NASA STUDENT LAUNCH 2019

CRITICAL DESIGN REVIEW

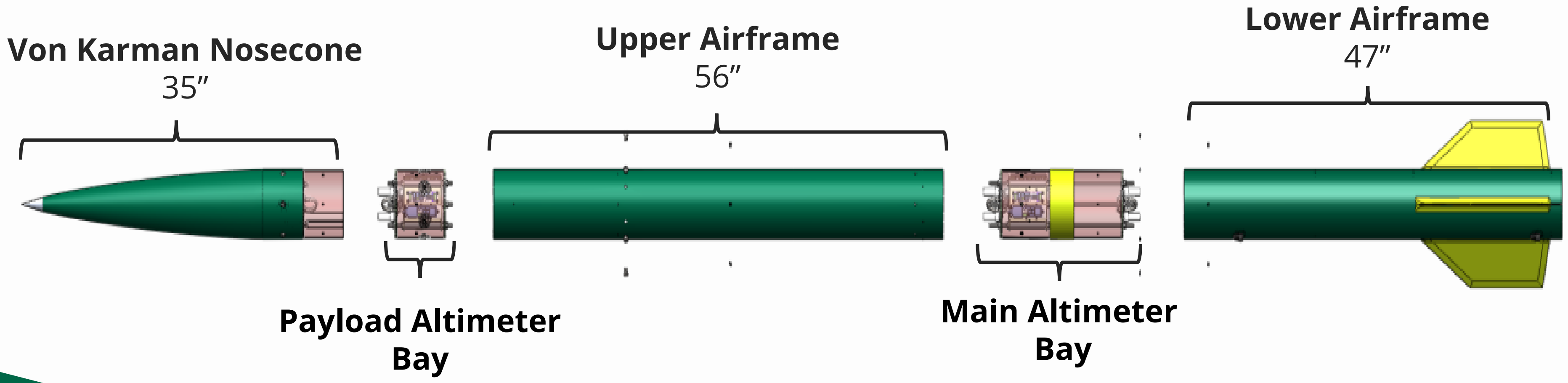
SOCIETY OF AERONAUTICS AND ROCKETRY
UNIVERSITY OF SOUTH FLORIDA

AGENDA

1. **Vehicle Criteria**
2. Recovery
3. Test Plans
4. Subscale Vehicle
5. Payload
6. Project Plan

LAUNCH VEHICLE AND PAYLOAD DIMENSIONS

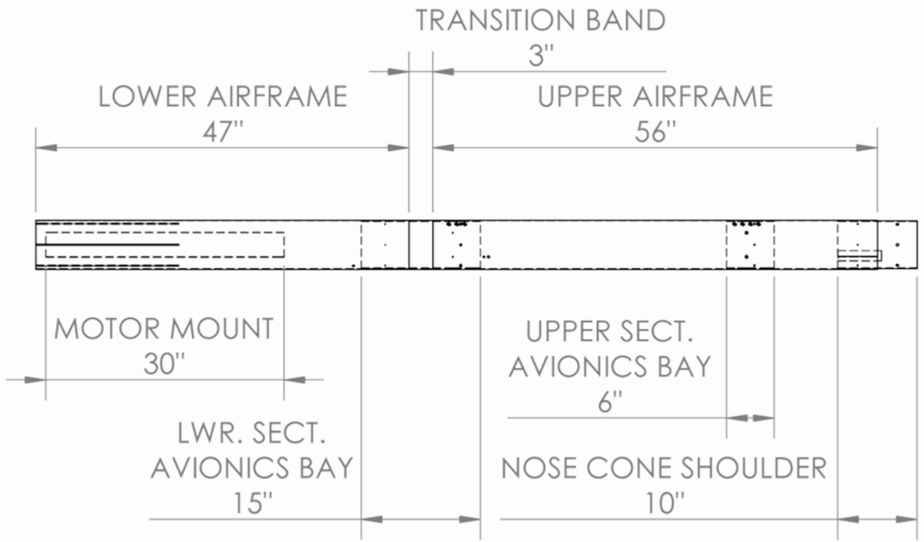
Vehicle Property	Value
Diameter	6"
Length	141"
Projected Unloaded Weight	36.7 lb
Projected Loaded Weight (with motor)	53.9 lb
Estimated Max Payload Weight	8 lb
Estimated Max Payload Length	15"

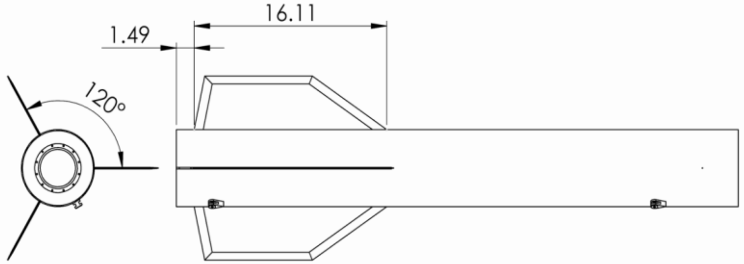


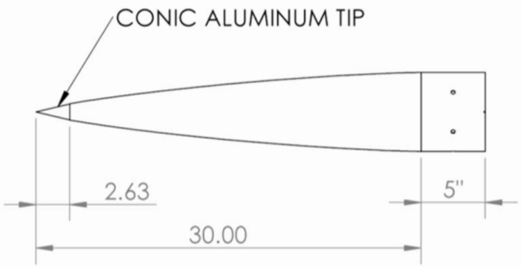
KEY DESIGN FEATURES

Two Separately Tethered Sections:

- Upper Section
  - Upper Section Avionics Bay
  - Upper Airframe
  - Payload Descent Leveling Subsystem (PDLS)
  - Upper Section Main Parachute
  - Adjustable Ballast Subsystem (ABS)
  - Payload
- Lower Section
  - Lower Section Avionics Bay
  - Dynamic Apogee Adjustment Subsystem (DAAS)
  - Lower Section Main Parachute
  - Drogue Parachute
  - Lower Airframe







KEY DESIGN FEATURES

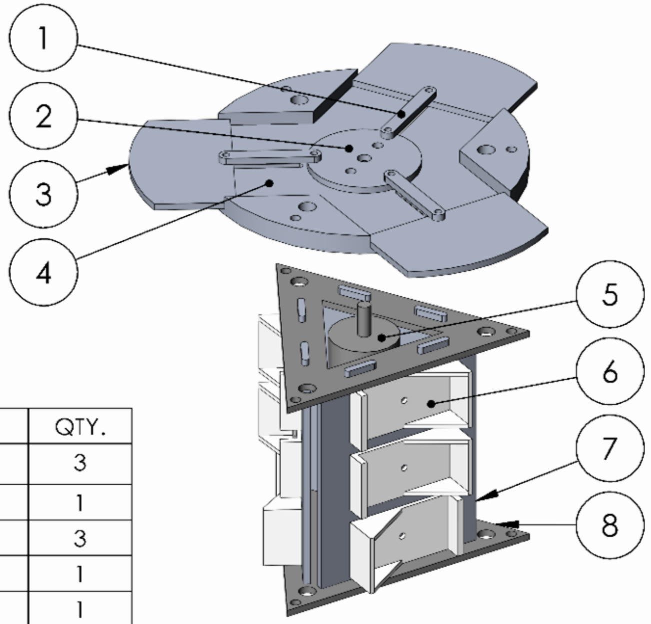
Vehicle Subsystems

- Adjustable Ballast System (ABS)
  - Removable mass within nosecone to allow for adjustment of the launch vehicle's mass and center of gravity (stability) prior to launch.
- Payload Descent Leveling Subsystem (PDLS)
  - Prevents the payload-exit side of upper airframe from impacting ground upon landing, instead causing the airframe to land horizontally under parachute.
- Dynamic Apogee Adjustment Subsystem (DAAS)
  - Airbrakes that will allow the launch to dynamically decrease the apogee during flight in order to reach **5,000 ft**.

- Recovery
  - Upper section main parachute for recovery of payload, upper airframe, and nose cone
  - Lower section main parachute for recovery of lower airframe and lower section avionics bay
  - Full real time GPS and flight data streaming

DYNAMIC APOGEE ADJUSTMENT SUBSYSTEM (DAAS)

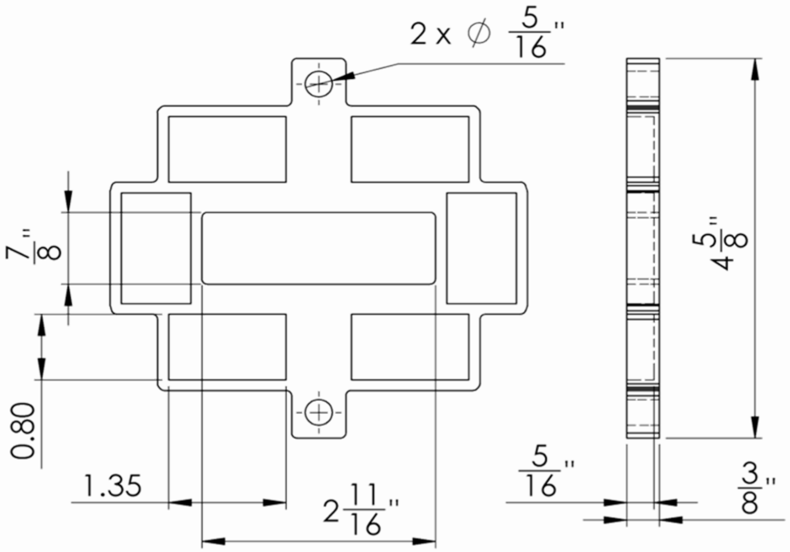
- Three equally spaced, deployable fins controlled by a stepper motor and crank-slider mechanism to dynamically modify vehicle drag forces
- Adafruit BNO055 internal measurement unit (IMU) and BMP280 pressure sensor will collect acceleration, pressure (altitude), orientation, and angular rotation during flight
- SparkFun LSM9DS1 IMU breakout board will be used to help correct any error, along with software Kalman filtering
- An Arduino microcontroller will process the data to control a motor controller powering a 960oz-inch, 12V, planetary geared DC motor with encoder

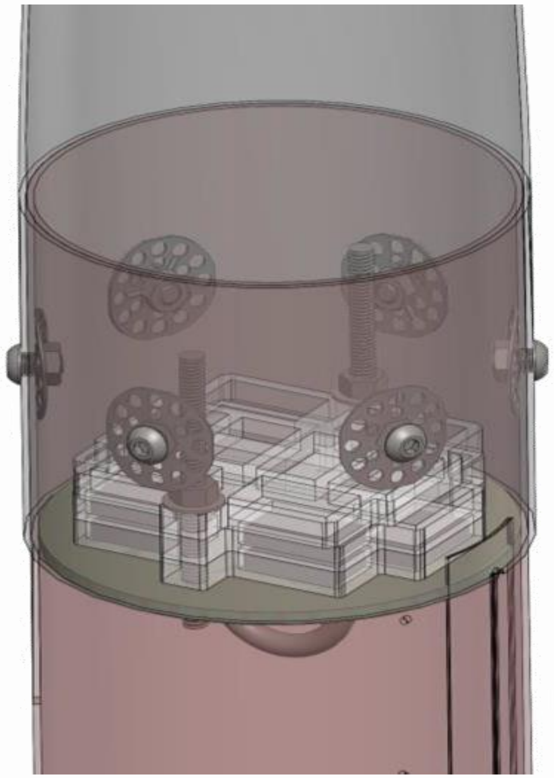


ITEM NO.	PART NAME	QTY.
1	Connecting Rod	3
2	Crank	1
3	Fin	3
4	Retainer	1
5	Motor	1
6	Battery Retainer	6
7	Electronics Sled	3
8	Eelectronics Cap	2

ADJUSTABLE BALLAST SUBSYSTEM (ABS)

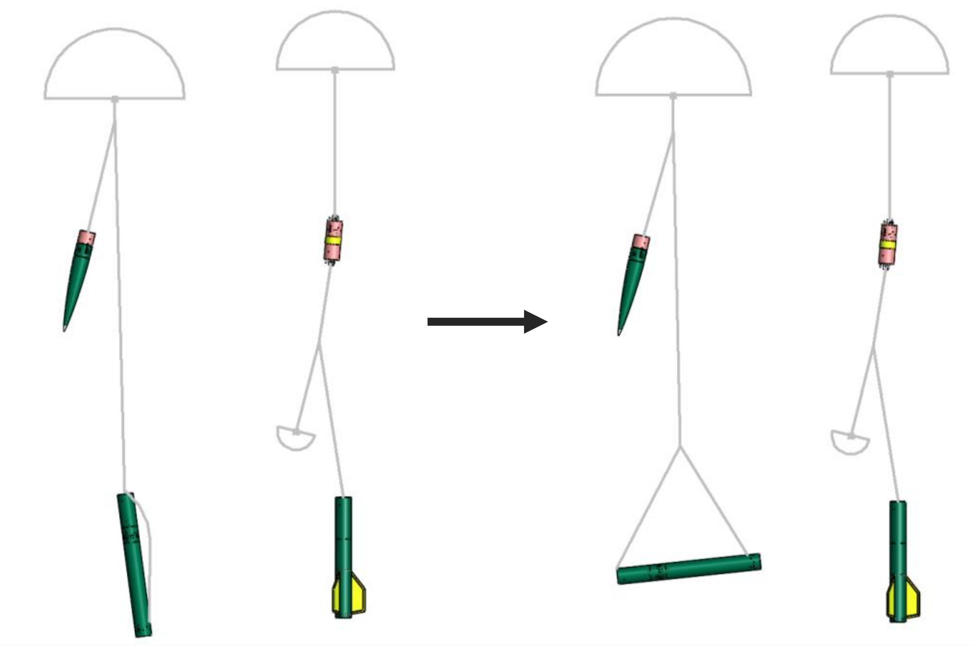
- Several stackable and removable weighted plates.
- Each plate will have several slots where 1-oz. weights can be placed
- Plates will be CNC-milled from clear acrylic for easy visibility





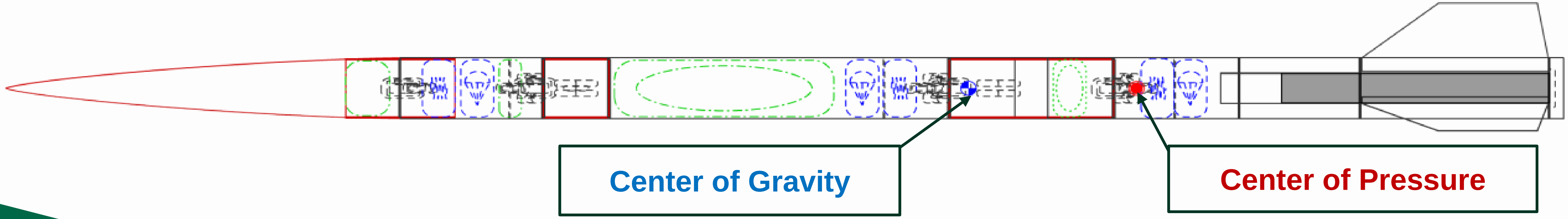
PAYLOAD DESCENT LEVELLING SUBSYSTEM (PDLS)

- Ensures a clear path for payload deployment A
- 1/16” stainless steel stranded wire will run along airframe exterior
- In lower end of the upper airframe, wire will be securely threaded into a standard 5/16” epoxy nut
- In upper end of the upper airframe, wire will attach to the upper section parachute shock cord
- Wire will be loosely taped to airframe to prevent entanglement
- Deployment will be controlled by Tender Descender and Missile Works RRC2+



STATIC STABILITY

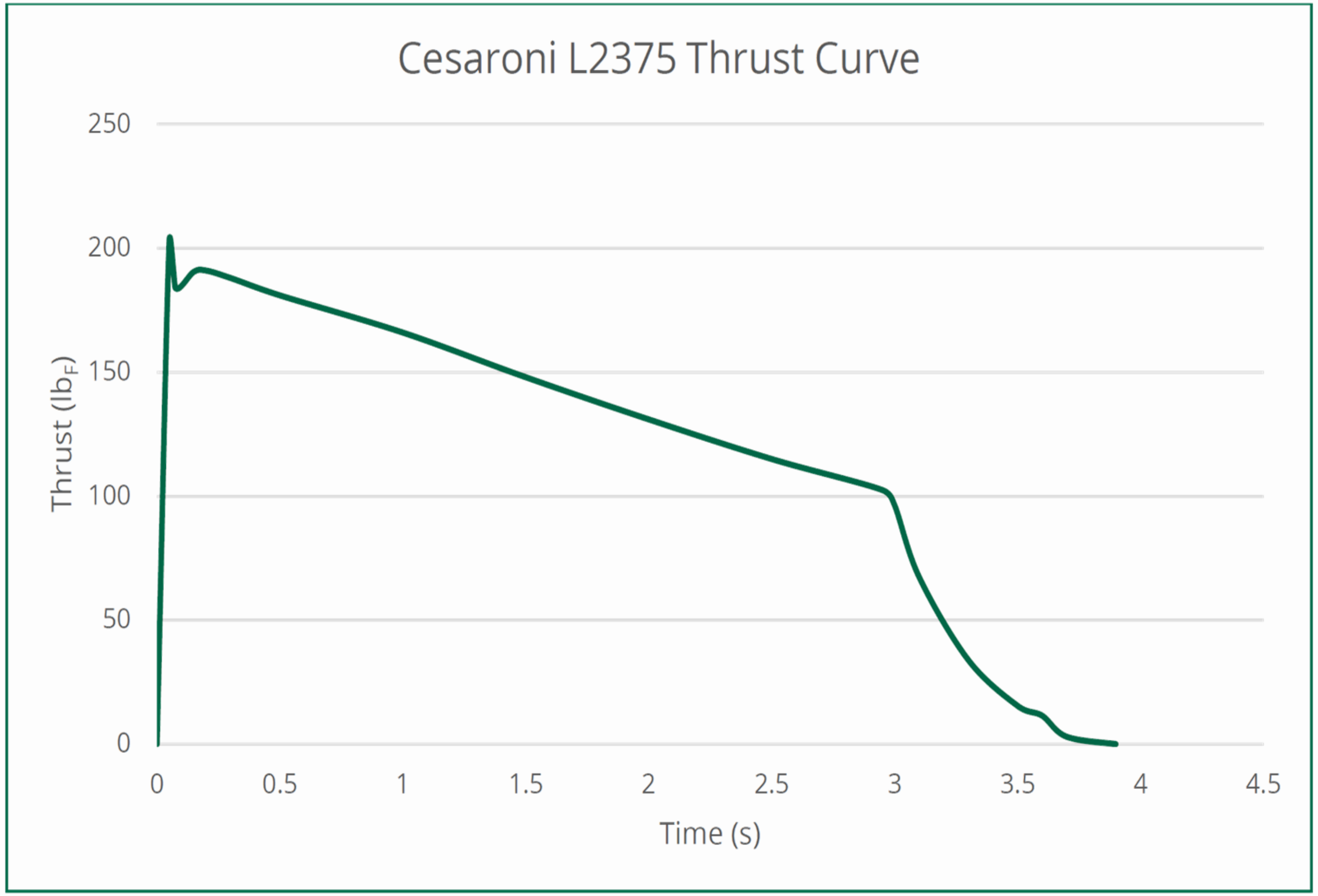
Stability Characteristic	Value
Center of Pressure (in. from nose)	102
Center of Gravity (in. from nose)	87.6
Static Stability Margin (on pad)	2.40
Static Stability Margin (at rail exit)	2.48
Thrust-to-Weight Ratio	10.22
Rail Size/Type and Length (in)	Type 1515, 144



MASS STATEMENT

Vehicle Section	Component / Subsystem	Mass (lb)	Total Section Mass (lb)
Upper	Nose Cone and Recovery Hardware	5.8	23.2
	Allotted adjustable ballast subsystem (without ballast)	0.0	
	Upper airframe	4.84	
	Forward altimeter bay (and attached hardware)	2.5	
	Payload (allotted)	8.0	
	Upper section main parachute	0.5	
Lower	Main altimeter bay (and attached hardware)	5.99	21.5
	Allotted airbrakes subsystem	3.0	
	Lower airframe and centering rings	6.09	
	Lower section main parachute	1.4	
	Drogue parachute	0.312	
	Fins	3.77	
	Motor mount	0.941	
		Total mass without motor	**44.7**

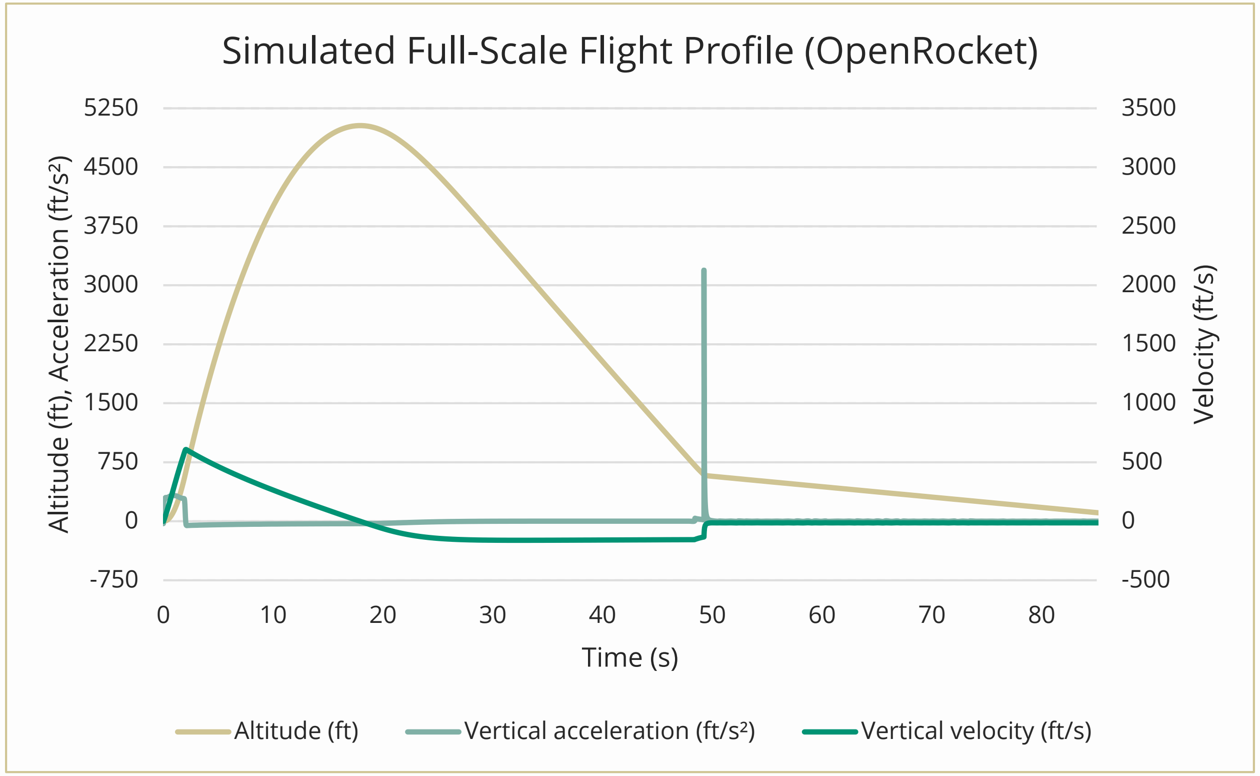
FINAL MOTOR SELECTION



Motor Property	Value
Name	Cesaroni L2375
Average Thrust	551 lbf
Maximum thrust	629lbf
Total Impulse	1093 lbf-s
Burn Time	1.9 s
Case Info	Pro75-4G

FLIGHT CHARACTERISTICS

Selected Target Apogee: **5,000 ft**



Flight Property	Value
Apogee	5,025*
Velocity off Rail	76.7 fps
Max. Velocity	608 fps
Max. Acceleration	328 ft/s^2
Ascent Time	17.9 s

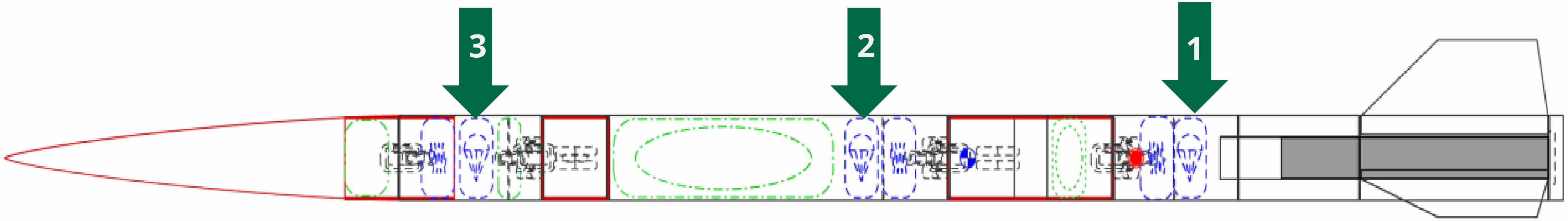
**Apogee calculated without airbrakes or ballast*

AGENDA

1. Vehicle Criteria
2. **Recovery**
3. Test Plans
4. Subscale Vehicle
5. Payload
6. Project Plan

RECOVERY OVERVIEW

1. **Drogue Parachute**: Stored in lower airframe between lower section avionics bay and motor
2. **Lower Section Main Parachute**: Stored in upper airframe between payload and lower section avionics bay
3. **Upper Section Main Parachute**: Stored in upper airframe between nose cone and upper section avionics bay



RECOVERY Process

A. Vehicle is launched

B. Apogee: Lower airframe separates and drogue is deployed

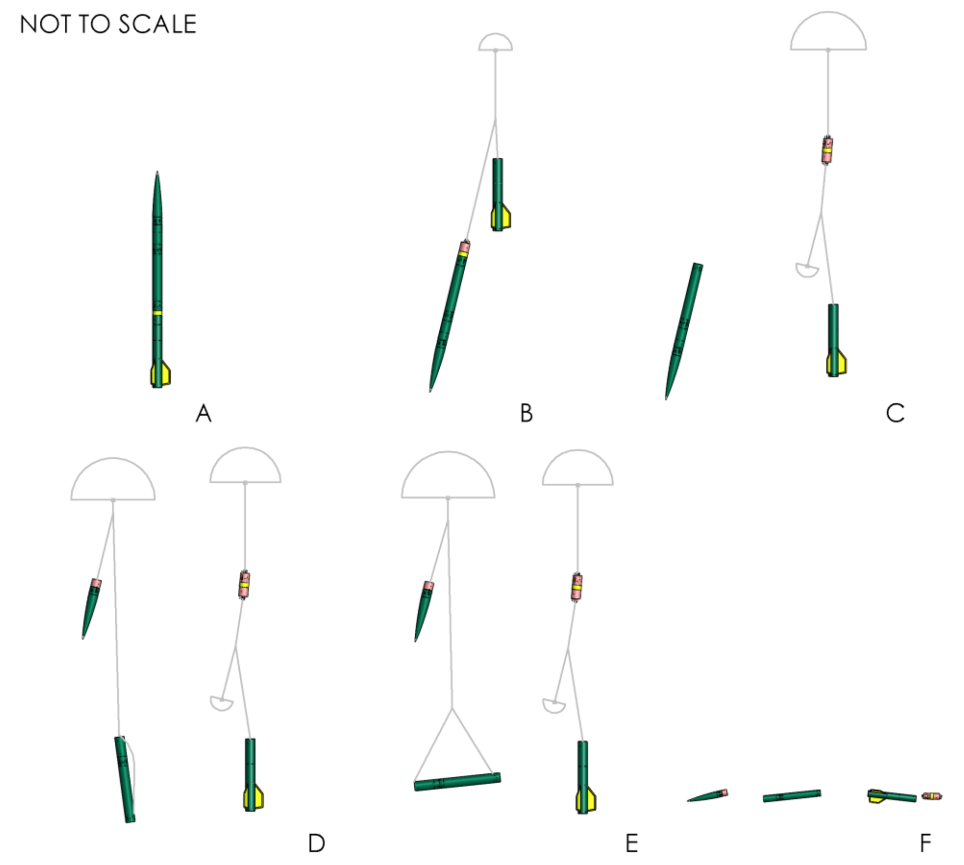
C. 750 ft: Upper section separated and lower section main parachute is deployed

D. 725 ft: Nose cone separates from upper airframe and upper section main parachute is deployed

- *Delay allows for separation to prevent entanglement*

E. 550 ft: PDLS actives Tender Descender, causing upper airframe to drop to horizontal position

F. Vehicle lands, tracking system continues to broadcast GPS coordinates

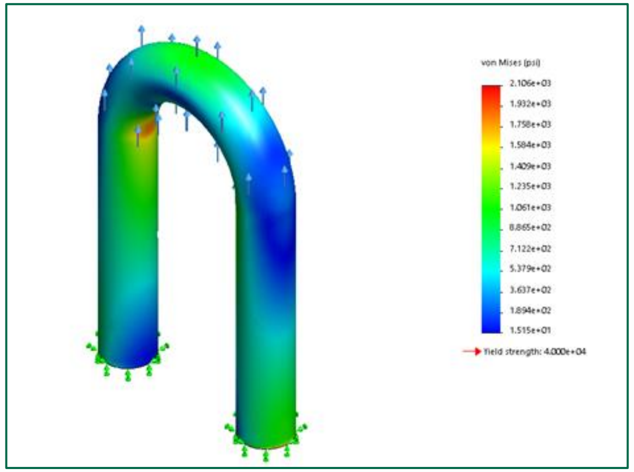


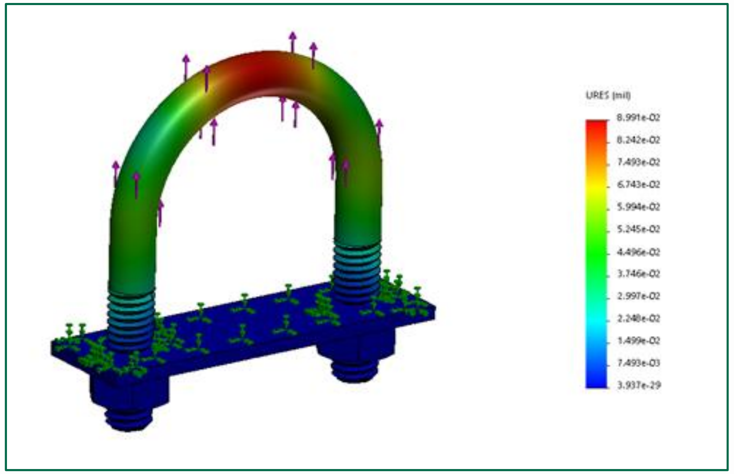
RECOVERY DETAILS

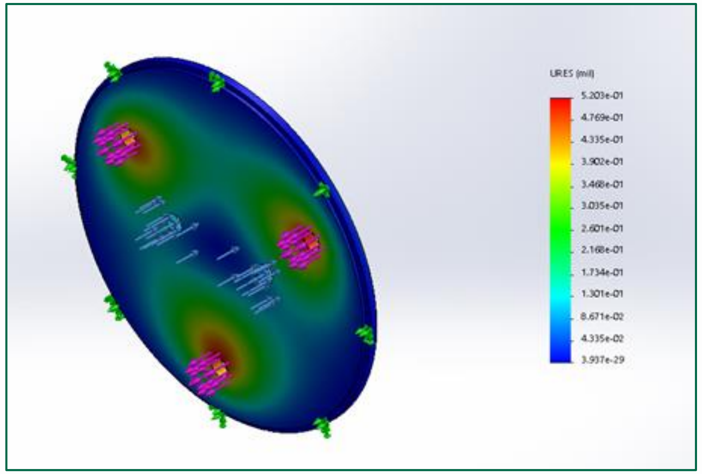
Parachute Name	Fruity Chutes Iris Ultra Standard 84”	Fruity Chutes Iris Ultra 96”	20’ inch SkyAngle Classic drogue
Deploy setting	725 ft	750 ft	Apogee
Backup Deploy Setting	710ft	735ft	Apogee + 1s
Material	1.1oz Ripstop Nylon	1.1oz Ripstop Nylon	Zero-porosity 1.9 oz. silicone-coated balloon cloth
Surface Area (sq ft)	38.48	50.2	4.4
Drag Coefficient	2.2	2.2	0.8
Number of Lines	13	13	3
Line Length (in)	33.5	33.5	25
Shock Cord	1/2" Tubular Kevlar	1/2" Tubular Kevlar	1/2" Tubular Kevlar
Descent Rate (fps)	15.01	13.49	133
Terminal Velocity (fps)	14.94	13.25	136

RECOVERY HARDWARE

- Tested / calculated to have minimum factor of safety of 3.0
- Expected maximum payload deployment shock force of 61.93 lbf
- All stainless-steel hardware, except fiberglass bulkheads







MISSION PERFORMACE PREDICTIONS

	Descent Time				Kinetic Energy at Landing
	Method 1 $V = \sqrt{\frac{2gm}{\rho a}}$		Method 2 {OpenRocket}		
Section	**Descent velocity (f/s)**	**Descent time (s)**	**Descent velocity (f/s)**	**Descent time (s)**	**Minimum A.Cd (ft^2)**
Nose Cone and Payload	14.44	51.94	13	55.38	93.7
Booster (with Main Altimeter bay)	14.99	43.46	13	46.15	80.5

MISSION PERFORMANCE PREDICTIONS

Lower Section				
	OpenRocket Simulation		Manual Calculation $d = v_w t$	
	Simulation 1	Simulation 2	Simulation 1	Simulation 2
Wind Speed (mph)	**Drift (ft.)**			
0	0	0	0	0
5	538.76	533.62	598.13	599.28
10	1095.85	1067.25	1196.26	1200.1
15	1614.8	1600.87	1794.4	1796.5
20	2161.62	2134.5	2392.5	2396.73

Upper Section				
	OpenRocket Simulation		Manual Calculation $d = v_w t$	
	Simulation 1	Simulation 2	Simulation 1	Simulation 2
Wind Speed (mph)	**Drift (ft.)**			
0	0	0	0	0
5	551.95	548.3	616.45	616.38
10	1104.65	1099.8	1232.91	1233.42
15	1654.4	1651.1	1849.36	1851.6
20	2193.88	2193.9	2465.8	2467.4

AGENDA

1. Vehicle Criteria
2. Recovery
3. **Test Plans**
4. Subscale Vehicle
5. Payload
6. Project Plan

TEST PLANS

Test Type	Reason	Status
Subscale Parachute Ground Tests	To ensure enough black powder is used in order to successfully eject the recovery components out of the airframe	Completed on 12/14/18
Subscale Launch	To ensure all systems perform as expected and verify that rocket can be recovered and reused	Completed on 12/15/18
Subscale Tender Descender Stress Test	To ensure the tender descender will remain intact after launch.	Completed on 12/15/18
Subscale Payload Descent Leveling Subsystem Test	To ensure the integrity and design of the PDLS and determine if there needs to be adjustments in the cord used, the length of the cords used, or if a different design needs to be implemented.	Completed on 12/15/18
Subscale Solenoid Retention Launch Test	To ensure the payload does not leave the launch vehicle prematurely.	1/18/19
Subscale Dynamic Apogee Adjustment Subsystem Test	To ensure the necessity of the DAAS and determine if there is a need for a fullscale version to be constructed	1/18/19

TEST PLANS

Test Type	Reason	Status
Full Scale Parachute Ground Tests	To ensure enough black powder is used to successfully eject the components out of the airframe	02/15/19
Full Scale Launch	To ensure all systems perform as expected and verify that rocket can be recovered and reused and that the rocket can reach apogee of 5,000 ft	02/16/19
Full Scale Payload Descent Leveling Subsystem Test	To ensure the integrity and design of the PDLS and determine if there needs to be adjustments in the cord used, the length of the cords used, or if a different design needs to be implemented.	02/16/19
Full Scale Solenoid Retention Launch Test	To ensure the payload does not go ballistic.	02/16/19
Full Scale Dynamic Apogee Adjustment Subsystem Test	To ensure the necessity of the DAAS and determine if there is a need for a fullscale version to be constructed	02/16/19

TEST PLANS

Test Type	Reason	Status
Wet Conditions test	To ensure the choice in wheel type and soil collection method is able to drive over different wet terrains for at least 10 feet and be able to collect at least 10 grams of soil	TBD
Rough terrain test	To ensure the choice in wheel type and soil collection method is able to drive over different rough terrains for at least 10 feet and be able to collect at least 10 grams of soil	TBD
Battery life	To ensure the batteries chosen are durable and can withstand the necessary time delays and still function properly	TBD
Signal strength test	To ensure the payload has a signal strength of at least 100ft	TBD

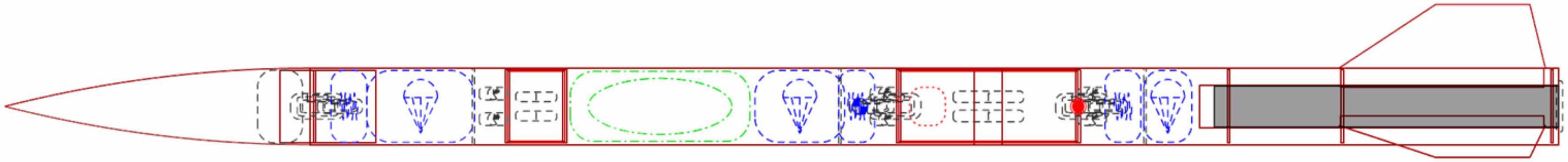
AGENDA

1. Vehicle Criteria
2. Recovery
3. Test Plans
4. **Subscale Vehicle**
5. Payload
6. Project Plan

SUBSCALE VEHICLE SUMMARY

- The Subscale, Apis III-S, was constructed to be ⅔ scale of the full-scale vehicle.
  - CG: 47.64 in. from tip
  - CP: 59.80 in. from tip
  - Stability: 3.04 calipers

Subscale Components	Length (in)	Mass (lbs)
Upper Section (without altimeter bay or payload)	37.0	5.43
Upper Section Altimeter Bay	4.00	1.57
Simulated Payload	10.0	6.00
Lower Section Altimeter Bay	10.0	2.50
Lower Section (without altimeter bay)	31.0	4.38



SUBSCALE RECOVERY SUMMARY

Lower Section

- SkyAngle Classic 20" Drogue parachute attached to shock cord that is attached to U-bolt on lower end of altimeter bay and on the booster section
- SkyAngle Cert 3 Large attached to shock cord that is attached to U-bolt on upper end of altimeter bay

Upper Section

- Fruity Chutes Iris Ultra 60" attached to shock cord that is attached to nosecone U-bolt and payload altimeter bay U-bolt

SUBSCALE GROUND DEPLOYMENT TEST

Ground Test Results:

- 1.5 grams of black powder for the Drogue Parachute
- 2.0 grams of black powder for the Upper Section Main Parachute
- 3.0 grams of black powder for the Lower Section Main Parachute

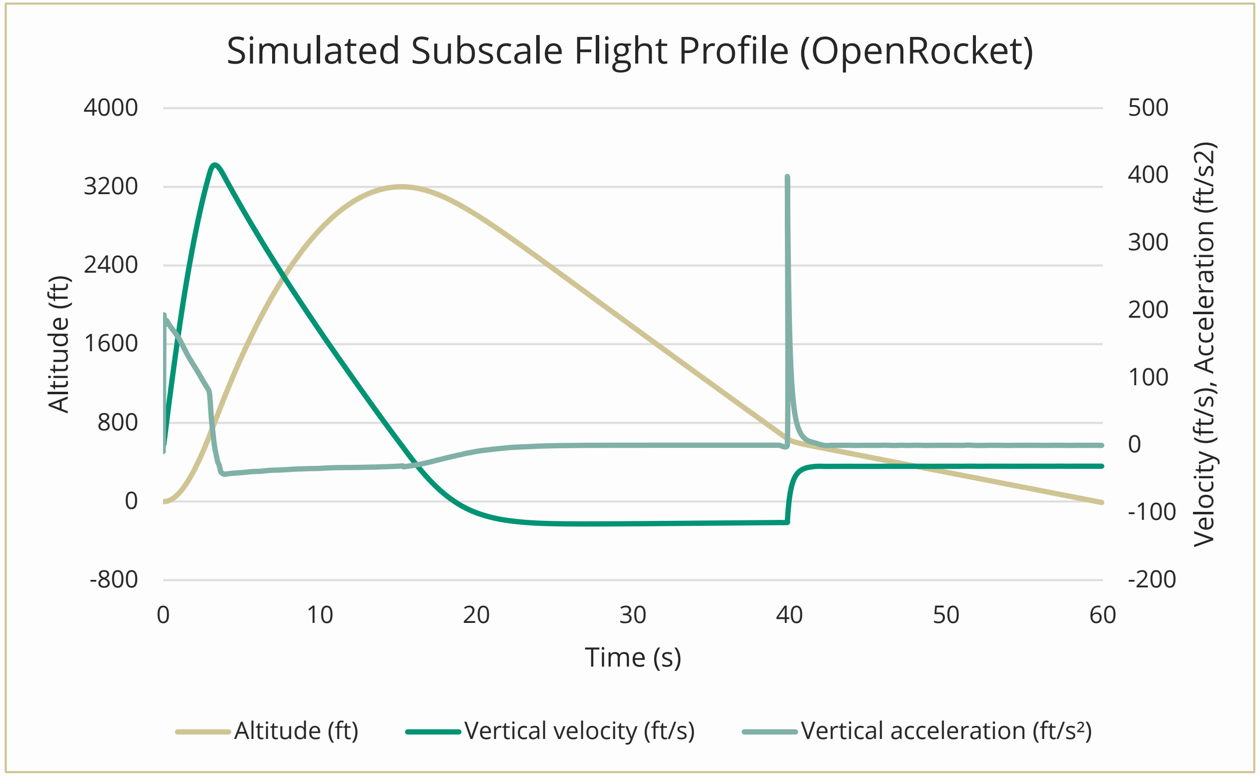
Drogue Parachute

Lower Section Main Parachute

Upper Section Main Parachute

SUBSCALE FLIGHT SIMULATION

Flight Property	Value
Apogee (ft)	3199
Maximum Velocity (ft/s)	418
Maximum Acceleration (ft/s2)	194
Time to Apogee (s)	15.2
Descent Time (s)	45
Main Descent Rate (ft/s)	31.0



SUBSCALE LAUNCH 1 CONDITIONS

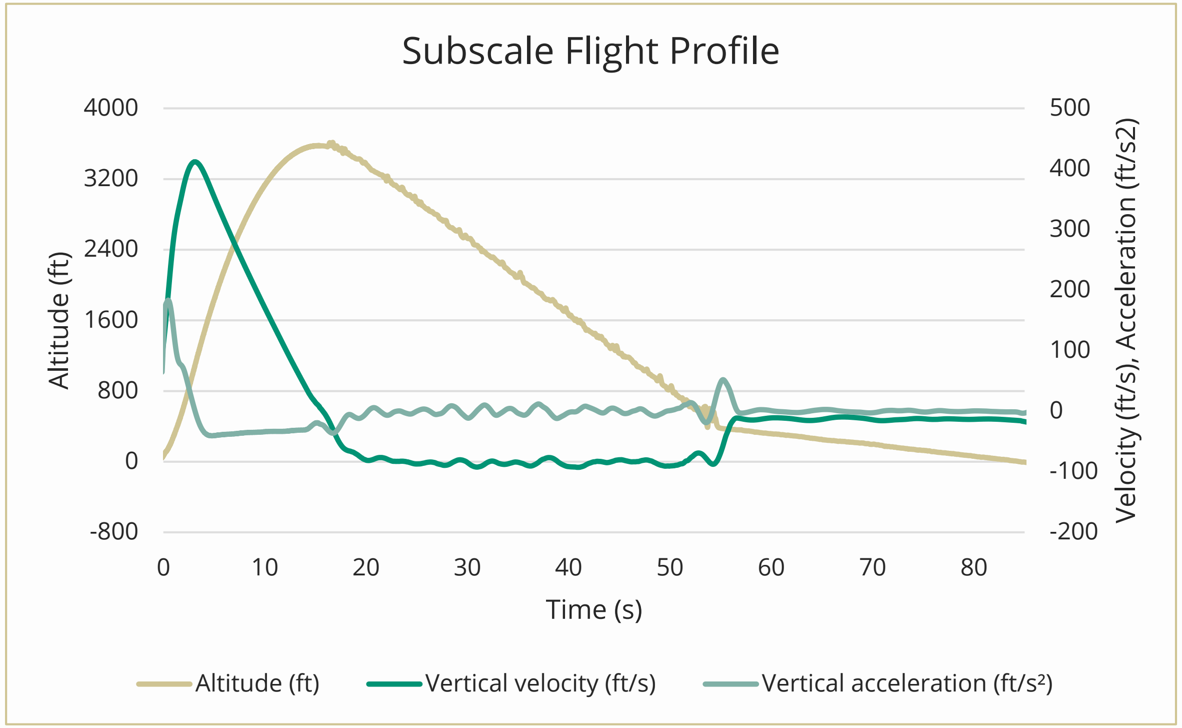
Subscale Launch Conditions	
Average Windspeed (mph)	10
Wind Direction (º)	45
Temperature (ºF)	68
Pressure (mbar)	1012
Latitude (ºN)	28.1
Longitude (ºE)	-82.2
Altitude (ft)	5
Length of launch rod (in)	40

SUBSCALE LAUNCH 1 RECOVERY

- The entire launch vehicle being recovered successfully without significant damage
- All three parachutes were successfully deployed at their programmed altitudes
- One deployment charge failed to ignite due to the loss of altimeter power, but this failure was mitigated by the fully redundant altimeter system setup.
- PDLS-S successfully produced a clear vehicle exit to deploy a payload without any foreign debris blocking the exit

SUBSCALE LAUNCH 1 SUMMARY

Flight Property	Value
Motor	Cesaroni K570
Apogee	3600.1ft
Time to Apogee	13.7 s
Max Velocity	418.7 fps
Descent Rate	10.1 fps
Total Flight Time	66.6 s



SUBSCALE LAUNCH 1 DATA

Altimeter	Altitude (ft)	Peak Velocity (ft/s)	Time to Apogee (s)	Descent Time (s)	Main Descent Rate (ft/s)
RRC3 (A)	3598	423	15	N/A (lost power)	
RRC3 (B)	3599	423	15	64	7
RRC2+ (A)	3598	-	-	-	-
RRC2+ (B)	3600	-	-	-	-
EasyMini	3605.6	410.1	15.4	69.2	13.2
Average	**3600.1**	**418.7**	**15.1**	**66.6**	**10.1**

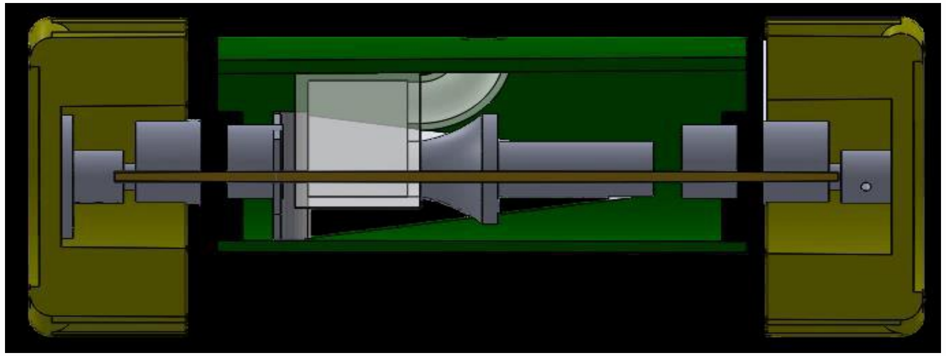
Flight Characteristic	Relative Error in Simulation (%)
Altitude	11.14
Peak Velocity	0.17
Time to Apogee	0.66
Descent Time	32.43
Main Descent Rate	206.93

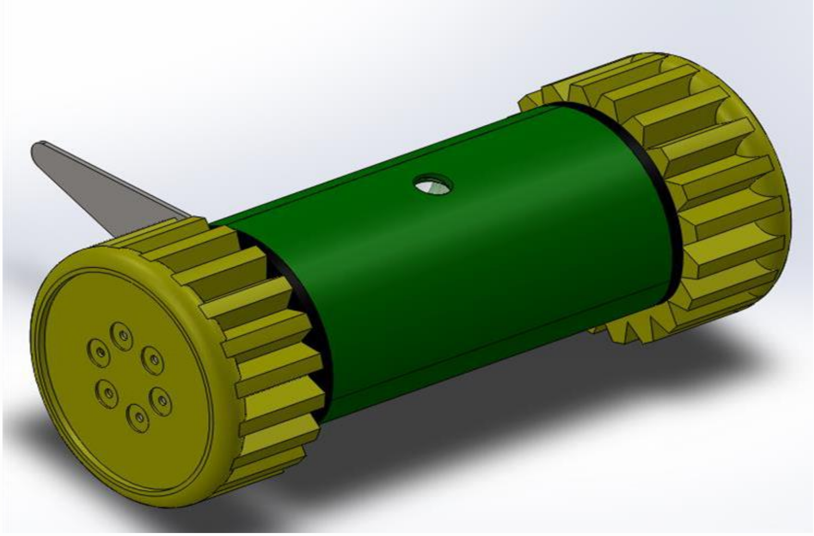
AGENDA

1. Vehicle Criteria
2. Recovery
3. Test Plans
4. Subscale Vehicle
5. **Payload**
6. Project Plan

PAYLOAD SUMMARY

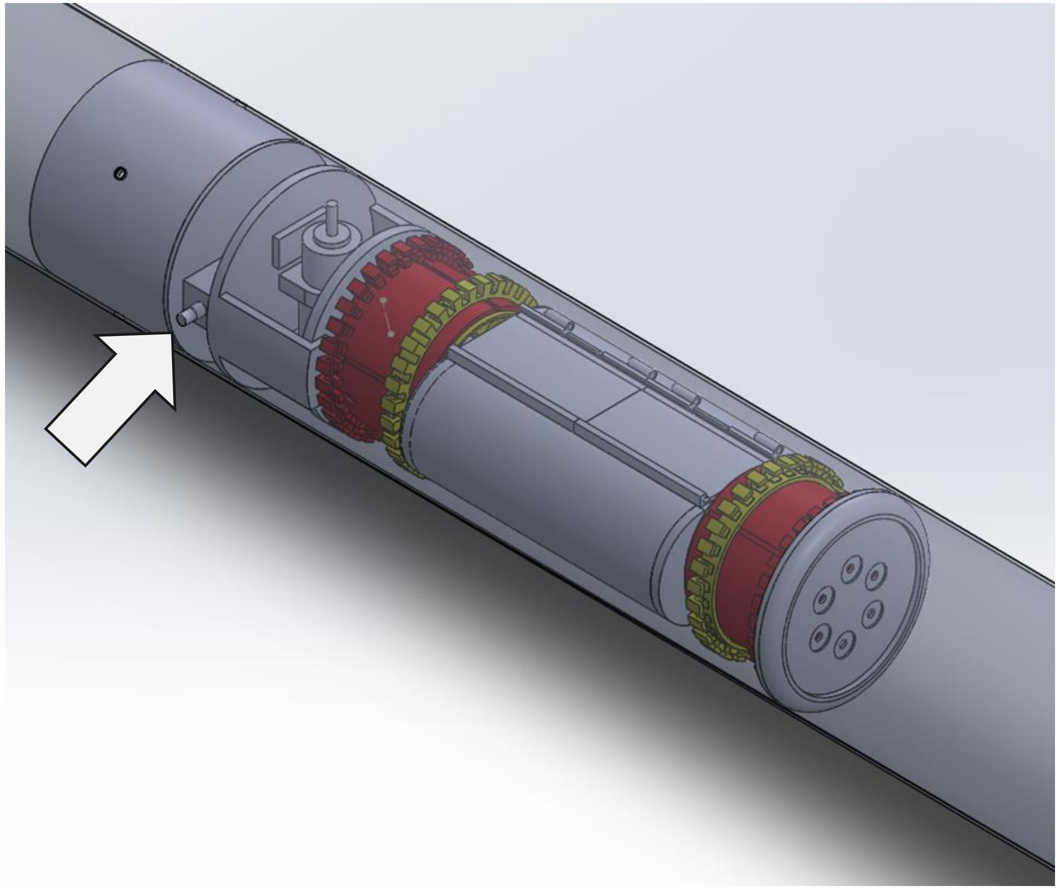
Component	Value
Max Weight	8 lbs
Diameter	5.92 in
Max Length	19 in
Motor	TBD
Projected Motor Run Time	TBD
Stall Torque	TBD





PAYLOAD RETENTION AND DEPLOYMENT

- Two solenoids will be attached to the deployment system and will secure the rover to the launch vehicle in a failsafe position.
- Once the ground team send the signal the solenoids will release and allow the rover to me deployed from the launch vehicle.
- This design was in our rocket last year and has proven reliability.



PAYLOAD INTERFACES

Loading the Payload

- Situated on a precisely designed retention system intended to prevent movement during flight and premature release after separation
- Rover and deployment system are located just below the upper section avionics bay and will be loaded into the appropriate section before final assembly

Payload Deployment

- Deployment system will once a signal is received from the ground team which will release the solenoids and start the deployment process.
- A motor will have a spool of line, which will run along the inside of the rocket body tube between the rover and the airframe. When the motor engages, the line will be retracted into the spool.
- The motor itself will be installed on a moving plate which, when the fishing line is retracted, will pull itself out of the rocket.

AGENDA

1. Vehicle Criteria
2. Recovery
3. Test Plans
4. Subscale Vehicle
5. Payload
6. **Project Plan**

OUTREACH OVERVIEW

- 7 of 16 planned events completed
- 9 upcoming events
- Reached 657 participants

Student Count Table		
	NASA Requirement	**Team Goal**
Required Amount	200	1000
Amount remaining to reach requirement	0	343
Verification Status	COMPLETE	

REQUIREMENTS COMPLETION PLAN

		General	Vehicle	Safety	Recovery	Payload
NASA Requirements	**Completed**	10	33	1	6	3
	Awaiting Completion	6	25	16	14	5
Derived Requirements	**Completed**	none	1	none	1	0
	Awaiting Completion	none	5	none	0	3

SOCIETY OF AERONAUTICS AND ROCKETRY

Special thanks to our sponsor, CAE USA