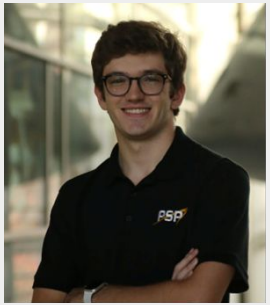
Project Moses

Critical Design Review
PSP-SL 2024

Purdue University Executive Board



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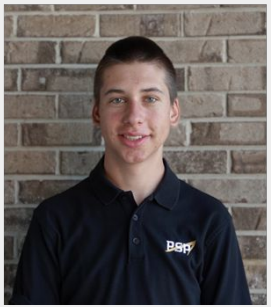

Payload Team Lead
Gabe Kurfman

Team Mentor
Mateusz Jaszczuk

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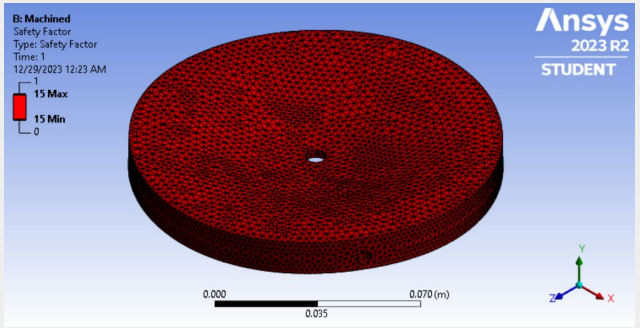
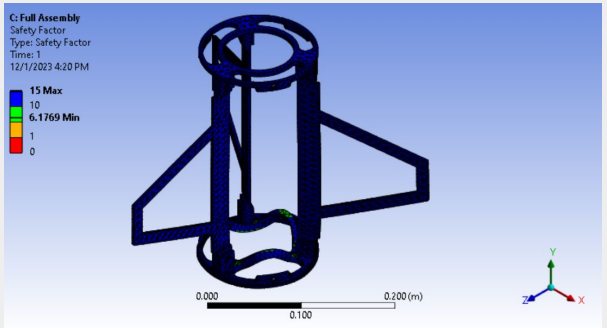
Construction

Changes Since PDR

1. Internal pressurization bulk plate in the booster section
    a. 6061 aluminum, ⅛” in the center
2. Four independent sections instead of three
    a. Nose cone will now officially be mechanically deployed to release sail
    b. Nose cone is tethered to the rest of the vehicle using a tether
3. Altered rail button placement to increase stability on the launch rail
    a. Rail button will also be used as a fastener in MFSS
4. Nose cone will be manufactured with PETG rather than ASA





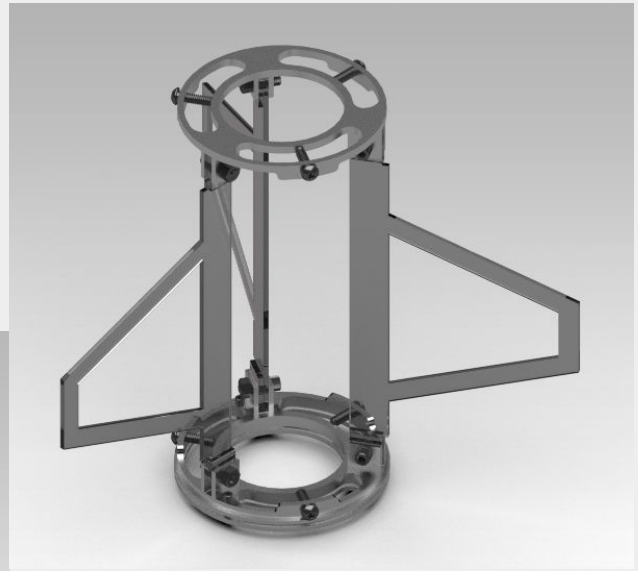
Launch Vehicle Dimensions

Vehicle Predicted Mass	41.7lbs	**Number of Fins**	3
Vehicle Outer Diameter	5.15”	**Booster Airframe Section Length**	35”
Vehicle Length	92.5”	**Avionics and Recovery Section Length**	25.5”
Vehicle Independent Sections	4	**Payload Section Length**	32”

Booster Section Key Design Features

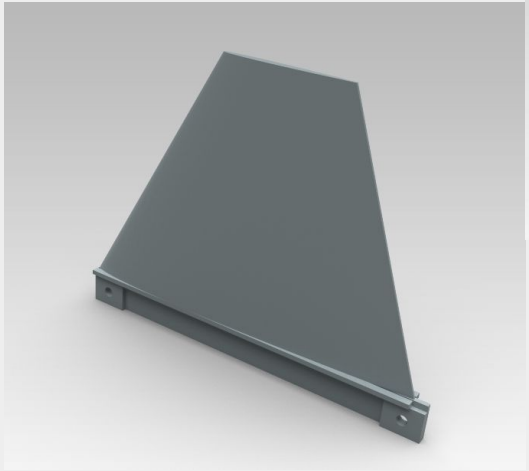
Motor Fin Support Structure

- Easily assembled and disassembled
- Machine toleranced aluminum 6061
- Keeps motor and fins secure and aligned
- Aluminum 6061 internal pressurization bulk plate



Fins

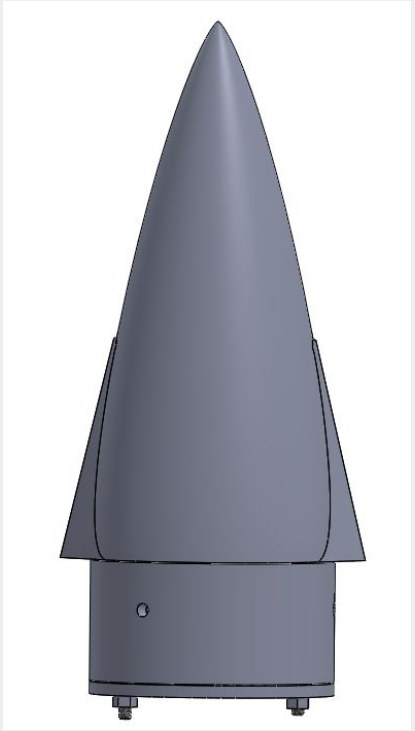
- Trapezoidal geometry
- Based on NACA 0006 airfoil
- Resin cast for consistency
- G10 Fiberglass insert for rigidity

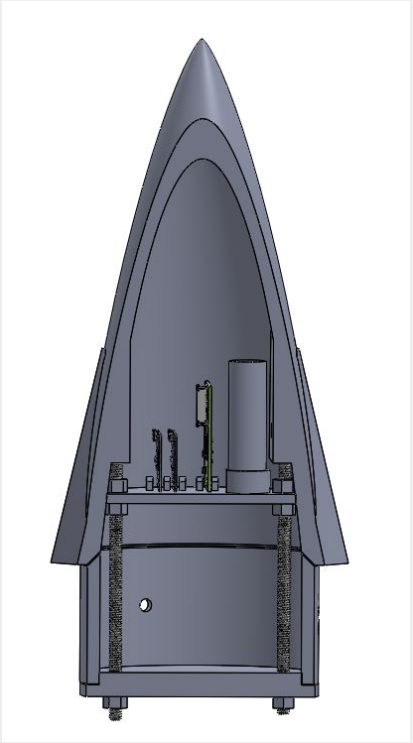


Payload Section Key Design Feature

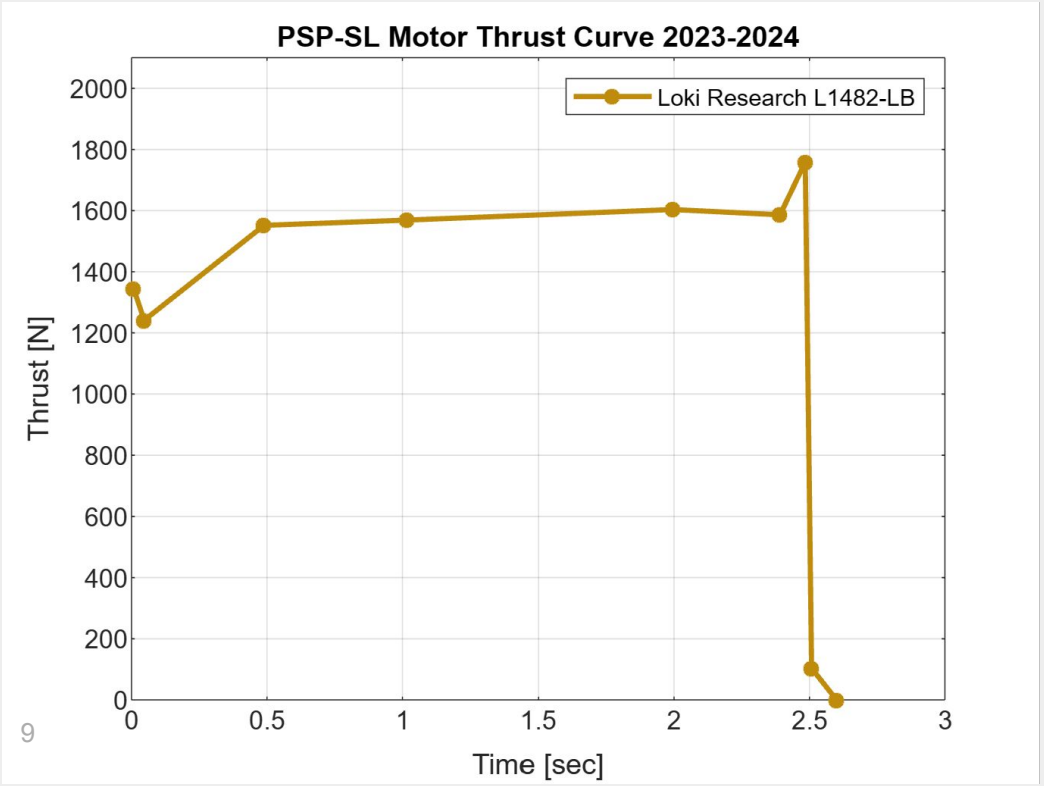
Nose Cone Camera Bay:

- **11” tall** 5.15” diameter LV-Haack
- 3D printed **PETG**
- Aft facing cameras
- 2.5” shoulder
- **0.5” bulkplate** to connect and mount payload hardware



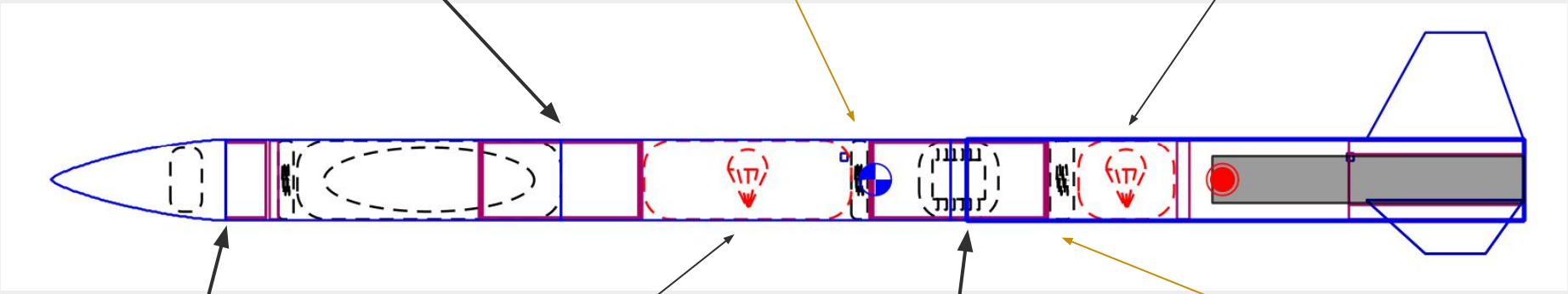


Final Motor Choice

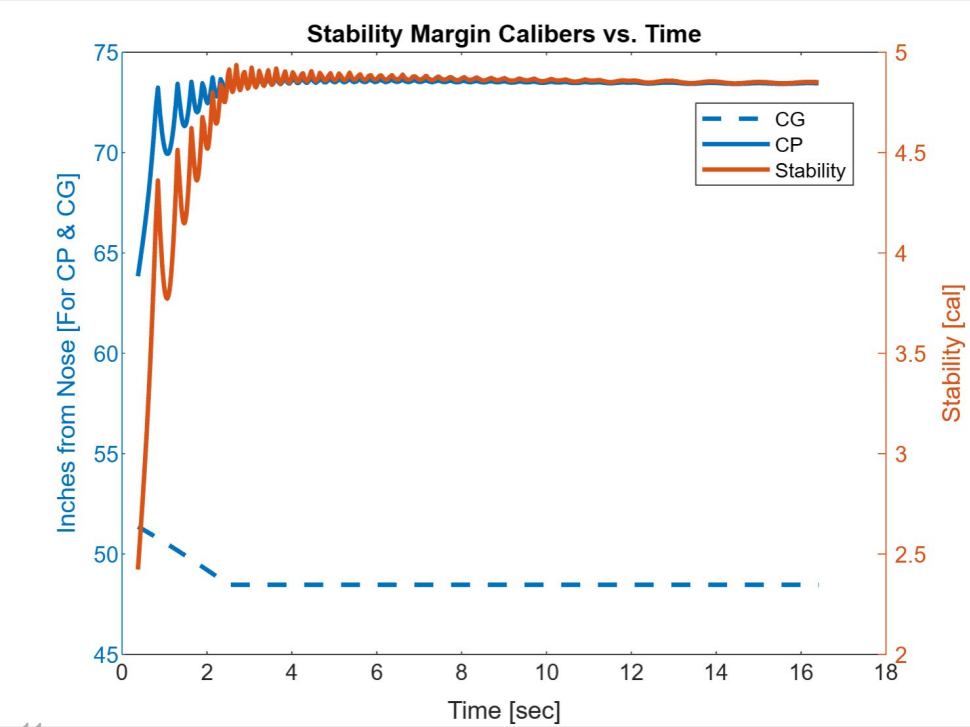


Loki Research L1482-LB	Value	Pass/Fail
Impulse	3,882 Ns (51% L)	PASS
Avg Thrust	344 lbf	N/A
Max Thrust	395 lbf	N/A
Burn Time	2.52 sec	N/A
Thrust to Weight	8.1:1	PASS
Rail Exit Velocity	70.9 ft/s	PASS

Points of Separation, Energetic Materials



Vehicle Stability Margin

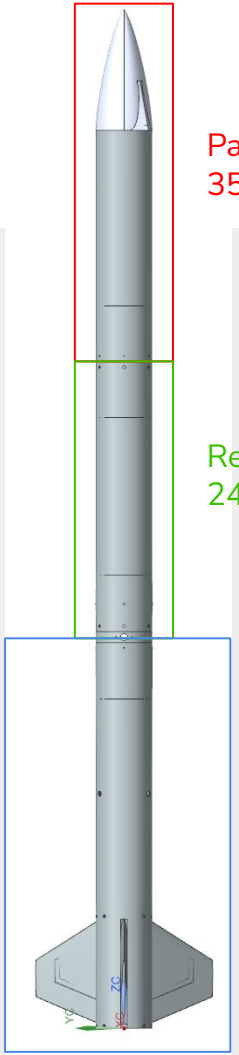


Worst Case Scenario (20 mph, 10 deg) Stability

Stability Margins	Predicted	Pass/Fail
Worst Case Scenario off Rail Stability (20 mph 10 deg)	2.42 cal	PASS
Center of Gravity	51.77 in from nose	N/A
Center of Pressure	73.56 in from nose	N/A

Mass Margin

Component(s)	Mass (lb)
Nose Cone	2.16
Camera Bay	1
Payload	11.5
Upper Recovery (w/ main parachute)	6.21
Avionics	4.07
Booster (w/o fins, MFSS, motor)	6.21
Motor Fin Support Structure	0.755
Fins	2
Motor	7.8
Estimated Total	**41.7**



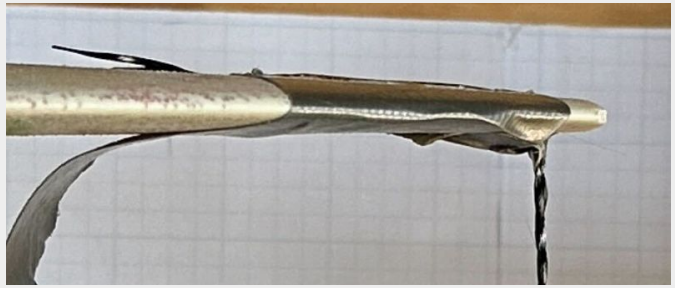
Payload: 14.66lb
35.2% of mass

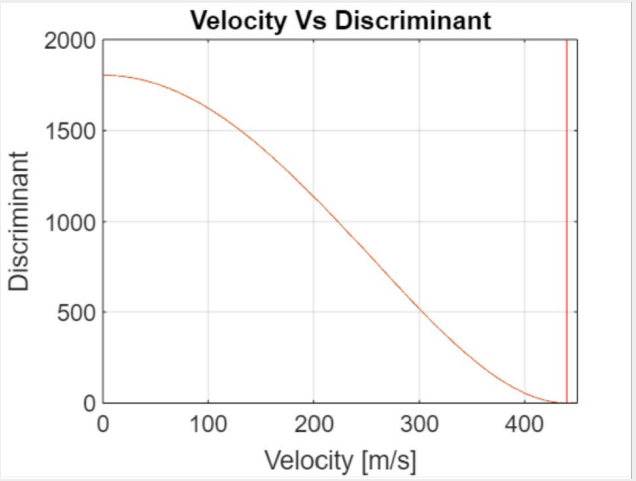
Recovery: 10.28lb
24.6% of mass

Booster: 16.76lb
40.2% of mass

Composite Fin Testing

- Tested composite fins by suspending a 7lb weight from the tip (bending) and from a rod 12” long on the tip at a 90° angle (torsion)
- **Result:** maximum safe velocity before critical flutter is **440 m/s**
  - Far below anticipated maximum velocity of 184 m/s



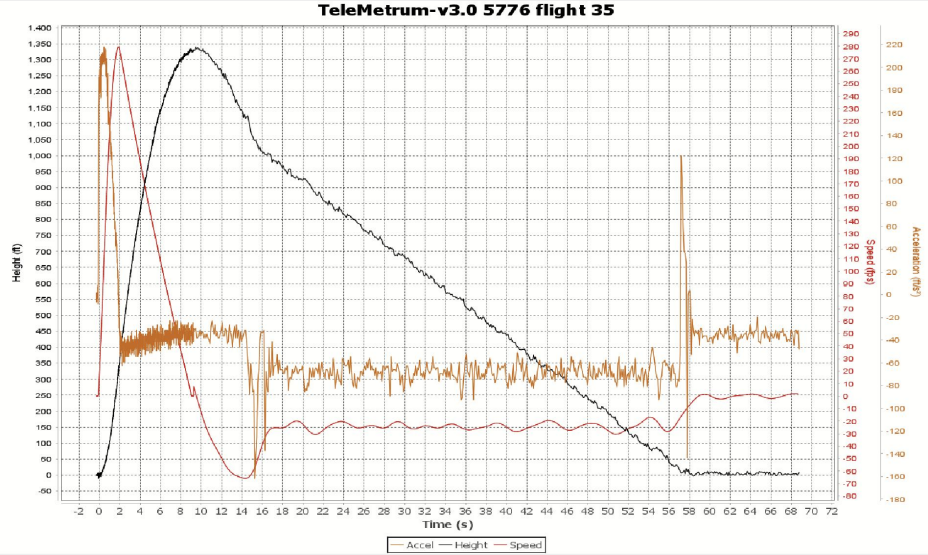


Subscale Flight

Subscale Flight

Launch Date	11/28/2023
Weather	Sunny
Temperature	42℉
Pressure	29.3 inHg (0.98 atm)
Wind Speed	6 mph SW, 10 mph gusts
Location	Purdue Dairy Farm

Subscale Flight



Subscale Flight Data	Actual	Predicted
Apogee	1340’	1343’
Maximum Velocity (ascent)	279.40 ft/s	272 ft/s
Maximum Acceleration (ascent)	225 ft/s^2	159 ft/s^2
Descent Time	47.8 s	61.2 s
Landing Velocity	24 ft/s	22 ft/s
Drift Distance (total)	898 ft	283 ft

Avionics and Recovery

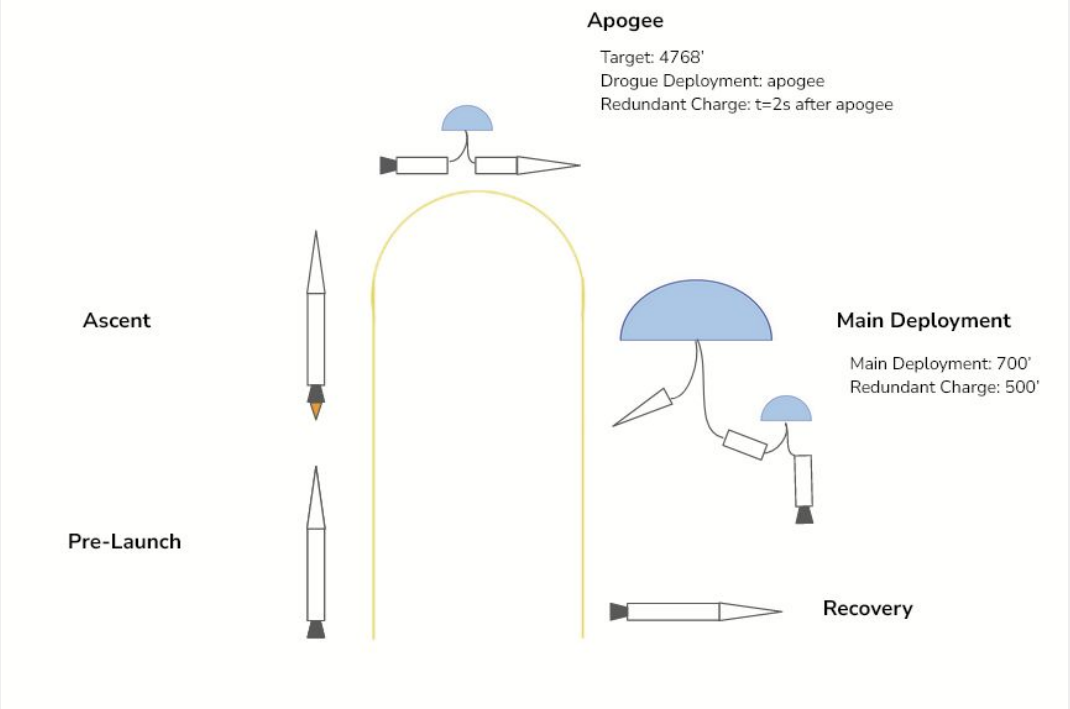
Recovery System Concept of Operations

Phase 1: Preparation

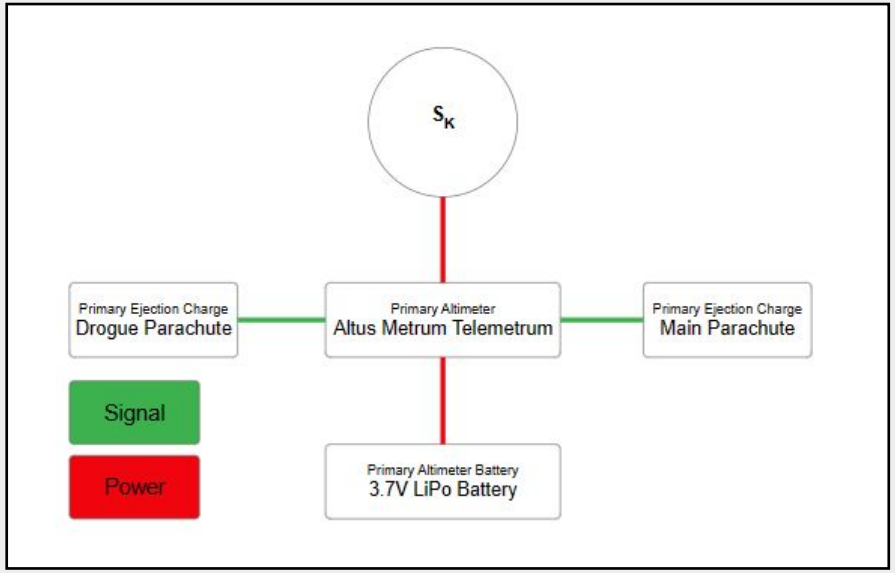
Phase 2: Initiation

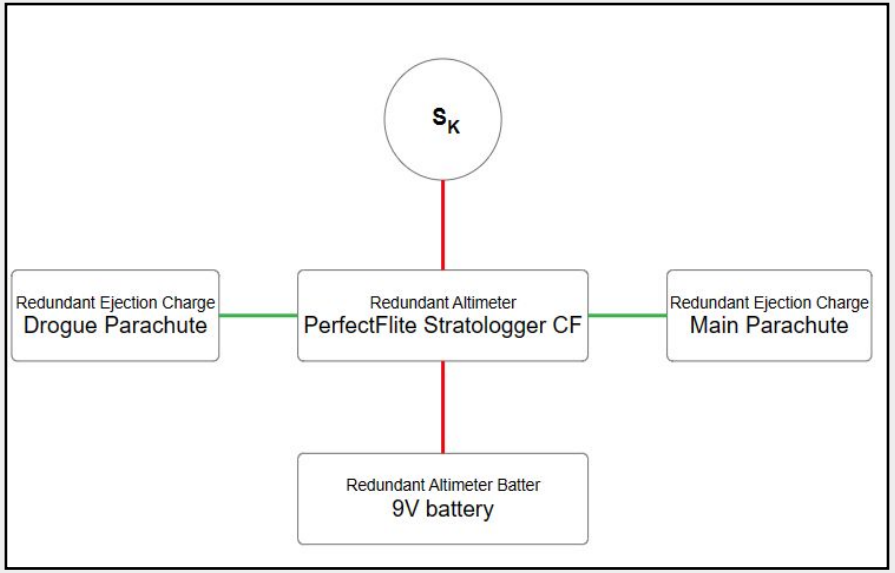
Phase 3: Flight

Phase 4: Retrieval



Primary and Redundant Systems





Parachutes

Parachute	Main: 120” Rocketman High Performance Parachute	Drogue: 15” Fruity Chutes Elliptical Parachute
Material	Ripstop Nylon	Ripstop Nylon
Harnesses	250 lb nylon shroud lines 3000 lb swivel	220 lb nylon shroud lines 1000 lb swivel
Descent Rate	16.1 ft/s (with SAIL weight) 15.0 ft/s (without SAIL weight)	129.2 ft/s

Attachment Hardware

Hardware	Material	Working Load
Main Shock Cord	⅜” tubular Kevlar, 50’ long	3600 lb
Drogue Shock Cord	⅜” tubular Kevlar, 30’ long	3600 lb
Payload Shock Cord	⅛” nylon and poly blend	160 lb
Quick Links	¼” stainless steel	880 lb
Eye Bolts	¼” stainless steel	500 lb

Avionics Bay Design

Coupler length	11 in
Overall Weight	~4 lbs
Switch Type	Key switch
Ejection Charge Configuration	Upper bulkhead: main charges - Primary: 2.5 g - Redundant: 3 g Lower bulkhead: drogue charges - Primary: 1.5 g - Redundant: 2 g

Kinetic Energy

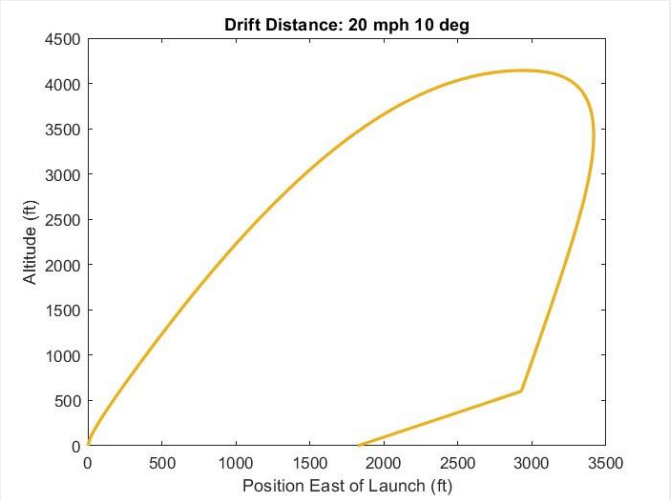
Vehicle Section	Landing Kinetic Energy with SAIL deployment (ft-lbf)
Nose Cone	11.1
Payload	22.7
Recovery	22.7
Booster	37.2

Vehicle Section	Kinetic Energy under main before SAIL deployment (ft-lbf)
Payload with Nose Cone	59.1
Recovery	26.2
Booster	42.9

Vehicle Section	Kinetic Energy under drogue (ft-lbf)
Upper	2757
Booster	6470

Predicted Drift Distance

Launch Conditions	Drift Distance (ft)
0 mph wind, 5° launch angle	366
5 mph wind, 5° launch angle	37
10 mph wind, 7.5° launch angle	489
15 mph wind, 10° launch angle	985
20 mph wind, 10° launch angle	1564



Mission Performance Predictions

Parameter	Value	Pass/Fail
Predicted Apogee	4865’	–
Ascent Time	18.4 s	–
Drogue Descent Velocity	129.2 ft/s	–
Landing Velocity	15.0 ft/s	–
Descent Time	73.3 s	PASS
Drift Distance	37 ft	PASS
Rail Exit Velocity	77.5 ft/s	PASS
Landing Kinetic Energy of Heaviest Section	37.2 ft-lbf	PASS

Note: Predicted values were based off 5 miles per hour wind speeds and launch angle of 5 degrees with successful SAIL deployment

Avionics and Recovery Testing

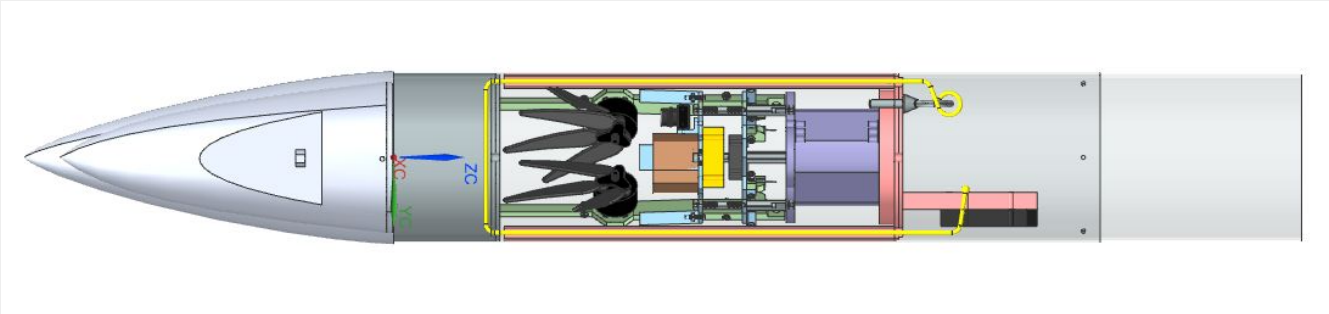
Test	Goal/Description	Status
Altimeter Continuity and Battery Drain	Altimeters and batteries can function in all launch conditions	In Progress
Altimeter Ejection Vacuum	Altimeters will deploy parachutes at correct altitude	Incomplete
Black Powder Ejection	Black powder will properly separate the airframe sections	Incomplete
Black Powder Ejection Proof of Concept	The drogue parachute gravity aided deployment mechanism is feasible	Complete
Parachute Drop	Parachutes open within a reasonable time frame	In progress

Payload

Payload Overview

System	Function
Deployment System	Retain the SAIL until proper altitude is reached
SAIL	Slow descent speed without parachute
STEMnaut Capsule	Store and protect the four STEMnauts

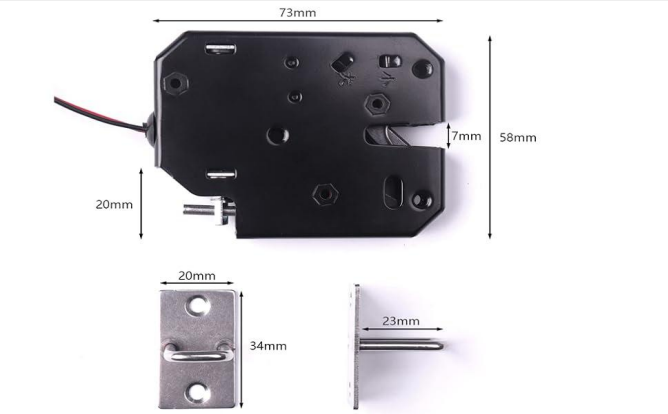
Mission Statement: The payload will be capable of deploying the SAIL quadcopter, which will then safely navigate the STEMnauts to the ground without a parachute.



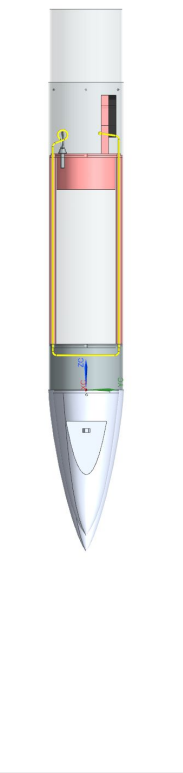
Top-Level Payload Assembly

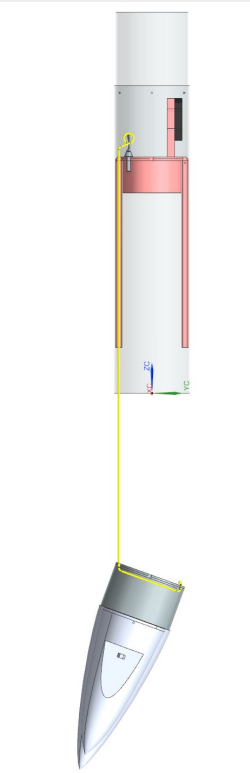
Final Design - Deployment

Subsystem	Function
Upper Coupler	Contains retention mechanism and jettison electronics
Nose Cone Bulkhead	Retains nose cone and secures tether release



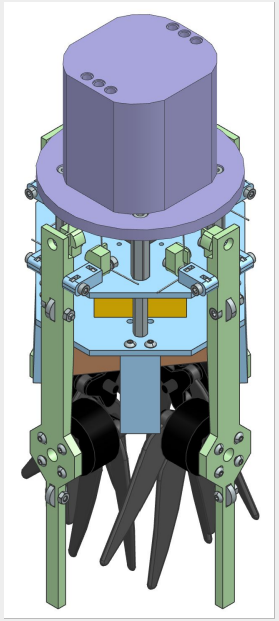
Electronic Latch


Retained State

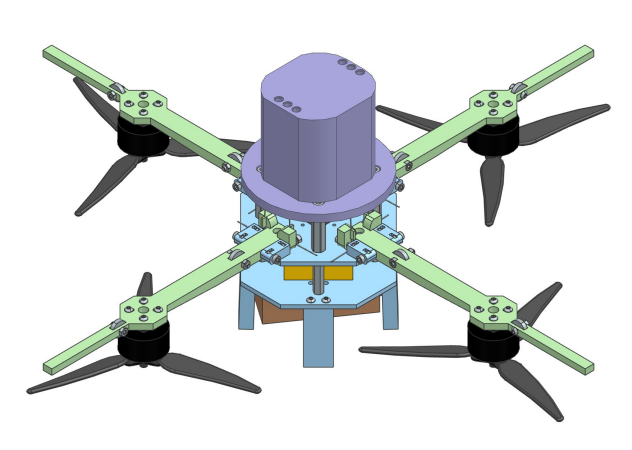

Deployed State

Final Design - SAIL

Subsystem	Function
Motor Arms	Locks descent motors into position after deployment
Electronics Stack	Controls quadcopter & logs flight data
Quadcopter Frame	Connects SAIL components and landing legs
STEMnaut Capsule	Retain and protect the STEMnauts during flight



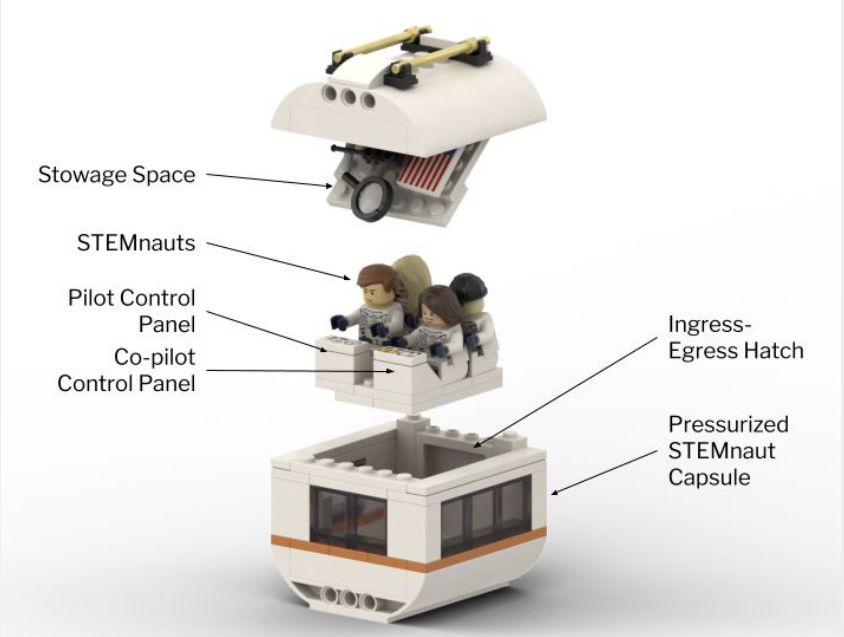
Retained State



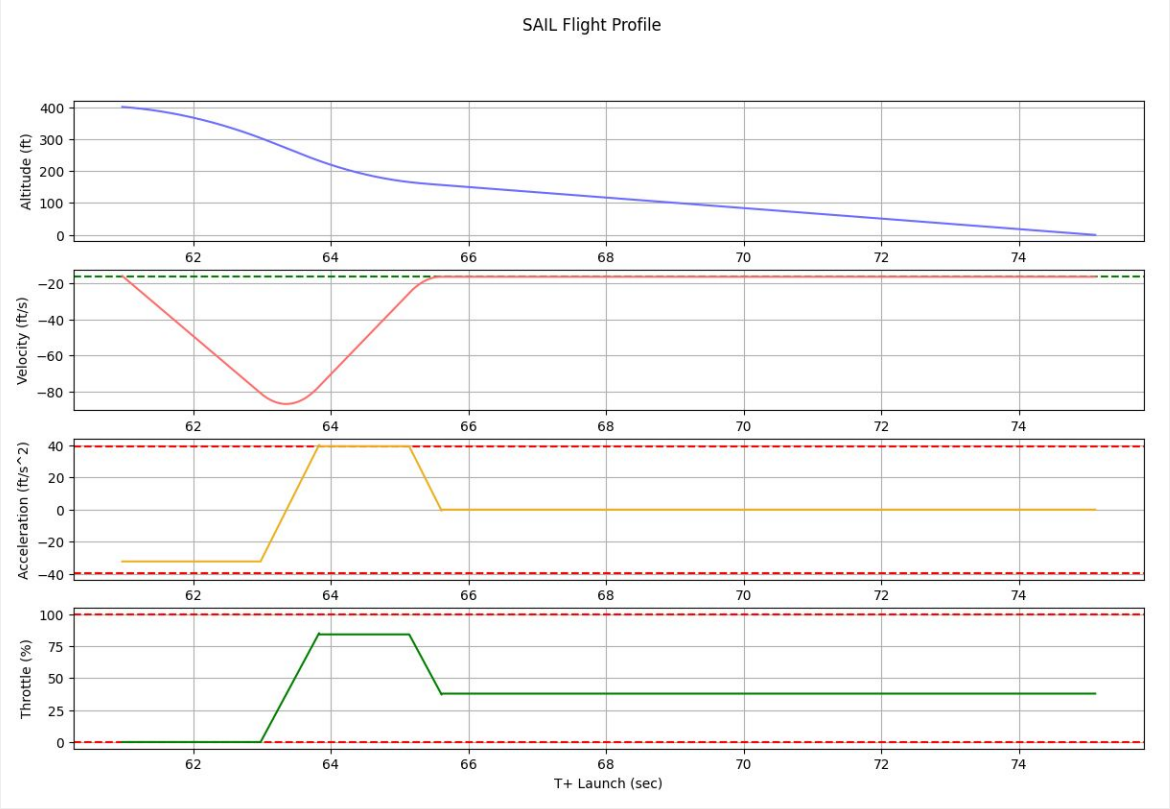
Deployed State

Final Design - STEMnaut Capsule

- 4 notable Purdue figures as STEMnauts
- Seated orientation for safety
- Stowage space for personal items and experiments



Payload Flight Profile



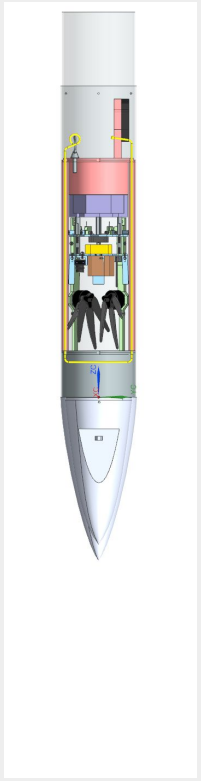
Descent Time to Release Altitude	T+60.97 s
Release Altitude	400’ AGL
Initial Velocity (Main Parachute)	16.03 ft/s
SAIL Mass	5 lb

Maximum Motor Thrust	3.31 lb
Deploy Delay (worst case)	2 s
Landing Velocity (worst case)	16.4 ft/s
Maximum Acceleration Endured	39.37 ft/s^2
Maximum Throttle Change	100 %/s

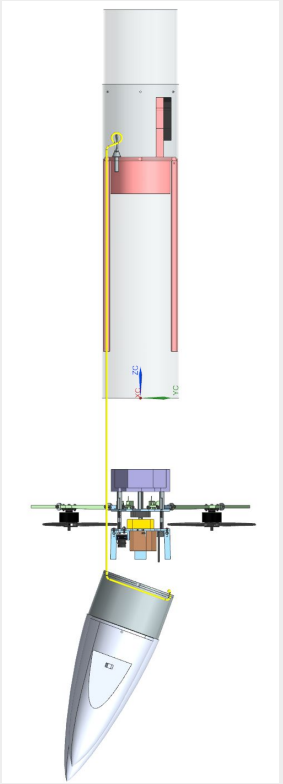
Payload Integration Plans

Integration Steps:

1. Unlock quadcopter arms and fold into compressed position
2. Tension tether and lock into latch
3. Slide assembly into airframe and secure at the payload coupler with nuts on threaded rods



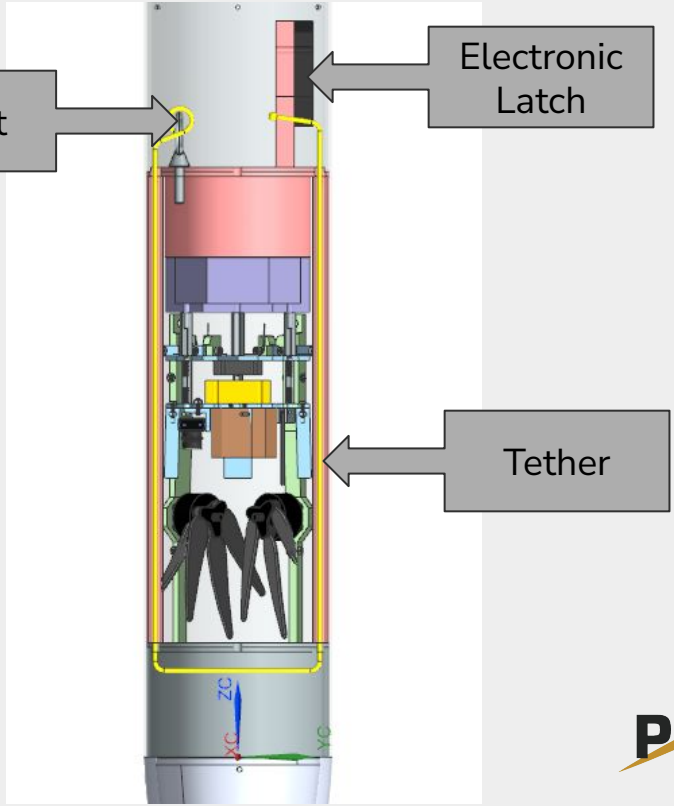
Retained State



Deployed State

Payload Retention System

Component	Load Rating
Electronic Latch (steel)	330 lb (150 kg)
Tether (⅛” nylon)	160 lb (72.6 kg)
Eyebolt (steel)	500 lb (226 kg)



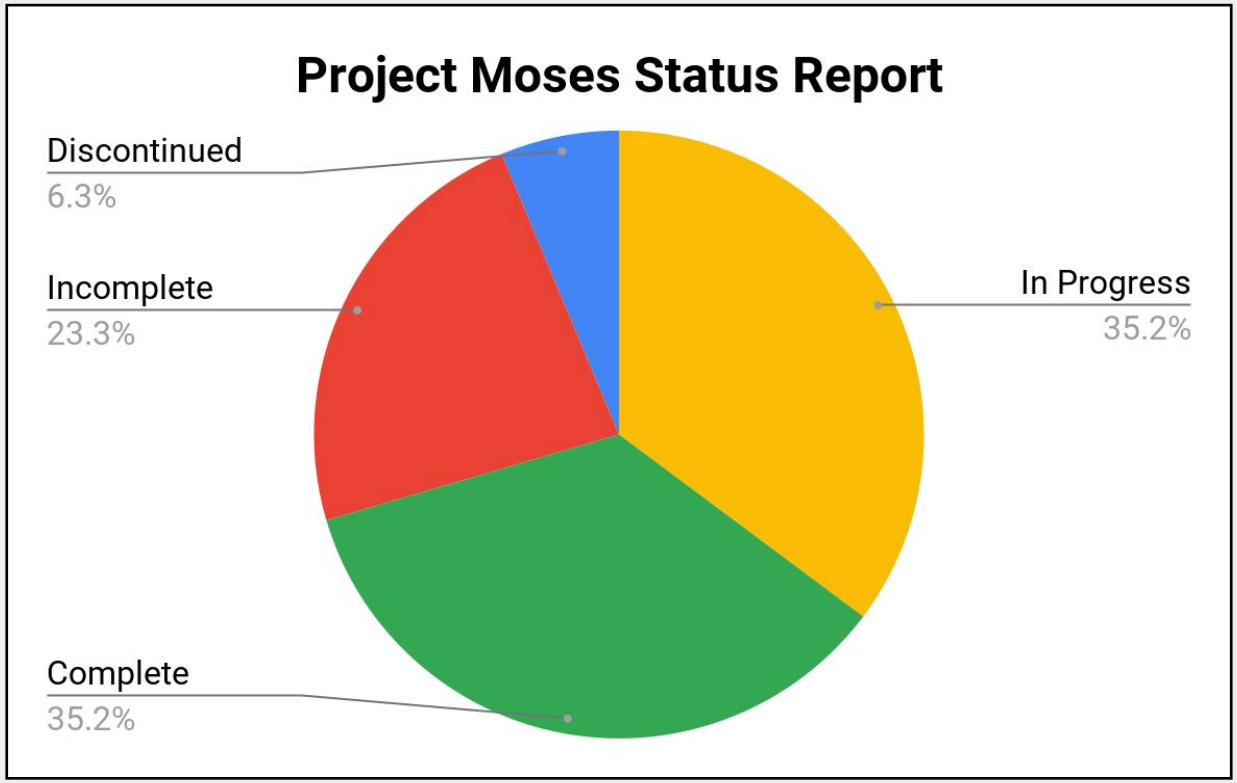
Notable Payload Testing

Completed	
Test	**Result**
Radio Range Test	1300’ (completed during subscale)
Deploy Latch Test	5 consecutive successes, 0 failures
Retention Load Test	30 lb load, no noticeable deformation
SAIL Radio/Motor Test	Successful remote motor control
SAIL Thrust Test	3.31 lb single motor, 1.94 thrust-to-weight ratio

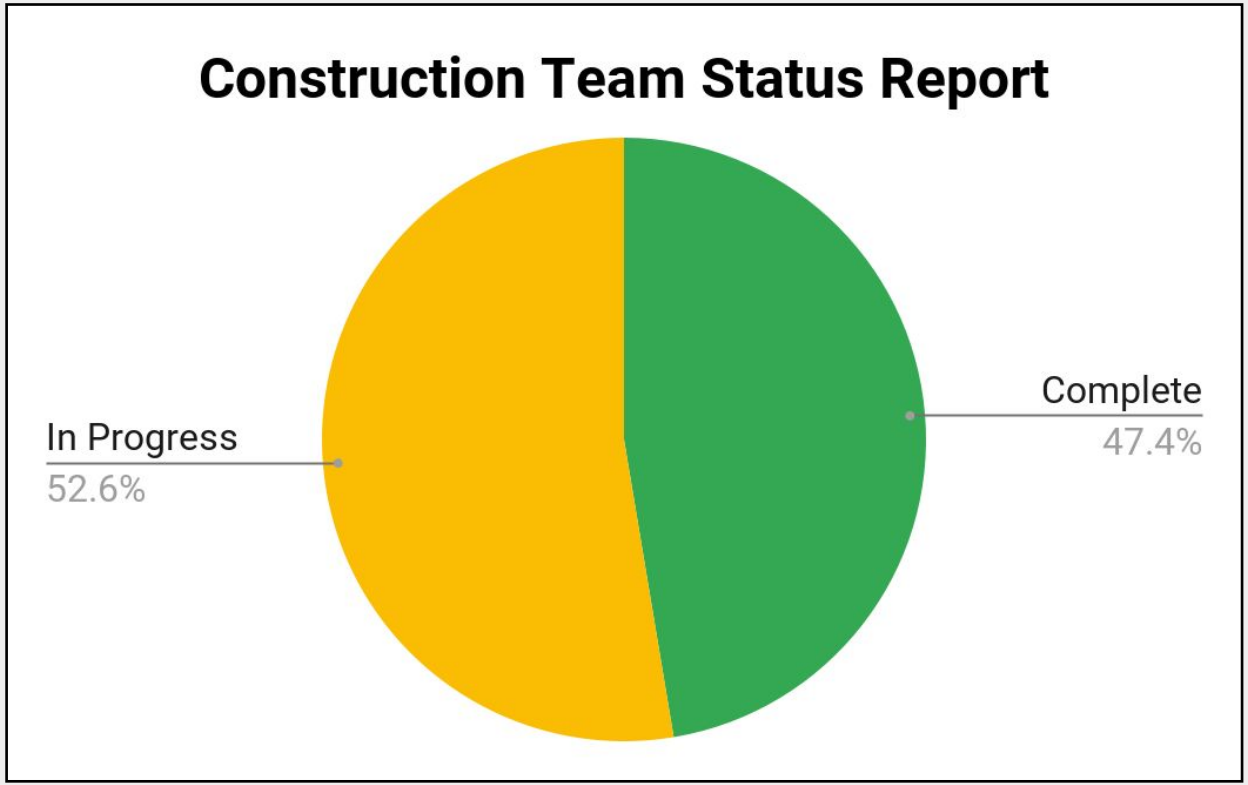
In Progress	
Test	**Goal**
SAIL Flight Test	Show the SAIL can accelerate 5 lbs
SAIL Survivability Test	Show the SAIL does not exceed the determined maximum forces
Deployment Test	Show successful deployment with all SAIL hardware
Flight Test	Show the entire payload system is successful in-flight (VDF)

R&VP Plan

R&VP Plan


Project Moses Status Report
Discontinued
6.3%
Incomplete
23.3%
In Progress
35.2%
Complete
35.2%

R&VP Plan


Construction Team Status Report
In Progress
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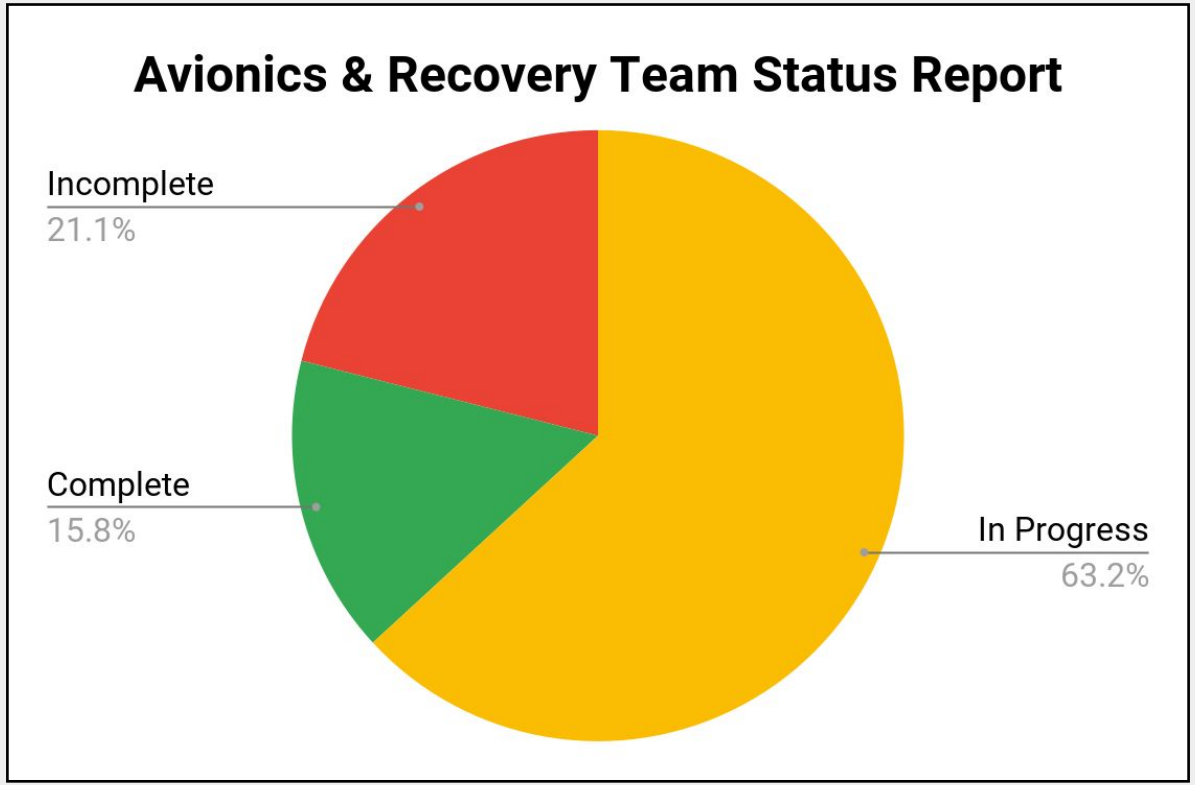
Complete
47.4%

R&VP Plan


Avionics & Recovery Team Status Report
Incomplete
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Complete
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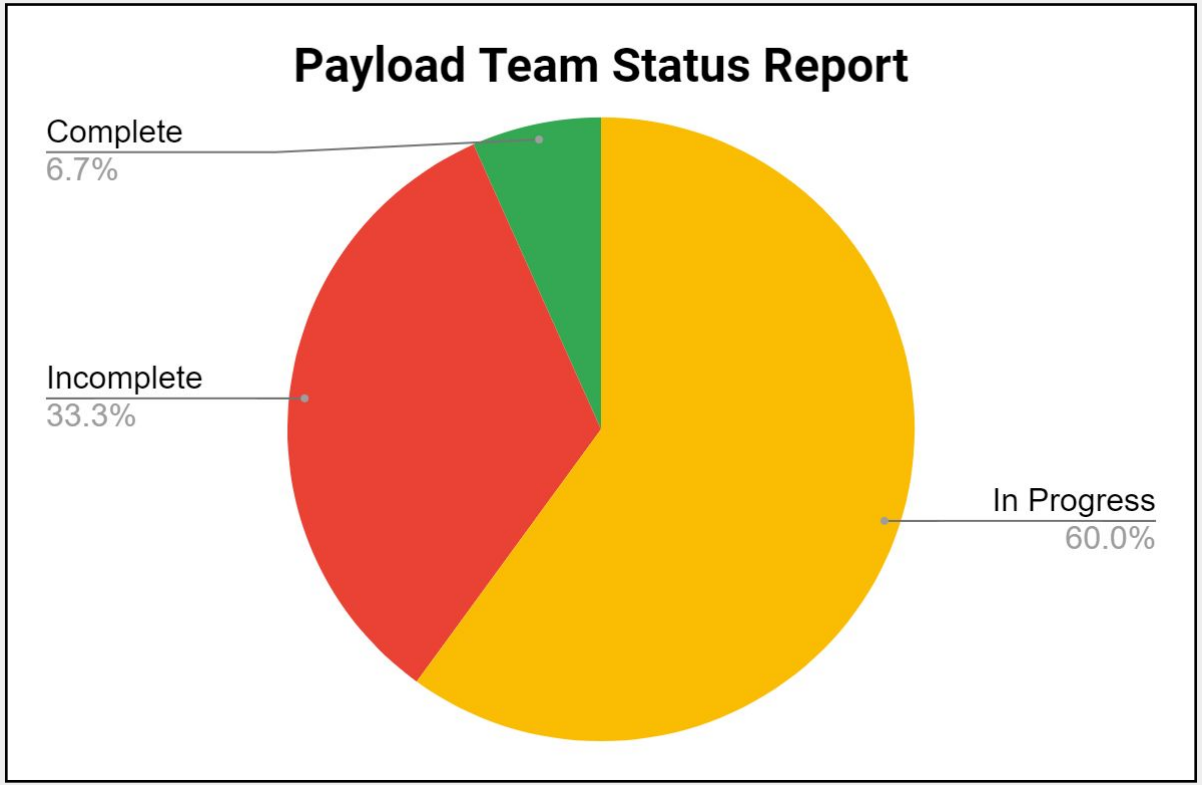
In Progress
63.2%

R&VP Plan


Payload Team Status Report
Complete
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Incomplete
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In Progress
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