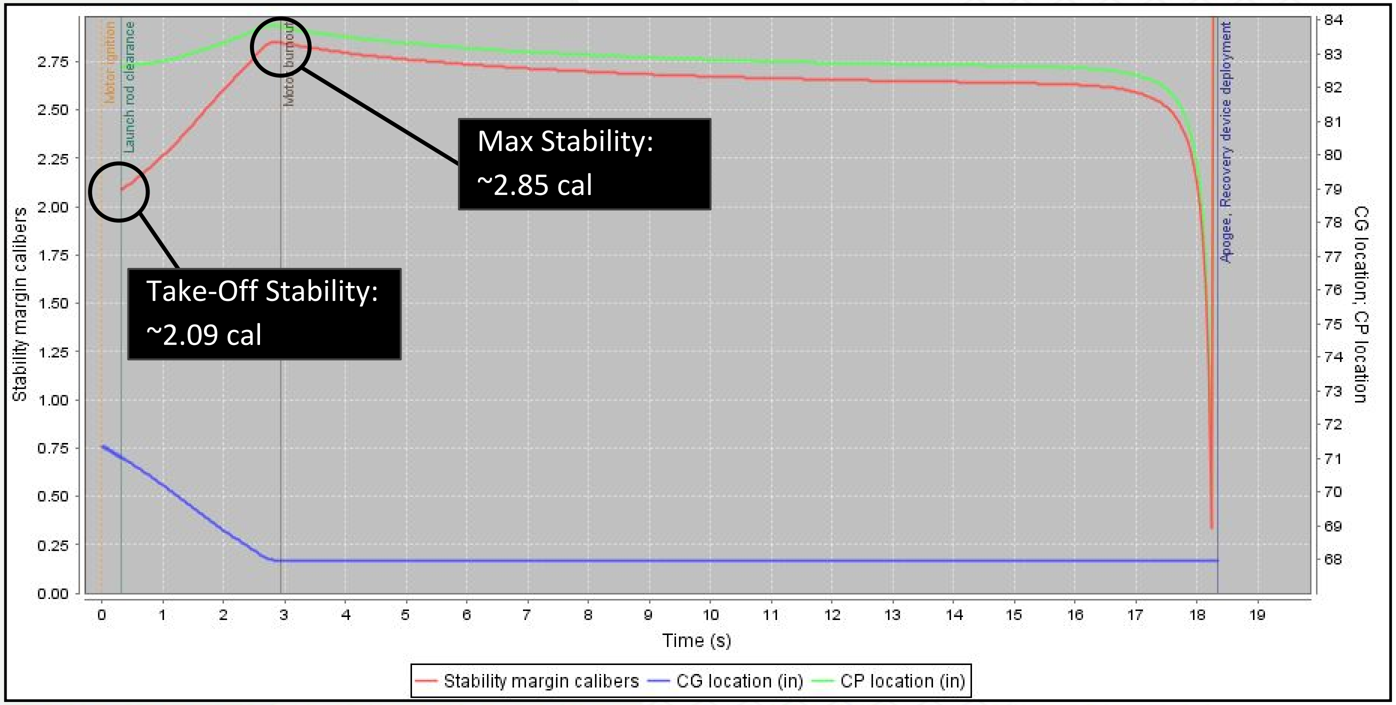


Flight Drift

Drift distance of the launch vehicle due to different wind speeds

Wind condition (mph)	Hand calculation predicted drift distance (ft)	OpenRocket predicted drift distance (ft)
0	0	8.2
5	716.5	364.3
10	1432.9	947.1
15	2171.4	1401.2
20	2868.8	2039.6

Drift distance = Wind speed * $(t_{landing} - t_{apogee})$



Recovery overview

Parachute specifications

Property	Main	Drogue
Diameter	96 in	36 in
Material	Ripstop Nylon	Ripstop Nylon
Shape	Toroidal	Octagon
Coefficient of Drag	2.2 Cd	0.8 Cd
Velocity at deployment	70.6 ft/s	17.3 ft/s

Shock cord specifications

Property	Value
Material	9/16 in Tubular nylon
Length	240 in

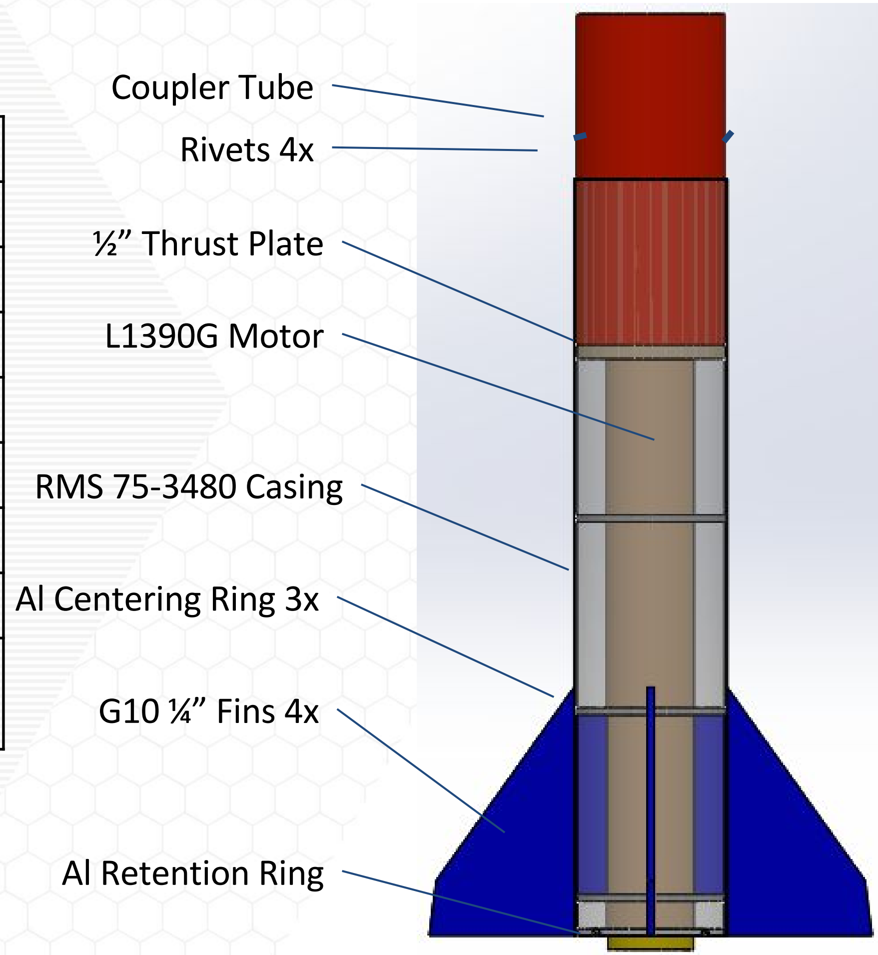
Kinetic energy at landing

Section	Value (ft/lb)
Nose cone + Rover housing	30.68
Avionics Bay	62.18
ATS + Booster	14.92

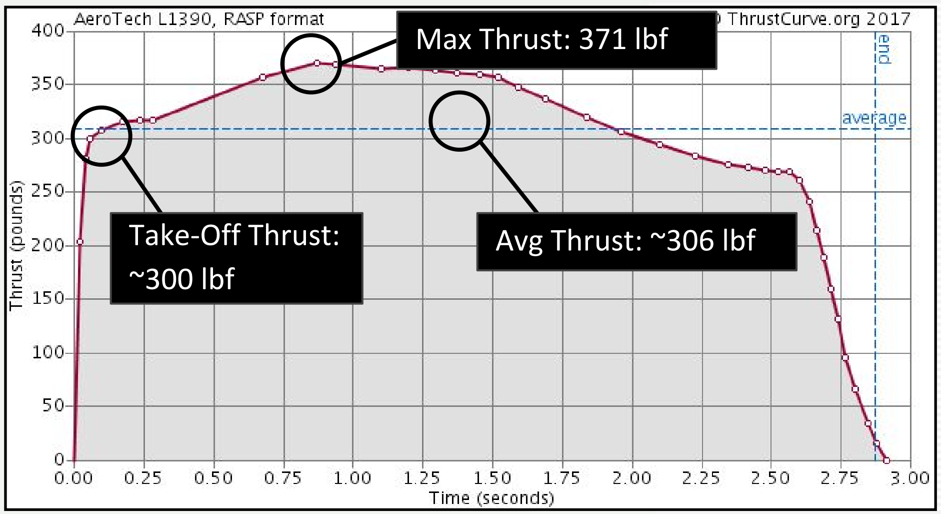
Booster Section Overview

Mass Breakdown by Component

Component	Material	Mass (oz)	Location (in)
Coupler	G12 fiberglass	22.00	0.00
Body tube	G12 Fiberglass	46.80	6.00
Thrust plate	G10 Fiberglass	4.13	12.00
Motor mount tube	White kraft paper	6.76	12.50
Centering ring	6061-aluminum	1.35	12.15, 19.15, 25.9
Fin (x3)	G10 Fiberglass	9.55	31.90
Retention ring	6061-aluminum	5.79	27.15
Motor (with propellant)	N/A	136.83	6.5



Final Motor Choice



AeroTech L1390 G-P Thurst curve

AeroTech L1390 G-P Specifications

Property	Value
Diameter	2.95 in (75.0 mm)
Length	20.87 in (530.10 mm)
Total mass	136.72 oz (3876 g)
Propellant mass	69.60 oz (1973 g)
Average Thrust	305.63 lbs (1359.49 N)
Maximum Thrust	370.90 lbs (1649.83 N)
Total Impulse	887 lbf · s (3946 N · s)
Burn time	2.91 s

Airframe Failure Modes and Effects Analysis

Components	Function	Failure	Potential Causes	Detection Method	Impact	Severity (1 -3)	Detection Difficulty (1 -3)	Probability (1 - 3)	Risk (1-27)	Risk Priority Number (Risk/27)
Bolts and nuts	holds components	threadlocker breaks and twists out	Vibration	N/A	Components may be disassembled; Due to imbalanced force, moment is created	3	3	3	27	1.00000
Motor board	received signal from Pi and actuates motor	cannot actuate motor	Faulty Wiring	Check wiring before flight	ATS is not actuated	2	1	1	2	0.07407
			Faulty Board	Run simulation before flight to check the board	ATS is not actuated/ actuated at wrong time	3	1	1	3	0.11111
Ring Connector	connects motor driver to stepper motor	connection severs	vibration	N/A	ATS is not actuated	2	1	3	6	0.22222
Motor	Provides thrust	explosion	- motor manufacture error	N/A	- rocket disintegrates -rocket falls to the ground	3	1	1	3	0.1111111111
		no ignition	- ignition wire not connected properly to the motor	N/A	- rocket does not fly	3	1	1	3	0.1111111111
Thrust plate	Prevents the motor from damaging other sections of the rocket	structural integrity fails	- material used to make thrust plate was already compromised	N/A	- motor shoots through rocket, damaging all systems	3	1	1	3	0.1111111111
Centering rings	Aligns the motor to the launch vehicle	all breaks during flight	- epoxy failed - material used did not have enough strength		- motor tilted, forcing the rocket to arc	2			0	0
Fins	Provides aerodynamic forces to the rocket for stability	fin(s) separate(s) during flight	- epoxy failed	N/A	- the rocket losses stability - the rocket may arc during flight	3	1	2	6	0.2222222222

Vehicle FMEA

Hazard	Causes	Impacts	Risk	Mitigation Strategy
Structural cracks in the body airframe	heat from motor	rocket buckles mid-flight and make the rocket fail and not land safely	1C	insulate motor from airframe body
	impulses from parachute deployment			verify there are no cracks in body before launch
thrust plate structural integrity fails	material used to make the thrust plate was already compromised and wasn't checked before manufacturing	motor shoots through rocket, damaging all systems	1B	verify there are no cracks in thrust plate before it is inserted into body
	epoxy used to secure thrust plate failed			use enough epoxy to establish acceptable factor of safety
motor explodes	motor manufacture error	rocket disintegrates or falls uncontrollably to the ground, most if not all subsystems useless	1B	verify motor housing and mount are free of defects before insertion into the body
	inappropriate propellant was used			verify that the correct propellant was selected, order and used

The remainder of the Vehicle FMEA can be found in the CDR Documentation

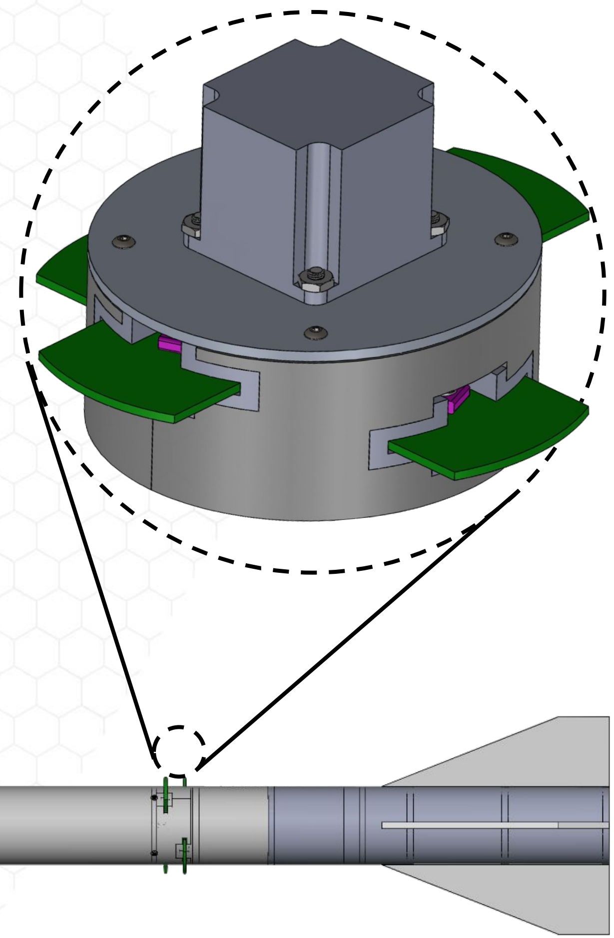
Payload - ATS

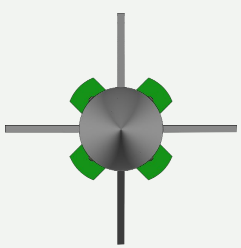
ATS Payload Overview

Purpose - Actively deploy set of drag surfaces to control and target an apogee of 5280 ft

Method of Operation - 4-bar linkage mechanism controlled by stepper driver. Stepper driver operated from a Raspberry Pi that in actively predicting vehicle flight path using altitude data from the Altimeters, and acceleration data from the Sense HAT Accelerometer

Component	Material	Mass (oz)	Location (in)
Body tube	G12 fiberglass	35.50	0.00
Drogue Chute	Ripstop nylon	2.54	9.375
Shock cord	Tubular nylon	3.44	7.375
Bulkhead	G10 fiberglass	9.10	14.375
ATS system	N/A	32.60	14.75





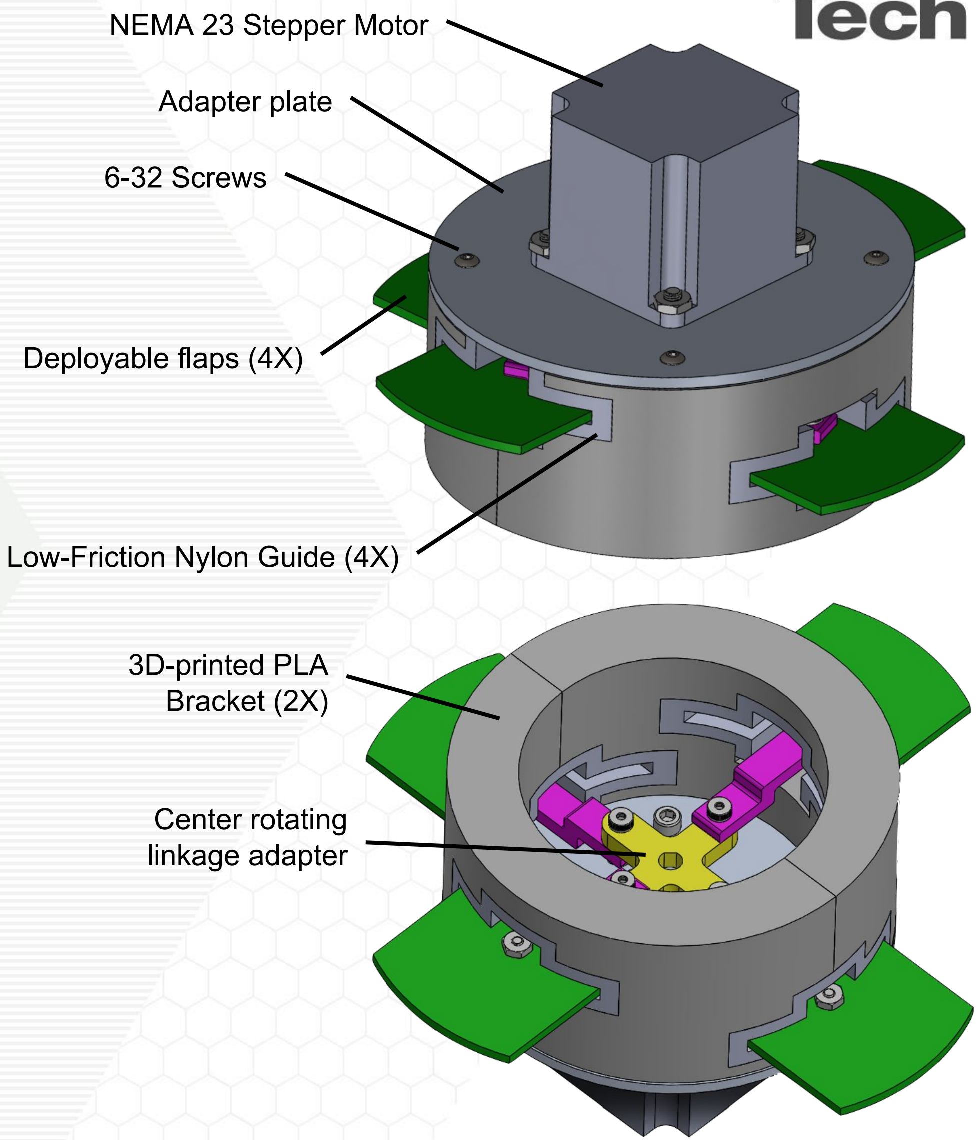
ATS Payload - Mechanics

Linkage

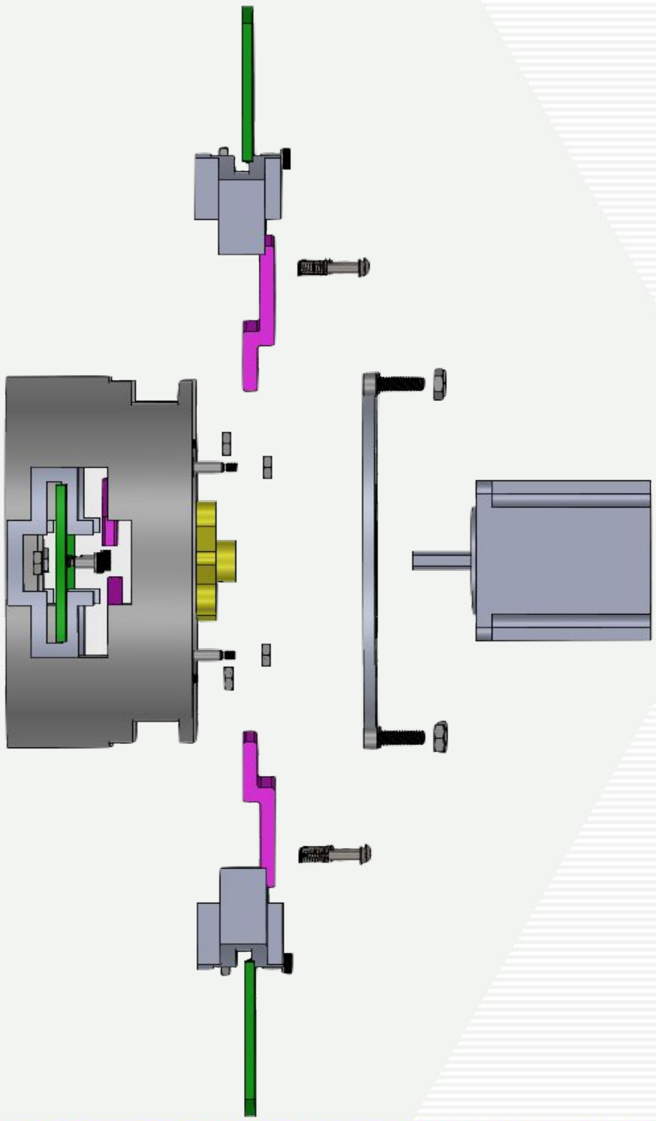
- 4-bar linkage
- Mechanically bound to prevent uneven flap deployment
- Shoulder screws to join linkage bars and minimize friction
- ⅛" Aluminum flaps
- Motor shaft directly drives center rotating linkage adapter

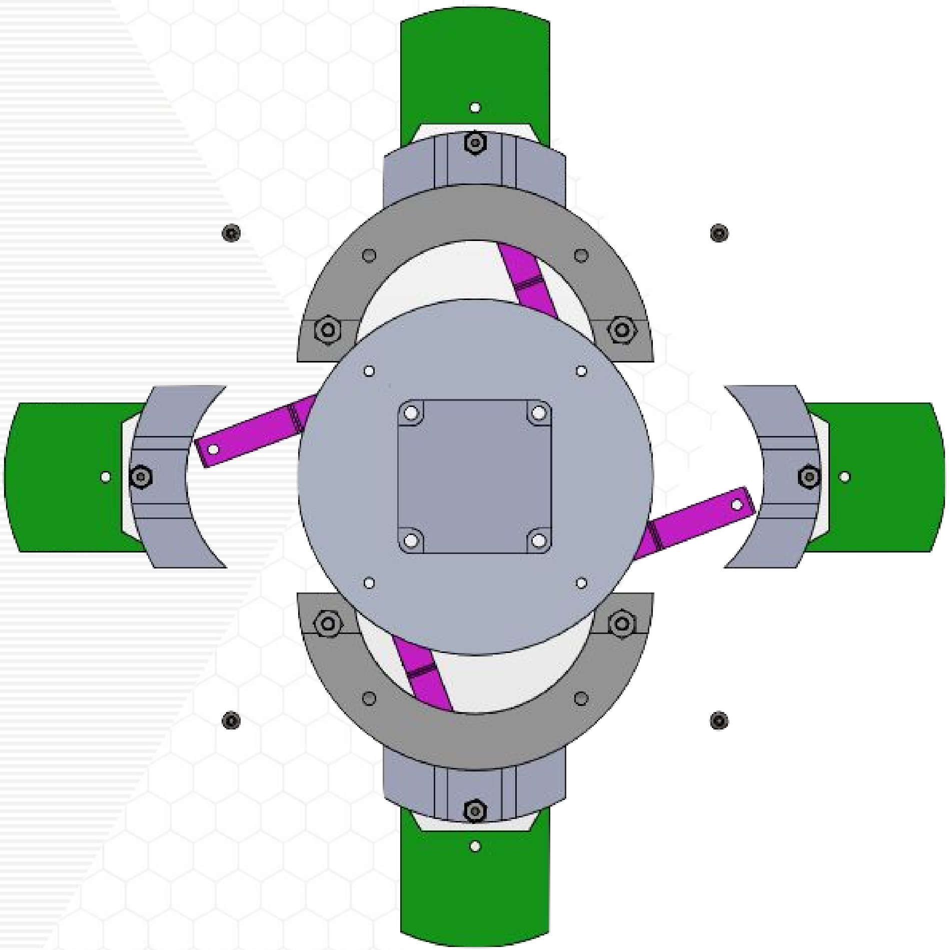
Bracket

- Safety Factor > 2 everywhere
- PLA 3D printed brackets to house linkage bar
- Nylon guides glued in to minimize friction with flaps

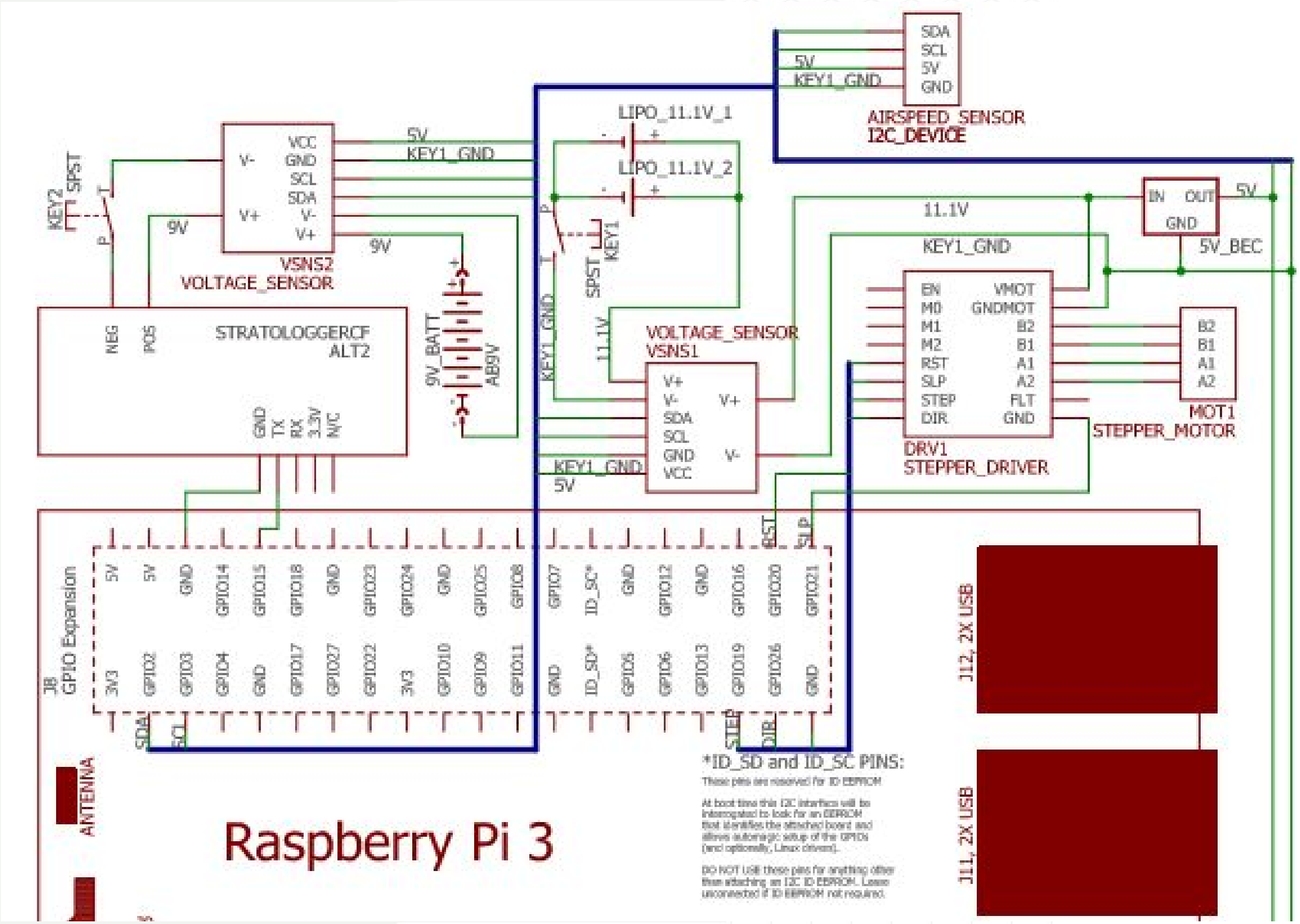


Exploded Views

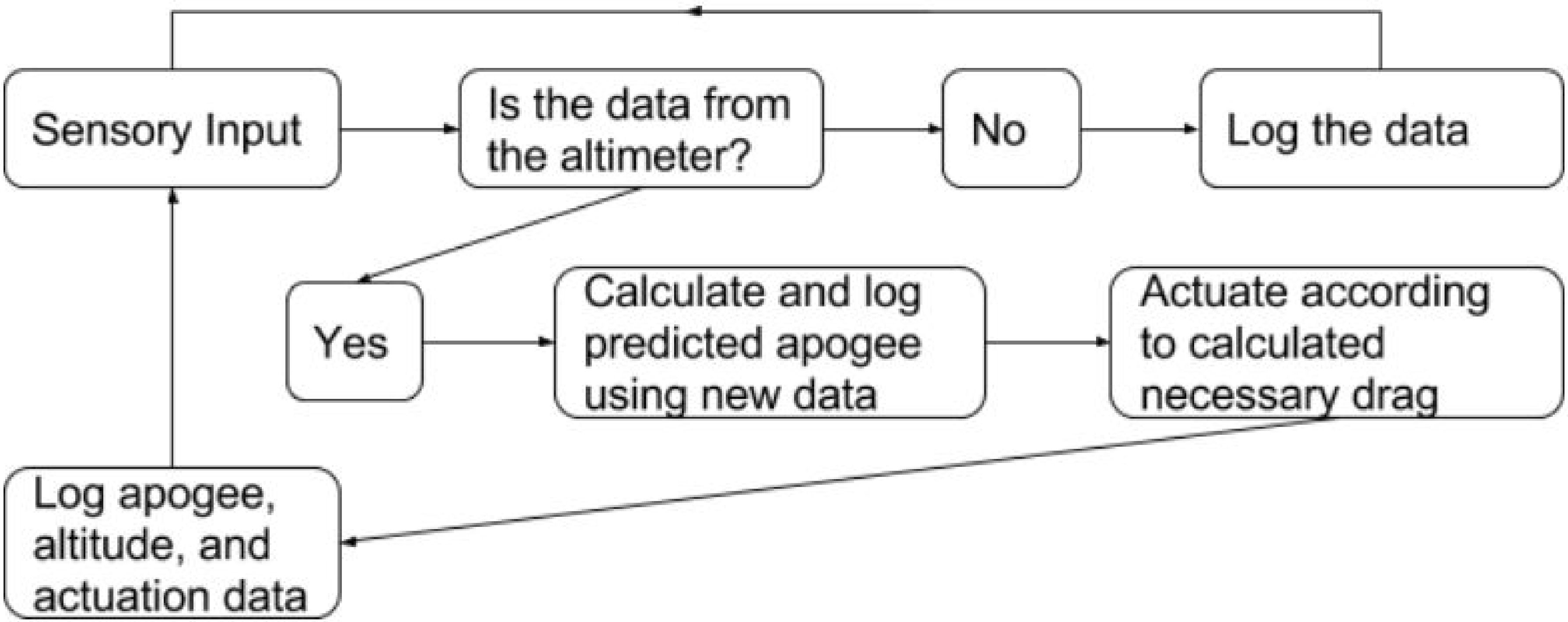




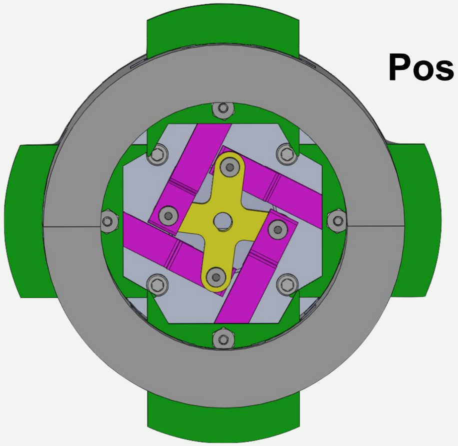
ATS Payload - Electronics



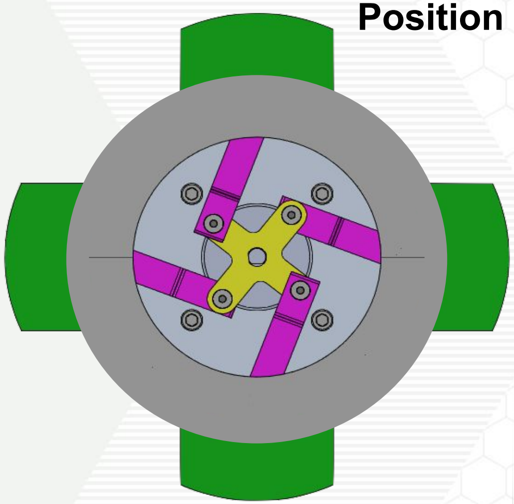
ATS Software Flowchart



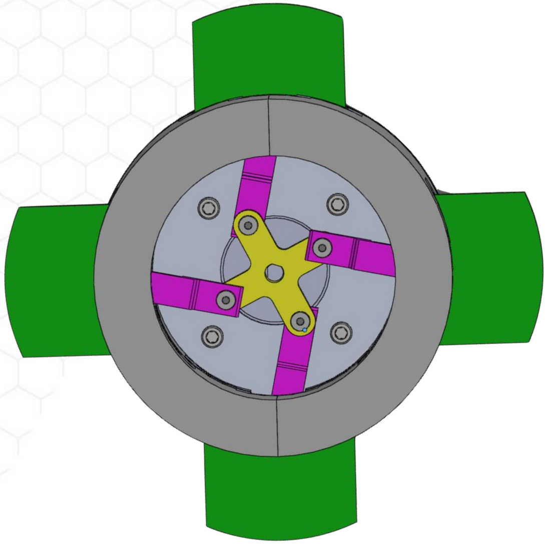
ATS Payload - In-flight functionality



Position 1: ⅓ of full extension



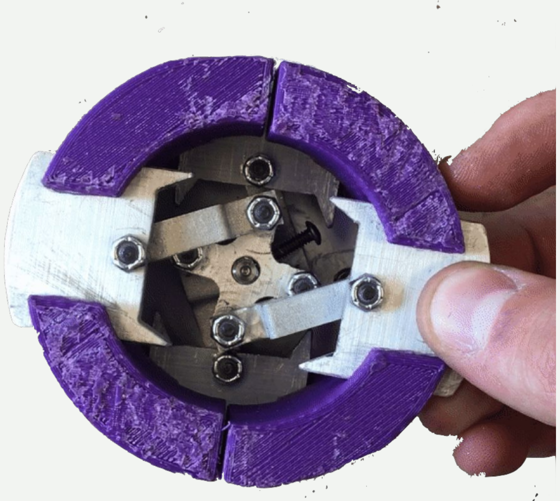
Position 2: ⅔ of full extension

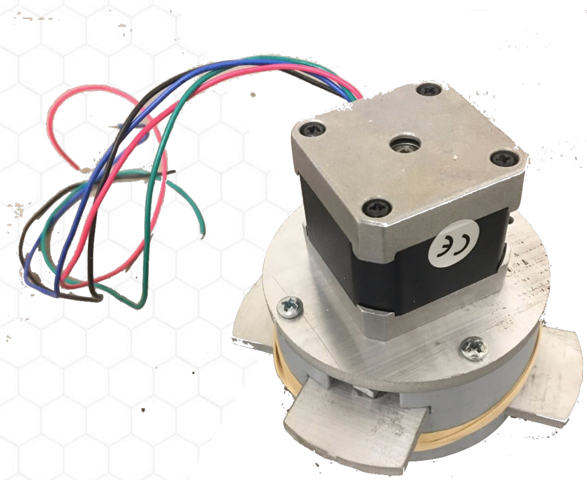


Position 3: Full extension

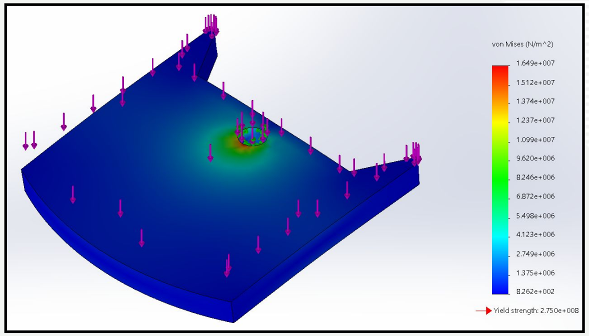
Description:
- 3 deployment positions
- Positioning determined by computer (rasp pi)
- Factors to determine position
  - real-time predicted apogee
  - desired apogee
  - current deceleration rate

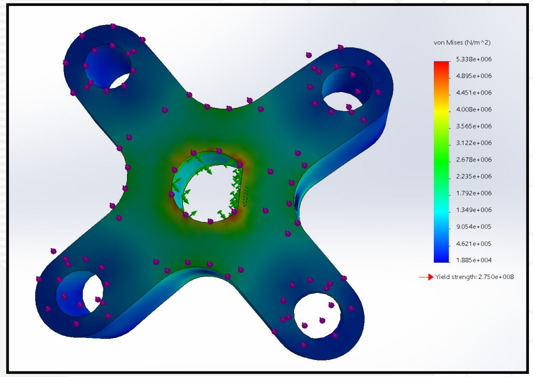
Demonstration of Prototype

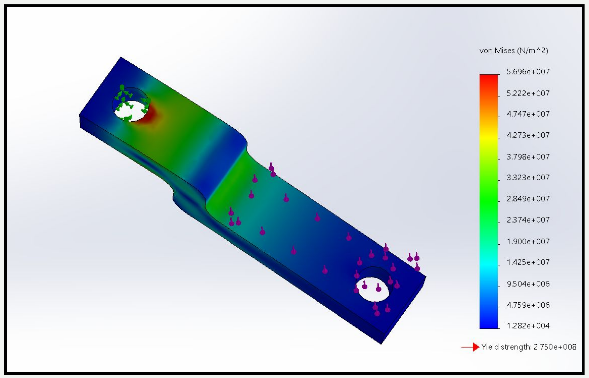


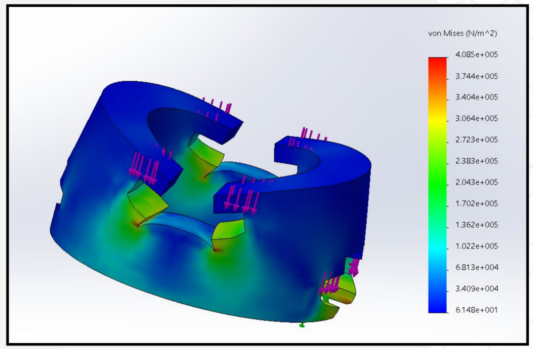


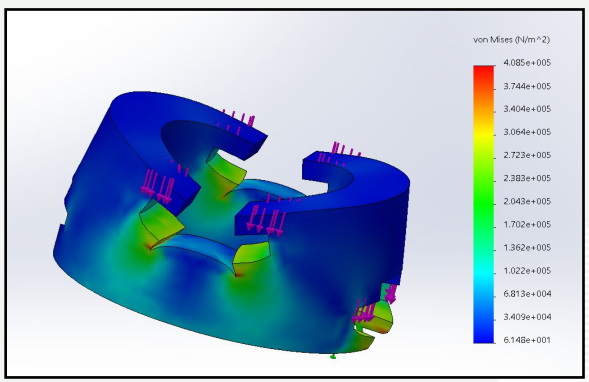
FEA Simulations - ATS

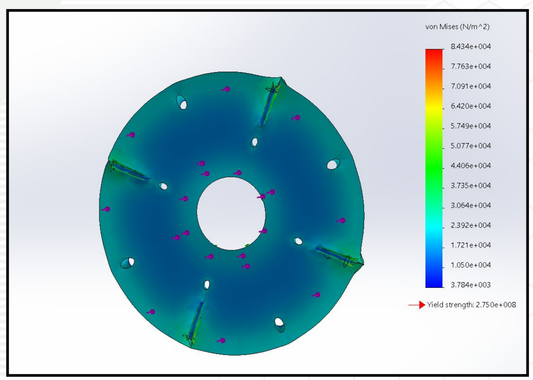












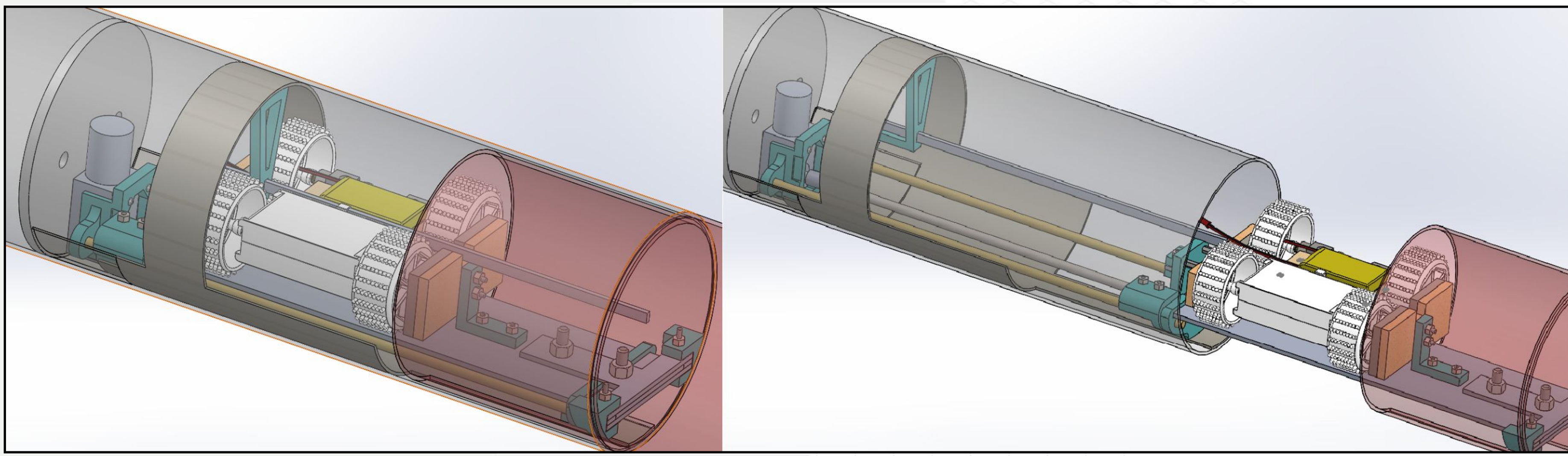
- Design requirement: FOS > 2
- FEA completed on each part to observe stress concentrations and deformation regions
- Highest stress occurs when fully deployed

Payload - Rover

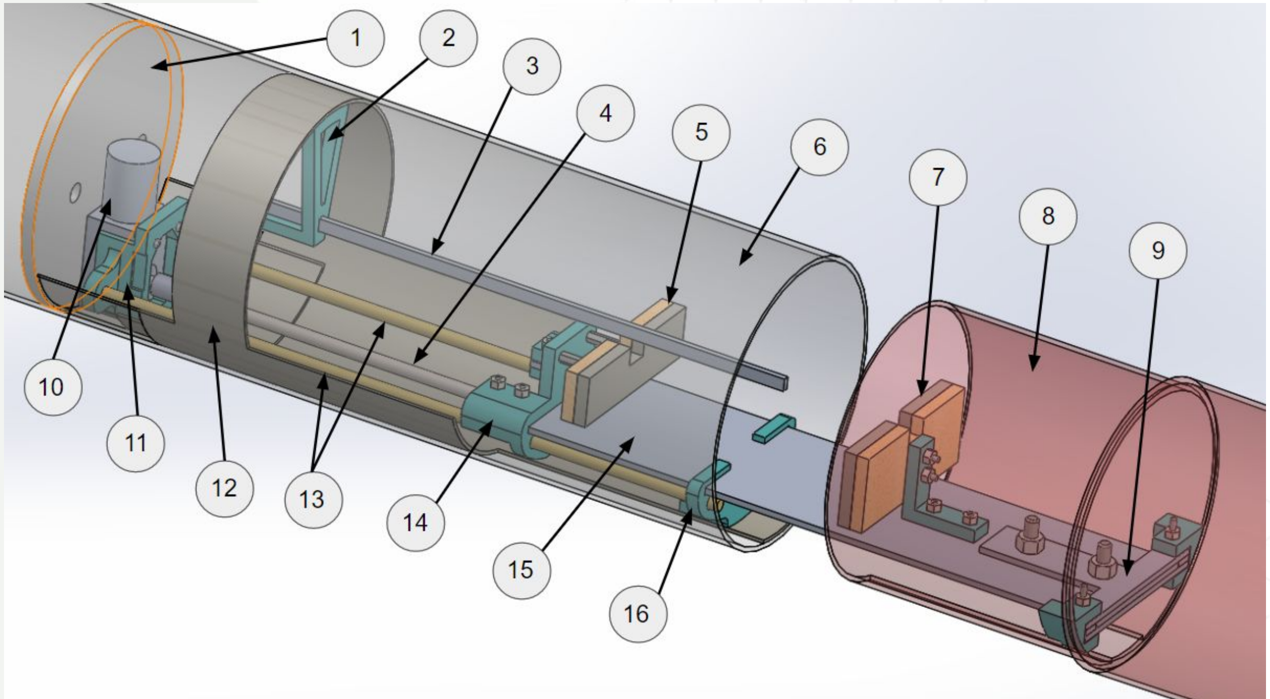
Rover Deployment

Final design decision: Axial lead screw

Chosen for its mechanical simplicity, payload safety, and and reliability



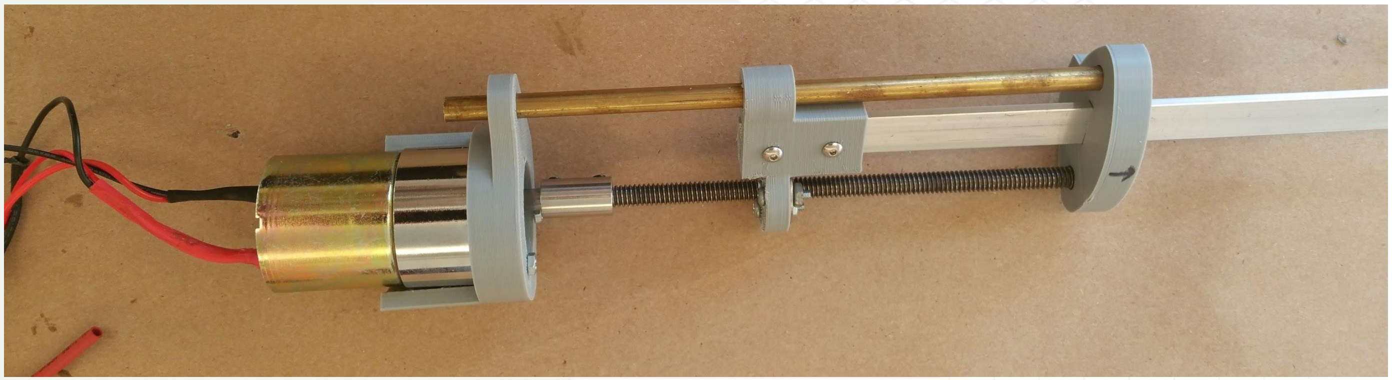
Deployment Exploded View

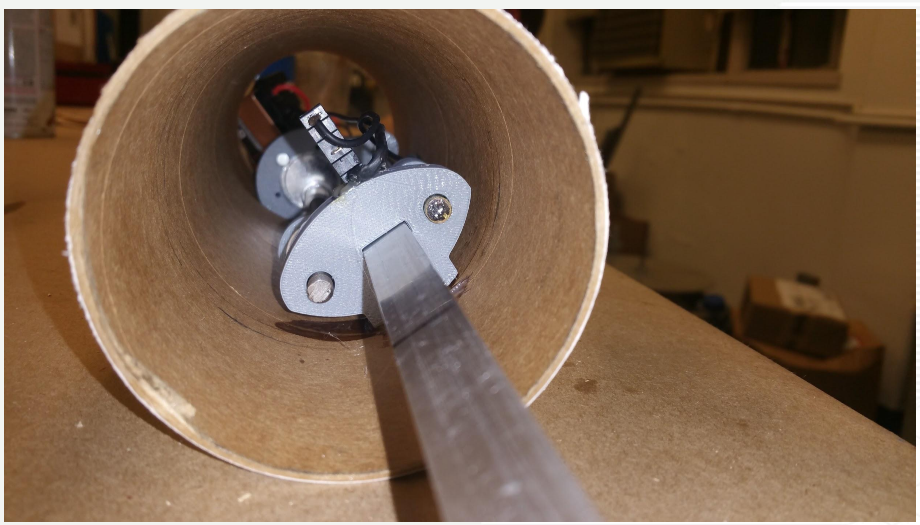


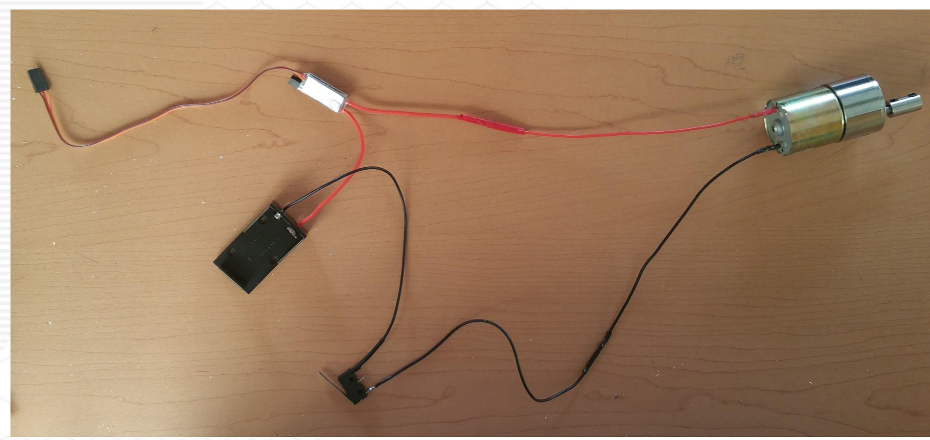
Number	Component	Number	Component	Number	Component
1	Bulkhead	6	Rover Bay Tube	11	Motor Bracket
2	Rover Rail Bracket	7	Pusher	12	Tray
		8	Nose Cone	13	Guide Rails
3	Rover Rail	9	Nose Cone Bracket	14	Carriage
4	Threaded Rod			15	Support Plate
5	Pusher	10	Deployment Motor	16	Front Support Bracket

Rover Deployment

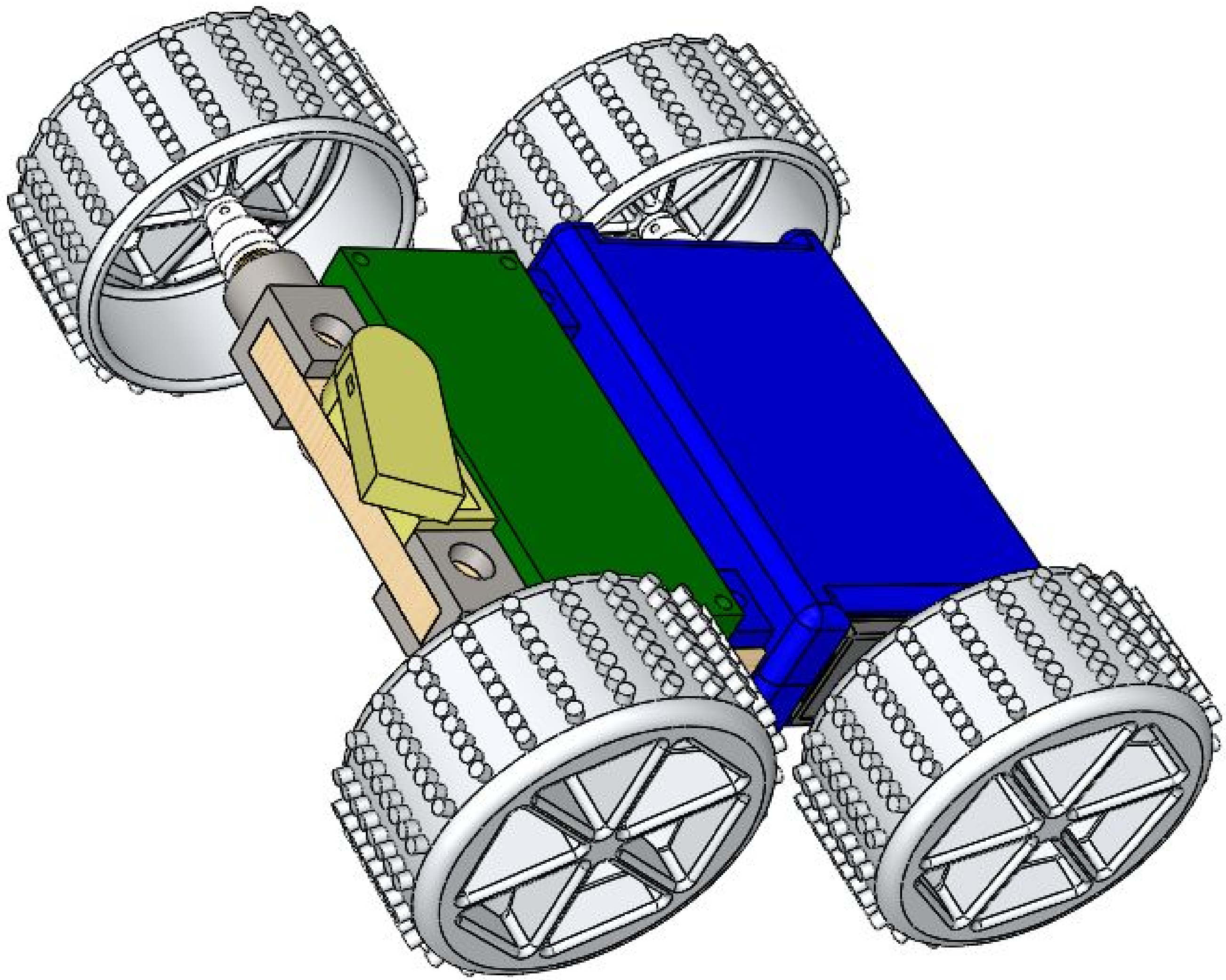
Prototyping: Lead Screw Mechanism



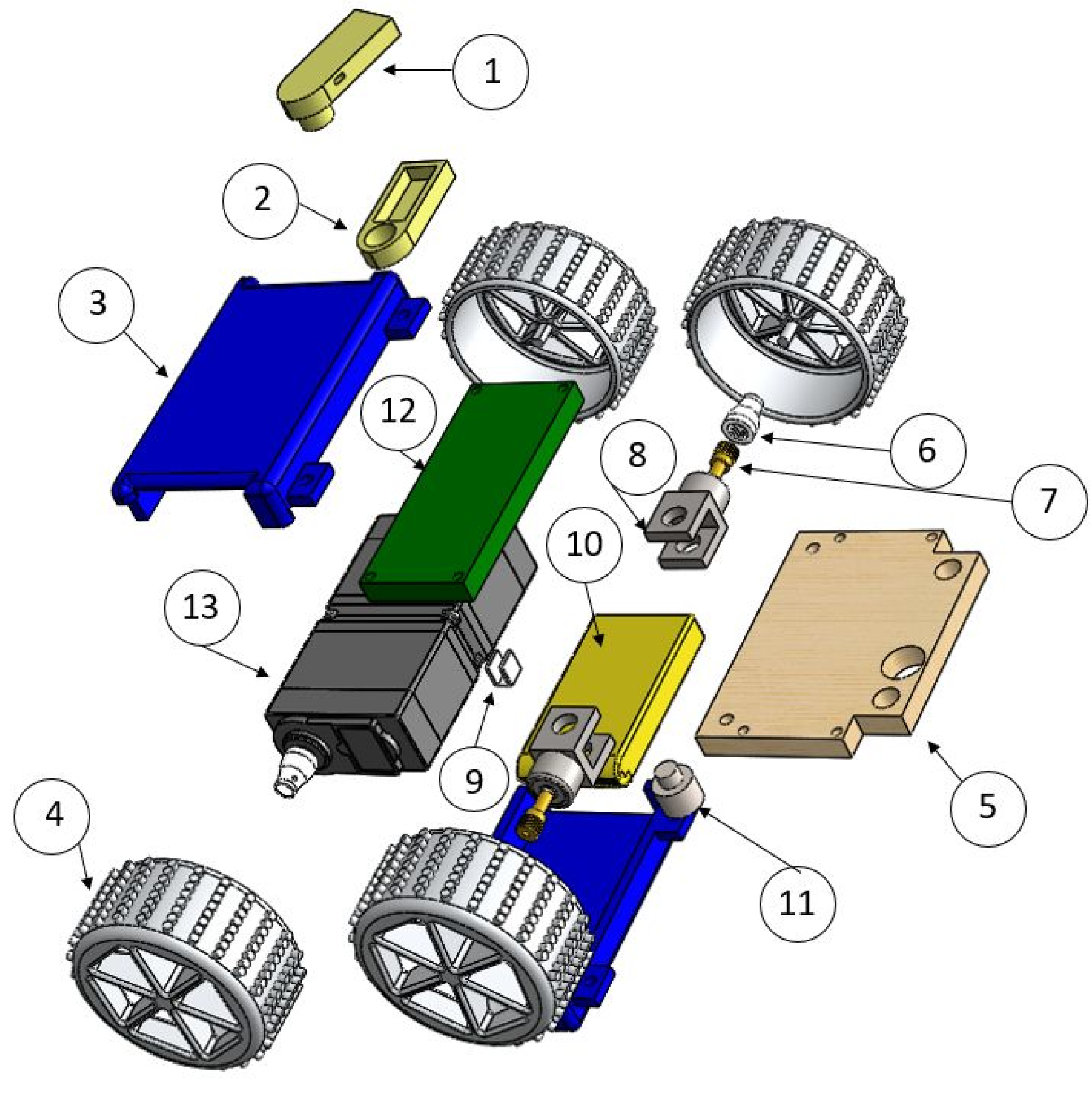




Rover Assembly

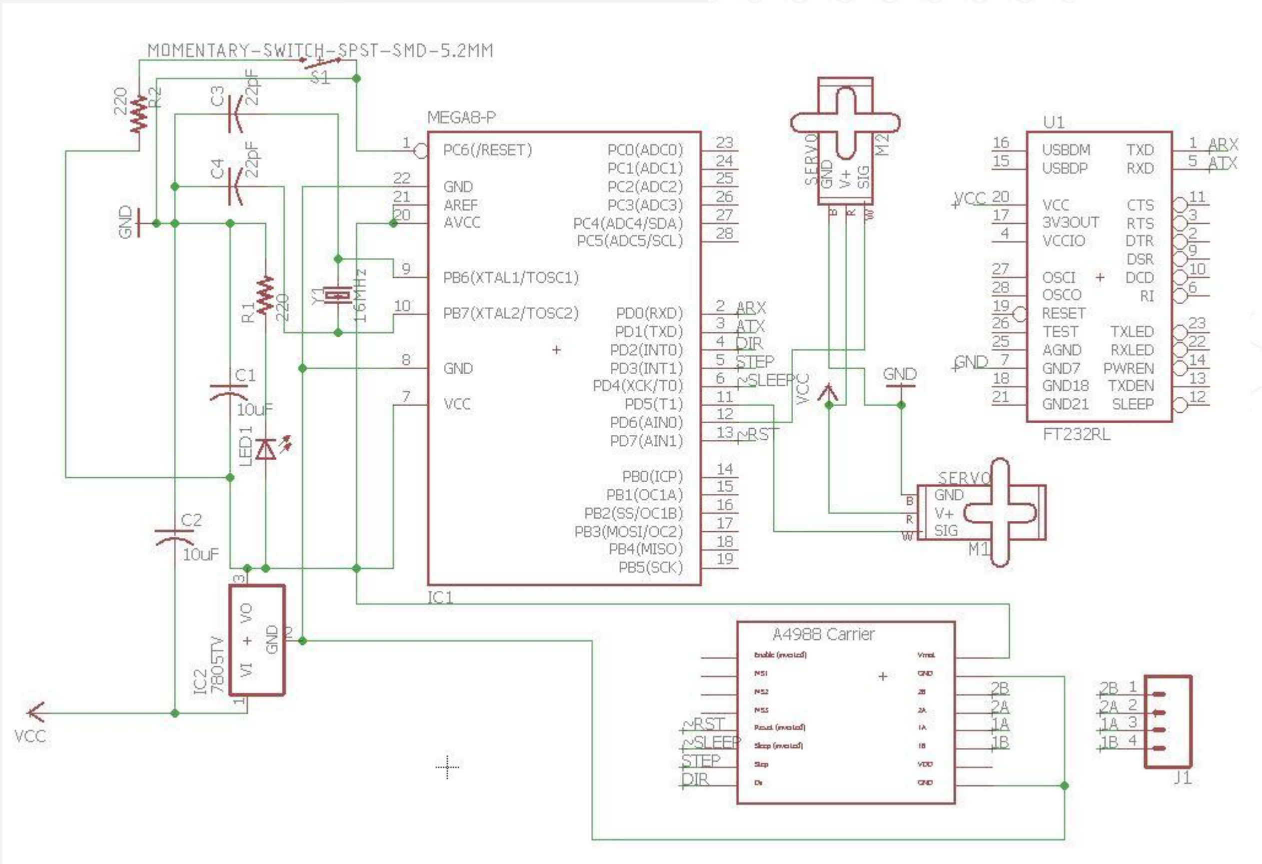


Rover Exploded View

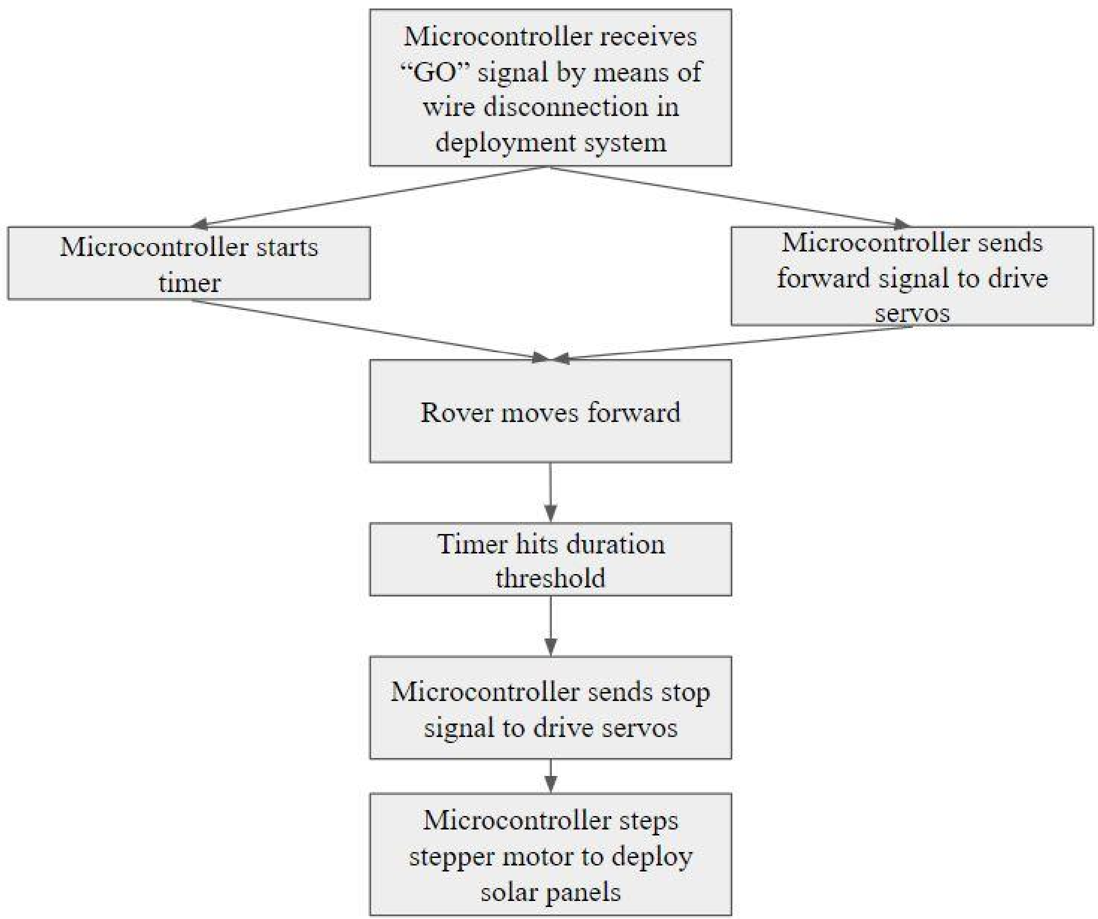


1	Solar Panel Housing Top
2	Solar Panel Housing Bottom
3	Servo Mount
4	Wheel
5	Base Plate
6	Servo Horn / Wheel Adapter
7	Front Wheel Axle
8	Bearing Mount
9	Rover Detachment Bracket
10	Battery
11	Solar Panel Stepper Motor
12	Control Board
13	Servos

Rover Controller Layout



Rover Software Block Diagram



Rover FMEA

Hazard	Causes	Impacts	Risk	Mitigation Strategy
Rover deployment actuates during flight	Signal interference Coding error Improper wiring Component failure in a non safe mode	Creates highly unstable flight leading to loss of vehicle, Challenge incomplete	1C	Rover deployment system does not actuate unless sensors indicate that the rocket has landed
Rover deployment mechanism structural failure	Preexisting crack propagation Delamination of printed material Adhesive improperly mixed and set Hard impact with ground	Slight imbalance affecting flight path, Premature rover deployment, Rover unable to deploy, Challenge incomplete	2D	Deployment mechanism components will undergo structural testing to ensure they can withstand all loads with a factor of safety of 2
Rover deployment does not activate	No signal reception Depleted 9V battery Component structural failure Coding error	Solar panels unable to actuate, Rover drivetrain unable to move, Challenge incomplete	4C	System will be tested in advance, receiver will have a large antenna

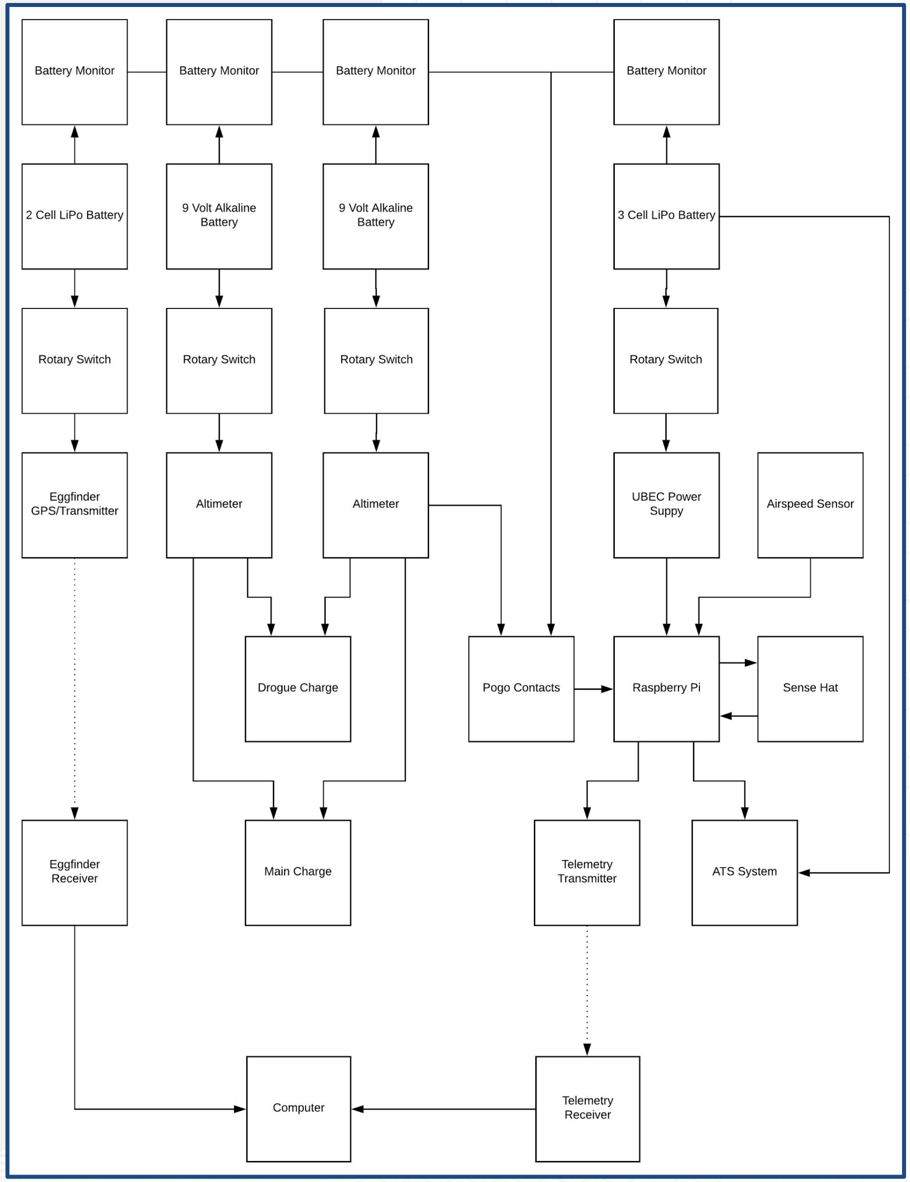
Remainder of Rover FMEA can be found in the CDR documentation

Flight Systems

Avionics Component Breakdown

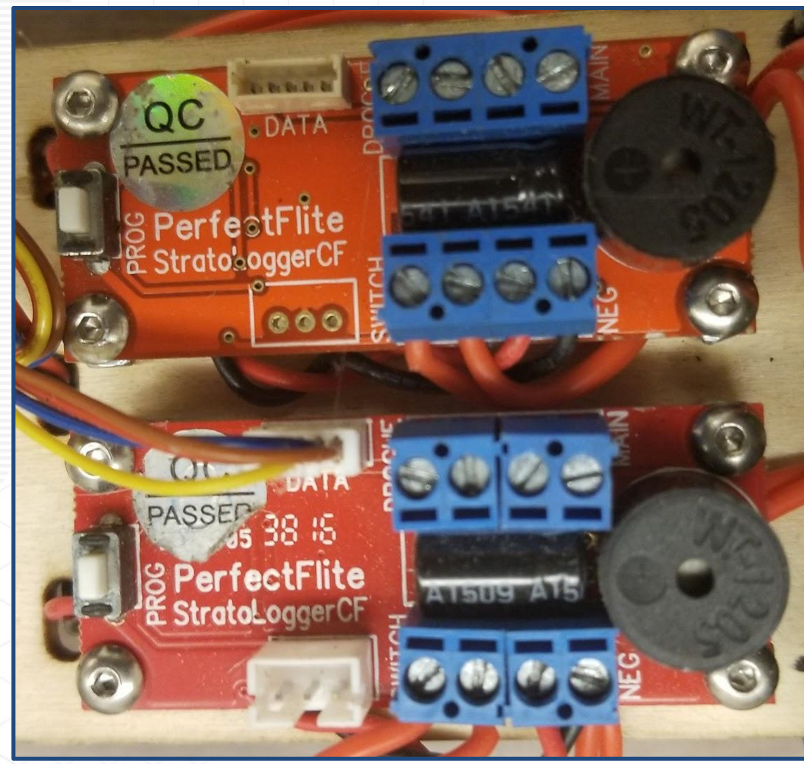
Part	Function
Stratologger CF x2	Altimeter - ignite ejection charges, record max altitude, send real time altitude data to ATS
Eggfinder TX/RX Module	GPS module - used to track the rocket in real time
9V Alkaline Batteries	Provide power to the altimeters

Avionics System Block Diagram

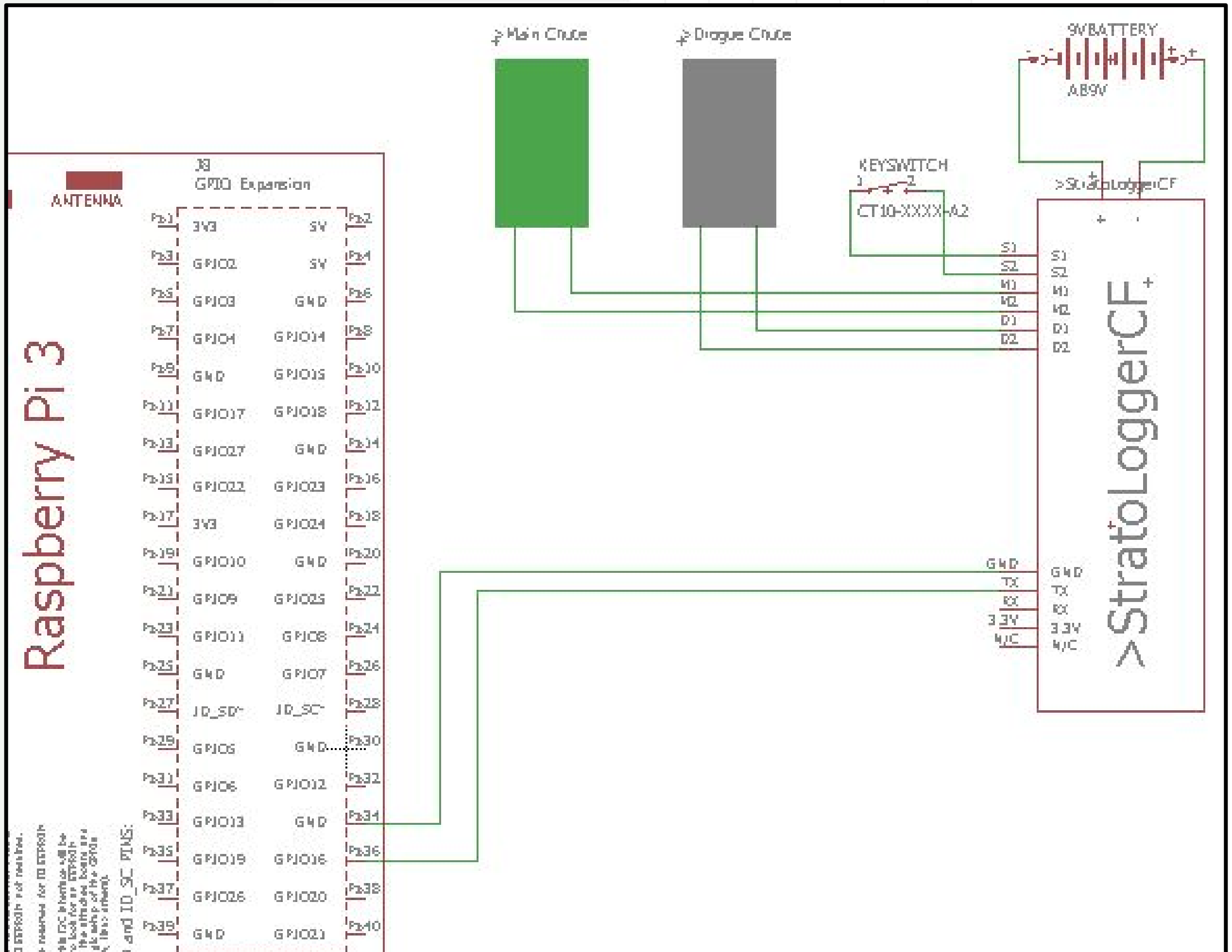


Altimeters

- Two altimeters will be used for redundancy
- The four pyro outputs will be wired to two electric matches
- Max Altitude: 100,000 ft
- 20 samples per second
- one foot resolution < 38,000 ft
- Voltage in: 4-16 V
- Dimensions: 2.0"L x 0.84"W x 0.5"H
- Weight: 0.38 oz



Deployment Wiring Diagram

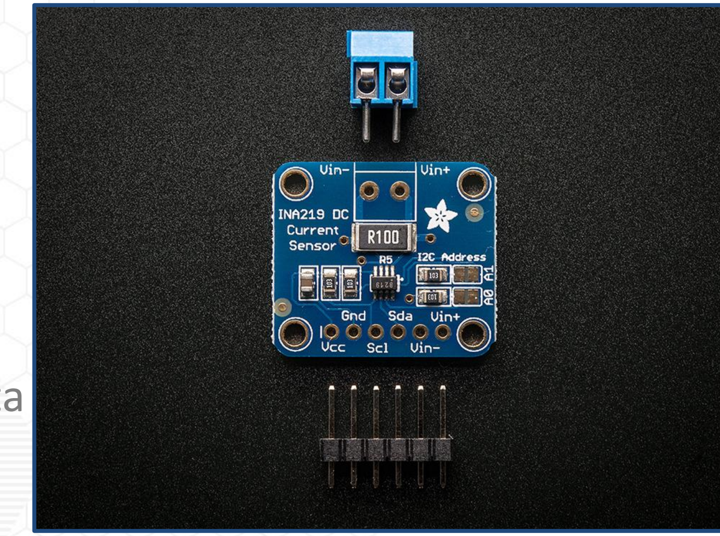


GPS

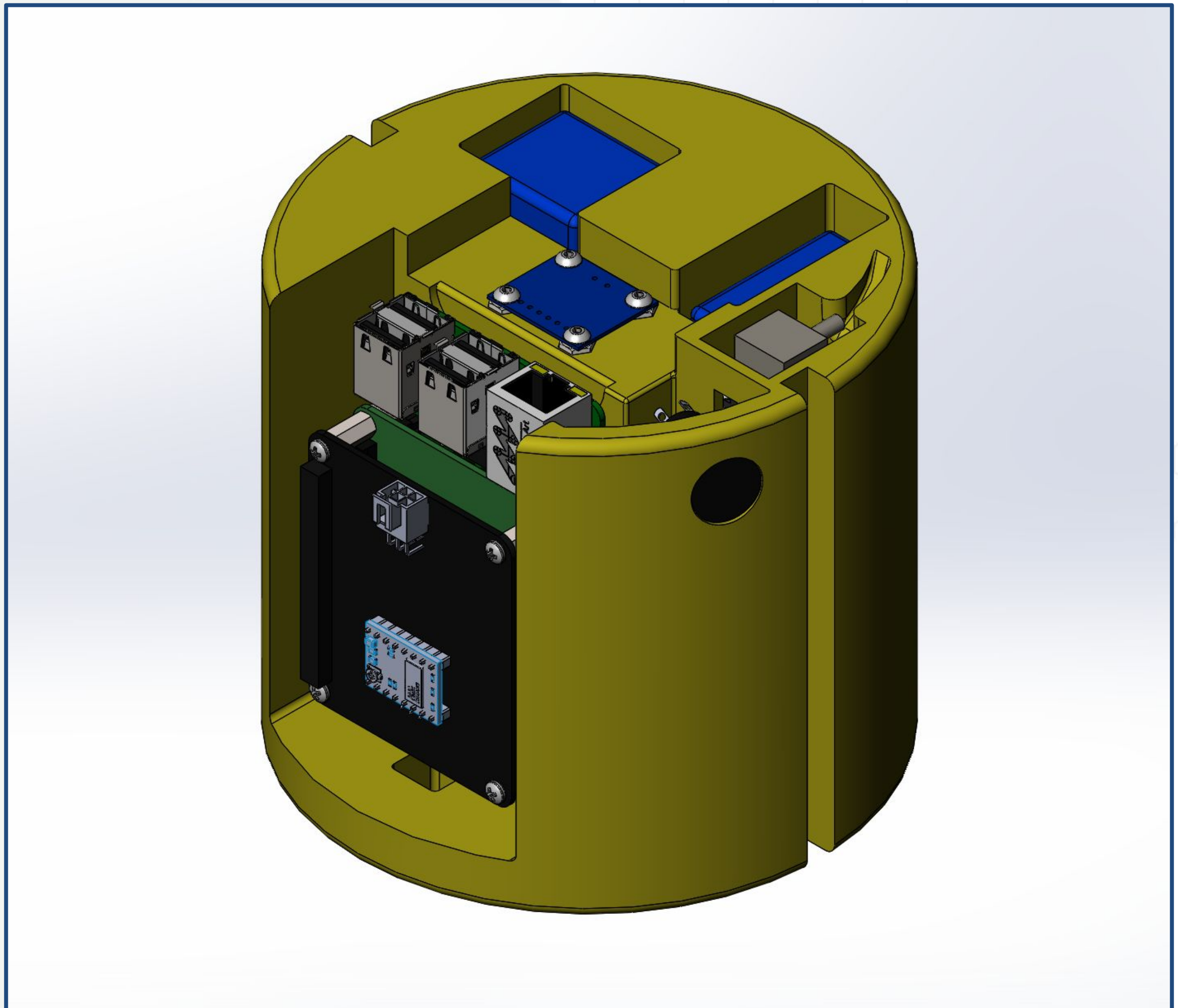
- Eggfinder Transmitter and Receiver Pair
- Laptop will be used to display and record data from receiver
- Transmits on 900 MHz band at 100mW
- Packets sent at 9600 baud, 8 bits, and no parity
- Tx Mass: 20 grams
- Power: 2 cell lipo
- Current Draw: 70-100 mA
- Dimensions: .9"W x 3"L x .4" H

Telemetry

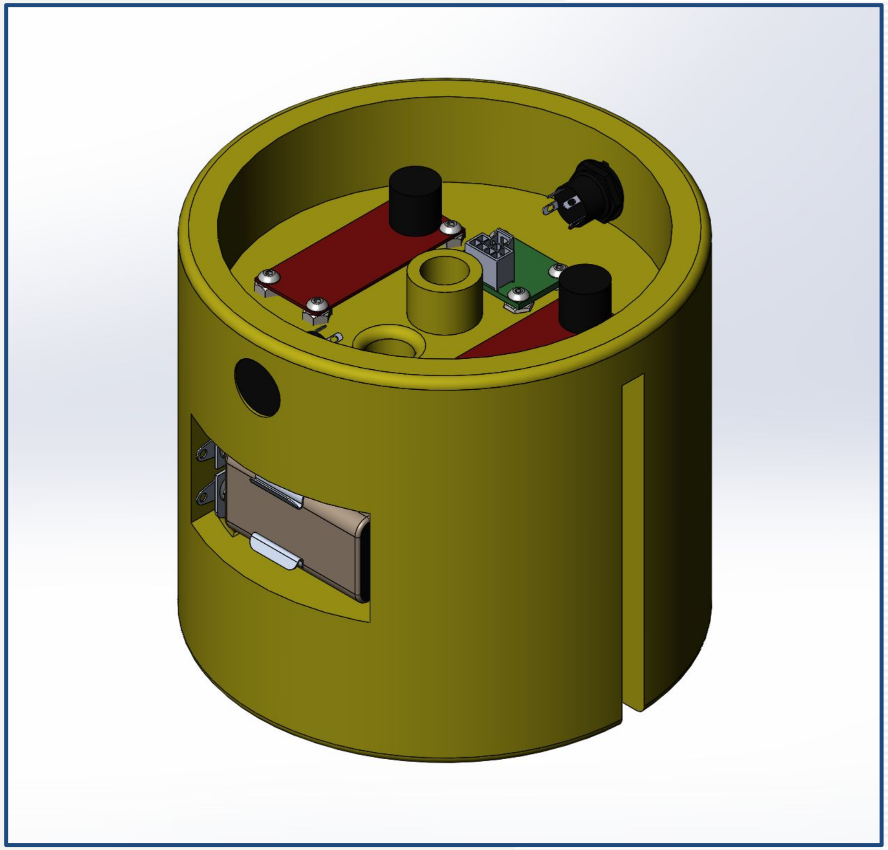
- Relays system information to the ground station
  - Battery voltages
  - Sensor data
  - ATS system events
- INA219 High Side DC Current Sensor
- Laptop will be used to display and record received data
- HKPilot Transceiver Telemetry Radio Set V2
- Transceiver transmits at 433mhz at 100mW

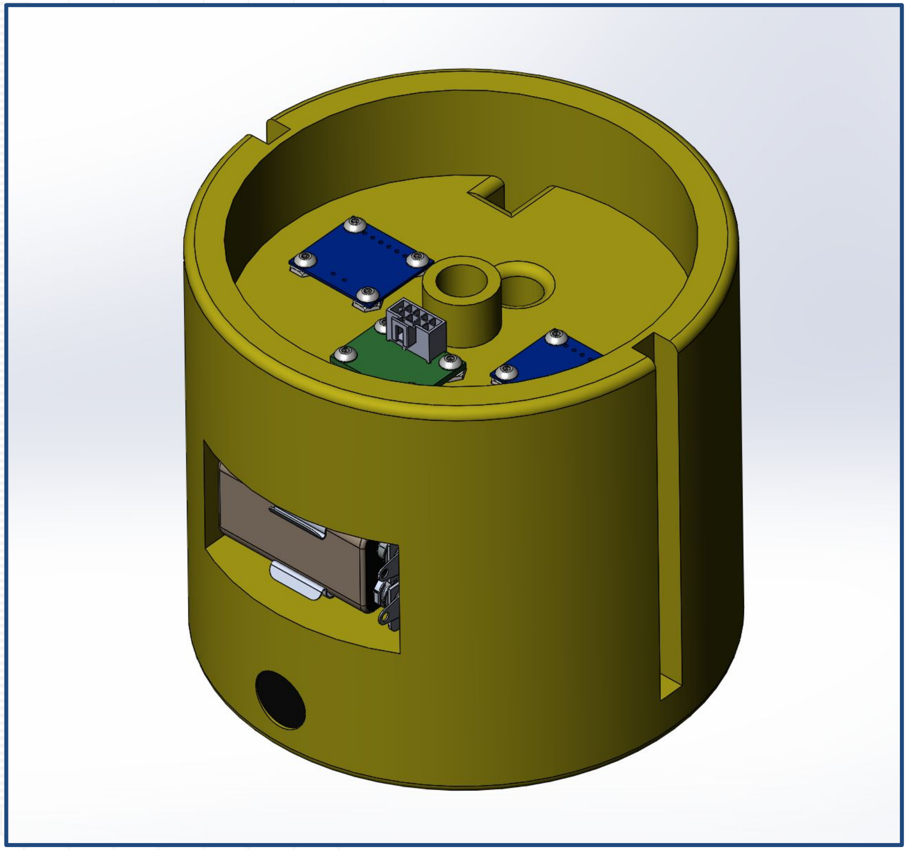


ATS Section Housing

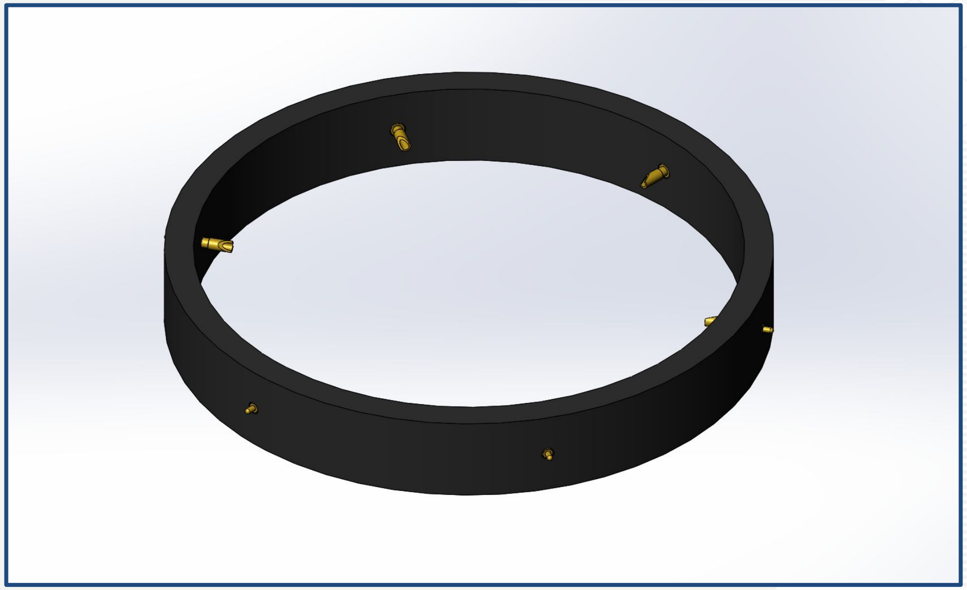


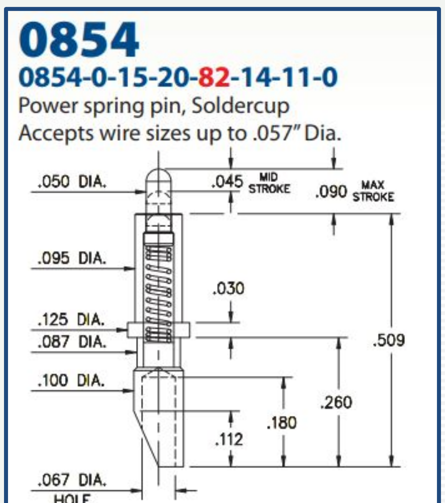
Avionics Section Housing

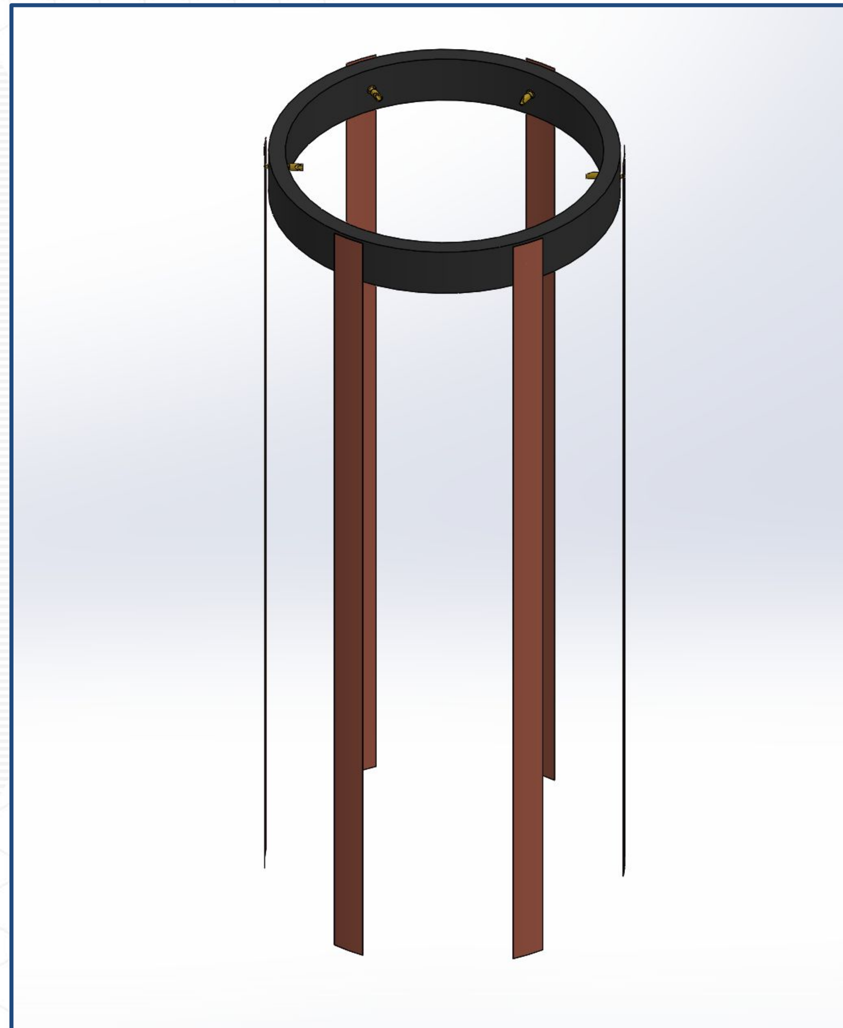




Pogo Contact Assembly







Test Plans and Procedures

Test Plans and Procedures

By utilizing the requirements given by NASA the team was able to derive additional requirements and subsequent tests to verify each requirement.

Such tests are scheduled for the future and greater detail in the CDR document.

Requirement Tested	Test Description	Pass/Fail Criteria	Status
Rover is not damaged by vibrations/landing	Rover will be enclosed in bay, and dropped from heights of 1 and 2 stories	Critical rover systems will remain intact after test	Incomplete
The rover must deploy in the proper orientation	The deployment system will be triggered in several different orientations, three times each.	The rover will deploy in the proper orientation for all tests	Incomplete
The rover can deploy regardless of rocket orientation	The rocket will be placed in several roll orientations. Each test will be conducted three times.	The rover will be successfully deployed at least 7/9 times, with no more than 1 unsuccessful deployment per orientation	Incomplete

Requirement Tested	Test Description	Pass/Fail Criteria	Status
Rover is not damaged by vibrations/landing	Rover will be enclosed in bay, and dropped from heights of 1 and 2 stories	Critical rover systems will remain intact after test	Incomplete
The rover must deploy in the proper orientation	The deployment system will be triggered in several different orientations, three times each.	The rover will deploy in the proper orientation for all tests	Incomplete

Requirements Verification

Requirements Verification

Team has taken into account the NASA given requirements and derived several requirements in addition.

The requirements guided the implementation of the design features and creation of success criteria .

More detail is available in the CDR document.

Requirement	*Approach*	*Requirement Verification*	*Success Criteria*
The vehicle will safely deliver the payload (deployable rover) to an apogee altitude of 5,280 feet AGL and return to ground	The motor will overshoot the rocket beyond target apogee of 5,280 ft and the ATS system will retract in response to the altimeter reading to reduce the apogee	Gathering data from flight altimeter after test launch	The vehicle reaches the apogee within 2%
The vehicle will carry altimeters to record data of the rockets ascent	The avionic bay will be housing two altimeters for recording the ascent	Inspection	Altimeter records data during flight
Each altimeter will be armed by a dedicated switch accessible from the outside of the rocket	Three key holes are made on the avionics bay which make the switch accessible from the exterior	Inspection	The altimeters are turned on by the key rotation

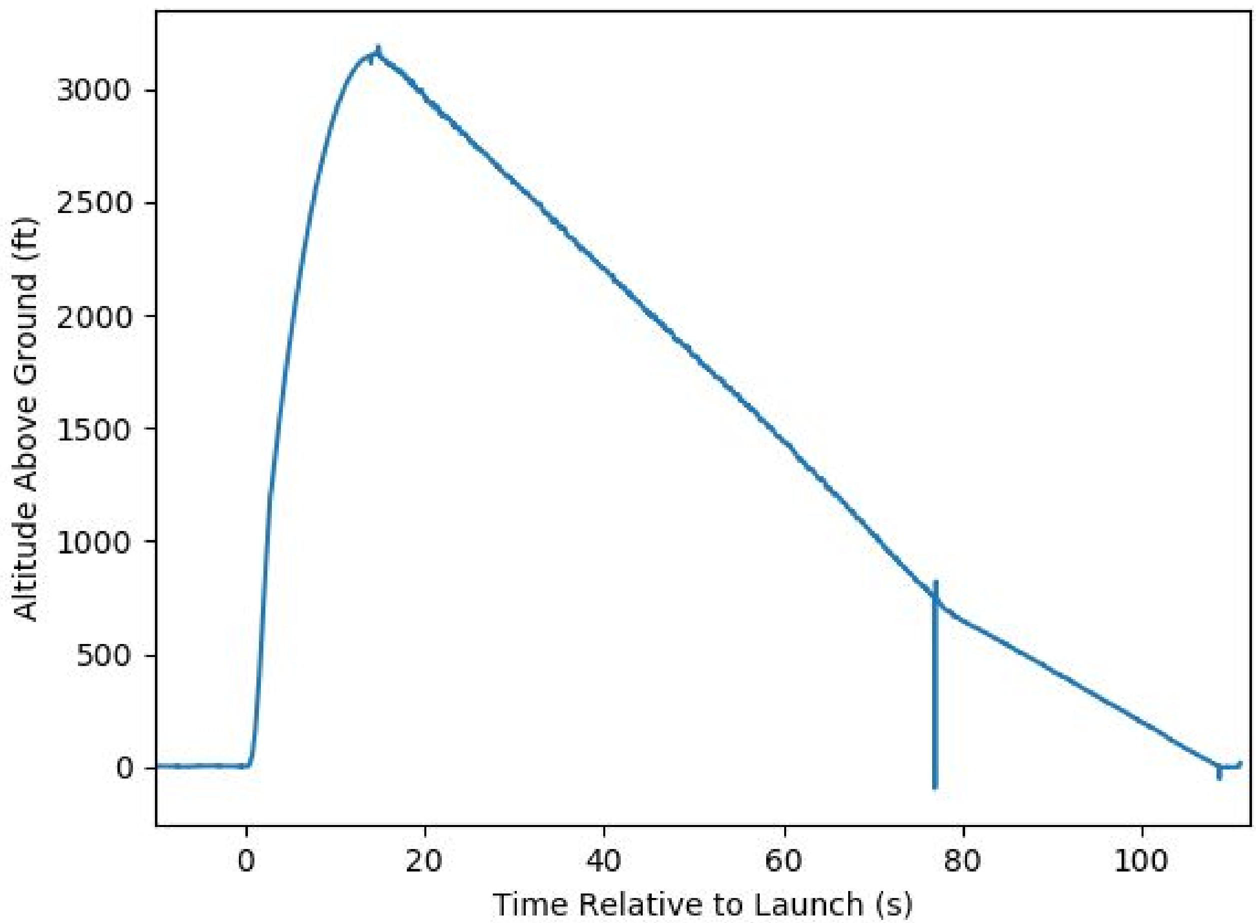
Requirement	*Approach*	*Requirement Verification*	*Success Criteria*
Each team will use a launch and safety checklist	The safety officer will be responsible to enforcing the safety checklist	The team will check that the safety officer has a safety checklist before launches	The safety checklist is used before every launch
Teams will abide by rules and guidance of the local rocketry club's RSO	The safety officer will communicate with the local rocketry club to ensure everybody is following the rocketry clubs rules	The local rocketry club will be contacted before launch to ensure Georgia Tech's rocket follows protocol	All rocketry club's rules are followed
Teams will abide by FAA rules	The safety officer will ensure the team is abiding by all FAA rules	Inspection	All FAA rules are followed

Subscale Flight

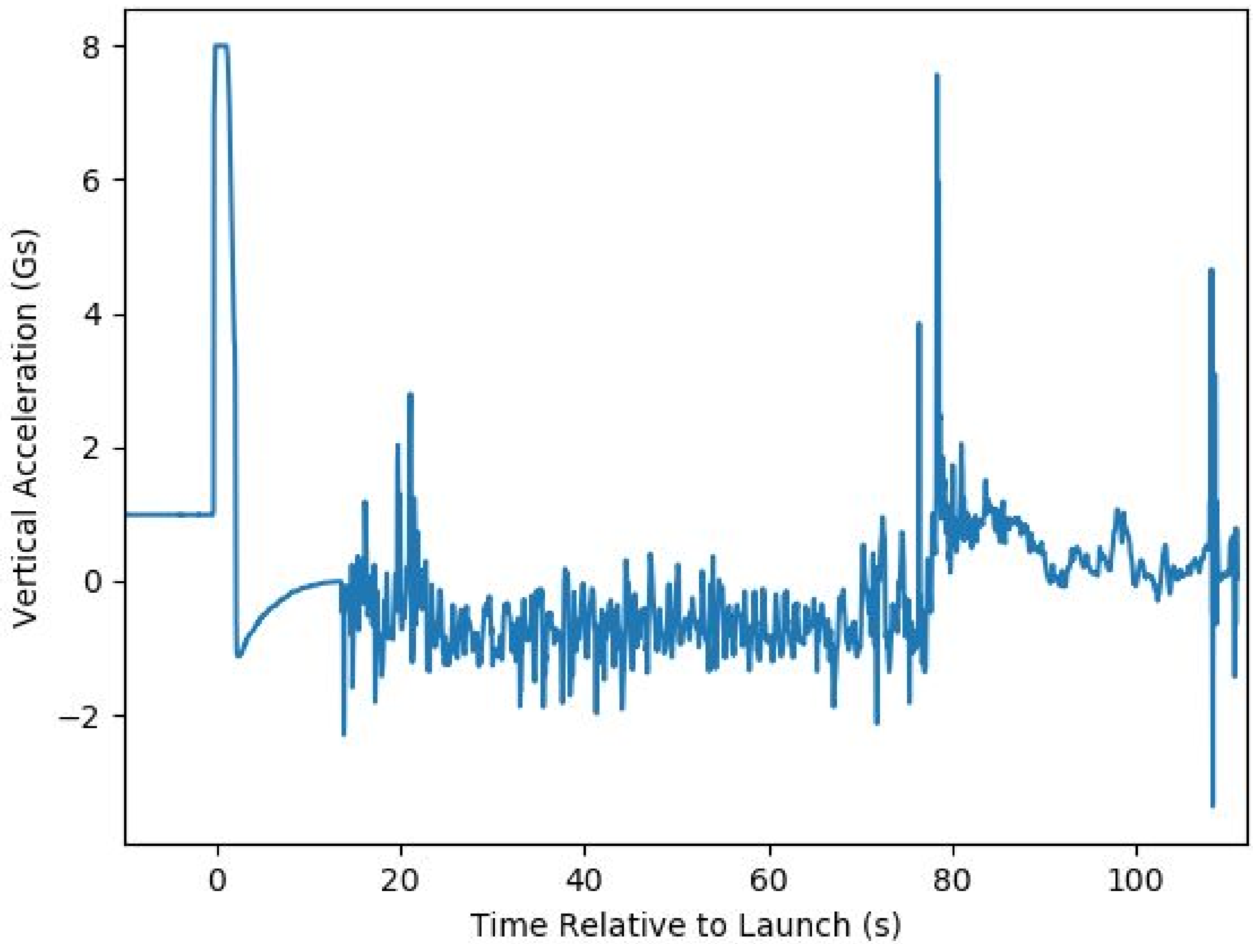
Subscale Flight Overview

- Launch conducted November 18th, 2917 in Talladega, AL
- Successful launch with proper testing of all essential rocket hardware, avionics, and recovery systems
- Rover deployment system ground testing conducted
- ATS did not deploy properly due to software error (hardware later tested on ground and confirmed fully operational)

Subscale Flight Data Analysis



Subscale Flight Data Analysis (cont.)



QUESTIONS?

2017-2018 NASA STUDENT LAUNCH

PRELIMINARY DESIGN REVIEW

NOVEMBER 13TH, 2017

CREATING THE NEXT®

Appendix A - Launch Checklist

Prepare Rocket Payload	
	Ensure all batteries are new/fully charged and connect to system electronics.
	Ensure vital electronics are all connected correctly to each other and running properly.
	Ensure recovery system is wired redundantly and correctly. Ensure again.
	Insert payload electronics into the avionics bay.
	Connect all external switches and motor control outputs.
	Arm altimeter and ensure that proper startup sequence follows.
	Disarm Altimeter.
	Arm apogee targeting system and verify that startup run as expected.
Prepare Rover	
	No rover for the subscale launch
Assemble Charges	
	Remove protective cover from e-match
	Place tape adhesive side up in fishtail shape >
	CAUTION: Black powder is highly flammable. Before measurement, make sure to keep away from all sources of flame and heat
	Measure amount of black powder decided in ejection charge testing using tared massing scale
	Place e-match on tape with adhesive side up at center of fishtail
	Pour black powder over e-match
	Seal tape in square pattern
Check Chute Connections	
	Ensure altimeters are disarmed
	Connect charges to ejection wells
	Turn on altimeters to verify continuity
	Disarm altimeters

Pack Parachutes	
	Connect ends of drogue shock cord to Booster and Avionics sections
	Attach drogue parachute to drogue shock cord using quick-link carabiner or bowline knot
	Fold parachute over itself until appropriate thickness is achieved
	Fold cord between carabiner and parachute over folded parachute
	Roll parachute tightly sleeping-bag style
	Insert rolled parachute into compartment between booster section and avionics bay
	Fold excess shock cord so it does not tangle
	Attach Nomex cloth to shock cord so it will enclose and shield the parachute while exposing only the Kevlar shock cord to ejection charge
	Ensure that parachute + cloth moves easily in/out of tube. If there is any undue resistance, remove parachute and repack tighter
	Insert cellulose wadding into drogue parachute bay between ejection charges and parachute
	Insert Avionics bay into Booster section, and secure with 4 shear pins
	Attach main parachute shock cord to eye-bolt on upper end of Avionics bay and U-bolt on bottom end of nose-cone
	Attach main parachute to main parachute shock cord via quick-link carabiner or bowline knot
	Fold parachute over itself until appropriate thickness is achieved
	Fold cord between carabiner and parachute over folded parachute
	Roll parachute tightly sleeping-bag style

Appendix A - Launch Checklist

	Ensure that parachute + cloth moves easily in/out of tube. If there is any undue resistance, remove parachute and repack tighter
	Insert cellulose wadding into main parachute bay between ejection charges and parachute
	Insert main parachute and shock cord into main parachute bay between avionics bay and nosecone section
	Fold excess shock cord so it does not tangle
	Attach Nomex cloth to shock cord so it will enclose and shield the parachute while exposing only the Kevlar shock cord to ejection charge
	Insert cellulose wadding into upper payload parachute bay between ejection charges and parachute
	Secure avionics bay and upper tube with 4 shear pins
Assemble motor	
	Note: Do not get grease on propellant grains or delay grain
	Note: Do not install igniter
	Follow manufacturer's instructions
	Note: ensure the motor remains vertically oriented until launch
	Unscrew motor retention cap and, while the rocket is in the upright position, slide in the assembled motor.
	Screw in motor retention cap to keep motor secure in rocket
	Check screws securing baseplate to the Booster tube to ensure they are not loose. If loose, apply a small amount of blue loctite and retighten

Launch Vehicle Prep	
	Inspect launch vehicle, check CG and make sure it is within specified range
	Bring launch vehicle to Range Safety Officer(RSO) for inspection
	CAUTION: Keep igniter clips away from all flammable materials, as sparking will occur. Cover eyes, and skin to prevent burns.
	Touch igniter clips together to make sure they will not fire the igniter when connected
	Connect igniter clips to motor igniter
Launch	
	Watch flight so launch vehicle sections do not get lost
Post Launch Payload/Vehicle Recovery	
	Use GPS (eggfinder tx) to locate launch vehicle
	Recover Payload Section and tethered Body/Booster Section
	Disarm Altimeters if there are unfired charges
	Disassemble launch vehicle, clean motor case, other parts, and inspect for damage
	Record altimeter data

Appendix B - Launch Preparation Procedures

Title: Launch Motor Preparation

Procedure

1. Delay Grain Assembly
    a. Without touching the ends of the delay grain, place the grey propellant cylinder into the delay insulator
    b. Slide this assembly into the delay spacer
    c. Grease the o-ring with synthetic teflon lube and place overexposed section of propellant grain
        ■ Be careful not to get any grease on the end of the propellant grain
2. Assembly of Delay Grain into FWD Closure
    a. Grease the inside of the fwd closure, make sure to clean the small hole if it become filled with grease in this step
    b. Place neoprene washer at the bottom on the well
    c. Press the delay grain assembly into the well, o-ring-side entering first
    d. Grease the main fwd o-ring, and place over the end of the fwd closure
3. Liner Insertion into Main Casing
    a. Slide liner into casing, check to ensure that it slides smoothly
        ■ If not, maybe have to sand down liner
    b. After ensuring fit, pull out liner, thoroughly grease the outsides, and push back in, wiping grease as it builds up around the edge. Leave .5” exposed
        ■ Do not grease if liner is black phenolic
    c. Place an insulator disk on top of the exposed liner, and push in until internal threads are exposed
    d. Screw on FWD closure assembly so that o-ring presses against the insulator disk
4. Grain Assembly into Casing
    a. Stand motor on FWD closure
    b. Pull liner out .5”
    c. Without touching the ends of the grain, drop the two propellant tubes into the liner
    d. Press insulator disk on top, and push down until liner stops moving
5. Aft Closure Assembly
    a. Place the nozzle into the hole
    b. Place a greased o-ring into casing, over the nozzle, so it sits on top of the insulator disk
    c. Screw the aft closure over the nozzle/o-ring
6. Final Steps
    a. Place the plastic nozzles over the aft and fwd closures

Min Personnel Requirements: 2 people
Materials (ref 3.6. Material Handling)
- Aluminum particles
- Ammonium perchlorate
- Iron oxide

Safety Equipment Required
- Safety glasses
- Latex/Nitrile gloves

Safety Officer Signature: ______________________________

Appendix B - Launch Preparation Procedures

Title: Folding and Packing Parachutes

Procedure

1. Folding Parachute
    a. "Fluff", or lay out, chute on a flat surface
    b. Straighten the lines so they come to a point away from the chute
        i. Untangle lines if tangled
    c. Grab all shroud lines and organize the panels of the chute
    d. Fold on the panel lines toward the center
    e. Continue folding until width is approx 2X length you desire it occupy in the rocket
    f. Bring shroud line bundle up through center, then fold over and pull back down so a small length lies outside the parachute
    g. Fold one more time, over the shroud lines
    h. Wrap up the chute from the tip, tightly packing as you go
2. Attaching to Shock Cord
    a. Tie a knot in the shock cord line, about ⅓ the length from the connection point to the above section
    b. Use a quicklink to connect the knotted loop to the end of the shroud lines sticking out of the packed parachute
3. Assembling into Tube
    a. Thread a kevlar parachute protector sheet over the shock cord until it reach the parachute (in its packed form still)
    b. Have another person bundle up the shock cord to one side of the parachute in a figure 8 pattern
    c. Push the bundled shock cord and packed parachute (now partially covered by the kevlar sheet) into the tube and push until it hits the bulkhead on the other end
    d. Bundle the shock cord on the other end of the parachute in a similar way and shove into tube
    e. Connect the two sections of the rocket to encapsulate the parachute+shock cord assembly in between the two sections of the rocket

Safety Officer Signature: ______________________________

Min Personnel Requirements: 2 people
Materials (ref 3.6. Material Handling)

- Nylon parachute
- Kevlar sheet
- Nylon shock cord

Safety Equipment Required

- N/A

Appendix B - Launch Preparation Procedures

Title: Shear Pin / Rivet Installation

Procedure

1. Shear Pin Installation
    a. Assemble rocket
    b. Using permanent marker, create two “witness marks” across the separation line between two sections of the rocket (for consistent future orientation)
    c. Drill X number of 1/16” dia holes, equally spaced, around the perimeter of the tube
        i. Ensure that sections do not “wiggle” while drilling holes as may cause misaligned of previously drilled holes
        ii. Ensure that rocket tube is empty before drilling, as there is a high risk of drilling into parachute or shock cord and causing damage
    d. If tube is paper: place drop of glue inside to stiffen the walls of the hole
    e. If tube is hard (fiberglass, carbon fiber): tap the hole to create threads for the plastic screw, aka “shear pin”
    f. Thread or push shear pins into holes after aligning with the “witness marks”
2. Shear Pin Removal
    a. unscrew /pry out head of shear pin
    b. Use small drill bit to push in the other section of the pin lodged in the hole of the inner tube
3. Rivet Installation
    a. Repeat steps a & b from “Shear Pin Installation”, above
    b. Drill X number of 11/64” holes, equally spaced, around perimeter of tube
        i. Ensure that sections do not “wiggle” while drilling holes as may cause misaligned of previously drilled holes
        ii. Ensure that rocket tube is empty before drilling, as there is a high risk of drilling into parachute or shock cord and causing damage
    c. Assemble rocket sections
    d. Push shear pins into each of the holes
    e. Push heads of pins into the hole on top of each pin until it stops
4. Rivet Removal
    a. Pull head out of rivet
        i. May require flathead screwdriver to pry out
    b. Pry out rivet body

Safety Officer Signature: ______________________________

Min Personnel Requirements: 1 person
Materials (ref 3.6. Material Handling)

- Fiberglass (depending on tube material)

Safety Equipment Required

- Safety glasses
- >P90 Respirator (if fiberglass tubing used)
- Safety gloves (if fiberglass tubing used)

Appendix B - Launch Preparation Procedures

Title: Ejection Charge Assembly and Testing

Assembling Charges

1. Sizing Charges
   a. Using body tube diameter, and length of parachute sections, utilize online ejection charge calculator to estimate the amount of black powder needed
      i. Note: 4-shear pin design requires approx 40lb shear force to break
      ii. Using P = F / A, calculate the pressure needed to cause an appropriate shear force
      iii. Use F = P * A to calculate the force on the bulkheads during ejection events
2. Bagging and Storage
   a. Black powder is plastic-safe, but easily corrodes metals, so be sure to store in a plastic container
   b. Black powder must be stored in a dry environment so ensure water-seal
3. Placing in Vehicle
   a. With the ejection wells oriented upward, carefully pour the black powder into each well
   b. With the leads twisted together, place an e-match in each well so that the igniter lies inside the black powder
   c. Pack fiberglass insulation into the well and place a strip of tape over the top to keep the assembly packed inside the well
   d. Untwist the leads on the e-matches, and place them into the correct holes in the terminal block on the bulkhead
   e. Screw down the wires to secure them into the terminal block

Min Personnel Requirements: 2 people
Materials (ref 3.6. Material Handling)

- FFFF Black Powder
- Fiberglass insulation
- 9V Battery

Safety Equipment Required

- Safety glasses
- Latex/Nitrile gloves
- P95 Respirator Mask

Appendix B - Launch Preparation Procedures

Testing Charges

1. Lead Extension
   a. Measure out two strips of at least 5 ft long 22 AWG wire, preferably of different colors
   b. Strip end of wire
   c. Route ends of wire into respective holes in terminal block to connect to one of the e-matches connected to the other end of the terminal block
2. Vehicle Assembly
   a. Route the extension wires out of an access hole
   b. Close sections of rocket, with parachutes packed inside and protected with kevlar sheets
   c. Insert shear pins
3. Vehicle Positioning
   a. Position vehicle so it lies on its side
   b. Ensure the bottom is placed against a wall, or other solid surface
   c. Ensure the trajectory is clear of obstacles
   d. Angle rocket slightly so nose does not aim toward the ground
   e. Preferably tested outside on grass to prevent damage to tubes during impact
4. Personnel Hazard Mitigation
   a. Test outside, in an open space (>50 ft radius without other people or obstacles around)
   b. Stand at least 5 ft away from the vehicle, to its side, when shorting the leads to create the ejection event
   c. Make sure there are no loose object in the compartments that are undergoing ejection charge testing to minimize risk of ejecting solid objects at high velocities away from the rocket
   d. Have a fire extinguisher nearby in the case that a fire results from the ejection event
5. Test
   a. Standing >5 ft to the side of the vehicle, short the leads of the extension wire across a 9V battery
   b. Watch for flames
   c. Wait approximately 30s before touching components of rocket, as they may be hot

Safety Officer Signature: ______________________________

Appendix C: Fabrication Task Breakdown

#	Task Description	DONE ?	Material Handled	Fabrication Techniques	Est. Time	Fabrication Locations	Safety Precautions
1	3D Print Servo Brackets	NO	PLA/ABS	3D Printer	< 1hr	Inv Studio / AE MakerSpace	N/A
2	Cut Motor Tube to Length	NO	Cardboard	Chop Saw	< 1hr	Inv Studio / SCC	N/A
3	Cut Tubing to Length	NO	Fiberglass	Chop Saw	< 1hr	Inv Studio	2 ppl, shop vac, N95/P95 mask
4	Drill Shear Pin Holes (8)	NO	Fiberglass	Drill	< 1hr	RR room / Inv Studio	2 ppl, shop vac
5	Drill Rivet Holes (4)	NO	Fiberglass	Drill	< 1hr	RR room / Inv Studio	2 ppl, shop vac
6	Drill wire routing holes into bulkheads/centering rings	NO	Fiberglass	Drill	< 1hr	RR room / Inv Studio	2 ppl, shop vac
7	Drill Holes for Bottom Plate	NO	6061 Aluminum	Drill	< 1hr	RR room / Inv Studio	
8	Slots into Body Tubing	NO	Fiberglass	Jigsaw/Bandsaw/Chop Saw	2 hrs	Inv Studio / SCC	2 ppl, shop vac, N95/P95 mask
9	Cut out Thrust Plate	NO	Plywood	Laser Cutter	< 1hr	Inv Studio / AE MakerSpace	N/A
10	Fin Features for Brackets	NO	Fiberglass	Mill	1-2 hrs	BME Shop	2 ppl, shop vac, N95/P95 mask
11	Features for Brackets	NO	Fiberglass	Mill	1-2 hrs	BME Shop	2 ppl, shop vac, N95/P95 mask
12	Flats into Shafts	NO	1024 Steel	Mill/Grinder	1-2 hrs	Montgomery MM	N/A
13	Fin Brackets	NO	6013 Aluminum	Waterjet	1-2 hrs	Inv Studio / SCC	N/A
14	Avionics Bay Tray Brackets	NO	6013 Aluminum	Waterjet	1-2 hrs	Inv Studio / SCC	N/A
15	Fins Cut Out	NO	Fiberglass	Waterjet	2 hrs	Inv Studio	N/A
16	Avionics Bay bulkheads (2 coupler, 2 body)	NO	Fiberglass	Waterjet	1-2 hrs	Inv Studio	N/A
17	Cut Out Bottom Plate	NO	6061 Aluminum	Waterjet	1-2 hrs	Inv Studio / SCC	N/A
18	Cut Out Bevel Ring Gear	NO	6061 Aluminum	Waterjet	1-2 hrs	Inv Studio	N/A

Appendix C: Fabrication Tasks Breakdown

19	Cut Out Flaps	NO	6061 Aluminum	Waterjet	1-2 hrs	Inv Studio	N/A
20	Set Screws for gears / servo hub attachments	NO	Brass / Aluminum	Drill, Saws, etc...	2 hrs	Anywhere you can	N/A
21	Cut servo hub to length	NO	Aluminum		<1hr	Inv Studio	N/A
22	Drill gears bore diameter	NO	Brass	Drill	<1hr	Inv Studio	N/A
		NO					
21	Epoxy Fins + Centering rings to Motor Tube	NO		Booster			
22	Epoxy Thrust Plate Inside Body Tube	NO		Fins			
23	Assemble Avionics Bay (Tray, brackets, threaded rods, nuts)	NO		Avionics Bay			
24	Nose Cone Weight	NO		Recovery			
25	GPS Bay Epoxy	NO		Fin-Roll Mechanism			
26	Bottom Plate Brackets Installed	NO					
28	Motor Measured Out + Dimensional Sketch of Booster ASSY	NO					
29	GPS Bat ASSY (PVC fitting + Ubolt)	NO					
30	GPS Bay Epoxied	NO					
31	Fins Epoxied to Tubing (Nice, LARGE Fillets)	NO					
32	Shock Cord Cut to Length	NO					
33	Parachute Attached to Shock Cord & Quick Links	NO					
34	Ejection Charges Created	NO					
35	ATS System ASSY	NO					
36	Ground Ejection Test (main)	NO					
37	Ground Ejection Test (drogue)						