Georgia Tech

GIT LIT

2017-2018 NASA STUDENT LAUNCH

FLIGHT READINESS REVIEW

MARCH 13TH, 2017

CREATING THE NEXT®

AGENDA

1. Project Plan Update (5 Min)
2. Launch Vehicle Design (10 min)
3. Payload - ATS (6 Min)
4. Payload - Rover (7 Min)
5. Flight Systems (5 Min)
6. Full-Scale Flight (7 Min)
7. Requirements and Verifications (5 Min)
8. Questions (15 Min)

Project Plan Update

Payload Update

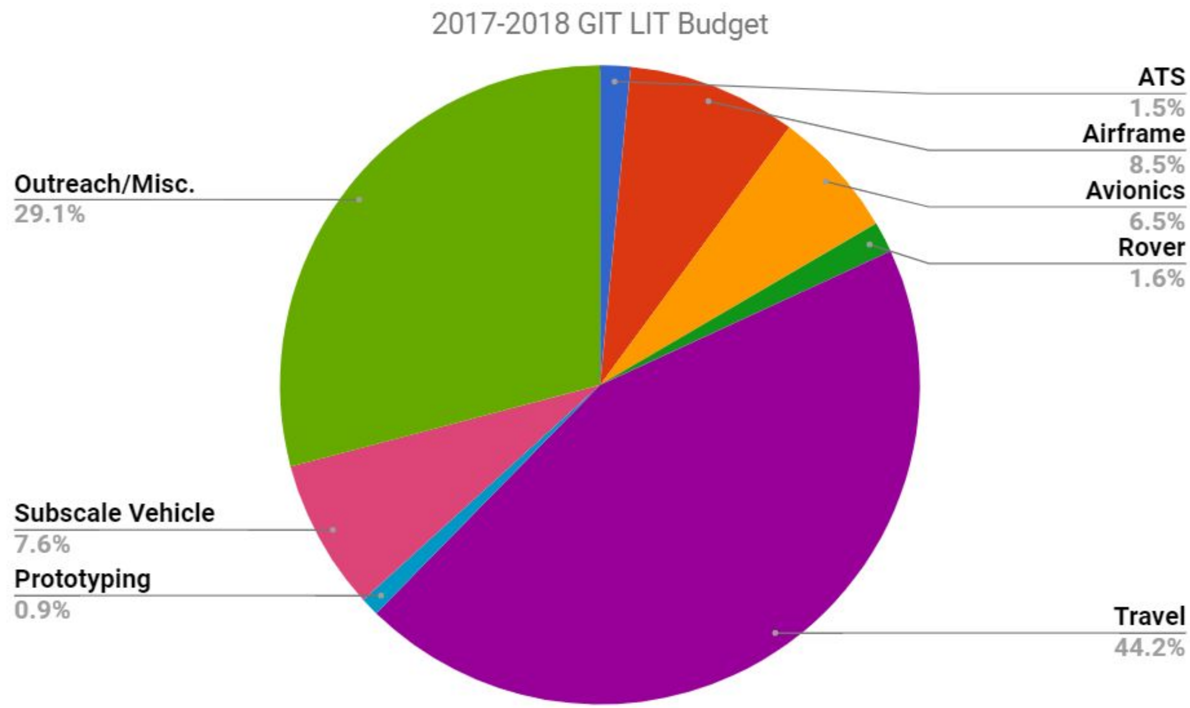
- ATS and Rover will be flown as inactive payloads for mass purposes
  - Incomplete assembly and testing for full scale rocket
  - Priority placed on construction and assembly for flight critical systems

Educational Outreach

1. Peachtree Charter Middle School
2. Boy Scout Merit Badge: **Robotics!**

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	$300	April 2018
Total	**$9,775.23 (est.)**	

CDR Action Items

- Ensure that drift will be under 2500 ft in 20 mph when calculated in the manner you used for your "hand calculations"

Launch Vehicle

Final Launch Vehicle Dimensions

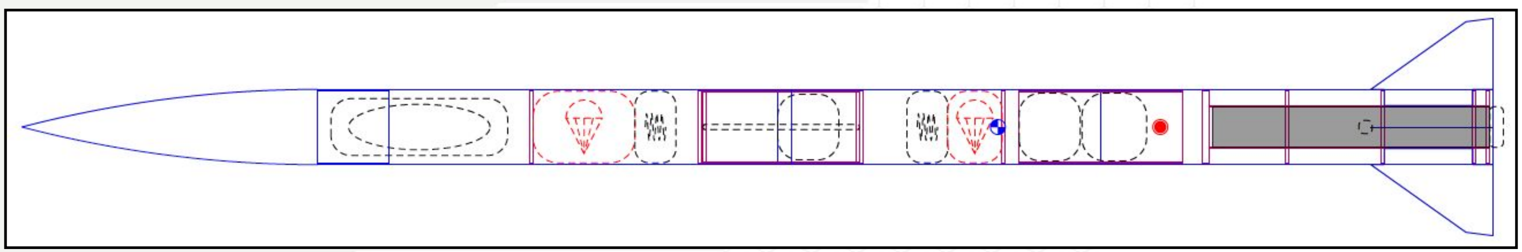
Overall Specifications

Property	Value
Overall length	108 in
Launch vehicle diameter	5.562 in
Overall mass with motor loaded	39.734 lb_m
Center of gravity (measured from nose cone)	71.926 in
Center of pressure (measured from nose cone)	83.764 in

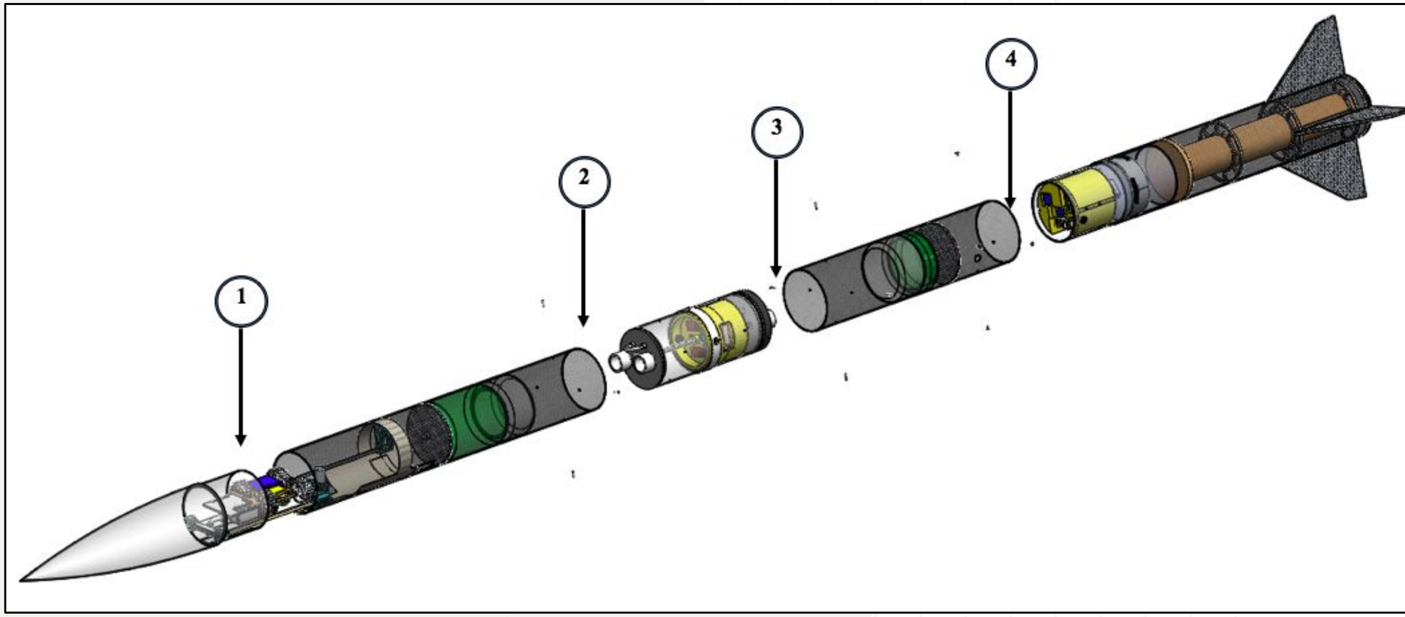
Mass Breakdown

Section	Mass (lb_m)	Length (in)
Nose Cone	1.050	21.75
Rover Housing	8.880	33.875
Avionics Bay	4.830	12
ATS Housing	3.650	22.75
Booster	21.324	28.875
Total	39.734	108

OpenRocket Model of Full Scale Launch Vehicle



Launch Vehicle Exploded View

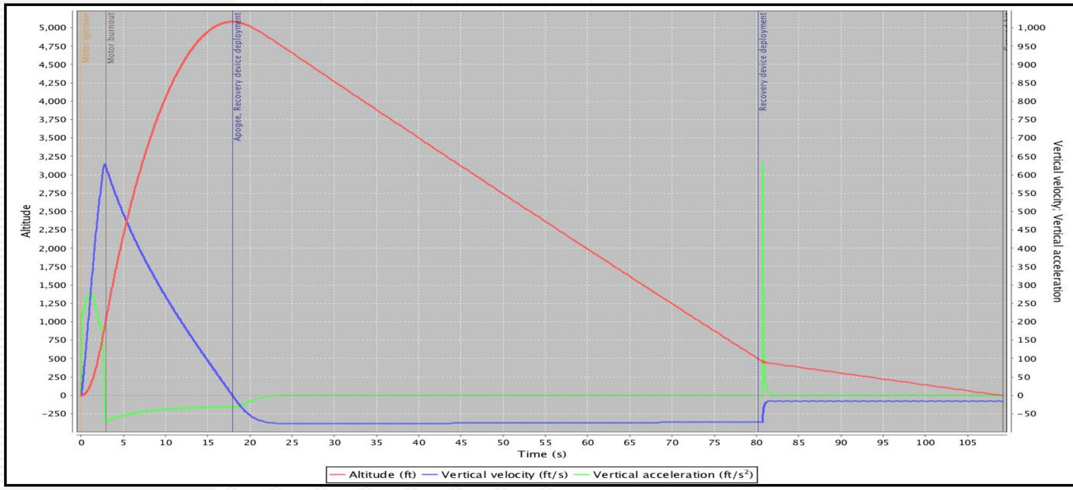


No.	Linkage mode	Separation Mechanism	Separation Event
1	Bracket from rover deployment system	Rover deployment system pushing the nose cone out of the rover housing	Post-landing (Rover deployment)
2	2-56 nylon shear pins	Pressure produced by ejection charge breaking the shear pins	Main parachute deployment
3	2-56 nylon shear pins	Pressure produced by ejection charge breaking the shear pins	Drogue parachute deployment
4	Removable plastic rivets	N/A	N/A

Flight Ascent Performance

Flight Performance

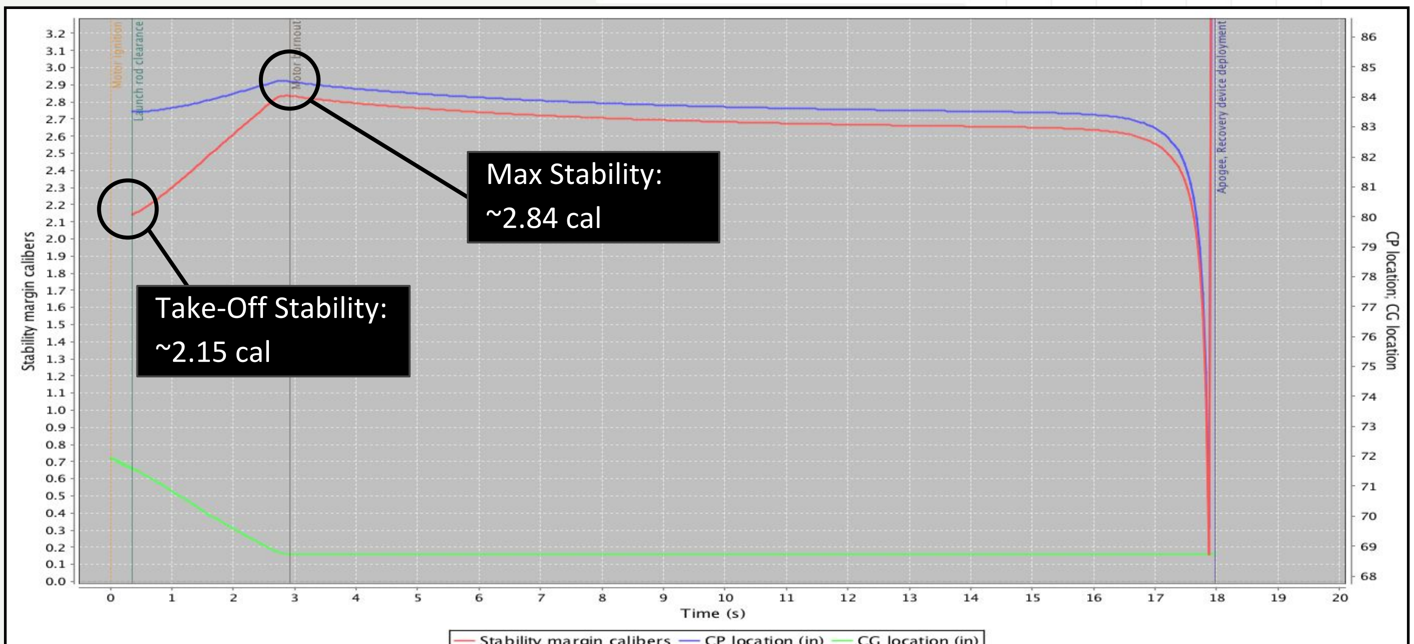
Flight Profile Behavior	Projected Values
Apogee	5081 ft
Rail Exit Velocity	73.8 ft/s
Maximum Velocity	628 ft/s
Maximum Acceleration	275 ft/s^2
Ground Hit Velocity	15.4 ft/s
Thrust-to-Weight Ratio	7.78 : 1
Center of Pressure (measured from nose cone)	83.764 in
Center of Gravity (measured from nose cone)	71.817 in
Static margin caliber	2.15



Flight Drift

Drift distance and apogee altitude under different wind conditions

Wind condition (mph)	Hand calculation predicted drift distance (ft)	Apogee altitude (ft)
0	0	5081
5	668	5073
10	1321	5043
15	1960	5028
20	2617	4999



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	0.75 Cd
Velocity at deployment	75.5 ft/s	11.2 ft/s

Shock cord specifications

Property	Value
Material	9/16 in Tubular nylon
Length	24 ft (Drogue) and 30 ft (Main)

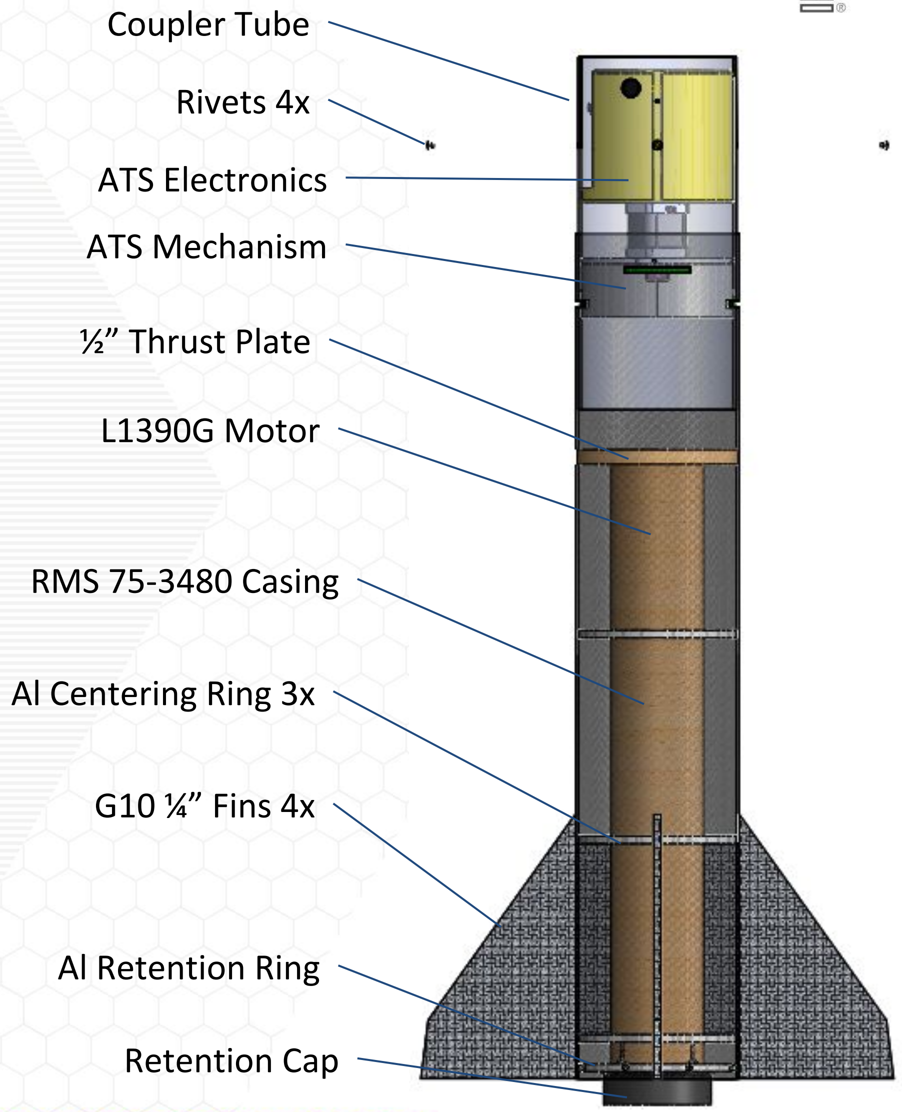
Kinetic energy at landing

Section	Value (ft-lb)
Nose cone + Rover housing	36.30
Avionics Bay	17.80
ATS + Booster	73.25

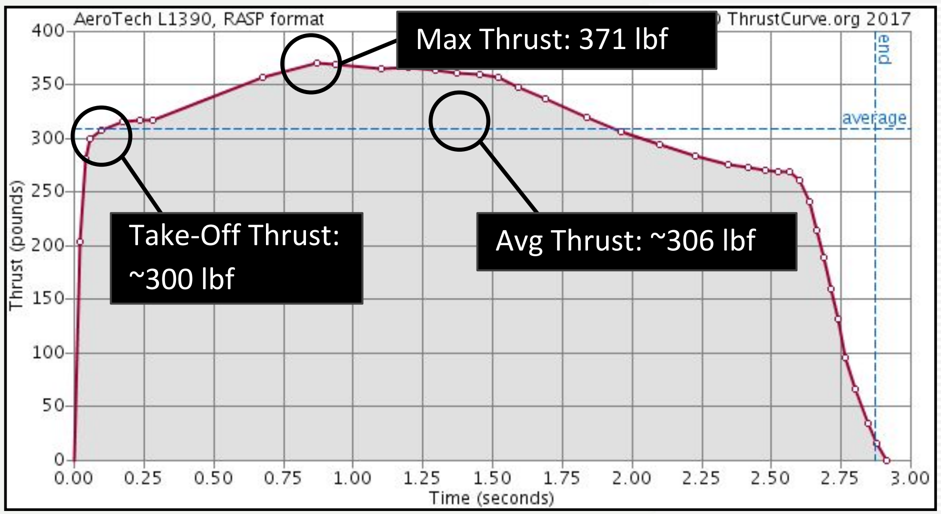
Booster Section Overview

Mass Breakdown by Component

Component/Subsystem	Material	Mass (lb_m)
Coupler tube	G12 fiberglass	1.30
Body tube (with rail button)	G12 Fiberglass	2.89
Thrust plate	Plywood	0.28
Motor mount tube	White kraft paper	0.50
Centering ring (x3)	6061-aluminum	0.13
Fin (x4)	G10 Fiberglass	0.58
Retention ring	6061-aluminum	0.36
Retention cap	N/A	0.26
Motor casing	N/A	4.35
Motor propellant	N/A	4.20
ATS mechanism	N/A	2.51
ATS electronics bay	N/A	1.38
Epoxy	Epoxy	0.58
Total		21.32



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

Summarized requirements

Requirement.	*Approach*	*Requirement Verification*	*Success Criteria*
The rocket should have a capability to reach 5,500 ft safely without the ATS system activated	The materials of each component as well as the dimensions are chosen so that the total mass of the vehicle is minimized	1.Analysis: Simulation based on OpenRocket and hand calculation will conducted so that the rocket will theoretically ascent 5,500 ft 2. Test: Several test flights without the ATS activated will be done to measure the apogee altitude without ATS activated	The rocket reaches an apogee of 5,500ft within 2% difference without ATS activated
The launch vehicle will have a stability margin greater than 2.2 at the point of rail exit	The vehicle equips four fins that produces enough aerodynamic forces to keep the stability margin high	Anaylsis: Simulation using OpenRocket will be conducted to predict the static stability margin at the point of rail exit	The launch vehicle's stability margin at point of rail exit is above 2.2
The centering rings, thrust plate, and the retention ring must have safety factor greater than 2	The materials as well as the designs of these components are chosen to minimize mass while maintaining safety factor above 2	1.Analysis: FEA using SolidWork's will be conducted for each component 2. Test: load test will conducted on the components	The factor of safety is in between 2 and 10

Vehicle test plans and procedures

Requirement Tested	Test Description	Pass/Fail Criteria	Status
Apogee altitude of 5,500 ft without ATS activation	Several test flights without the ATS fully activated will be done to measure the apogee	The rocket reaches an apogee of 5,500ft within 2% difference without ATS activated	Completed Failed
Recovery area of 2,500 ft	The launch vehicle will undergo several test flights to validate that it lands within 2500 ft radius from the launch pad	The rocket lands in the area less than 2,500 ft away from the launch pad	Completed Successful
Component load test	Load test of the centering ring, thrust plate, and bulkhead will be conducted to verify the FEA results that the component could withstand forces applied during the flight	The components do not break by the load applied	Completed Successful

Recovery Testing

Requirement Tested	Test Description	Pass/Fail Criteria	Status
Ejection Charge Testing	Ejection charges will be measured and loaded along with an electric match. Parachutes will be folded and packed. Electric matches will be ignited with a 9 volt battery and two long strands of wire.	The sections must separate cleanly forcefully. No damage must be present to any part of the rocket upon inspection.	Completed Successful
Continuity Check	A multimeter will be used to check continuity between the pyro outputs on the altimeters and the terminal blocks on the bulkheads.	No faults can be detected in the wiring. It must be shown that the proper pyro ports are wired to the correct terminals on the terminal blocks.	Completed Successful
Altimeter Code Check	Altimeter will be powered up. Error codes will be checked.	No critical error codes may be present. If an issue with the barometer is indicated by the error code, this constitutes an instant failure of the test.	Completed Successful
Visual Inspection	The recovery system(electrical components, wiring, parachutes, knots, hardware) will be checked for faulty workmanship.	Frayed wires, cold solder joints, frayed shock cord, improperly tied knots, and lack of lock-tight on critical hardware, constitute failure of this test.	Completed Successful

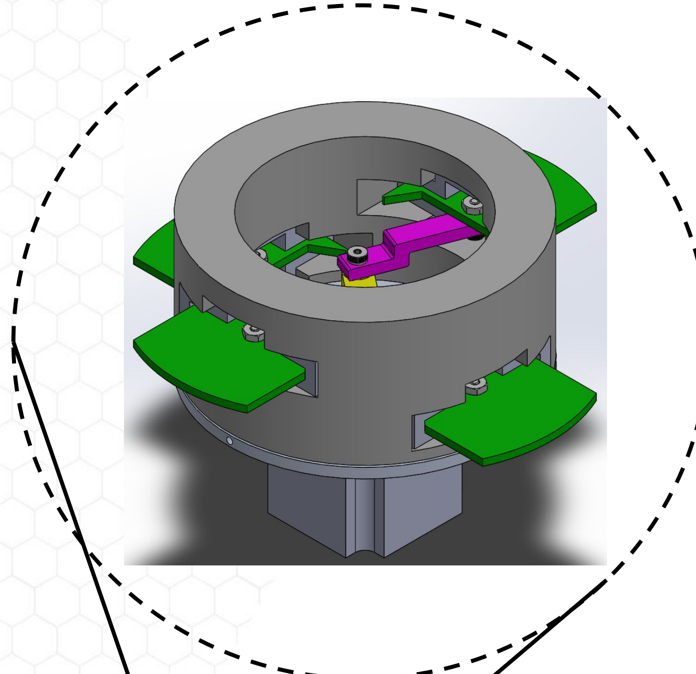
Payload - ATS

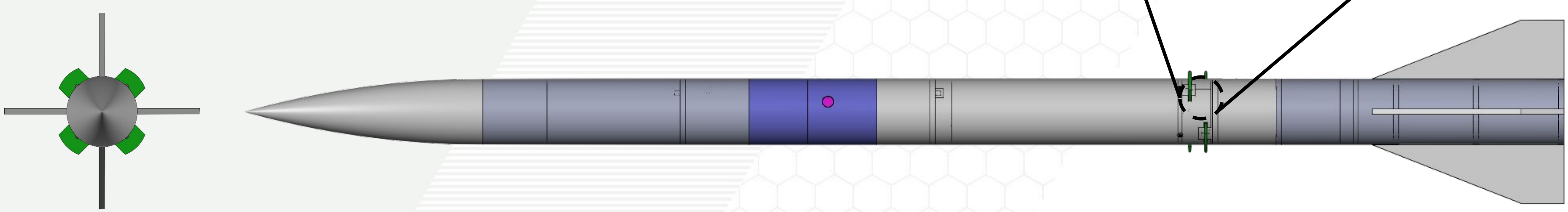
ATS Payload Overview

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

Net Weight	Mass of Mechanical System	Dimension (inches)
3.65 lbm	2.51 lbm	5.16' * 5.16' *4.79' (22.75')





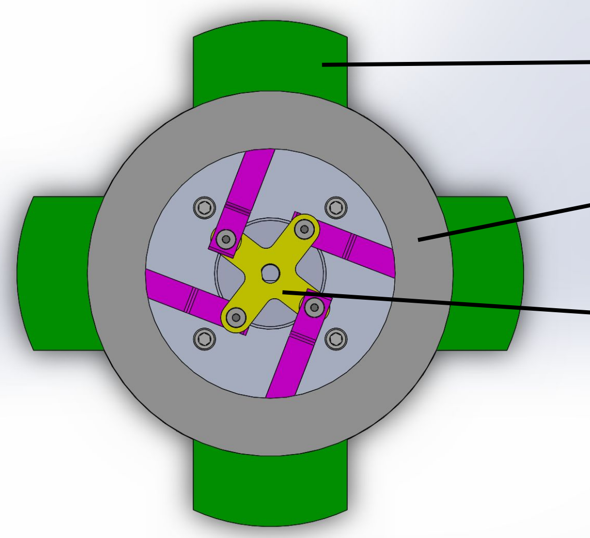
ATS Payload - Mechanics

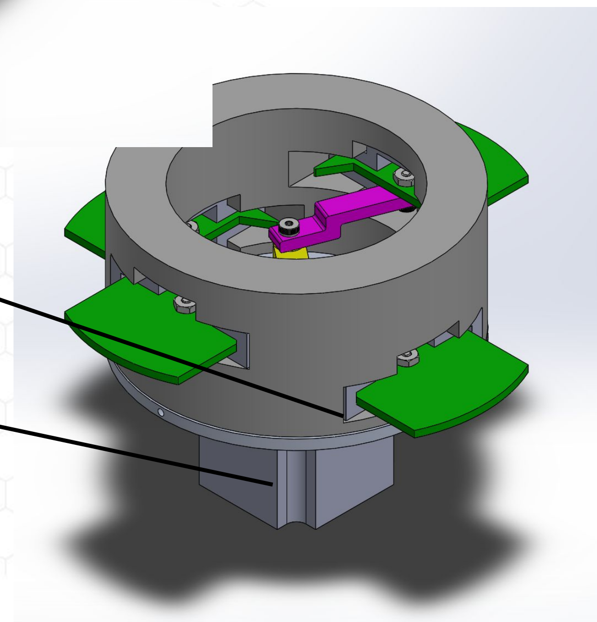
Linkage

- 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

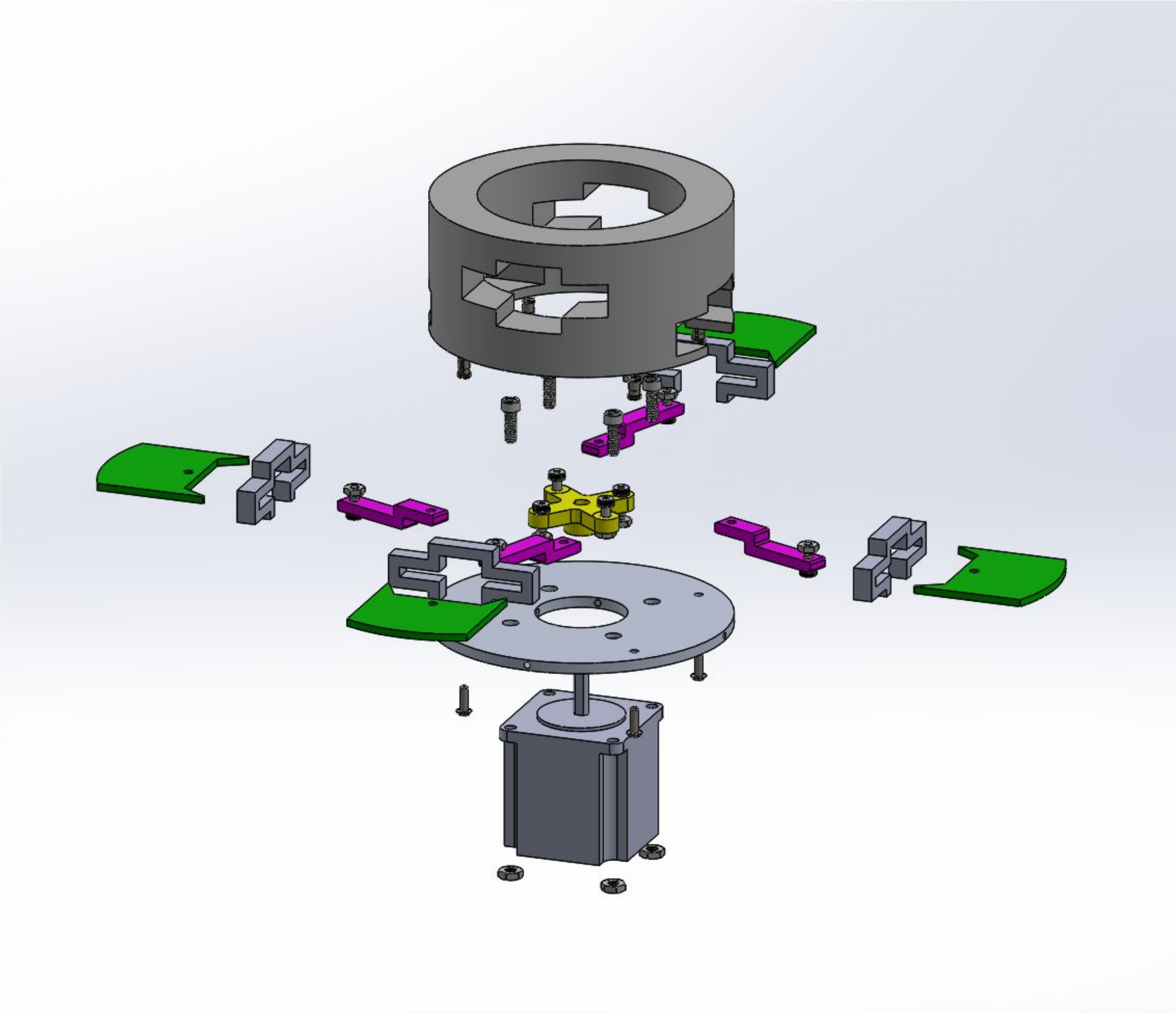
Bracket

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

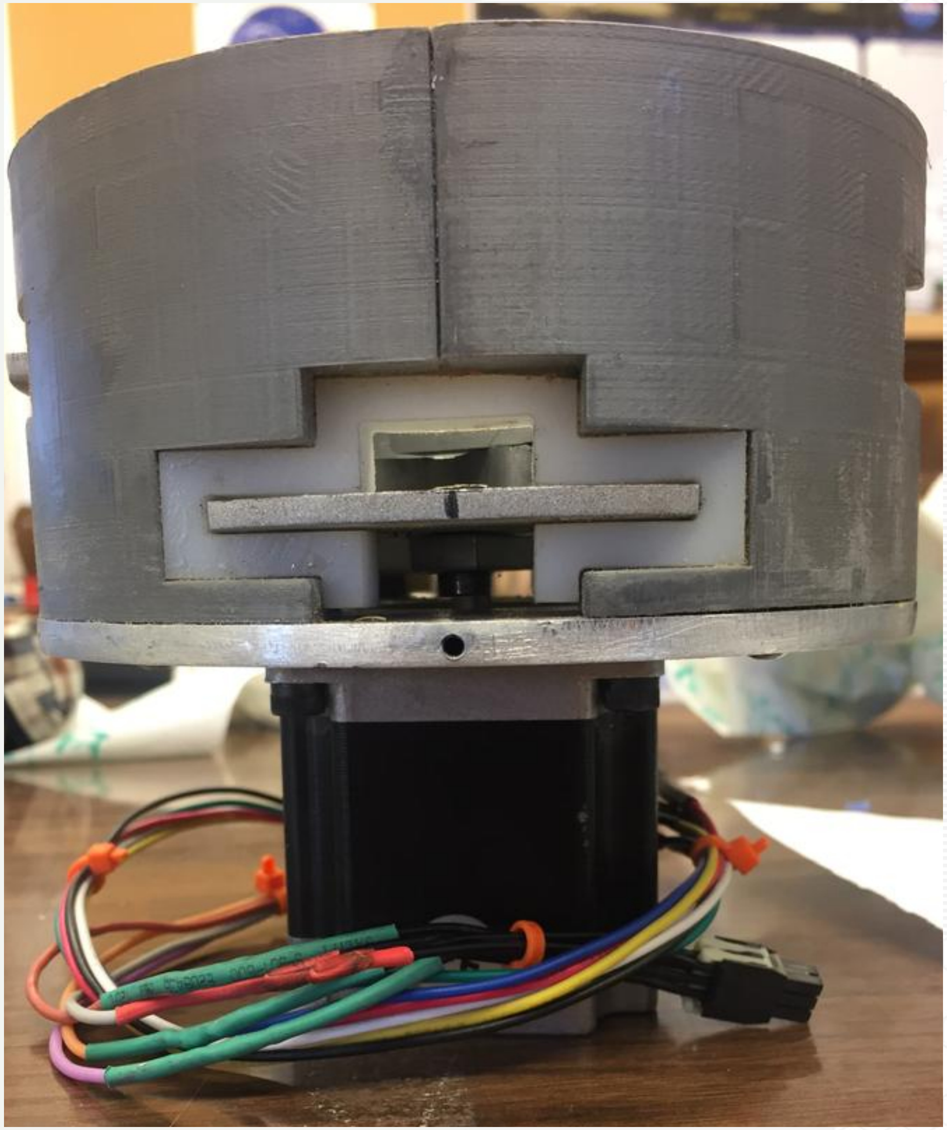




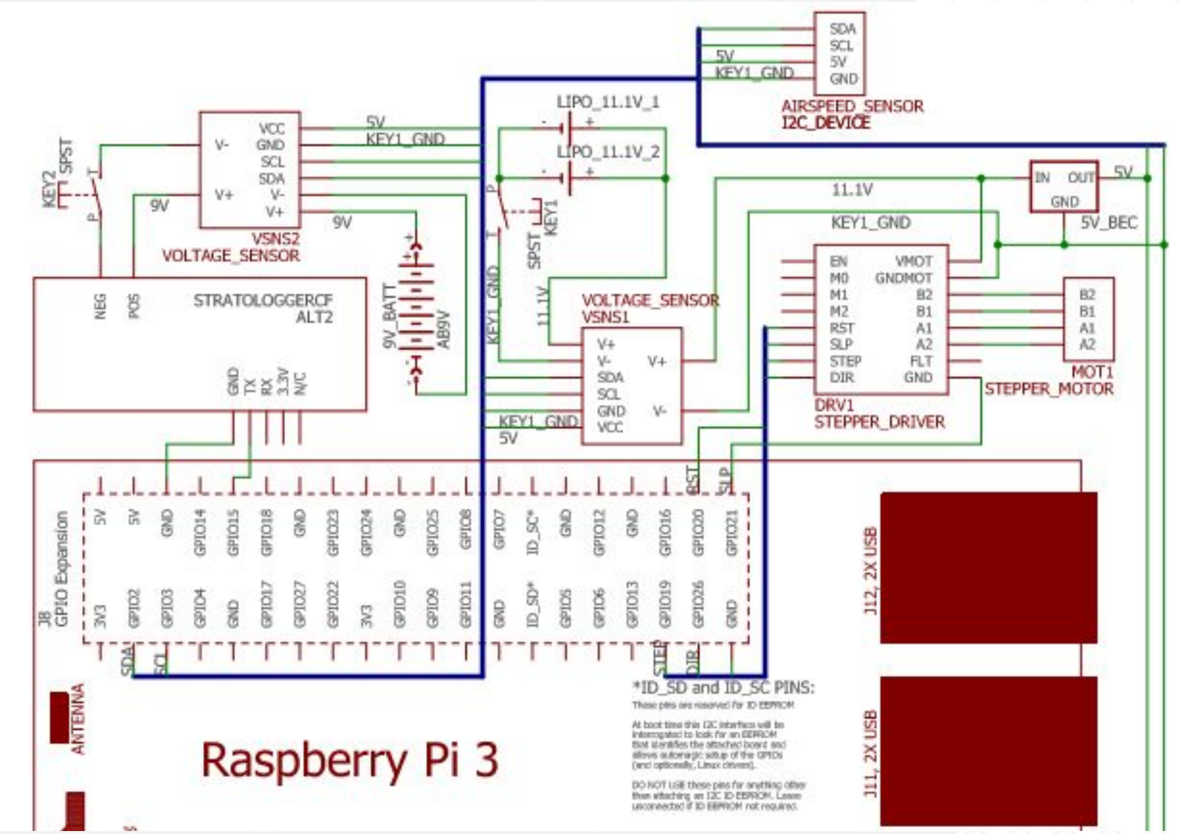
Exploded Views

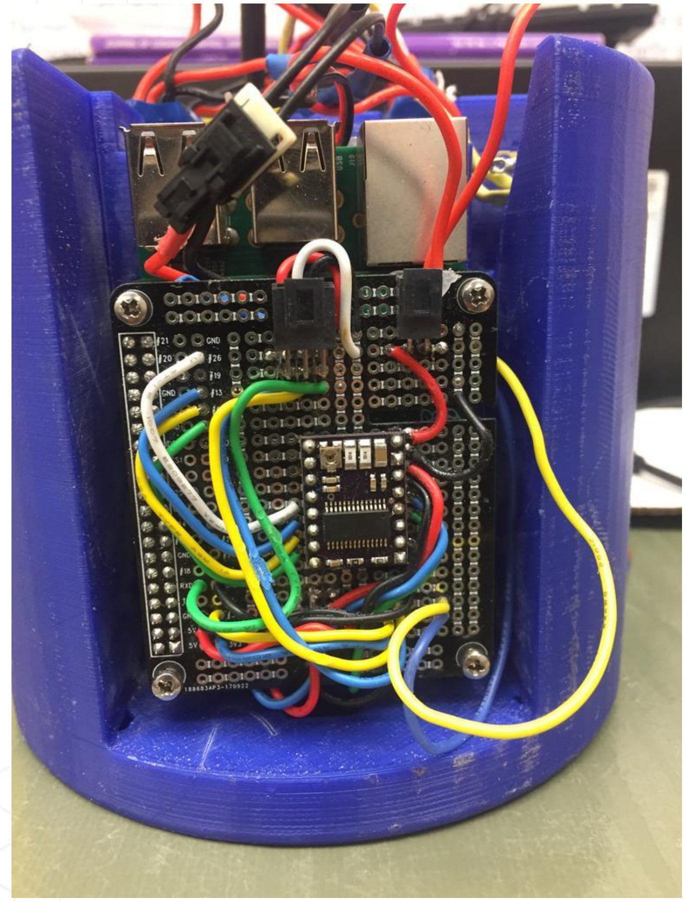


Manufactured ATS

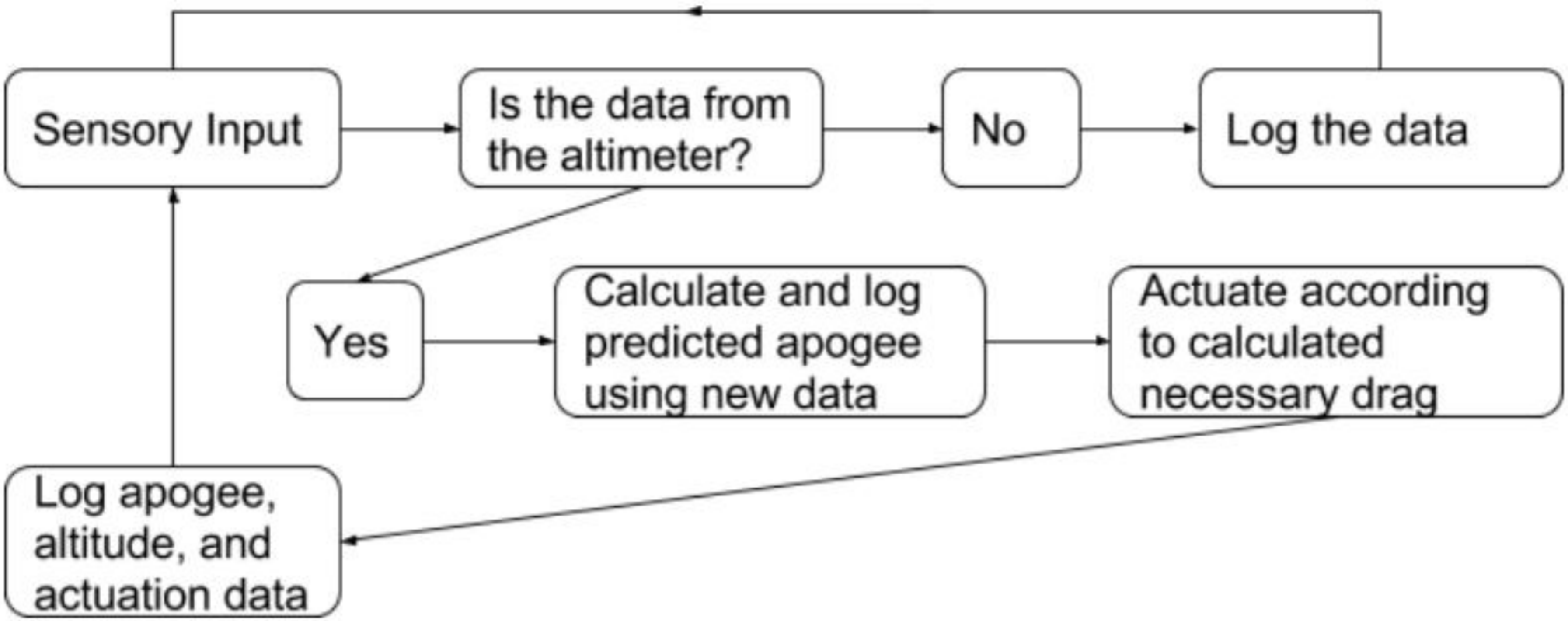


ATS Payload - Electronics





ATS Software Flowchart



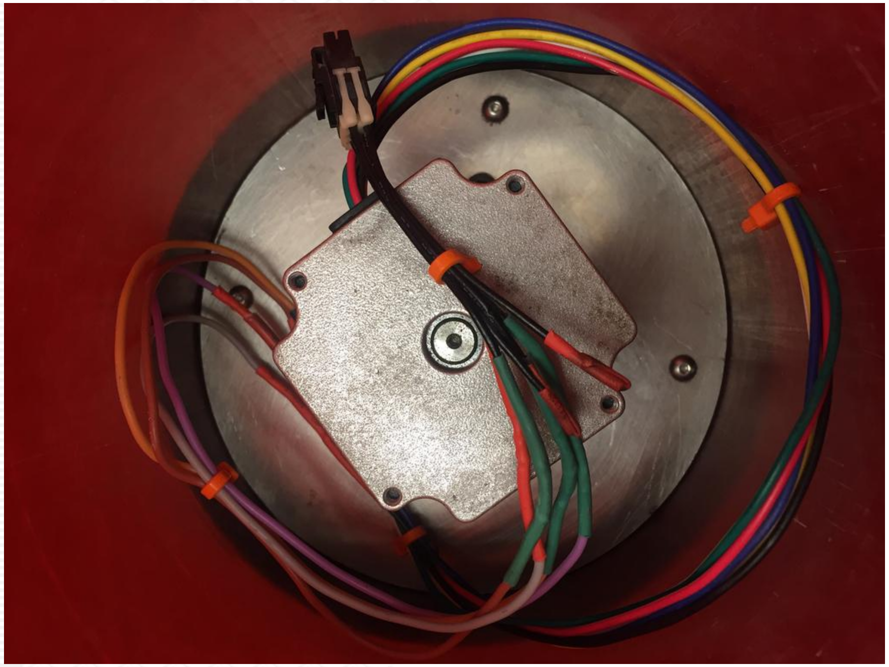
Summarized Requirement

Requirement	Approach	Requirement Verification	Success Criteria
All components in ATS must not experience material failure as a result of drag force	ATS component must have safety factor greater than 2	Analysis Using FEA, the factor of safety will be calculated	Factor of safety calculated by FEA must be over 2
ATS must be secured to the body tube in such a way that prevents motion/vibration	ATS will be secured using a combination of epoxy and mechanical constraints	Demonstration The body tube mounted with ATS will be shaken and held at different angles	ATS should not vibrate or move when it is shaken
Motor must be able to fully retract and extend all flaps without any hindrance	Slits will be cut in the body tube to allow the flaps to move without any hindrance	Test The motor will be actuated multiple times	The flaps should be able to fully extend and retract smoothly
ATS must not generate any moment on the vehicle when actuated	The flaps will be positioned opposite each other, so that the moments cancel	Analysis Using CFD, the pressure/ force on each flap will be calculated	Sum of moment generated by the flaps respect to center of gravity should be zero

Test Plan & Procedures

Requirement Tested	Test Description	Pass/Fail Criteria	Status
Actuation test before mounting	The assembled system will be tested before it is mounted on the rocket to identify faulty assembly	The flap must be able to be extended and retracted repeatedly	Completed Successful
Actuation test after mounting	The assembled system will be tested before it is mounted on the rocket to identify faulty mounting and wiring	The flap must be able to be extended and retracted repeatedly	Completed **Failed**
Altimeter Serial Connection	Check for successful data transmission between the altimeter in the avionics bay and the raspberry pi in the ATS bay	The raspberry pi must receive altitude data	Completed Successful
Altitude and Accelerometer Check	Altimeter and accelerometer data is used to ensure actuation does not occur before burnout	Using lower values for the minimum altitude and acceleration, check that the software progresses as intended	Completed Successful
Data Output	The software should output timestamped data from all sensors and continue running if a nonvital sensor is disconnected.	Datalog files contain all relevant expected information	Completed Successful

ATS Integration

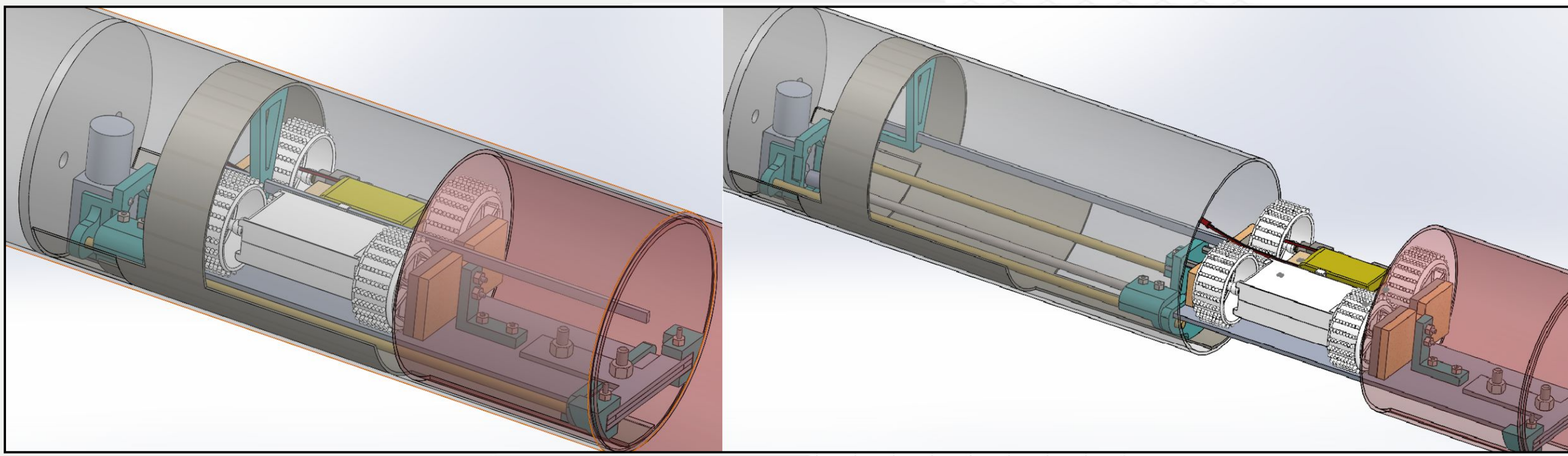


Payload - Rover

Rover Deployment

Final design decision: Axial lead screw

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



Deployment Exploded View

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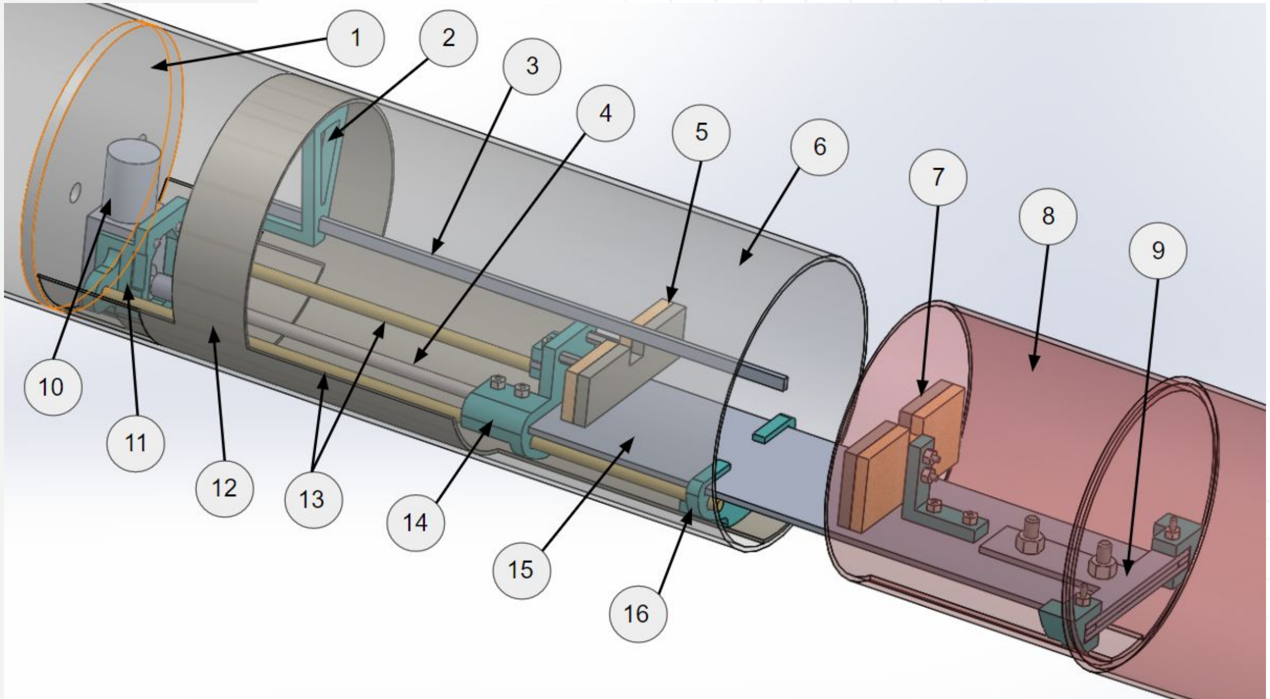
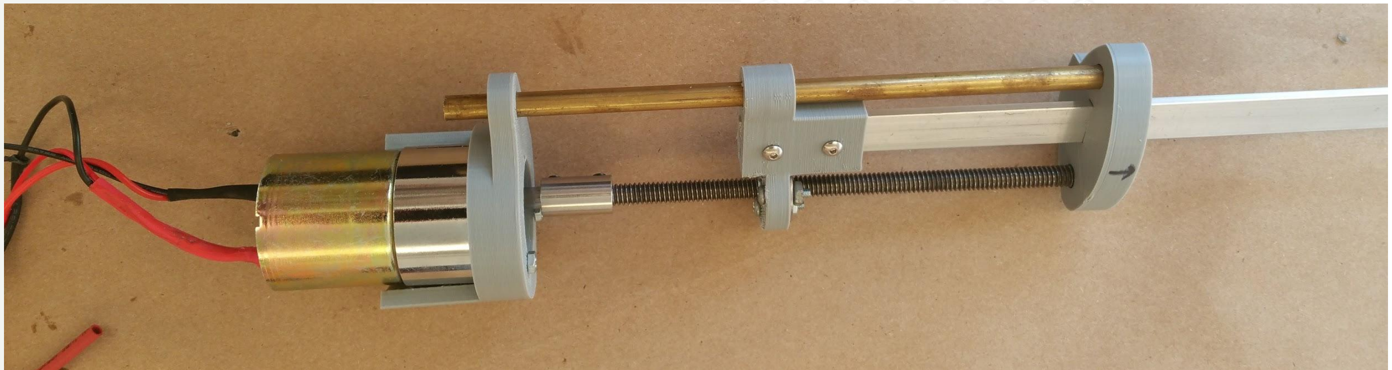
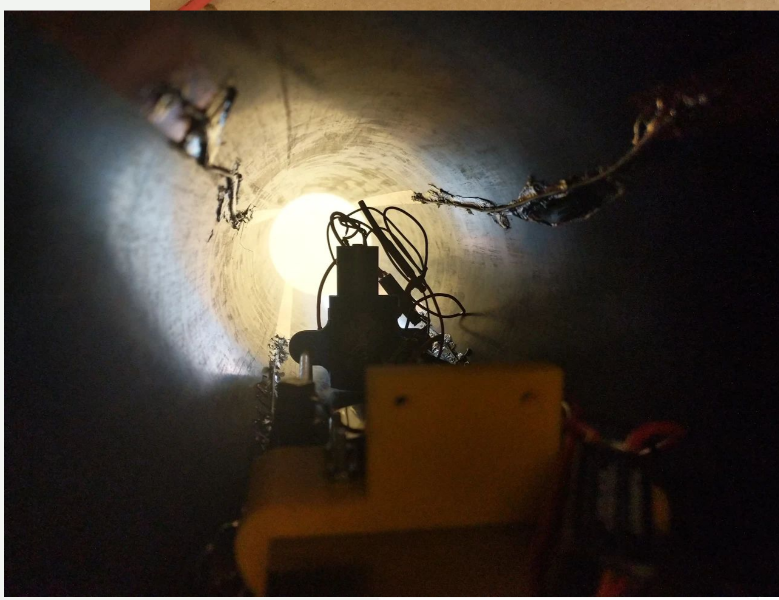


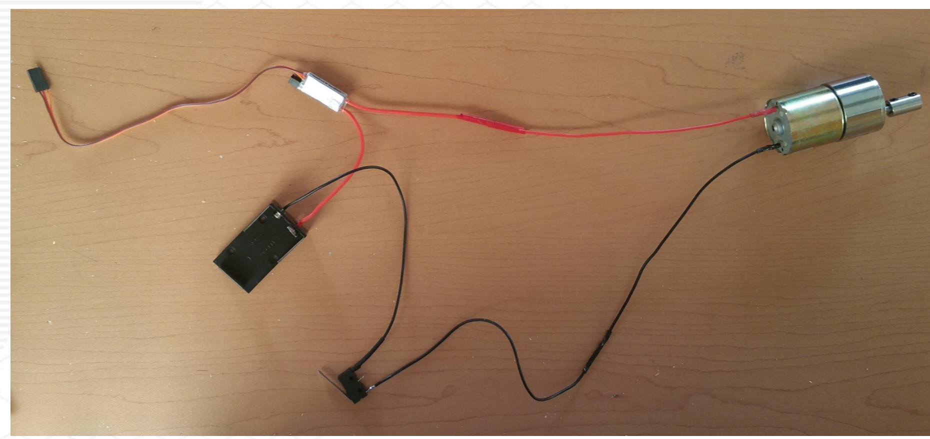
Number	Component	Number	Component	Number	Component
1	Bulkhead	6	Rover Bay Tube	11	Motor Bracket
2	Rover Rail Bracket	7	Pusher	12	Tray
		8	Nose Cone	13	Guide Rails
3	Rover Rail	9	Nose Cone Bracket	14	Carriage
4	Threaded Rod			15	Support Plate
5	Pusher	10	Deployment Motor	16	Front Support Bracket

Rover Deployment

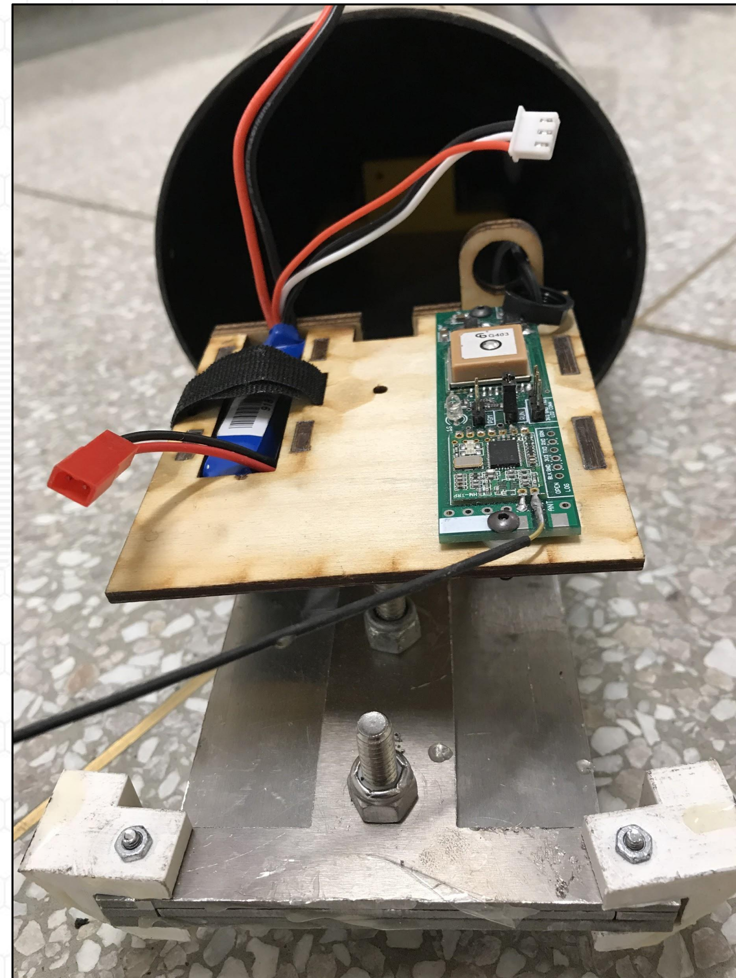
Prototyping: Lead Screw Mechanism



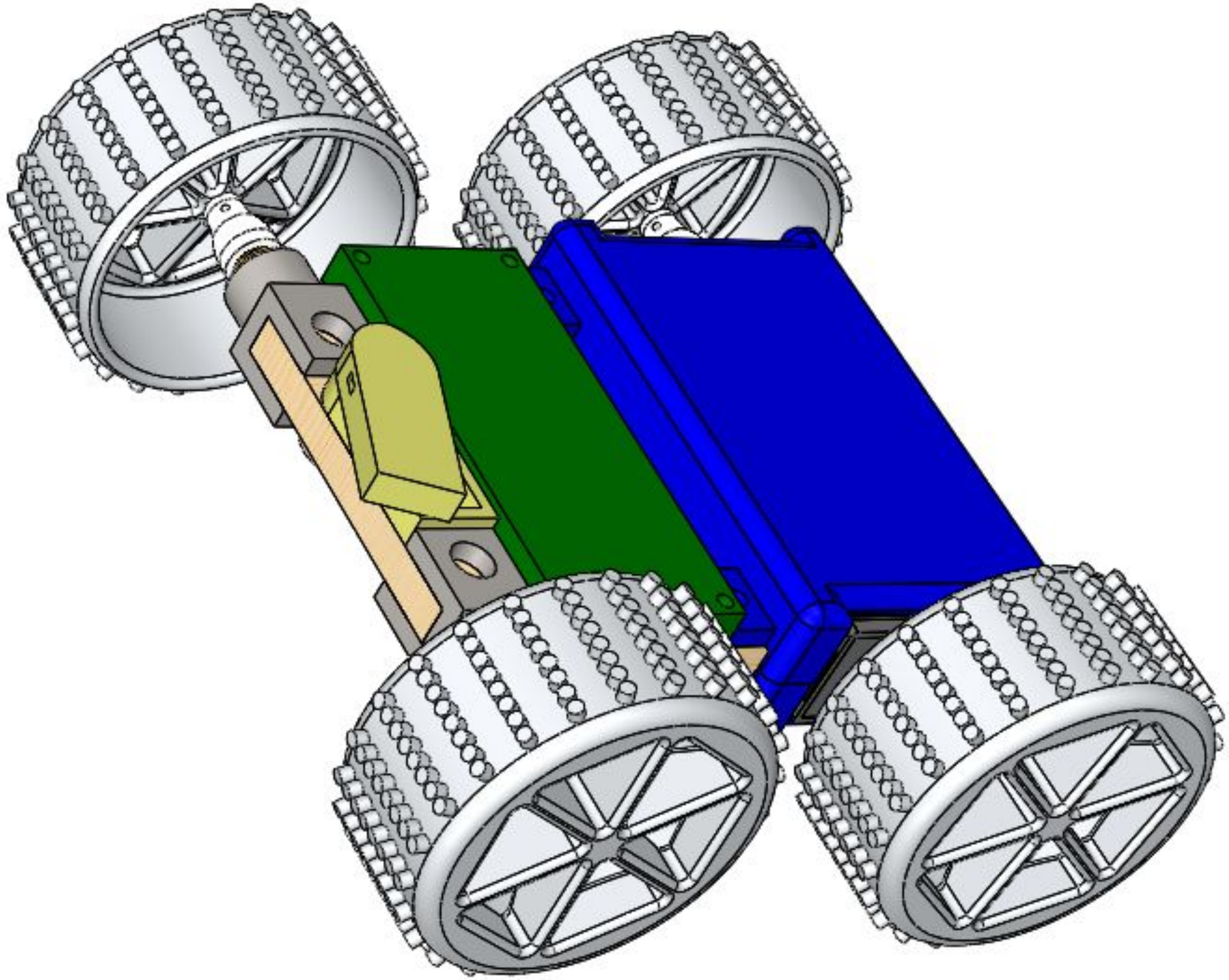




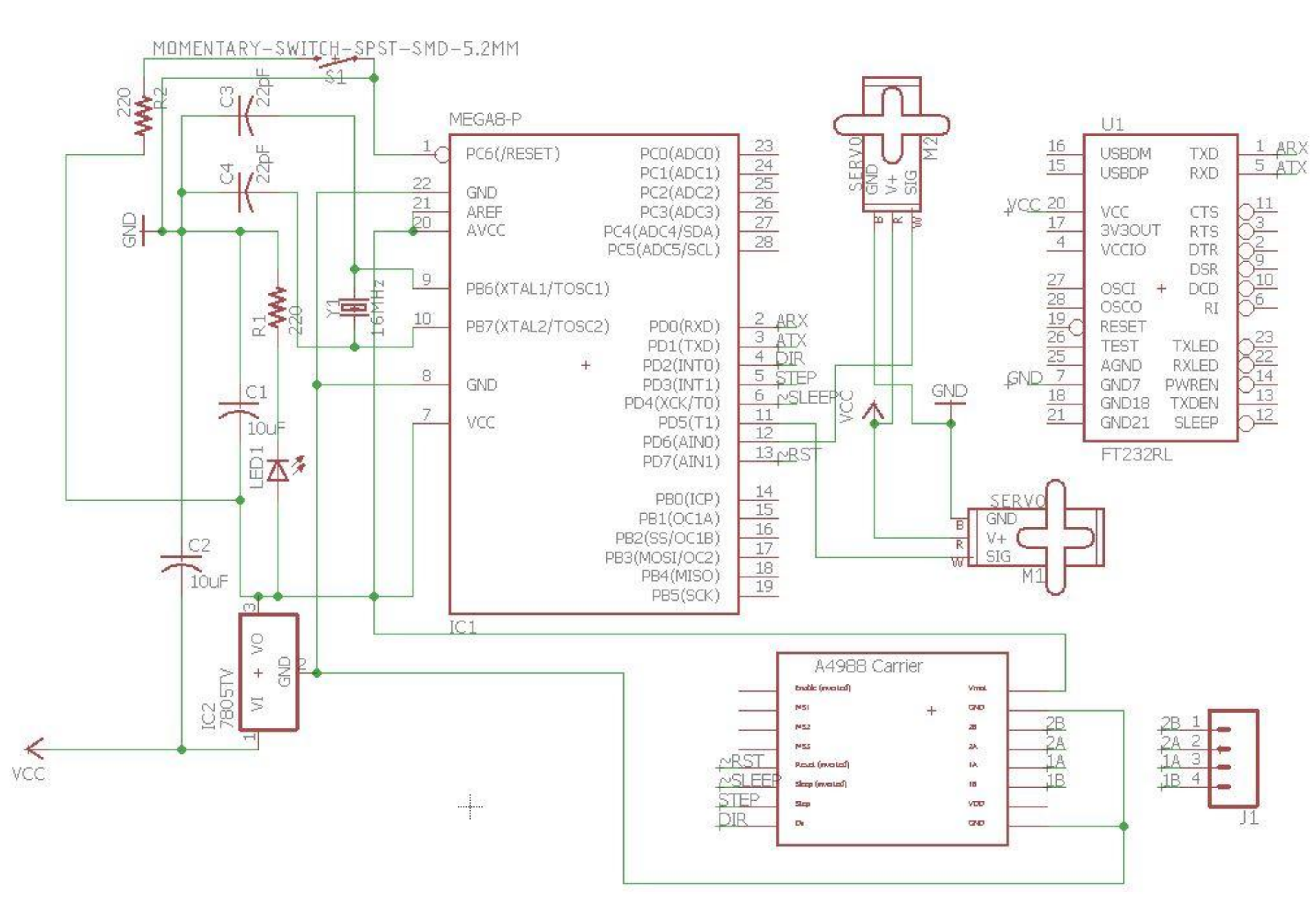
Rover Deployment Continued



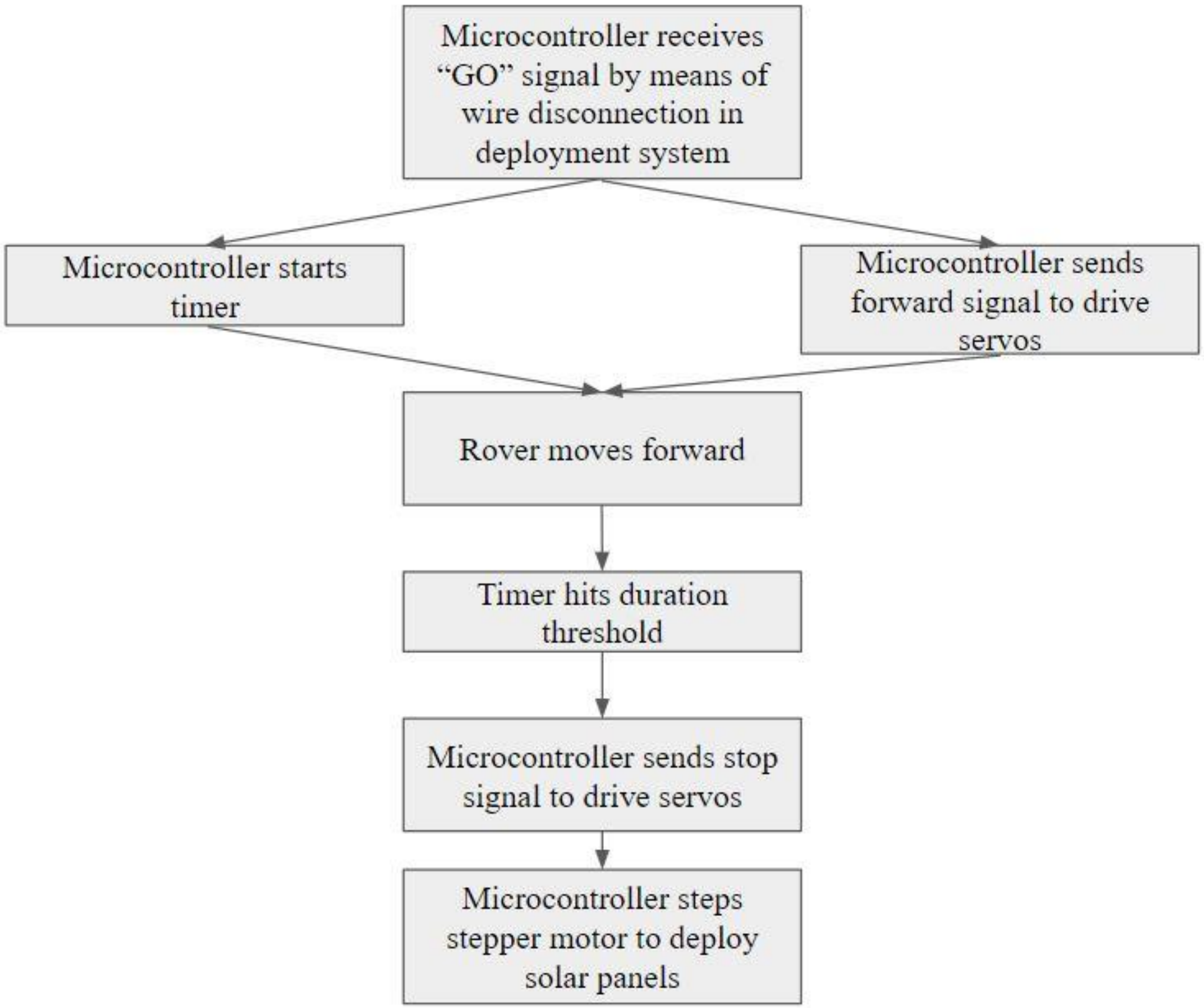
Rover Assembly



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

Summarized Requirement

Requirement	*Design Feature*	*Verification*	*Success Criteria*
Rover is not damaged by vibrations/landing	The rover will be secured by foam pads to damp motion within the rover bay	Test: Rover will be placed in bay and dropped from two stories to ensure that it can withstand the impact	Critical rover components remain intact and functional after landing
The rocket must open	A motor will turn a lead screw, which separates the body tube. This in turn opens the rover bay	Inspection	The rocket body opens wide enough for the rover to exit
The rover must deploy in the proper orientation	The rover can rotate inside of the rocket, so it will always land right side up	Test: The deployment system will be triggered in different orientations to ensure that the rover exits in the proper orientation	The rover will exit the rocket in a proper driving orientation
The rover must come out of the rocket	The rover drivetrain will carry it out of the rocket body	Inspection	The rover entirely exits the rocket body
Rover must not get stuck on rocket/parachute/cord	Rover will have obstacle detection	Inspection	Rover successfully navigates away from rocket body
The rover can deploy regardless of rocket orientation	The rover is mounted on a rail within the bay, allowing it to rotate with the launch vehicle	Test: The deployment system will be triggered in multiple orientations	The rover can deploy regardless of the launch vehicle orientation
Deployment system functions at long range	Deployment system will utilize long-range transmitter	Test: Rocket will be placed at various distances and deployment system will be triggered	Deployment system is functional up to 4,000 ft away from the team transmitter
Deployment system does not deploy prematurely	Deployment will be controlled by an RC receiver controlled switch, which is only operated by the team-controlled transmitter	Demonstration	Deployment system is only triggered by the team at the intended time, not prematurely
Rover has enough torque for uneven terrain	Wheels have studs, and are operated by powerful motors to cross over uneven terrain	Test: Rover will be operated on different types of uneven terrain to ensure functionality	Rover can drive on all possible conditions expected at launch site

Test Plan & Procedures

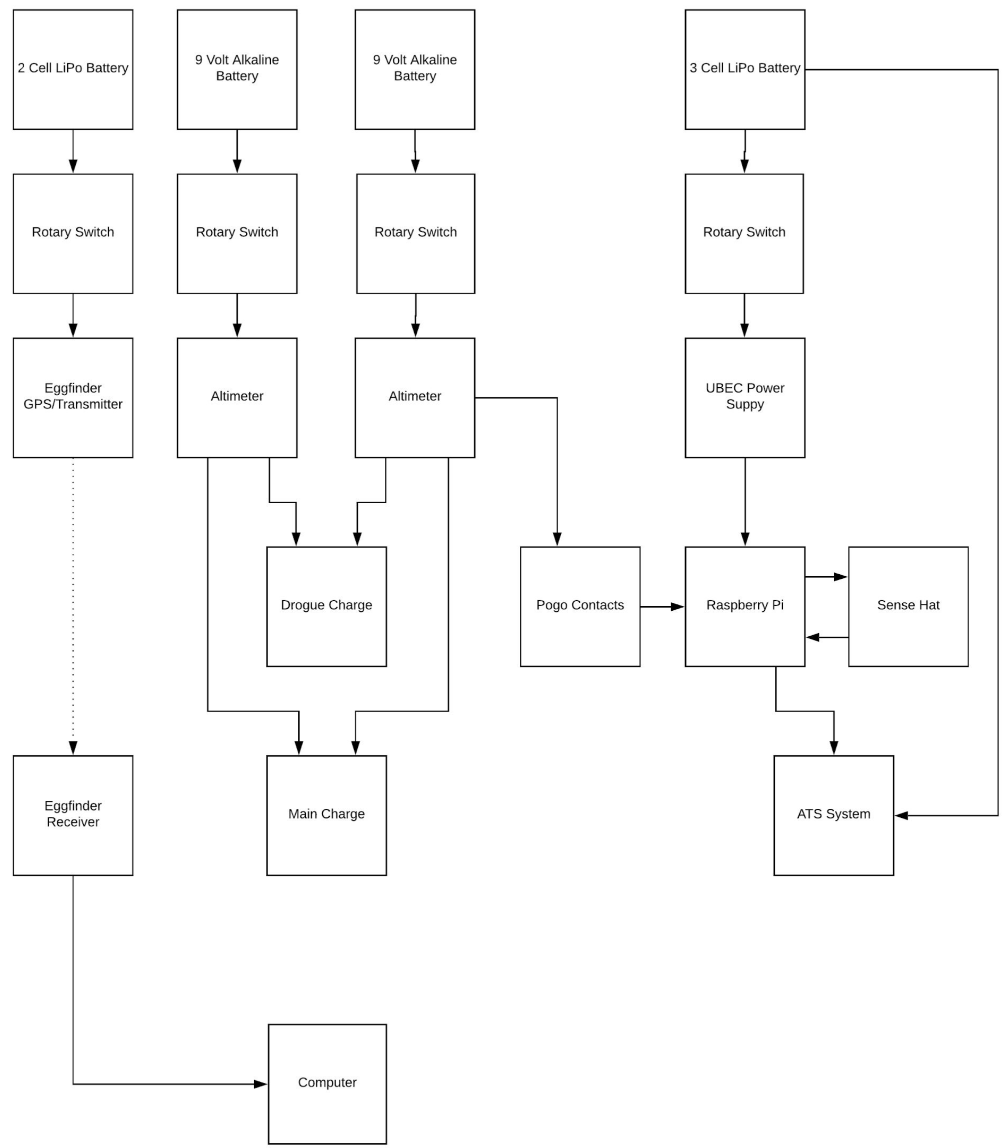
Requirement Tested	Test Description	Pass/Fail Criteria	Status
The rover deployment system must open the rocket	The deployment system will be triggered without the nose cone mounted	The rover tray will extend and retract completely when triggered	Completed on 2/16/18, Success
The rover deployment system must open the rocket	The deployment system will be triggered **with** the nose cone mounted	The rover tray will extend and retract completely when triggered	Completed on 2/23/18, **Failure** - Rescheduled for 3/26/18
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, Scheduled for 3/26/18
The rover can deploy regardless of rocket orientation	The rocket will be placed in several roll orientations. Each test will be conducted three times without the nose cone mounted.	The rover will be successfully deployed at least 7/9 times, with no more than 1 unsuccessful deployment per orientation	Completed on 2/23/18, Success
The rover can deploy regardless of rocket orientation	The rocket will be placed in several roll orientations. Each test will be conducted three times **with** the nose cone mounted.	The rover will be successfully deployed at least 7/9 times, with no more than 1 unsuccessful deployment per orientation	Completed on 2/23/18, **Failure** - Rescheduled for 3/26/18
Deployment system functions at long range	The rocket will be placed at 1,000, 2,000, 3,000, and 4,000 ft away from the transmitter, and deployment will be triggered.	The deployment system will function at all ranges	Incomplete, scheduled for 3/26/18

Flight Systems

Avionics Component Breakdown

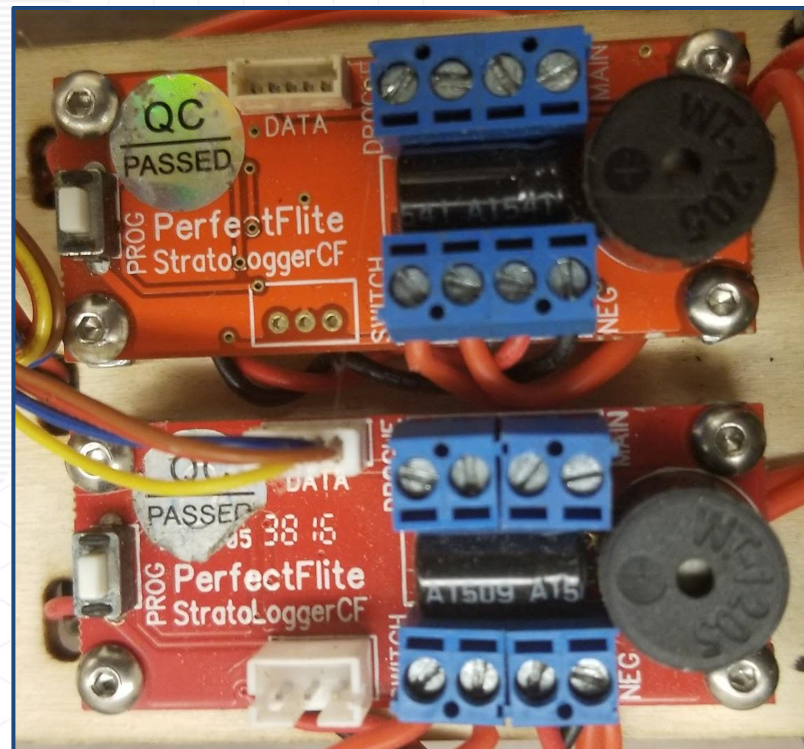
Part	Function
Stratologger CF x2	Altimeter - ignite ejection charges, record max altitude, send real time altitude data to ATS
Eggfinder TX/RX Module	GPS module - used to track the rocket in real time
9V Alkaline Batteries	Provide power to the altimeters

Avionics System Block Diagram

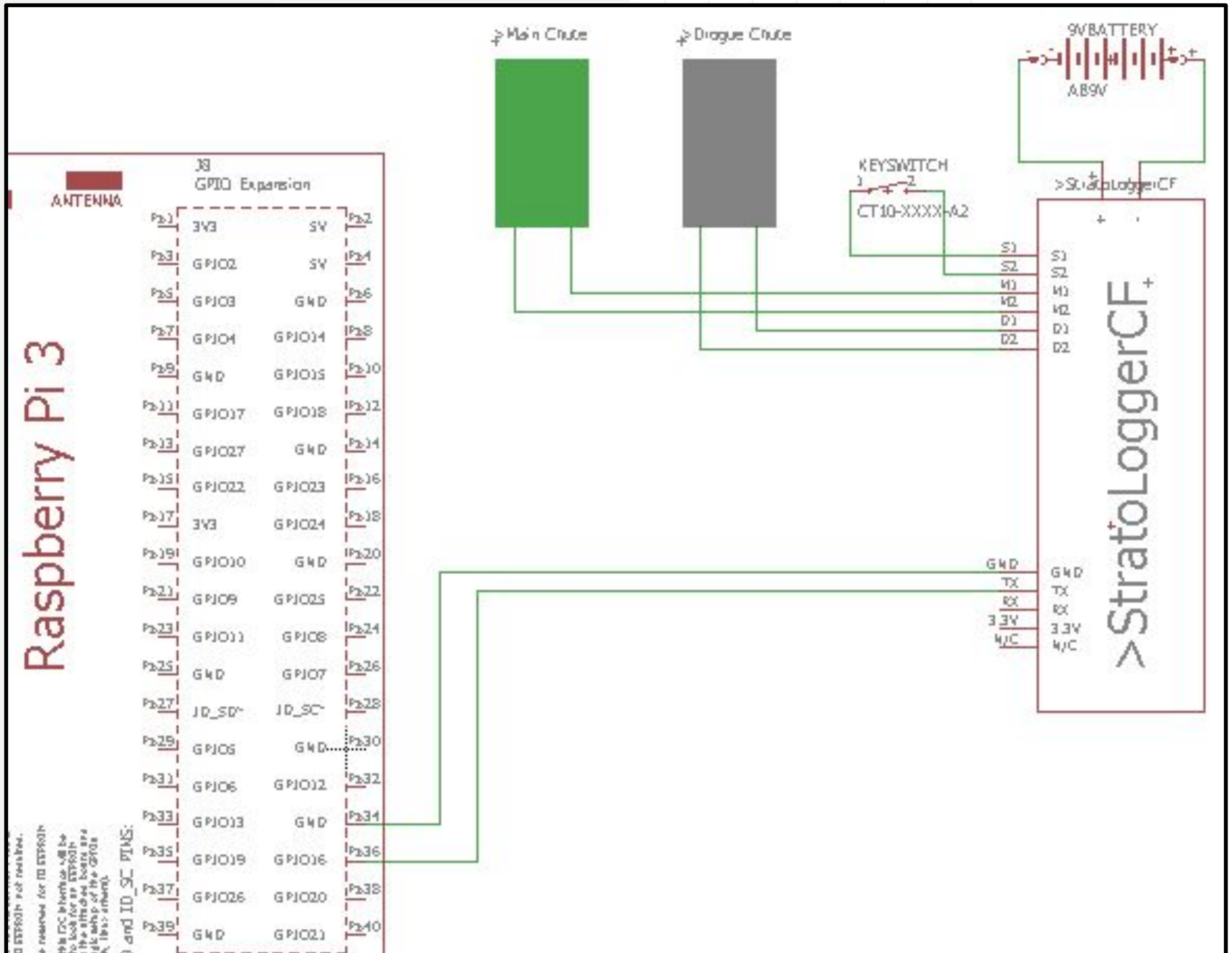


Altimeters

- 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



Recovery Redundancy

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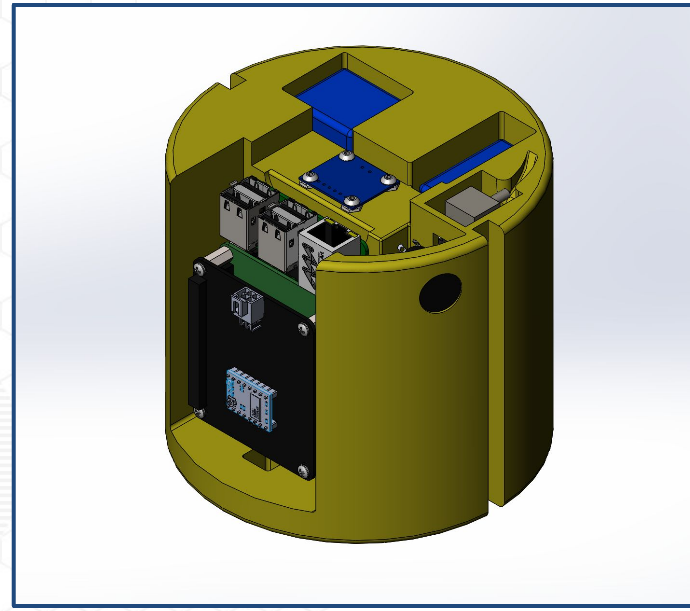
- Two identical Recovery systems
- Independently powered.
- Electrically Isolated
- Staggered Ignition

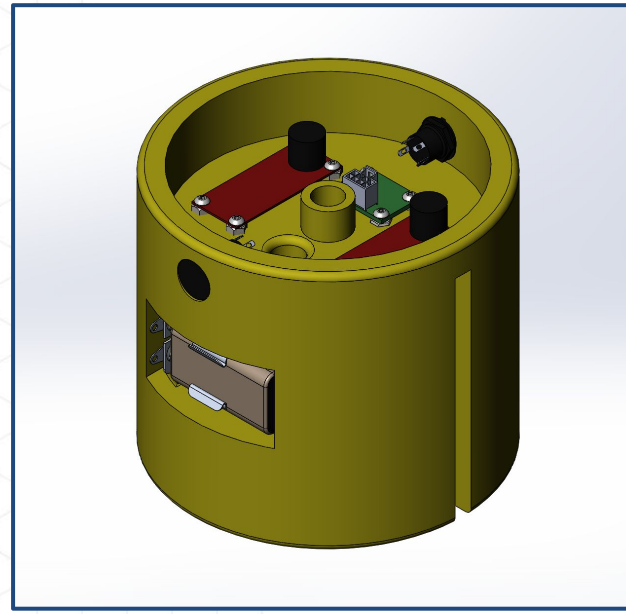
GPS

- 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

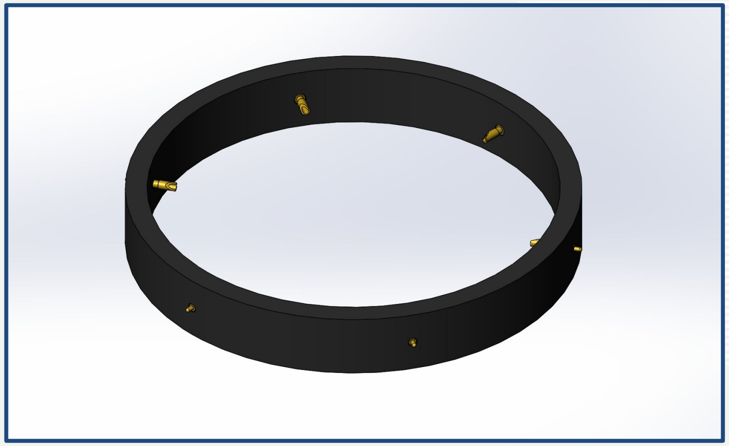
ATS Section Housing

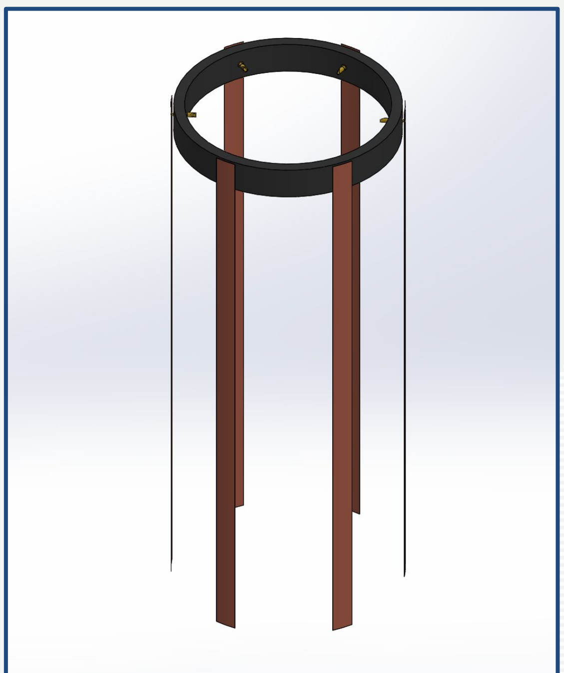


Avionics Section Housing



Pogo Contact Assembly





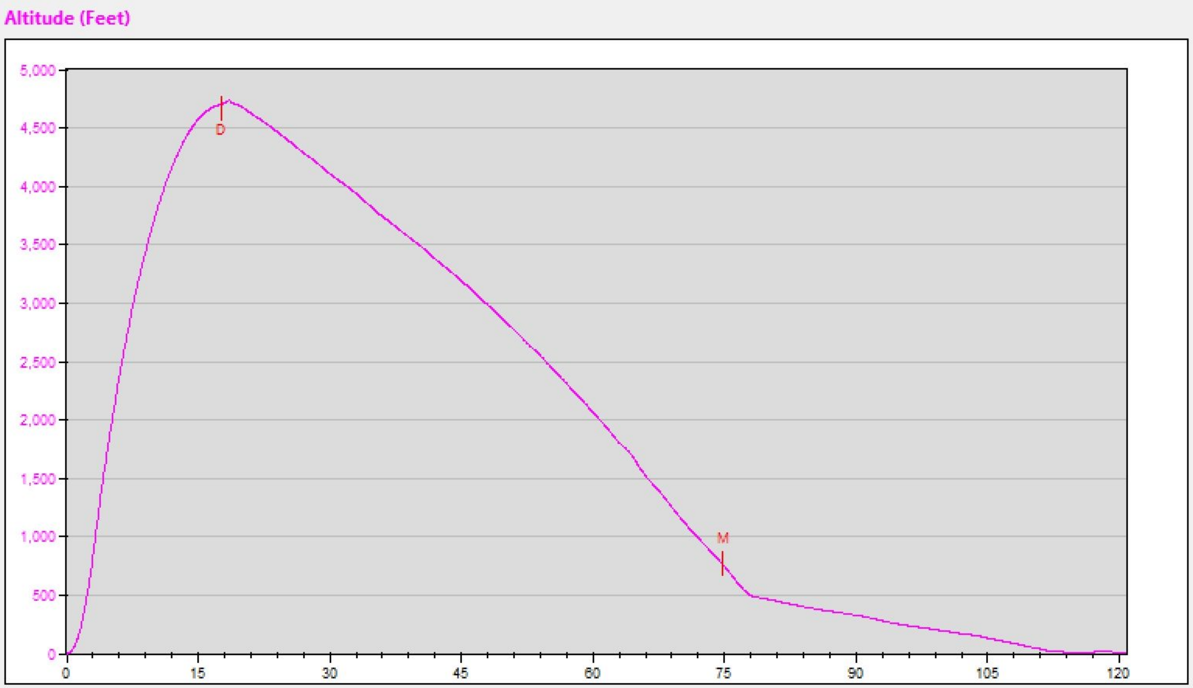
Recovery Assembled

Full Scale Flight

Full Scale Flight Overview

- Launch conducted February 24th, 2018 in Samson, AL
- Successful launch with proper testing of all essential rocket hardware, avionics, and recovery systems
- No active ATS or Rover systems

Full Scale Flight Data Analysis



Statistics:

Apogee Alt: 4734' AGL
Ground Elev: -97' MSL
NumSamps: 2416
Main Deploy: 750' AGL
Apogee Delay: 0 SEC
FlightNum: 12

Displayed

☐ Raw Altitude
☑ Smoothed Alt
☐ Velocity
Temperature
Voltage

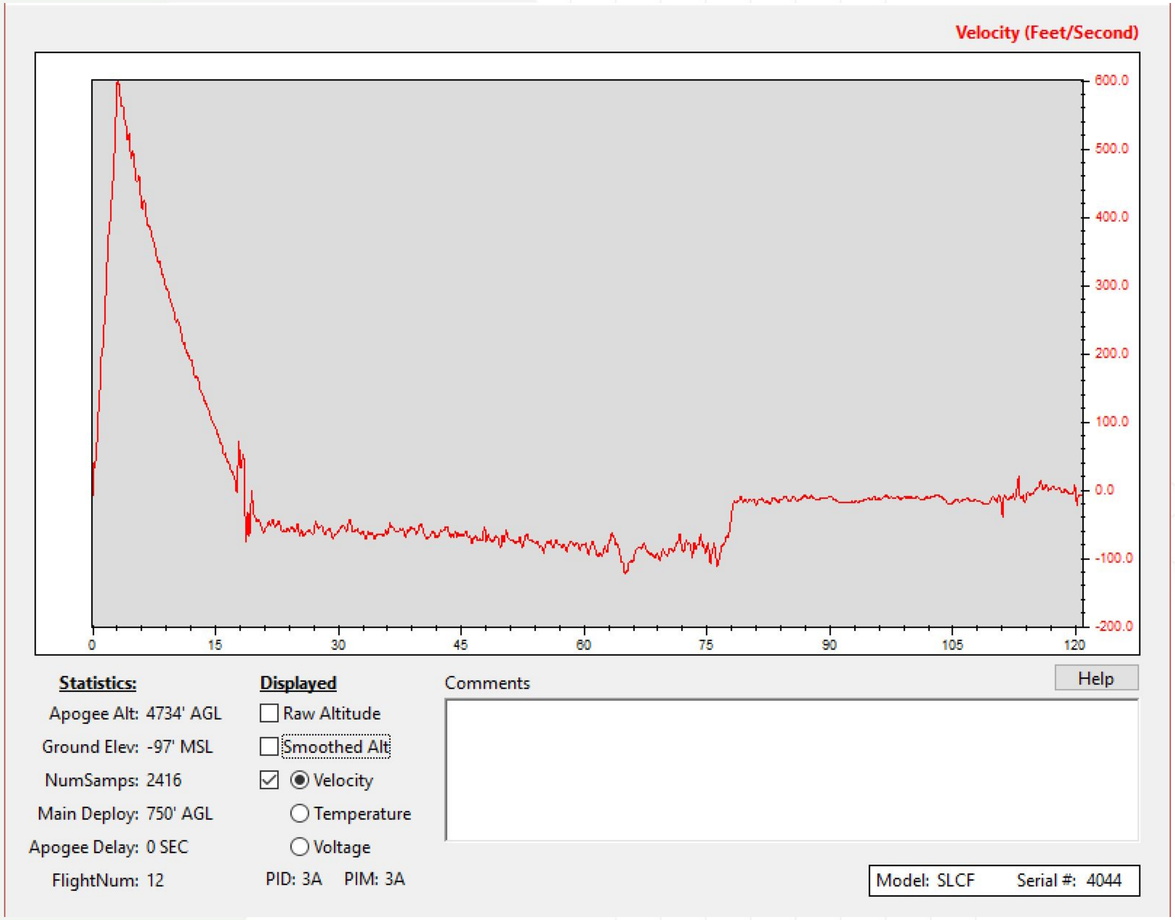
PID: 3A PIM: 3A

Comments

Help

Model: SLCF Serial #: 4044

Full Scale Flight Data Analysis (cont.)



	Predicted	Recorded	Difference
Apogee	5060 ft	4734 ft	6.44 %
Max Velocity	627 ft/s	600 ft/s	4.31 %

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 FRR 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

Georgia Tech

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

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)

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	Yes	PLA/ABS	3D Printer	< 1hr	Inv Studio / AE MakerSpace	N/A
2	Cut Motor Tube to Length	Yes	Cardboard	Chop Saw	< 1hr	Inv Studio / SCC	N/A
3	Cut Tubing to Length	Yes	Fiberglass	Chop Saw	< 1hr	Inv Studio	2 ppl, shop vac, N95/P95 mask
4	Drill Shear Pin Holes (8)	Yes	Fiberglass	Drill	< 1hr	RR room / Inv Studio	2 ppl, shop vac
5	Drill Rivet Holes (4)	Yes	Fiberglass	Drill	< 1hr	RR room / Inv Studio	2 ppl, shop vac
6	Drill wire routing holes into bulkheads/centering rings	Yes	Fiberglass	Drill	< 1hr	RR room / Inv Studio	2 ppl, shop vac
7	Drill Holes for Bottom Plate	Yes	6061 Aluminum	Drill	< 1hr	RR room / Inv Studio	
8	Slots into Body Tubing	Yes	Fiberglass	Jigsaw/Bandsaw/Chop Saw	2 hrs	Inv Studio / SCC	2 ppl, shop vac, N95/P95 mask
9	Cut out Thrust Plate	Yes	Plywood	Laser Cutter	< 1hr	Inv Studio / AE MakerSpace	N/A
10	Fin Features for Brackets	Yes	Fiberglass	Mill	1-2 hrs	BME Shop	2 ppl, shop vac, N95/P95 mask
11	Features for Brackets	Yes	Fiberglass	Mill	1-2 hrs	BME Shop	2 ppl, shop vac, N95/P95 mask
12	Flats into Shafts	Yes	1024 Steel	Mill/Grinder	1-2 hrs	Montgomery MM	N/A
13	Fin Brackets	Yes	6013 Aluminum	Waterjet	1-2 hrs	Inv Studio / SCC	N/A
14	Avionics Bay Tray Brackets	Yes	6013 Aluminum	Waterjet	1-2 hrs	Inv Studio / SCC	N/A
15	Fins Cut Out	Yes	Fiberglass	Waterjet	2 hrs	Inv Studio	N/A
16	Avionics Bay bulkheads (2 coupler, 2 body)	Yes	Fiberglass	Waterjet	1-2 hrs	Inv Studio	N/A
17	Cut Out Bottom Plate	Yes	6061 Aluminum	Waterjet	1-2 hrs	Inv Studio / SCC	N/A
18	Cut Out Bevel Ring Gear	Yes	6061 Aluminum	Waterjet	1-2 hrs	Inv Studio	N/A

Appendix C: Fabrication Tasks Breakdown

19	Cut Out Flaps	Yes	6061 Aluminum	Waterjet	1-2 hrs	Inv Studio	N/A
20	Set Screws for gears / servo hub attachments	Yes	Brass / Aluminum	Drill, Saws, etc...	2 hrs	Anywhere you can	N/A
21	Cut servo hub to length	Yes	Aluminum		<1hr	Inv Studio	N/A
22	Drill gears bore diameter	Yes	Brass	Drill	<1hr	Inv Studio	N/A
		Yes					
21	Epoxy Fins + Centering rings to Motor Tube	Yes		Booster			
22	Epoxy Thrust Plate Inside Body Tube	Yes		Fins			
23	Assemble Avionics Bay (Tray, brackets, threaded rods, nuts)	Yes		Avionics Bay			
24	Nose Cone Weight	Yes		Recovery			
25	GPS Bay Epoxy	Yes		Fin-Roll Mechanism			
26	Bottom Plate Brackets Installed	Yes					
28	Motor Measured Out + Dimensional Sketch of Booster ASSY	Yes					
29	GPS Bat ASSY (PVC fitting + Ubolt)	Yes					
30	GPS Bay Epoxied	Yes					
31	Fins Epoxied to Tubing (Nice, LARGE Fillets)	Yes					
32	Shock Cord Cut to Length	Yes					
33	Parachute Attached to Shock Cord & Quick Links	Yes					
34	Ejection Charges Created	Yes					
35	ATS System ASSY	Yes					
36	Ground Ejection Test (main)	Yes					
37	Ground Ejection Test (drogue)	Yes					