Georgia Tech

GIT LIT

2017-2018 NASA STUDENT LAUNCH

PRELIMINARY DESIGN REVIEW

NOVEMBER 13TH, 2017

CREATING THE NEXT®

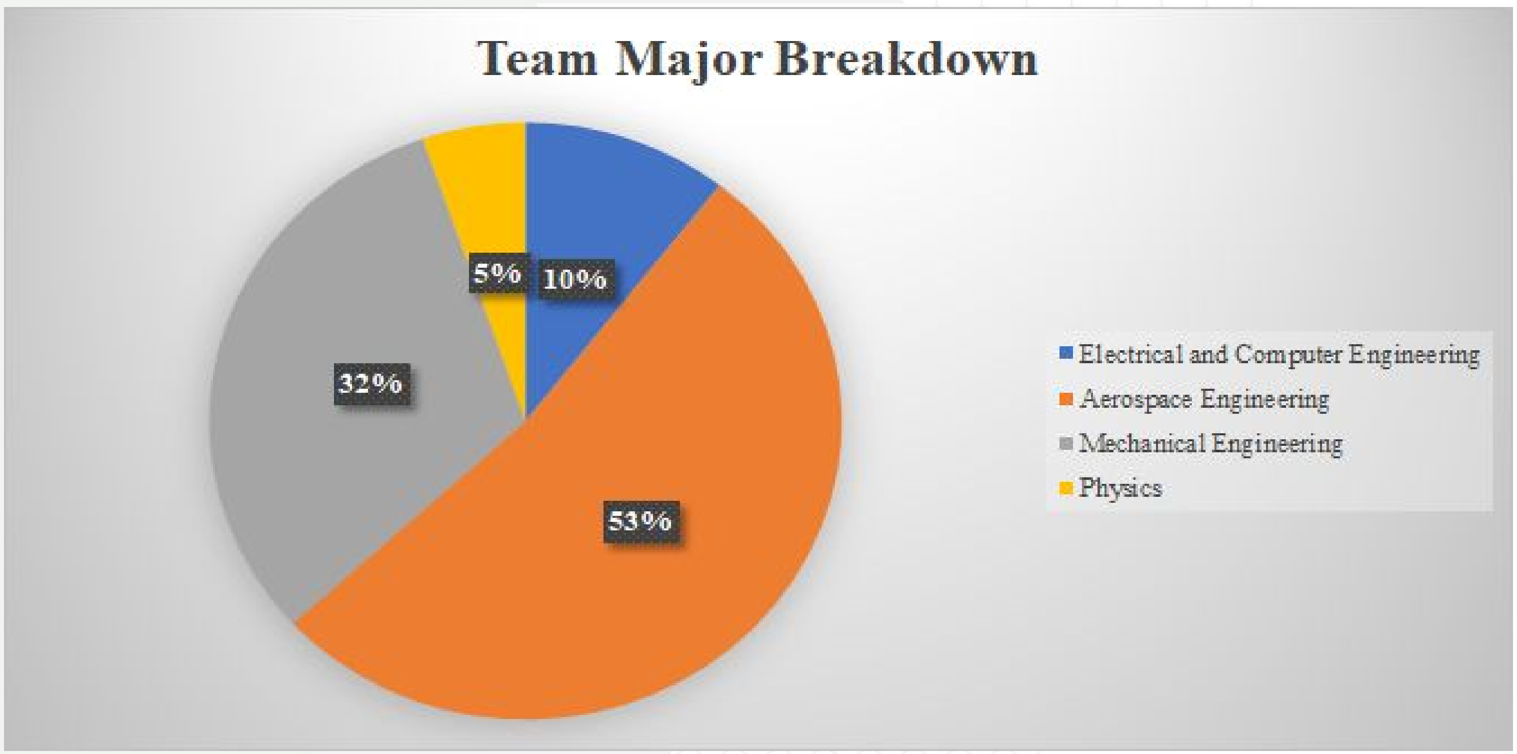
AGENDA

1. Team Overview (5 Min)
2. Educational Outreach (3 Min)
3. Safety (2 Min)
4. Project Budget (3 Min)
5. Launch Vehicle (10 min)
6. Payload - ATS (10 Min)
7. Payload - Rover (10 Min)
8. Flight Systems (10 Min)
9. Questions (15 Min)

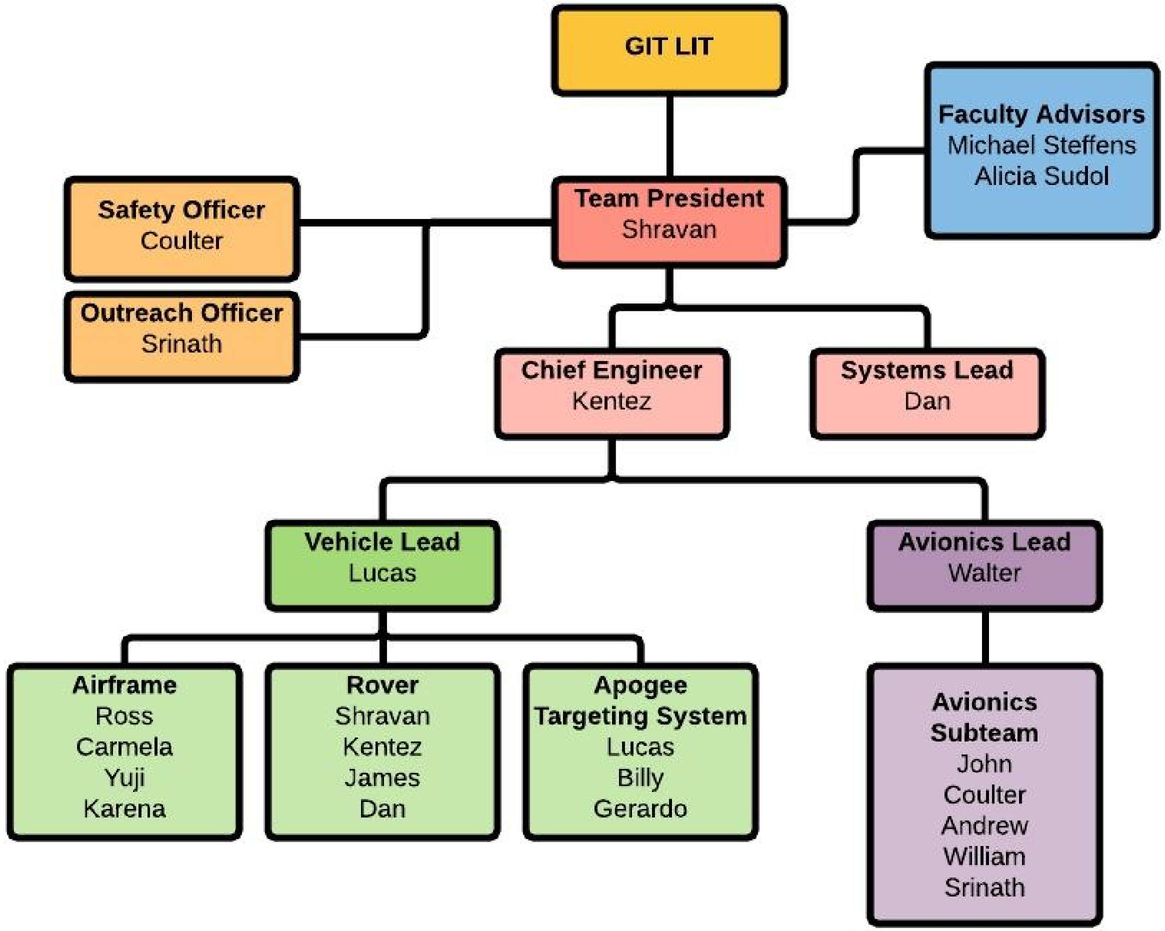
Team Overview

GIT LIT Team Overview

- 19 person team composed of undergraduate students
- Representing all four class standings and four majors



Team Breakdown



Educational Outreach

Educational Outreach

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

Safety

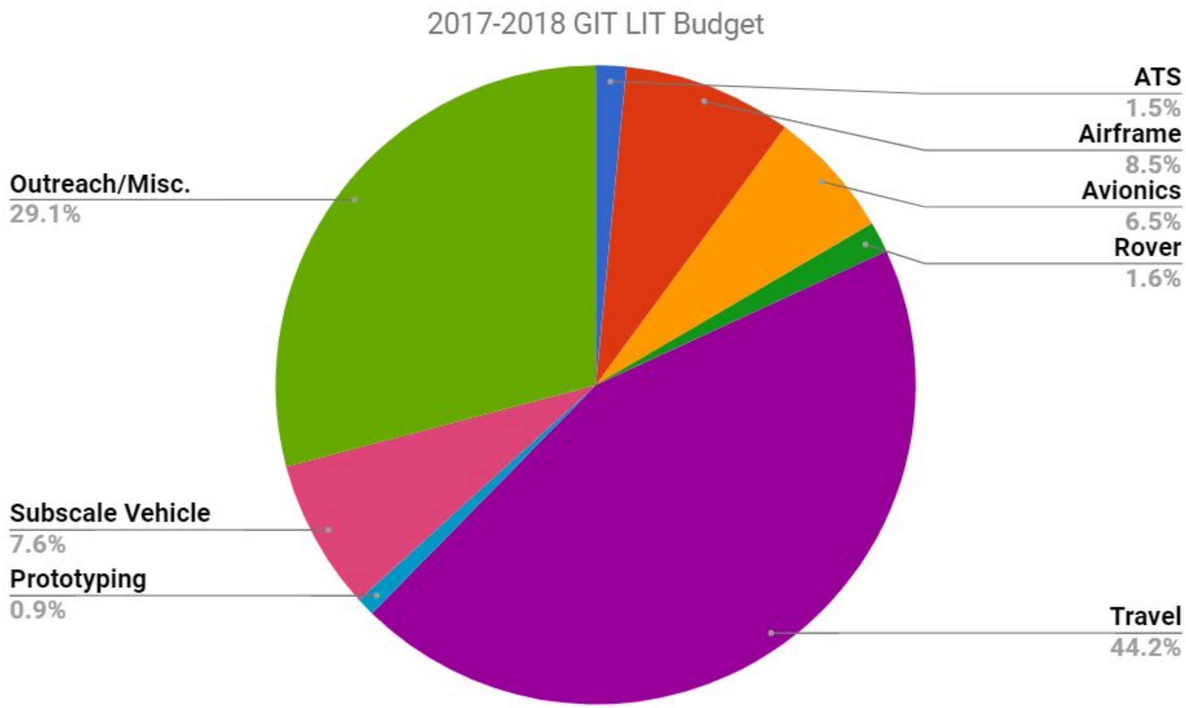
Risk Assessment & Launch Vehicle

- Hazard Identification
  - What has the potential to become a safety hazard?
- Risk and Hazard Assessment
  - What are the potential consequences of the hazard?
- Risk Control and Mitigation
  - What can be done to mitigate the risk?
- Reviewing Assessments
  - Are the mitigations working?

Project Budget

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.)	November 2017
Corporate Donations	$1,000 (est.)	January 2017
Orbital ATK Travel Stipend	$400 (est.)	April 2017
Total	**$9,875.23 (est.)**	

Launch Vehicle

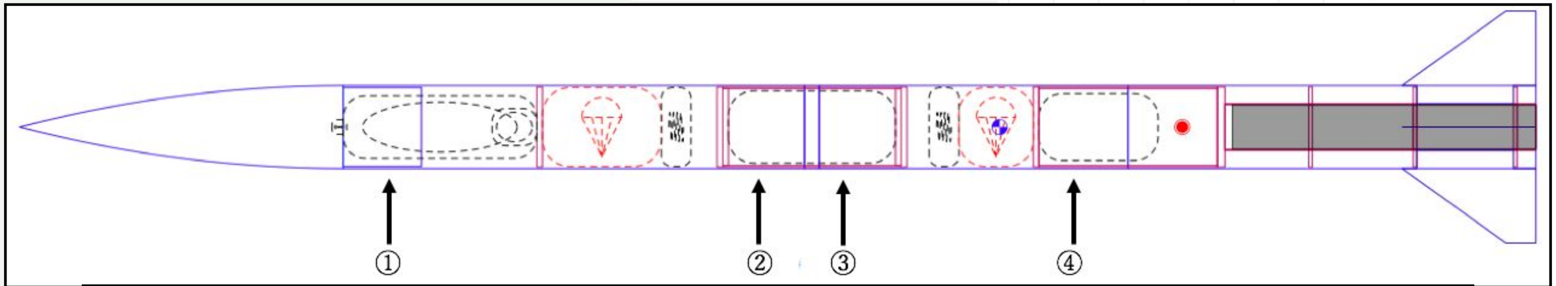
Launch Vehicle

Booster Overview

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

Mass Breakdown

Section	Gross Mass (oz)	Length (in)
Nose Cone	20.96	21.75
Rover Section	142.34	31.00
Avionics Bay	84.62	12.75
ATS Section	83.18	20.75
Booster Section	258.57	27.40
Total	589.67	101.9

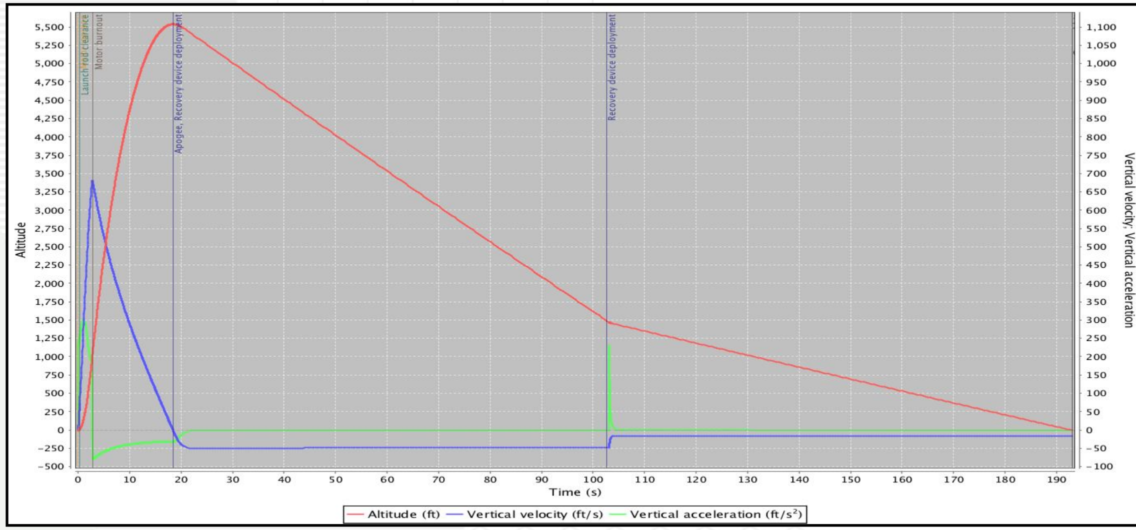


No.	Location	Separation Mode	Separation Event
1	Nose Cone + Rover Tube	Supporting beams from rover tube	Rover deployment
2	Rover Tube - Avionics Bay	Shear Pins	Main parachute deployment
3	Avionics Bay - ATS Tube	Shear Pins	Drogue parachute deployment
4	ATS Tube + Booster Stage	Rivets	Not applicable

Flight Ascent Performance

Flight Performance

Property	Value
Center of Gravity	65.879 in
Center of Pressure	78.148 in
Apogee altitude	5532 ft
Maximum velocity	679 ft/s
Maximum acceleration	237 ft/s^2
Rail exit velocity	70.3 ft/s
Thrust-to-weight ratio	8.39
Ground hit velocity	12.0 ft/s



1) Motor burning

$$y_b = \frac{\alpha}{M_{avg}} ln \left| cosh\left(\frac{\sqrt{\alpha\beta}}{M_{avg}} t_b\right)\right|$$

2) Coasting

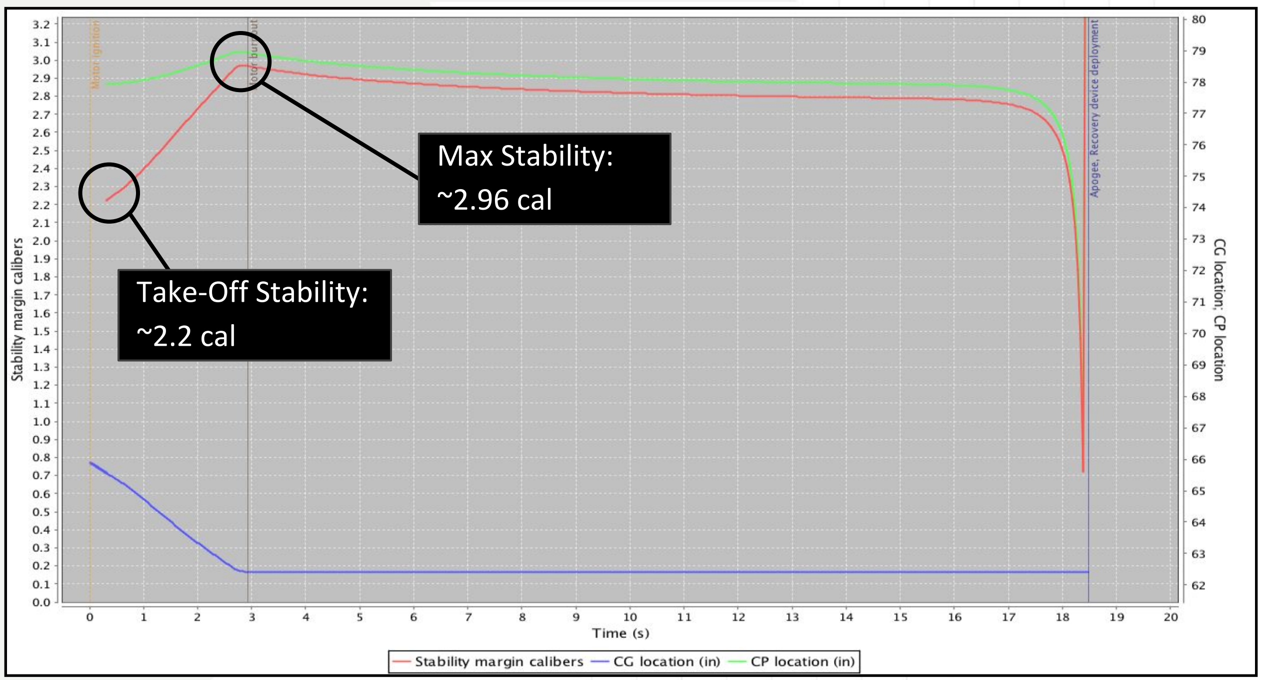
$$y_{max} = y_b + \int_{t_b}^{t_{max}} \sqrt{\frac{M_C g}{\beta}} tan\left(\sqrt{\frac{\beta g}{M_C}}(t_b - t) + arctan\left(\sqrt{\frac{\beta}{M_C g}} v_b\right)\right) dt$$

Flight Drift

Drift distance of the launch vehicle due to different wind speeds

Wind speed (ft/s)	Drift distance (ft)
0	0
5	722.5
10	1445
15	2167.5

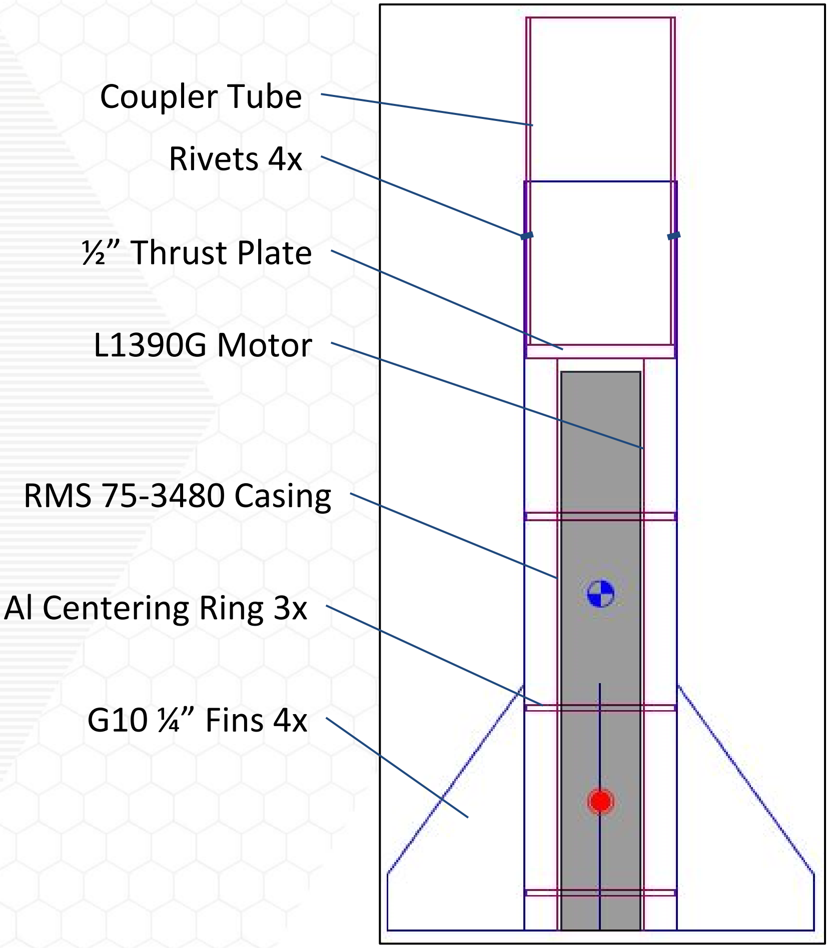
Drift distance = Wind speed * ($t_{landing}$ - t_{apogee})



Booster Section Overview (4)

Mass Breakdown by Component

Component	Material	Mass (oz)	Location
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-alum	1.35	18.25, 25.25
Fin	G10 Fiberglass	9.50	31.90
Retention ring	6061-alum	1.35	24.40
Motor (with propellant & casing)	N/A	136.83	13



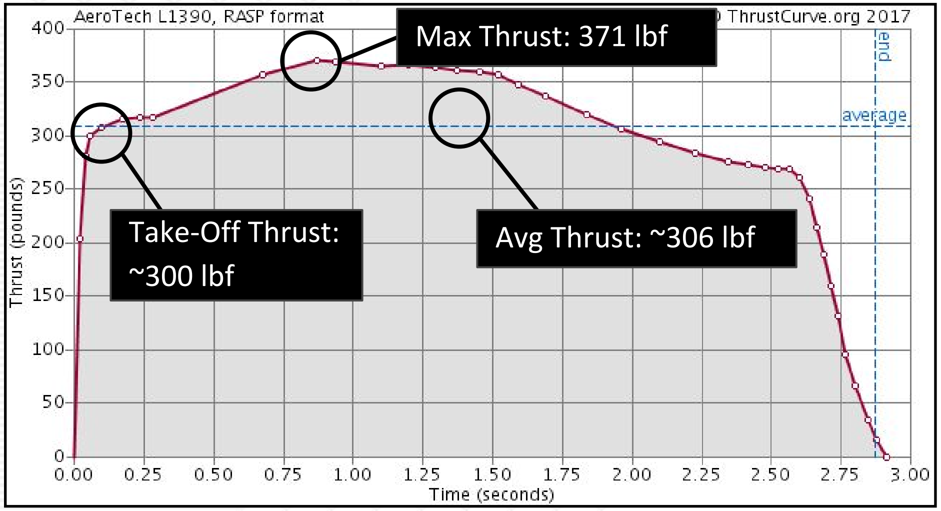
Motor Selection Process

Motor Simulation Results

Motor name	Total impulse	Vehicle mass (oz)
AeroTech L1150	784 lbf · s (3489 N · s)	501
Cesaroni L890SS	831 lbf · s (3695 N · s)	547
AeroTech L1520TP	847 lbf · s (3769 N · s)	557
AeroTech L1390G	887 lbf · s (3946 N · s)	593
Cesaroni L1355SS	905 lbf · s (4025 N · s)	622
Cesaroni L1350	962 lbf · s (4280 N · s)	656
AeroTech L1420	1038 lbf · s (4616 N · s)	726
Animal Motor Wk. L1400SK	1066 lbf · s (4741 N · s)	751
Cesaroni L2375-WT	1103 lbf · s (4905 N · s)	790
AeroTech L2200G	1147 lbf · s (5104 N · s)	833

Flight performance with 3 Different Motors

Property	L850W	L1150P	L1390G-P
Apogee altitude (ft)	5090	4732	5535
Rail exit velocity (ft/s)	61.8	67.7	70.3
Maximum velocity (ft/s)	585	600	679
Maximum acceleration (ft/s^2)	209	235	298
Time to apogee (s)	18.3	17.4	18.4



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)
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Airframe Failure Modes and Effects Analysis

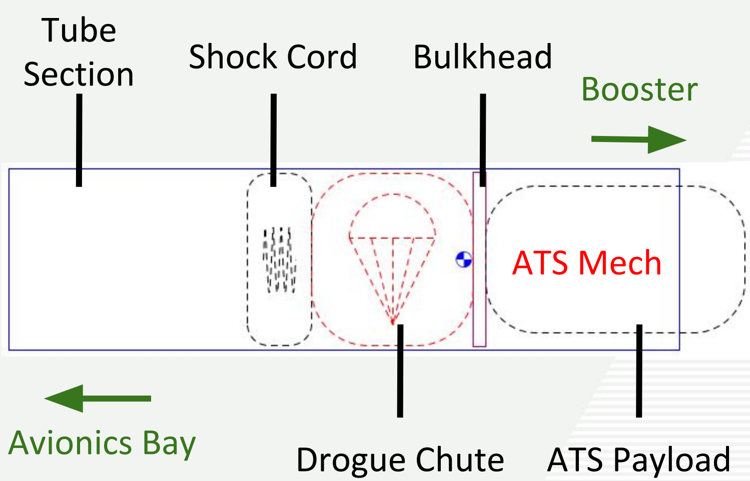
Components	Function	Failure	Potential Causes	Detection Method	Impact	Severity (1 -3)	Detection Difficulty (1 -3)	Probability (1 - 3)	Risk (1-27)	Risk Priority Number (Risk/27)
Bolts and nuts	holds components	threadlocker breaks and twists out	Vibration	N/A	Components may be disassembled; Due to imbalanced 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

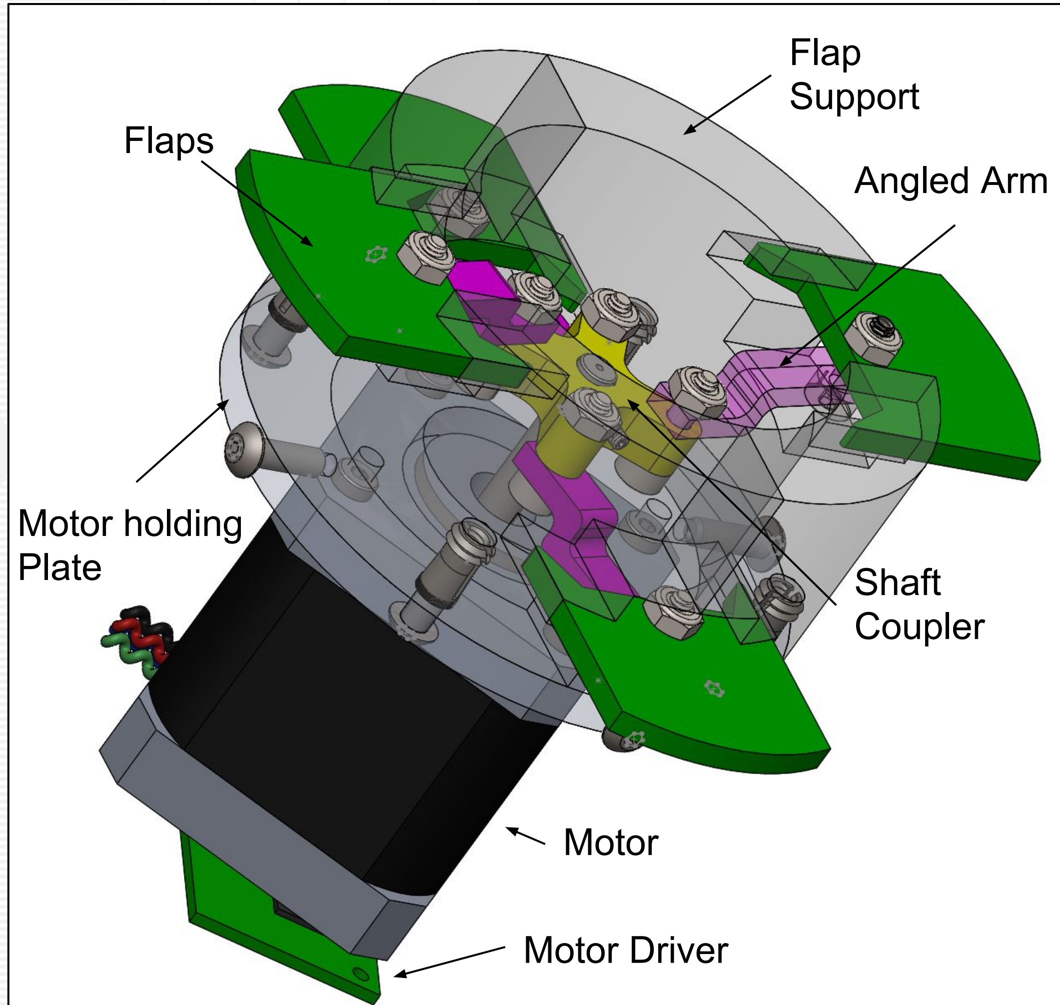
Payload - ATS

Apogee Targeting System (ATS) Overview

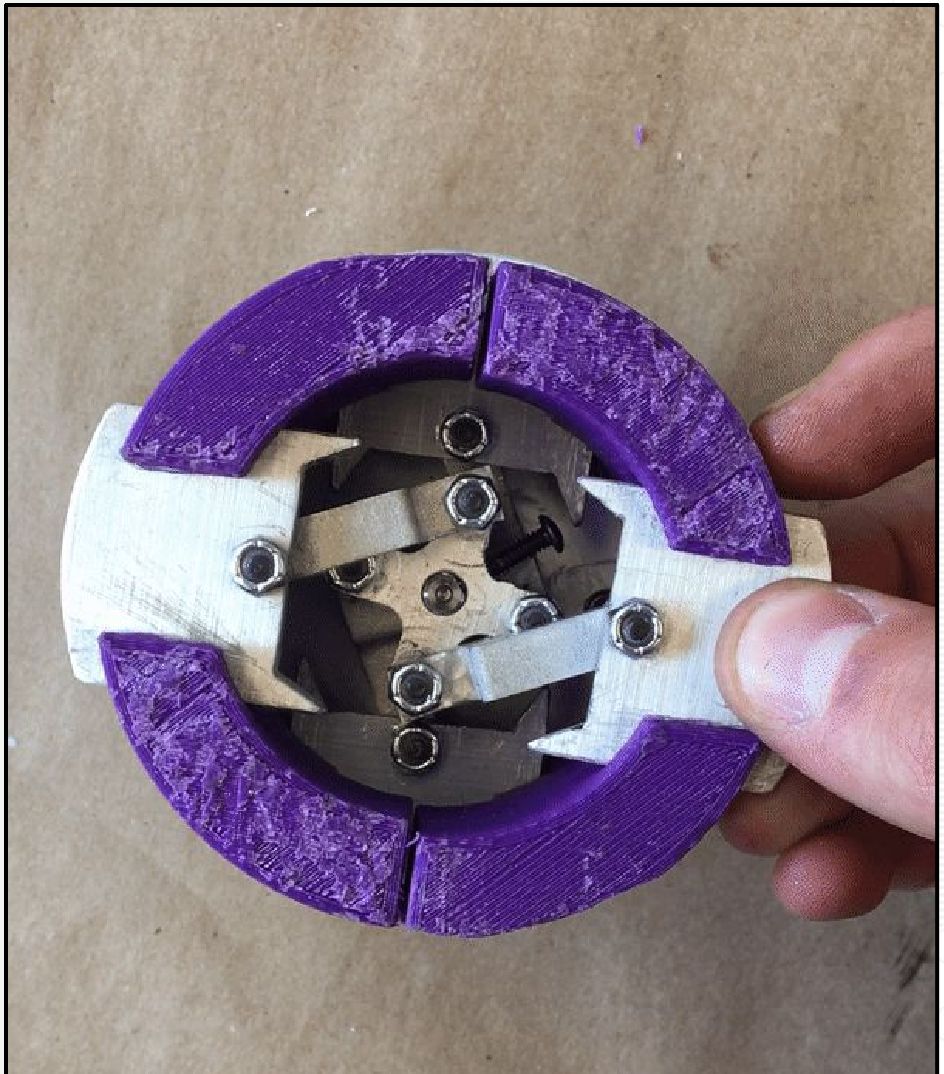
ATS Section Mass Breakdown

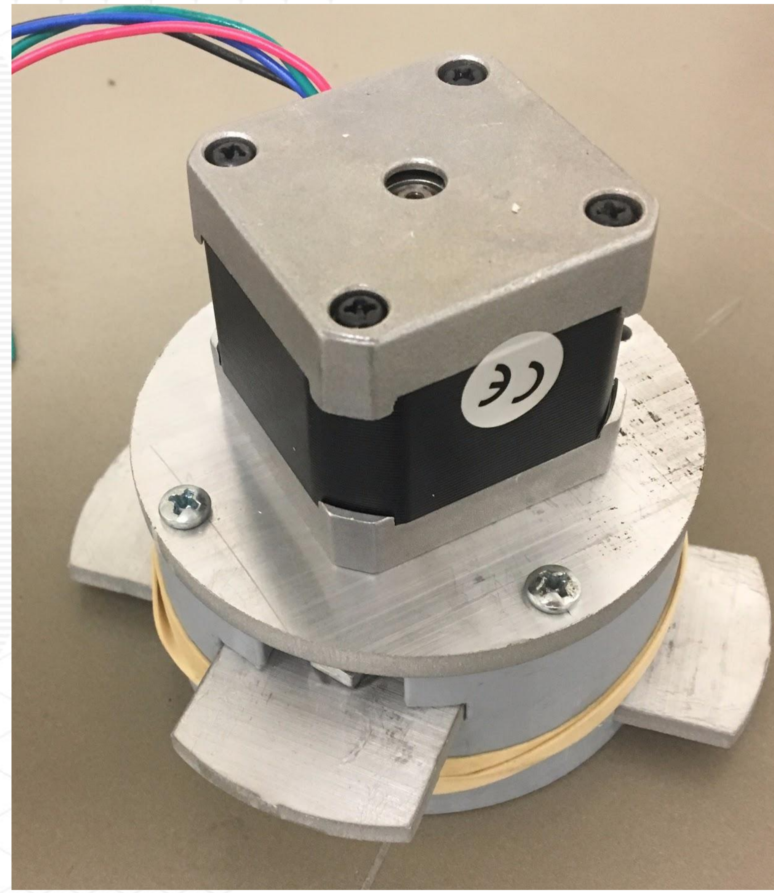
Component	Material	Mass (oz)	Location (in)
Body tube	G12 fiberglass	35.50	0.00
Drogue Chute	Ripstop nylon	2.54	9.375
Shock cord	Tubular nylon	3.44	7.375
Bulkhead	G10 fiberglass	9.10	14.375
ATS system	N/A	32.60	14.75



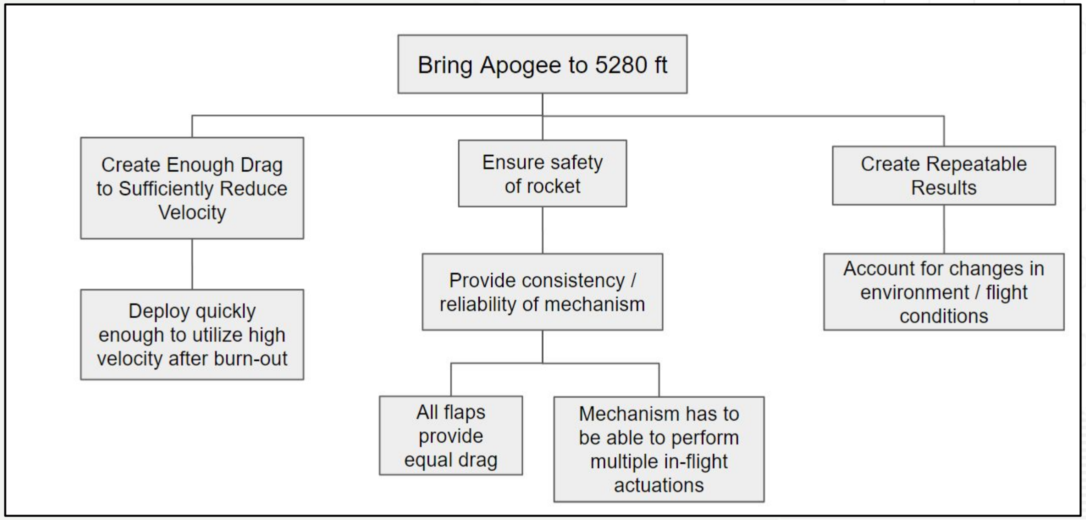


Demonstration of Prototype





ATS Concept Development & Evaluation



	Solutions		
Function	**1**	**2**	**3**
Deploy quickly enough to utilize high velocity after burn-out	Use high power DC motor	Use pneumatic motor	Use high powered servo motor
All flaps provide equal drag	Use microcontroller to determine and adjust positions of the flaps	Make system that only can fully open or close the flap	
Mechanism has to be able to perform multiple in-flight actuations	The motor must be bidirectional	Battery large enough for several actuations	Use compressed air tank to drive pneumatic actuator
Account for changes in environment / flight conditions	Make velocity adjustment towards the end of coasting	Maximize ballistic coeff	

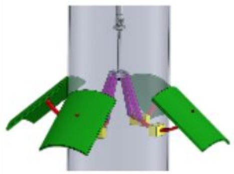
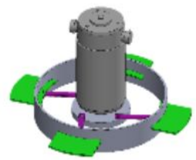
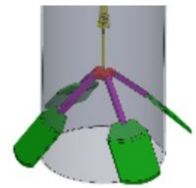
Function Tree

- Show basic requirements for mechanism
- Sub-functions until most fundamental requirements reached

Solution Table

- Lists lowest-level sub-functions of the function tree
- Possible solutions to approach each function with a unique idea

ATS Concept Evaluation

Concept		1		2		3	
Criteria	Importance						
Low Weight	5	1	5	2	10	1	5
Vertically Compact	7	2	14	3	21	1	7
Deployment Speed	10	3	30	2	20	3	30
Low Actuation Force Needed	10	1	10	3	30	2	20
High Drag per Surface Area	8	1	8	1	8	3	24
High Maximum Drag Force	8	3	24	2	16	2	16
High Manufacturability	8	1	8	3	24	2	16
Low Complexity	6	1	6	3	18	2	12
Ease of Maintenance	5	1	1	3	3	2	2
Inexpensive	2	1	2	3	6	2	4
Low Software Complexity	3	3	9	1	3	3	9
Total Possible:	**216**						
Total			117		159		145
Relative Total			54.17%		73.61%		67.13%
Scores Range: 1 - 3 (*1 = bad, 3 = great*)							

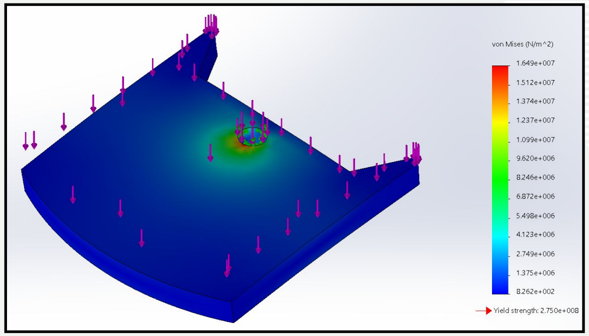
<u>Evaluation Matrix</u>

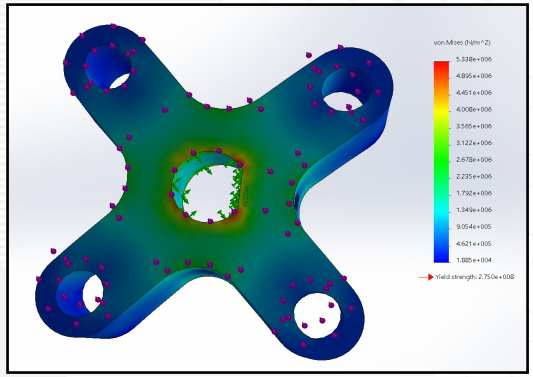
- 3 alternative concepts
- Criteria independent of each other
- Weights applied to each criteria
  - determined through impact on mission performance

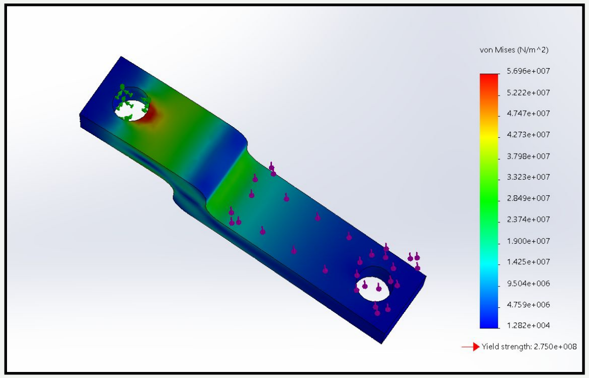
Failure Mode and Effect Analysis - ATS

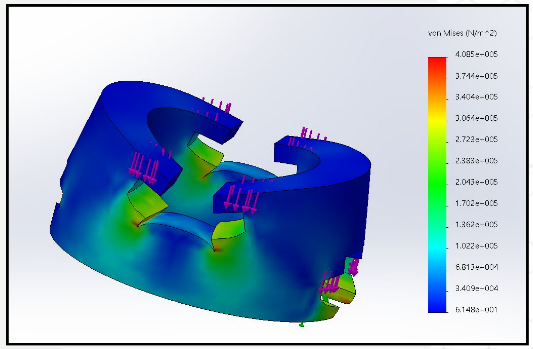
Components	Function	Failure	Potential Causes	Detection Method	Impact	Severity (1 -3)	Detection Difficulty (1 -3)	Probability (1 - 3)	Risk (1-27)	Risk Priority Number (Risk/27)
Raspeberry Pi	sends data to motor boards to actuate motor	Raspberry Pi sends bad data	Software Error	Check coding before launch	Motor does not actuate	2	1	1	2	0.07407
				Simulate flight using pressure/ vacuum chamber		2	1	1	2	0.07407
		Raspberry Pi fails to sends data	Faulty Wiring	Check wiring before flight	Motor does not actuate	2	1	1	2	0.07407
Altimeter	records the height at specified rate	Altimeter fails to send data due to internal error	Faulty Wiring	Check wiring before flight	ATS is not actuated	2	1	1	2	0.07407
			Faulty Altimeter	Simulate flight using pressure/ vacuum chamber	ATS is not actuated	2	1	1	2	0.07407
		Altimeter sends wrong data	Faulty Altimeter	Simulate flight using pressure/ vacuum chamber	ATS is actuated during burnout	3	1	1	3	0.11111
9V Battery	powers altimeter	The connection between the altimeter and the battery severs	Faulty Wiring	Check wiring before flight	ATS is not actuated	2	1	1	2	0.07407
		Battery dies during flight	Faulty Battery	Check the voltage of the battery before flight	ATS is not actuated	2	3	1	6	0.22222
3s LiPo battery	Powers motor	Battery dies during flight	Faulty Battery	Check the voltage of the battery before flight	ATS is not actuated	2	3	1	6	0.22222
		The connection between the motor and the battery severs	Faulty Wiring	Check wiring before flight	ATS is not actuated	2	1	1	2	0.07407

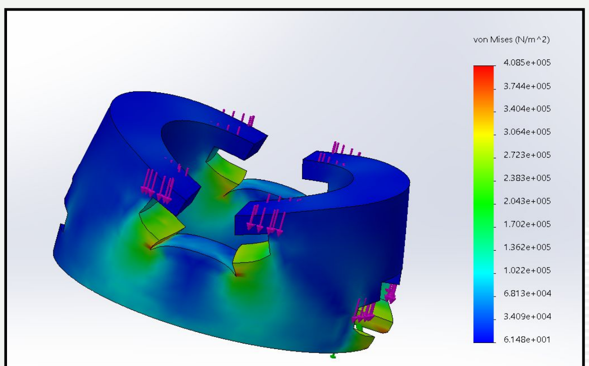
FEA Simulations - ATS

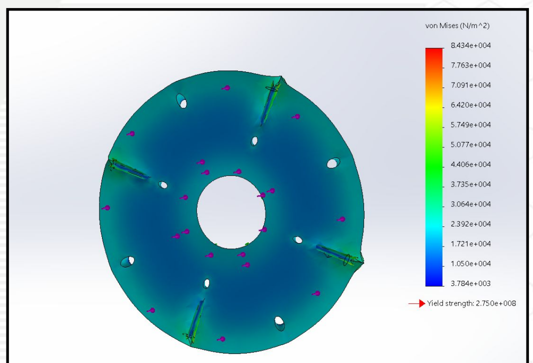








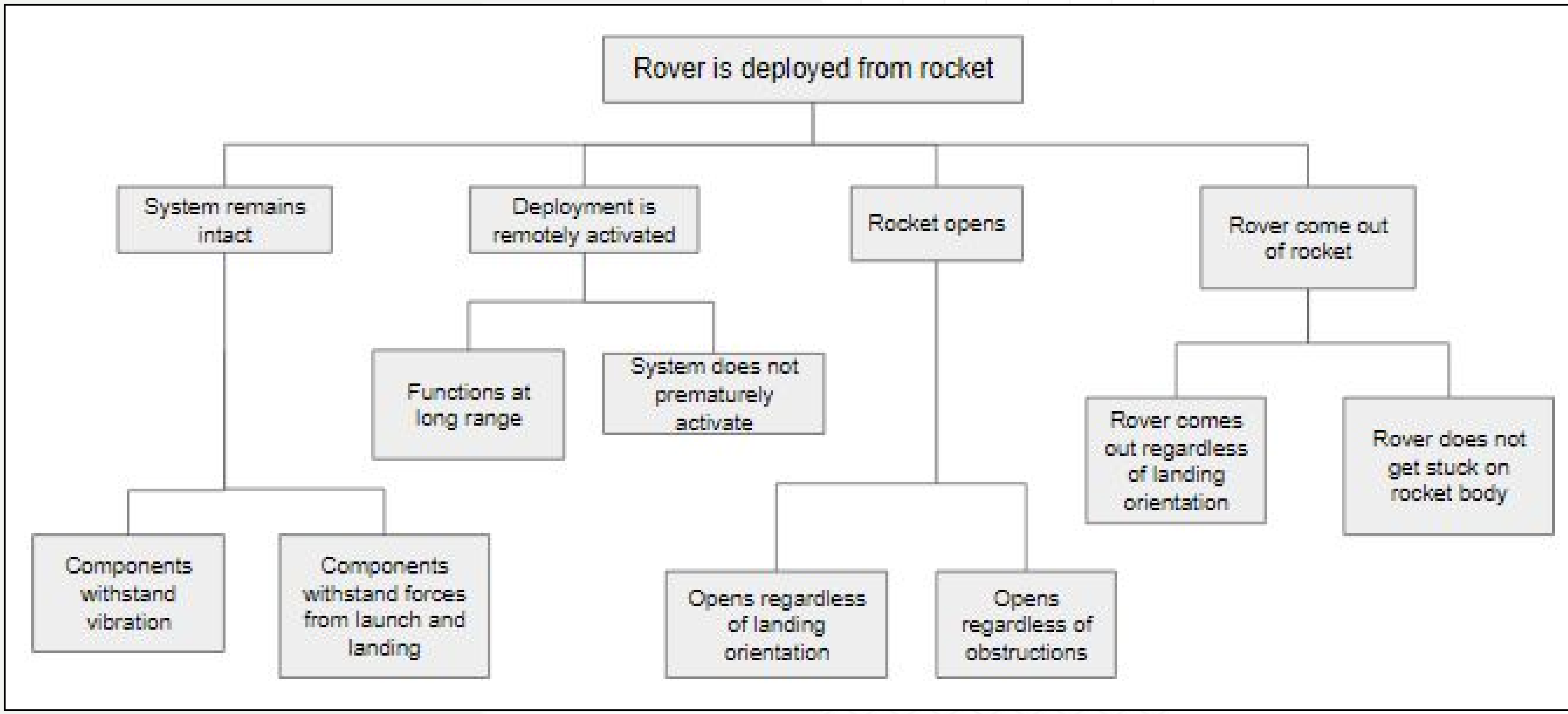




- Design requirement: FOS > 2
- FEA completed on each part to observe stress concentrations and deformation regions
- Highest stress occurs when fully deployed

Payload - Rover

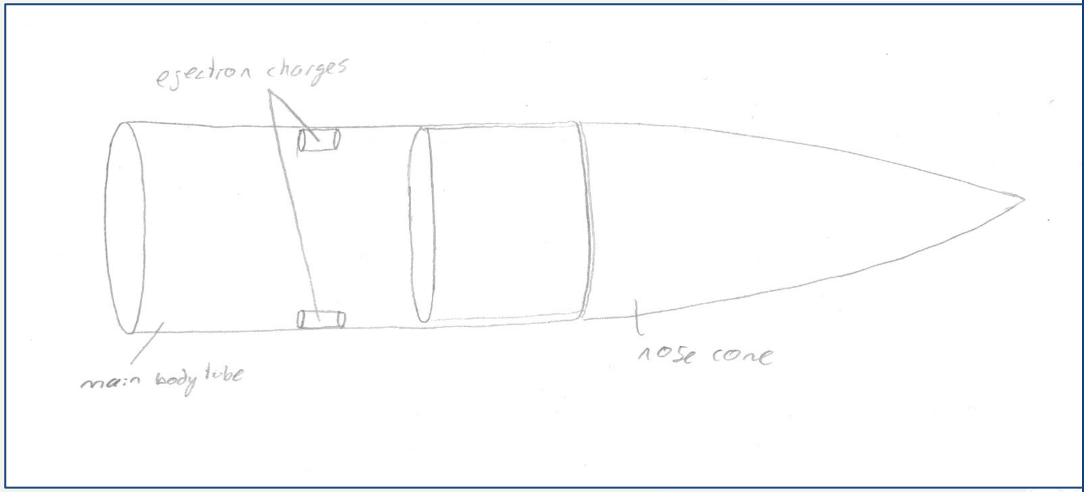
Rover Deployment



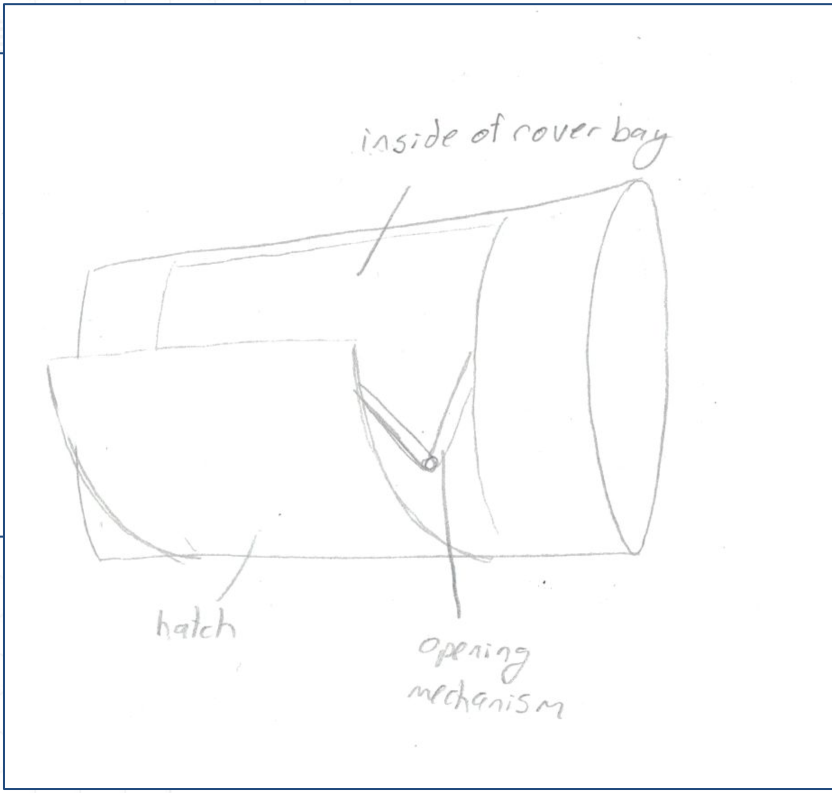
Rover Deployment

Alternative design options

Ejection charges



Side hatch

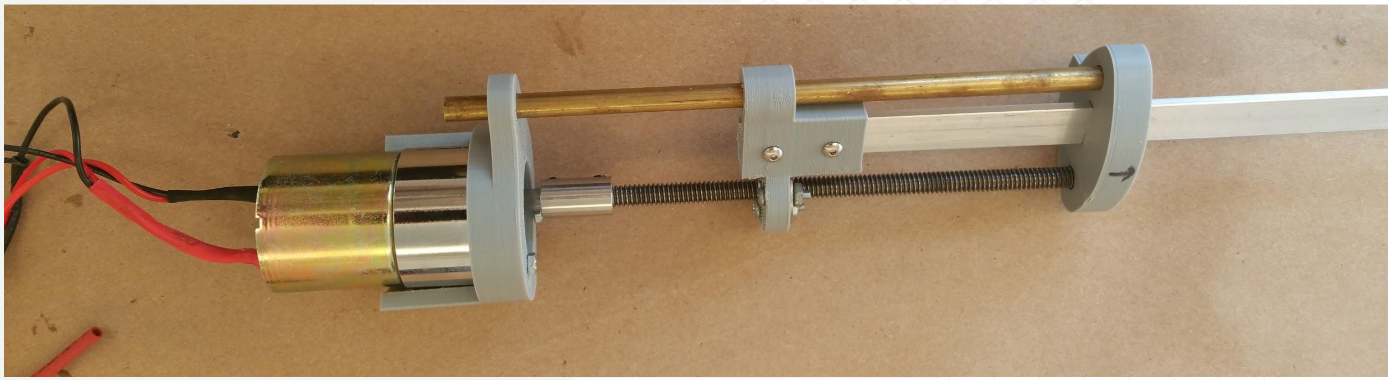


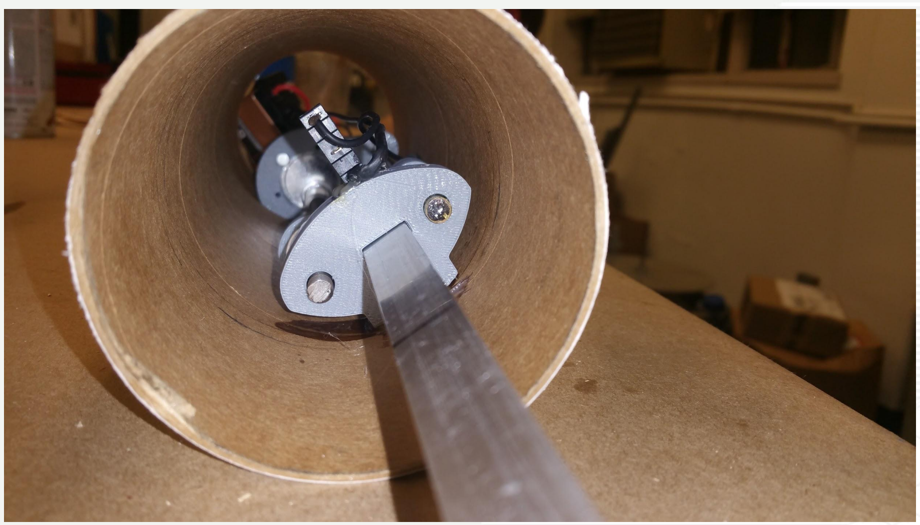
Rover Deployment

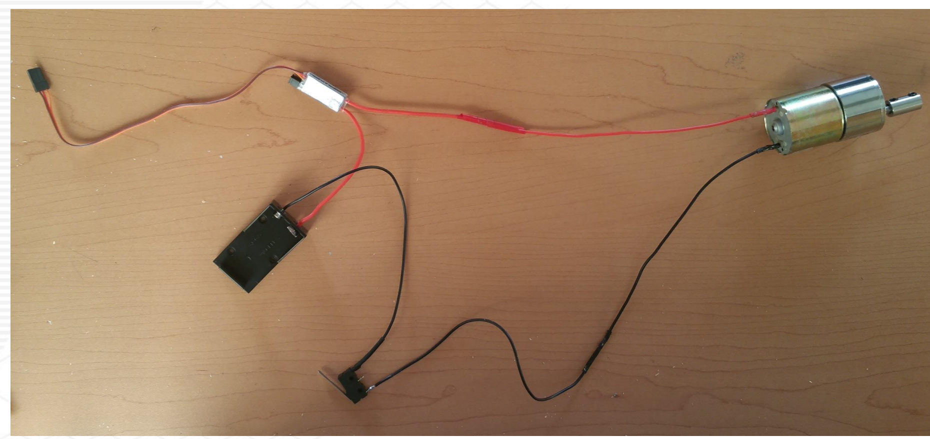
Concept		1		2		3	
Criteria	**Import-ance**	Lead Screw Separation		Ejection Charge Separation		Side Hatch	
Low Weight	6	2	12	3	18	2	12
High Manufacturability	8	2	16	3	24	`` 1	8
Low Complexity	6	1	6	3	18	1	6
Ease of Maintenance	4	1	4	2	8	1	4
Low cost	3	1	3	3	9	2	6
Low Software Complexity	3	2	6	3	9	2	6
Reliability	10	3	30	1	10	1	10
Payload Safety	10	3	30	1	10	3	30
Rover Orientation	8	3	24	2	16	1	8
Total Possible:	**174**						
Total			131		122		90
Relative Total			75.29 %		70.11 %		51.72 %
Scores Range: 1 - 3 (1 = bad, 3 = great)							

Rover Deployment

Prototyping: Lead Screw Mechanism



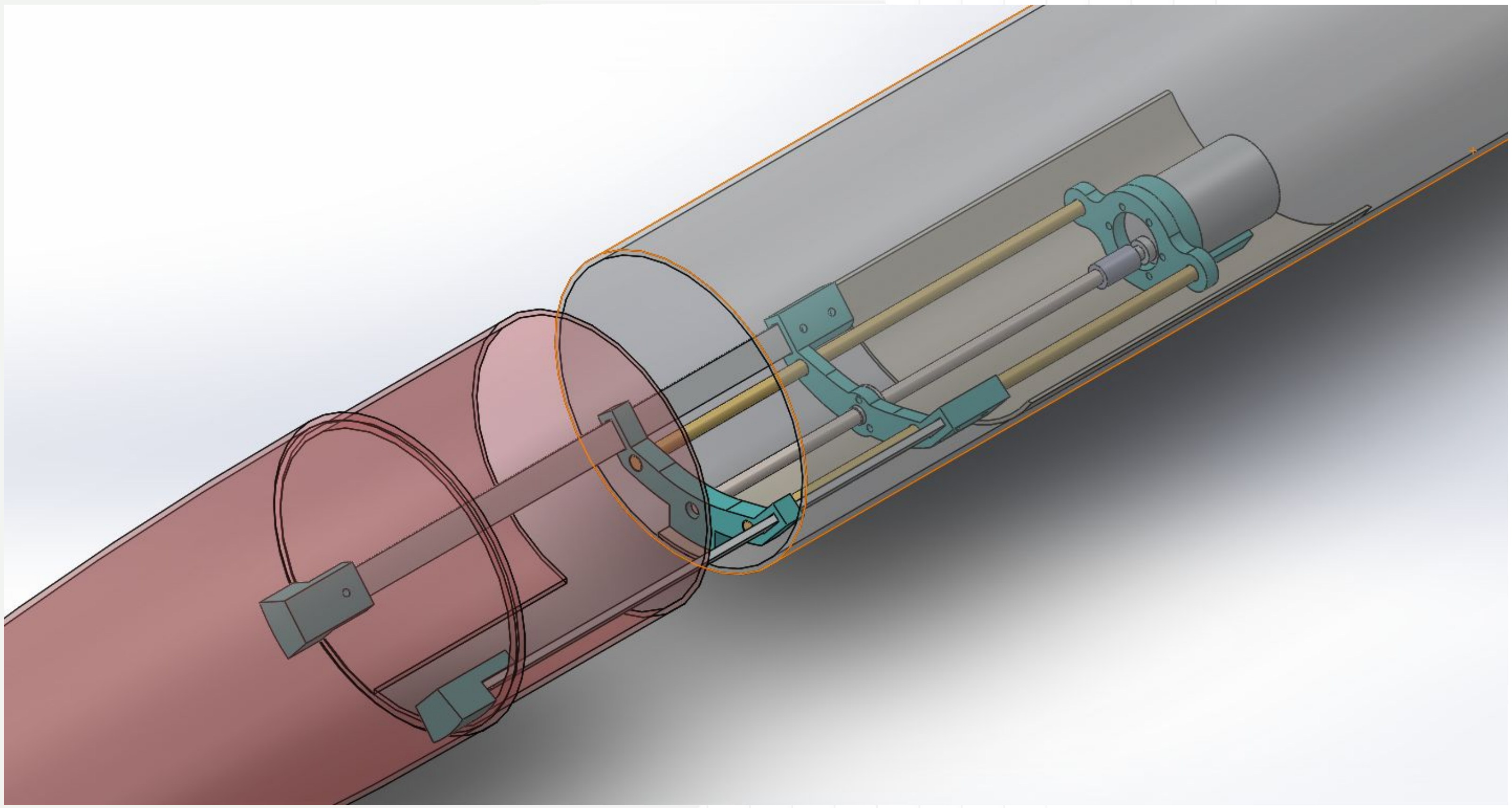




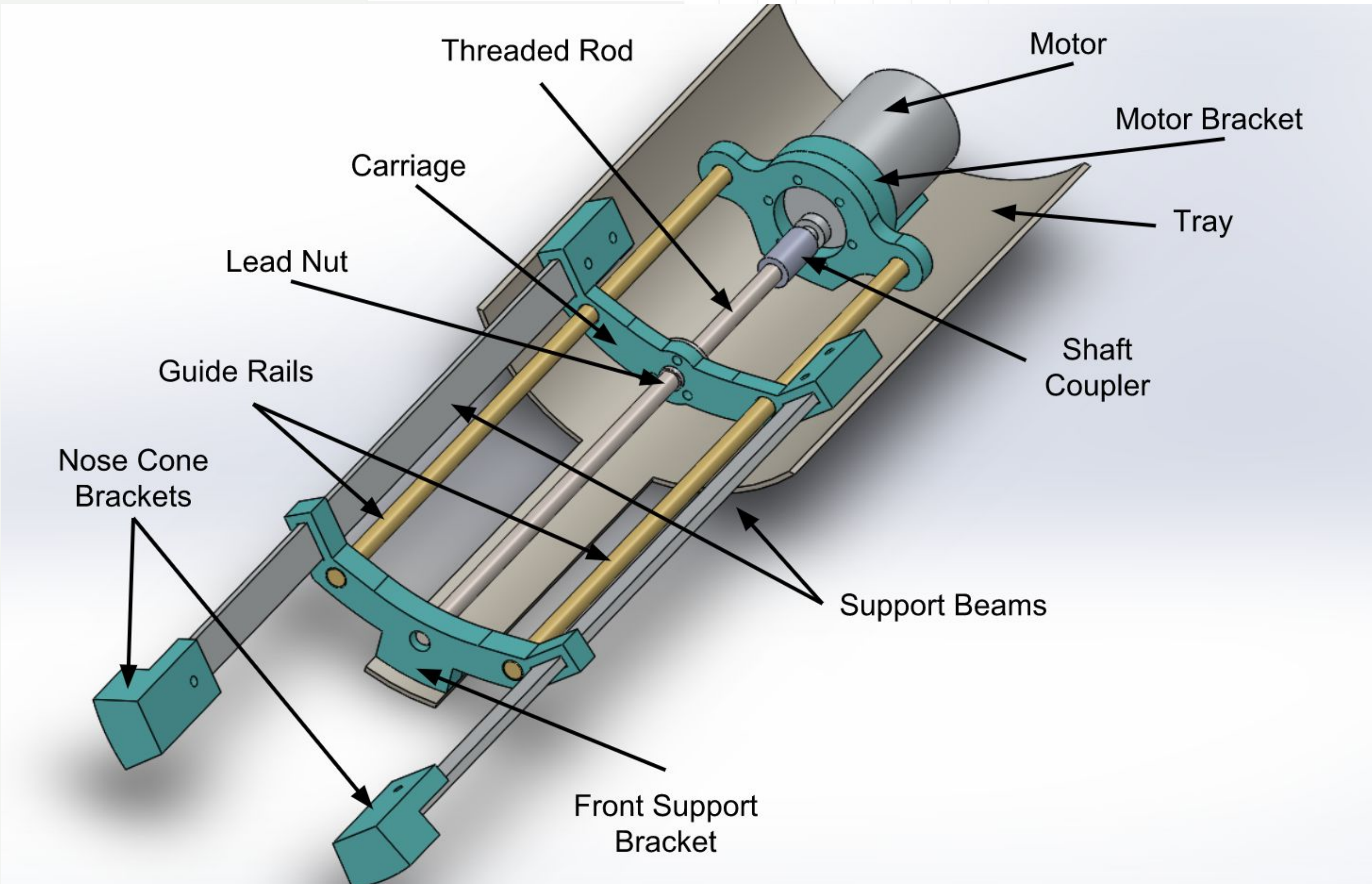
Rover Deployment

Final design decision: Axial lead screw

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



Rover Deployment



Rover Drivetrain

Concept		1		2	
Criteria	**Importance**	Wheels		Tracks	
Low Weight	6	2	12	2	12
High Manufacturability	8	3	24	2	16
Low Complexity	6	3	18	2	12
Inexpensive	3	2	6	2	6
Traction	10	1	10	3	30
Durability	7	3	21	3	21
Risk of Slippage	5	3	15	1	5
Reliability	8	1	8	2	16
Total Possible:	**159**				
Total			114		118
Relative Total			71.70%		74.21%
Scores Range: 1 - 3 (1 = bad, 3 = great)					

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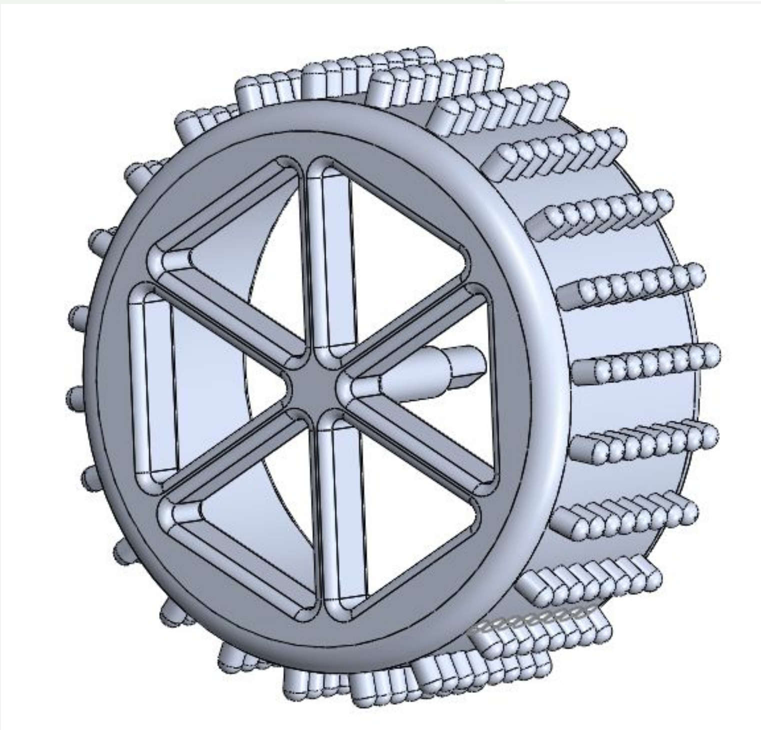
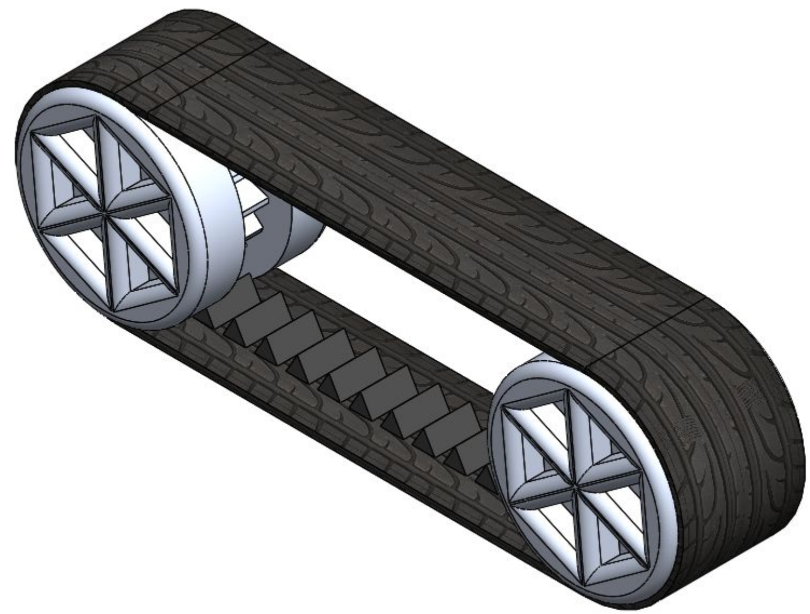
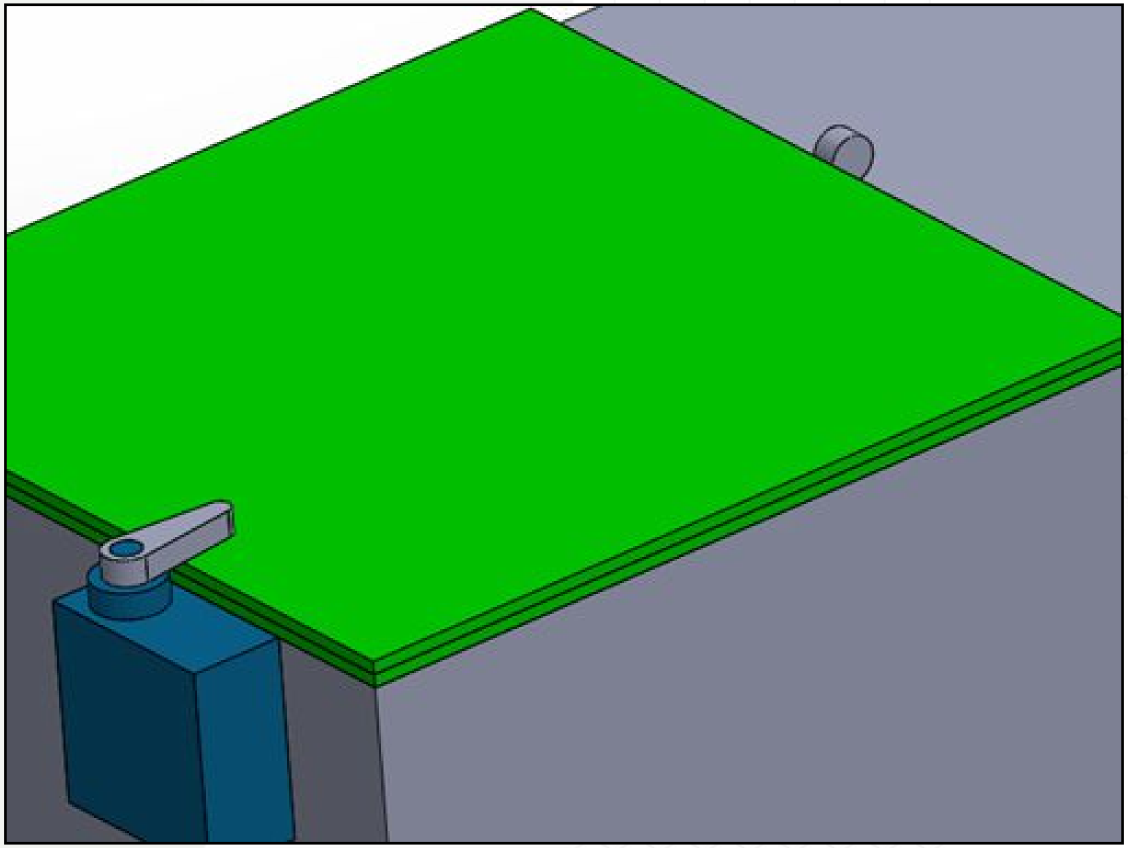
Rover Drivetrain





Rover Solar Panel Deployment

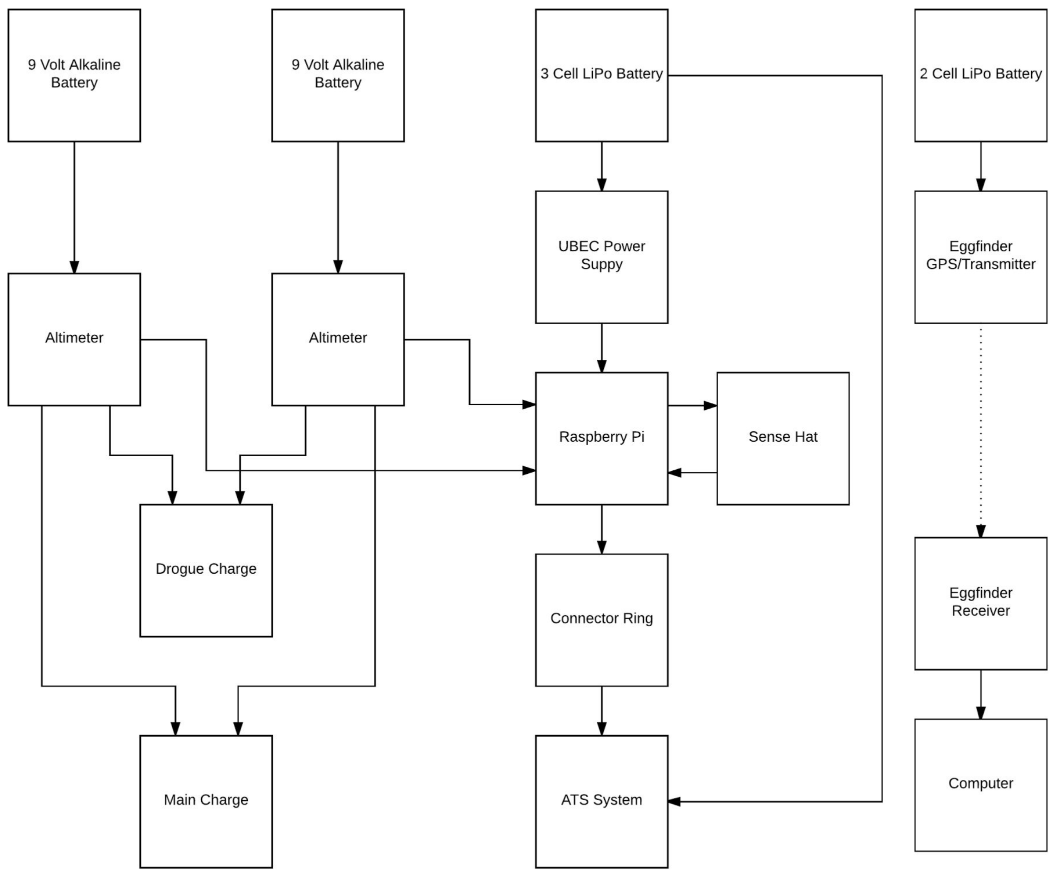


Flight Systems

Avionics Component Breakdown

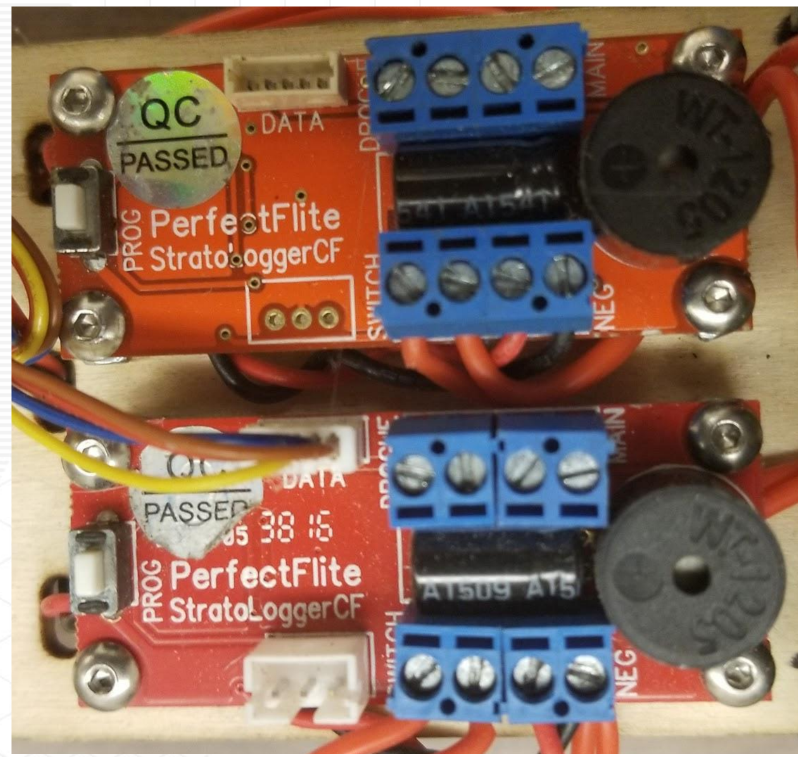
Part	Function
Stratologger CF x2	Altimeter - ignite ejection charges, record max altitude, send real time altitude data to ATS
Eggfinder TX/RX Module	GPS module - used to track the rocket in real time
9V Alkaline Batteries	Provide power to the altimeters

Avionics System Block Diagram

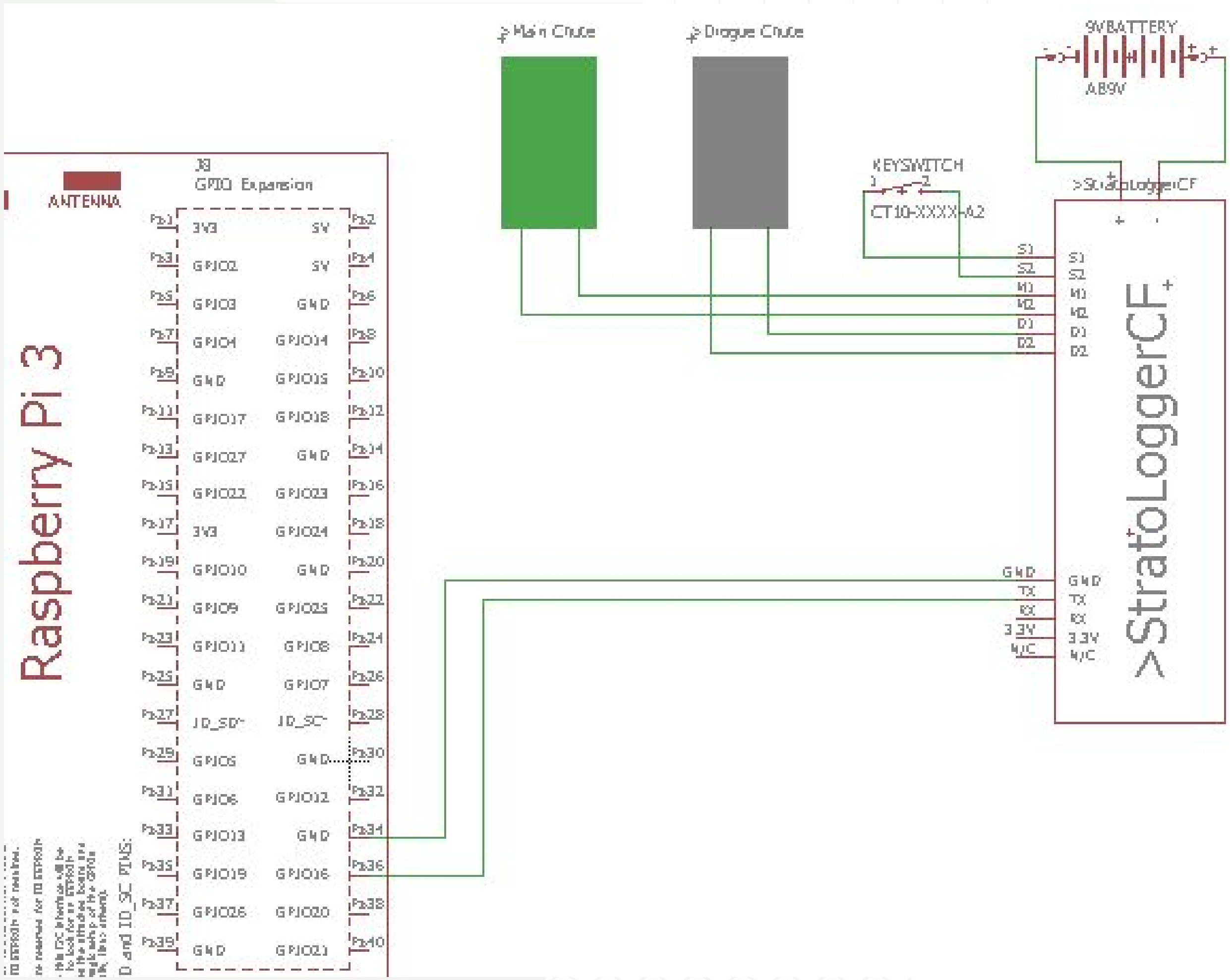


Altimeters

- 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

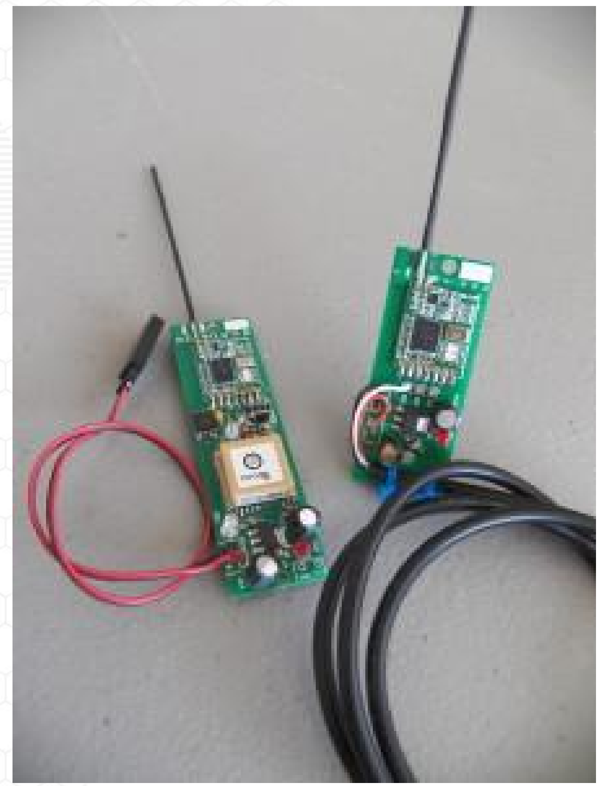


Deployment Wiring Diagram

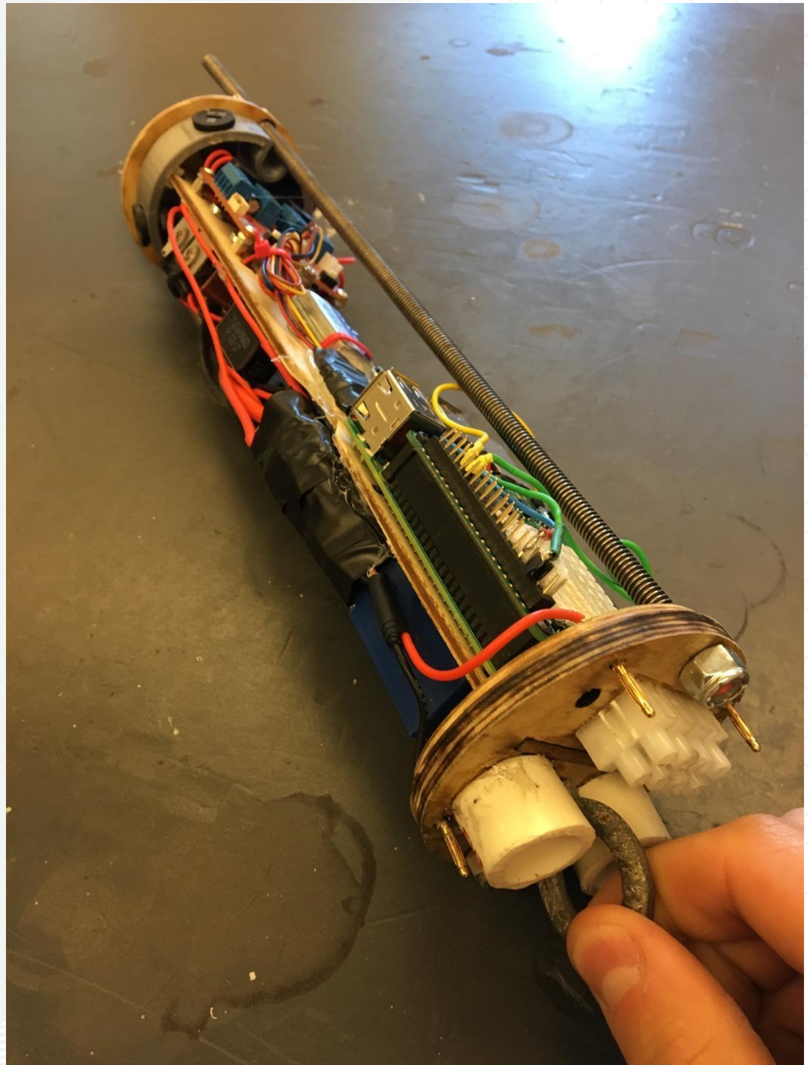


GPS

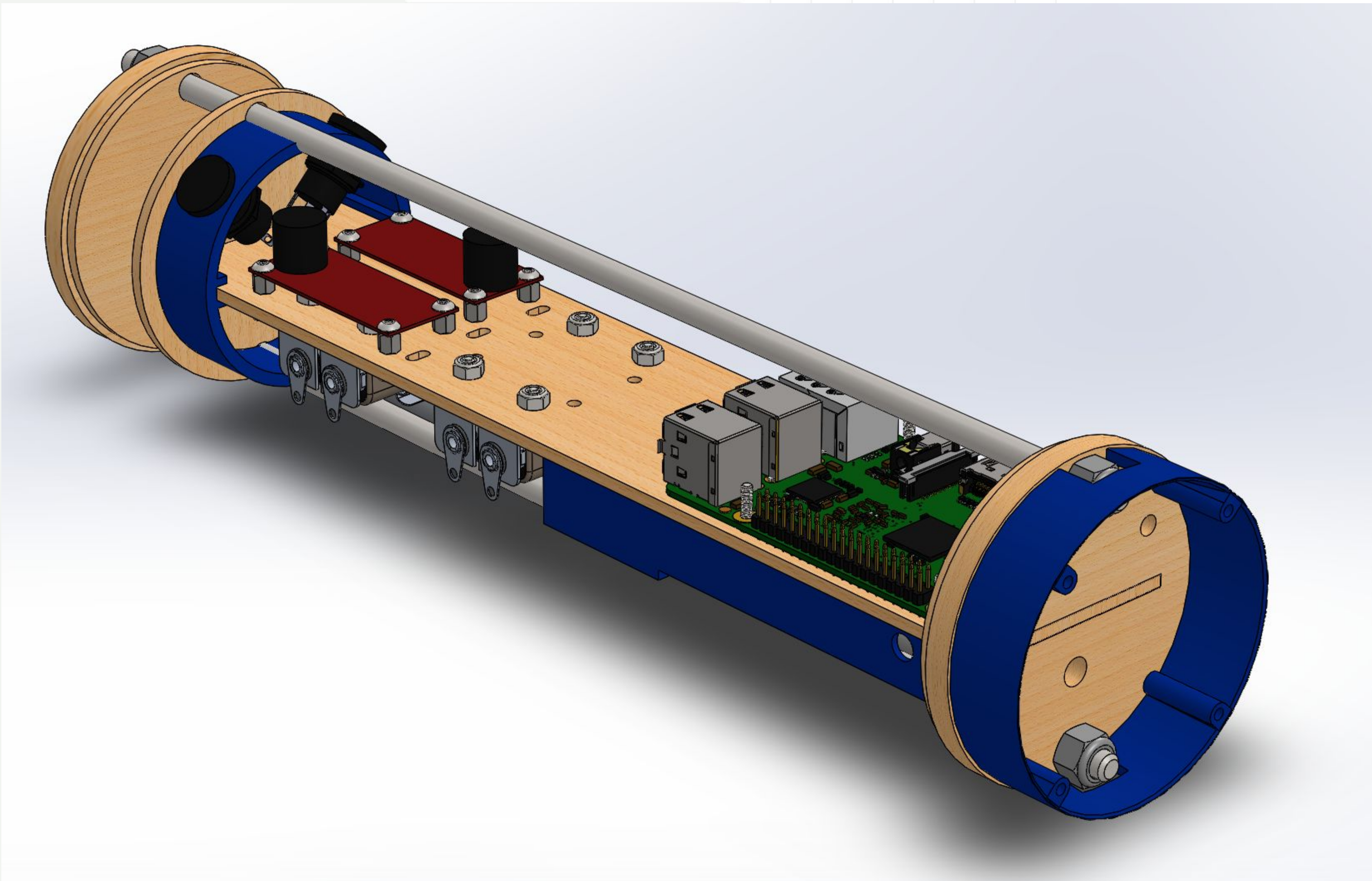
- Eggfinder Transmitter and Receiver Pair
- Laptop will be used to display and record data from receiver
- Transmits on 900 MHz band at 100mW
- Packets sent at 9600 baud, 8 bits, and no parity
- Tx Mass: 20 grams
- Power: 2 cell lipo
- Current Draw: 70-100 mA
- Dimensions: .9"W x 3"L x .4" H



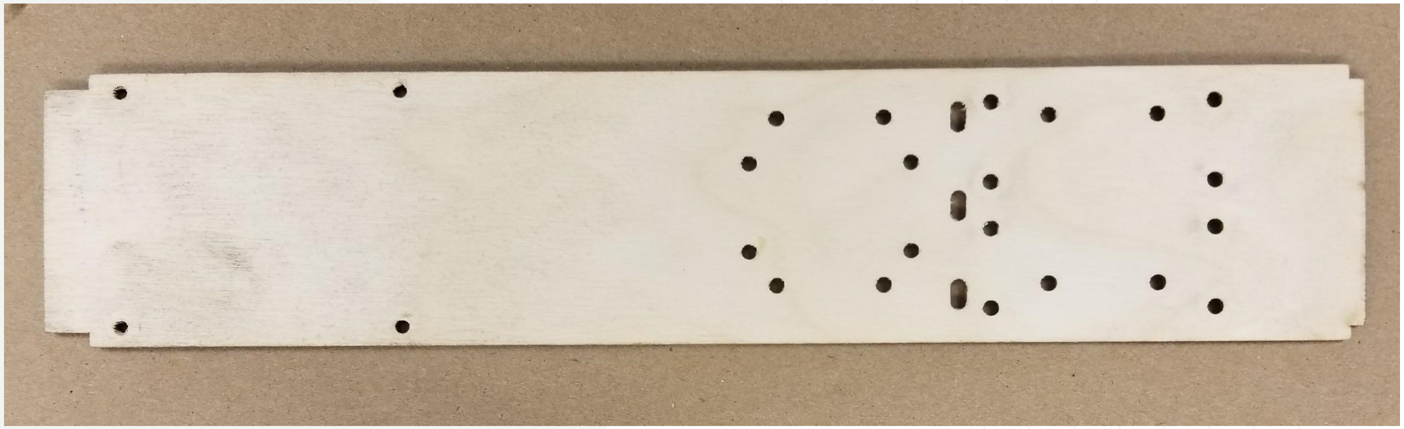
Subscale Avionics Bay Structure

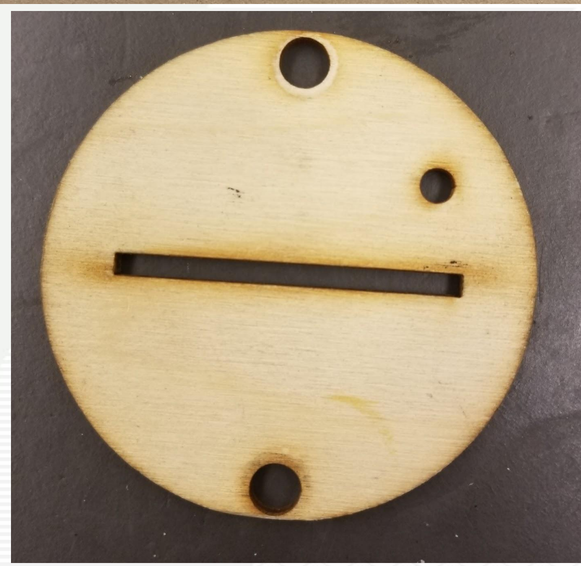


Subscale Avionics Bay CAD

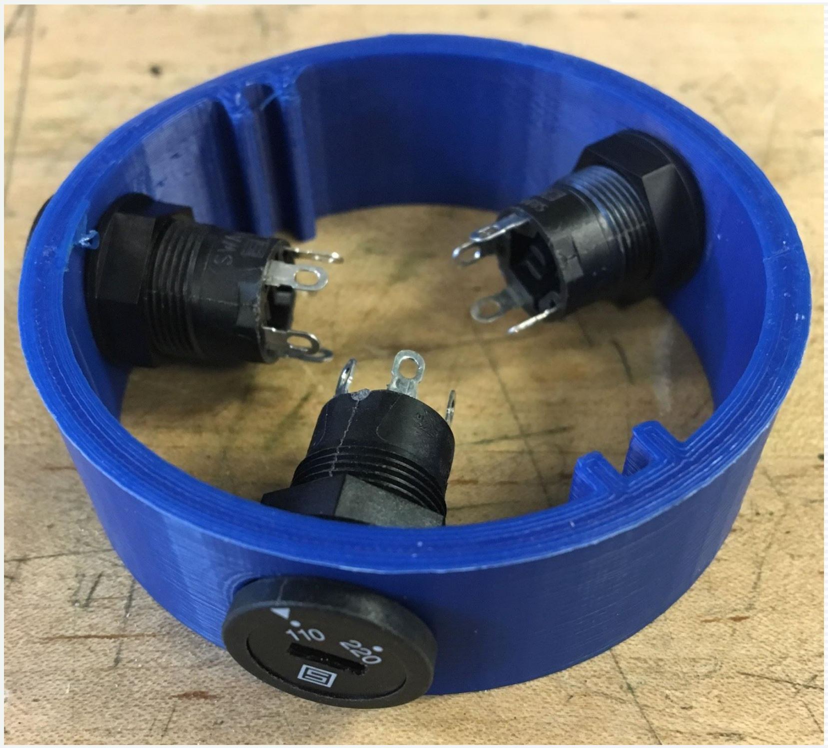


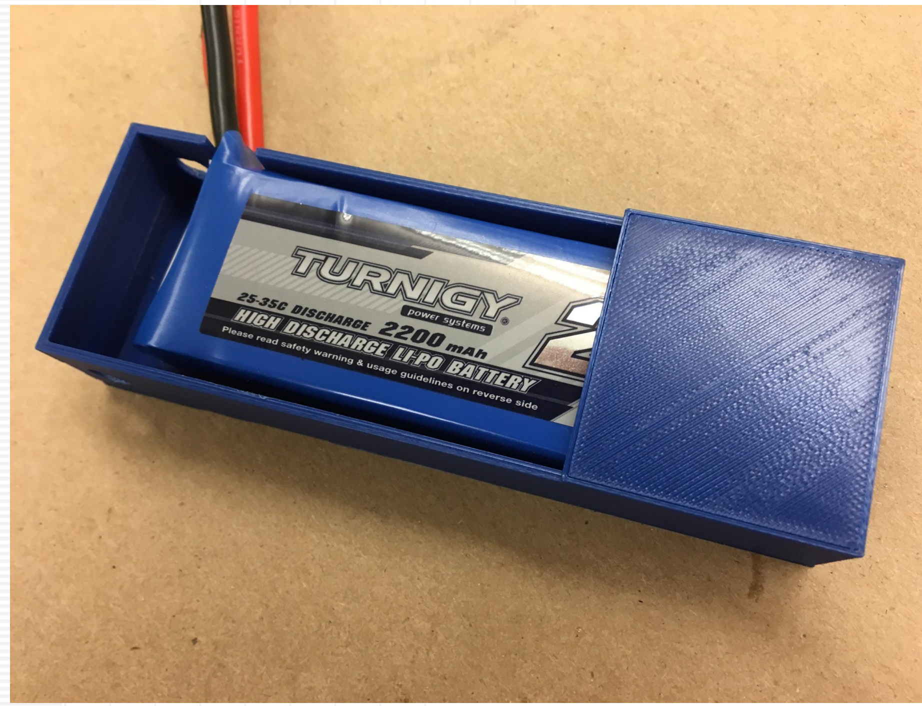
Subscale Laser Cut Parts





Subscale Avionics 3D Printed Parts





Flight Systems

Georgia Tech

QUESTIONS?

2017-2018 NASA STUDENT LAUNCH

PRELIMINARY DESIGN REVIEW

NOVEMBER 13TH, 2017

CREATING THE NEXT®