Project Casper

Flight Readiness Review

PSP-SL 2020

Mission Statement

Our mission statement can be broken into three distinct goals:

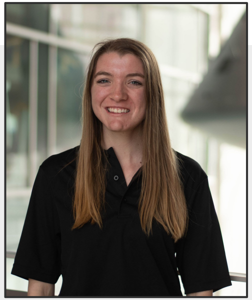
- Design, build, test, and fly a student-crafted launch vehicle to a predetermined altitude
- To carry a payload consisting of an unmanned aerial system (UAS) capable of collecting a lunar ice sample and moving it a set distance
- To ensure proper teaching in all aspects of High Power Rocketry

2020 Executive Board

Luke Perrin
Project Manager

Michael Repella
Assistant Project Manager

Noah Stover
Safety Team Lead



Natalie Keefer
Business Team Lead

Skyler Harlow
Social & Outreach Team Lead

Josh Binion
Payload Team Colead

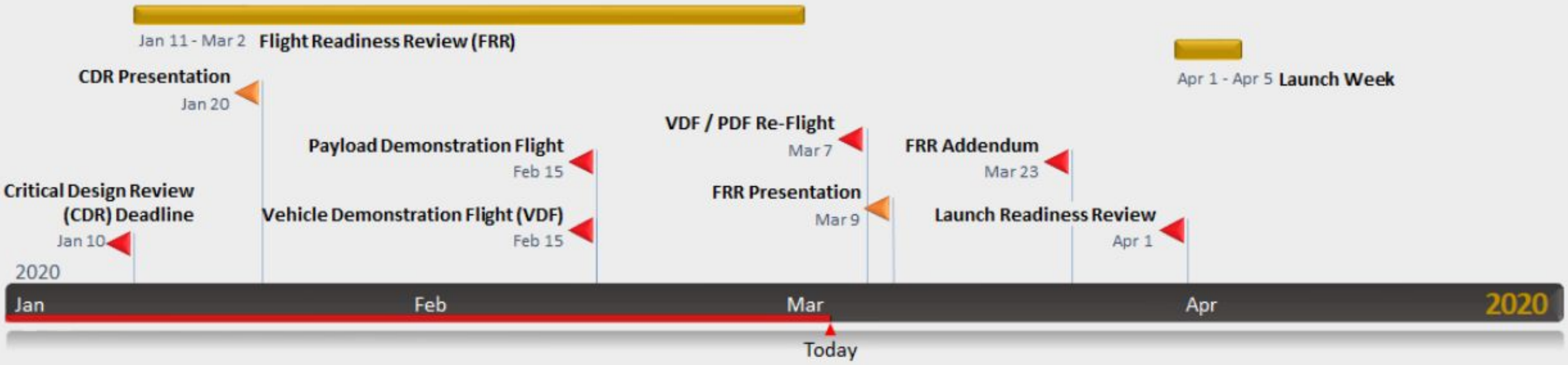
Hicham Belhseine
Payload Team Colead

Katelin Zichittella
Avionics Team Lead

Lauren Smith
Construction Team Lead

Zach Carroll
Construction Team Mentor

Current Timeline



Requirements

Requirement Verification Status

D	**Requirement ID:** 2.10.2 **Description:** Any motor change after CDR must be approved by the NASA Range Safety Officer (RSO) and will only be approved if the change is for the sole purpose of increasing the safety margin. A penalty against the team's overall score will be incurred when a motor change is made after the CDR milestone, regardless of the reason. 19 and 3	**Verification Plan:** If the team must use another motor, the team shall document the motor change after approval from the NASA RSO. **Comments:** The team purchased three motors for use with full-scale flights and does not anticipate any need to change. This requirement will be verified after either PLAR is completed or a motor change is conducted and verified by the NASA RSO.
	Status: *In Progress*	**Verification Test ID:** N/A

Inspection	Demonstration
Analysis	Test

Test Type	Completed	In Progress	To Be Completed
NASA Derived	78	26	4
Team Derived	20	21	0

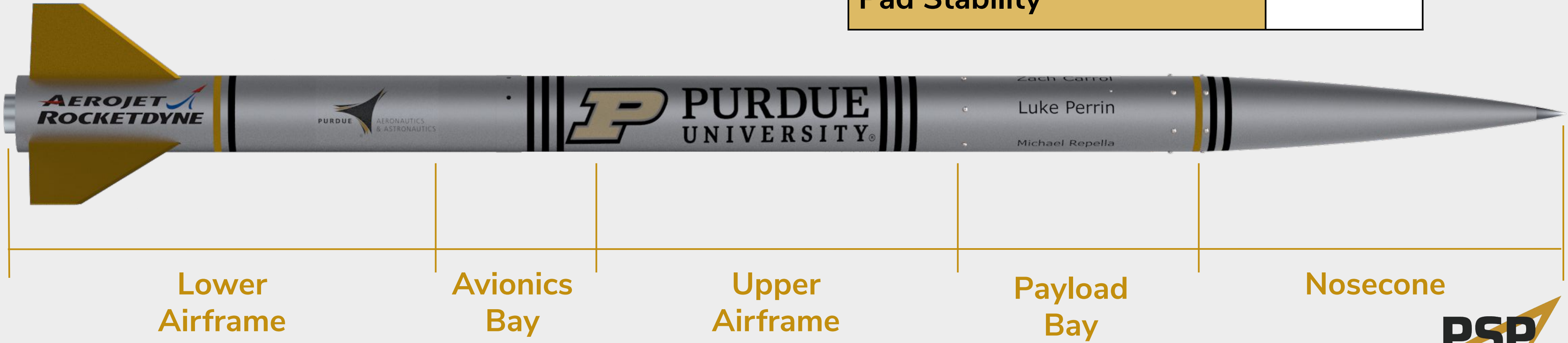
Construction Team

Team Lead: Lauren Smith
Team Mentor: Zach Carroll
Team Members: Ben Hausch | Dimitrios Michalaros | Justin Bagdan | Josiah Campbell | Martin Degener | Jason Hickman | Baoxuan Tao | Boyu Zhou | Hamza Fakhruddin

Launch Vehicle Topology

- Designed to carry a payload to a altitude of 4325’ while meeting aerodynamic stability, speed, and landing kinetic energy requirements
- Dual deployment landing system is utilized for safe landing

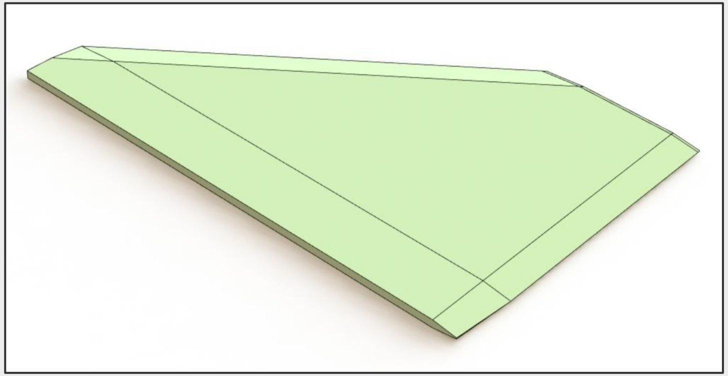
Overall Length	127”
Body Tube Inner Diameter	6”
Estimated Weight	53.1lbm
Estimated Average Launch Pad Stability	3.04cal



Fin Design

Function: Designed to reduce drag, increase stability, enable streamlining

Fin Count	3
Total Fin Set Weight	2.28lbm
Max Height	6.25”

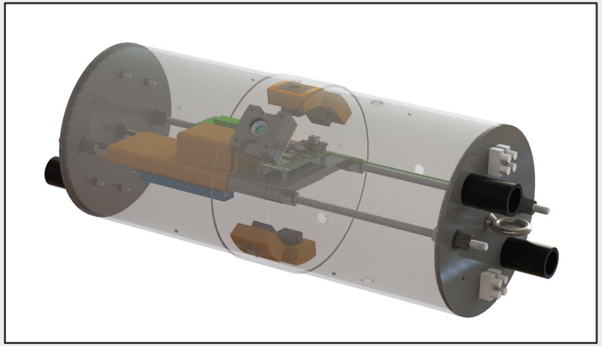


Tip chord of 4”, root chord of 12”, fin sweep angle of 50.5°

Avionics Bay

Function: House primary and redundant altimeter systems, house camera payload, initiate vehicle recovery system

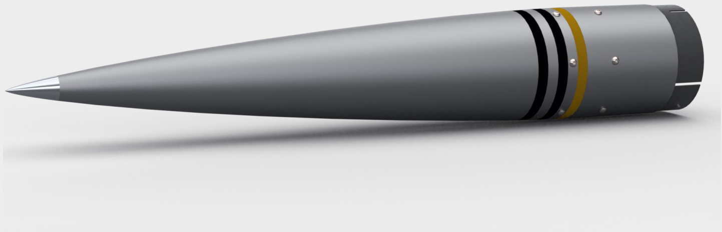
System Weight	6.34lbm
Outer Diameter	5.975”
Total Length	14”



Nose Cone

Function: Designed to reduce drag, features an increased interior volume for future payloads or electronics, and interfaces with upper payload coupler

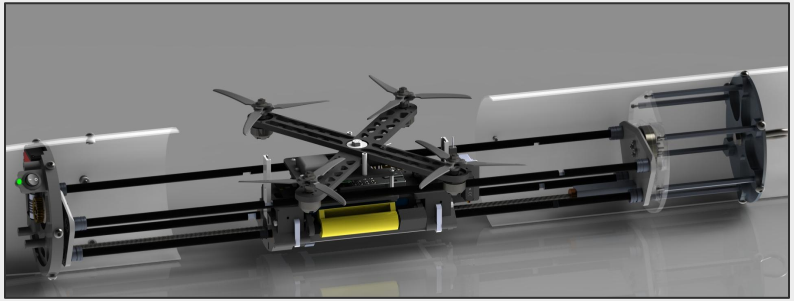
System Weight	2.8lbm
Total Length	36”
Nosecone Shape	Von Karman



Payload Bay

Function: Designed to hold the payload UAS and its retention and deployment system

System Weight	11.7lbm
Total Length	18”
Max Outer Dia.	5.775”

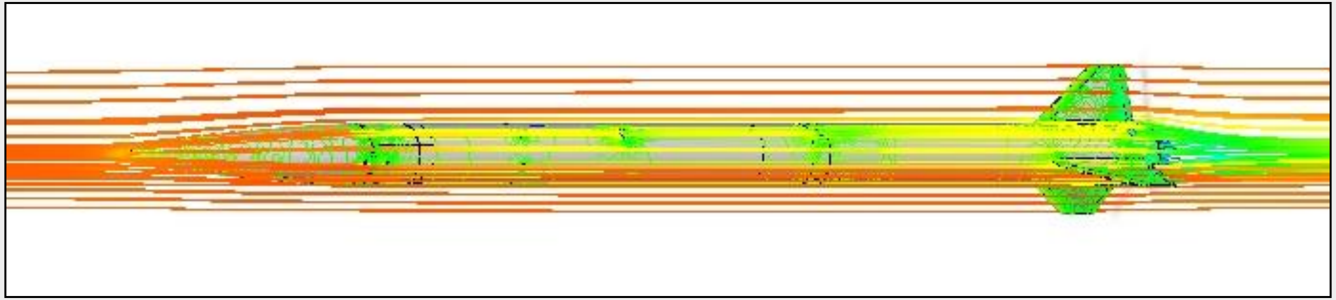


Revised Launch Vehicle Flow Analysis

Goal: Understand fluid dynamics around the fully assembled launch vehicle

Assumptions: no slip condition, ideal gas (air), standard sea level conditions, steady state

Results: smooth airflow around the whole airframe, velocity distribution as expected, pressure at expected levels, no pressure build-ups exceeding 15.89 psi according to isolines



Air Velocity	-560ĵft/s
Angle of Attack	0deg
Max Pressure	15.89psi

PSP™

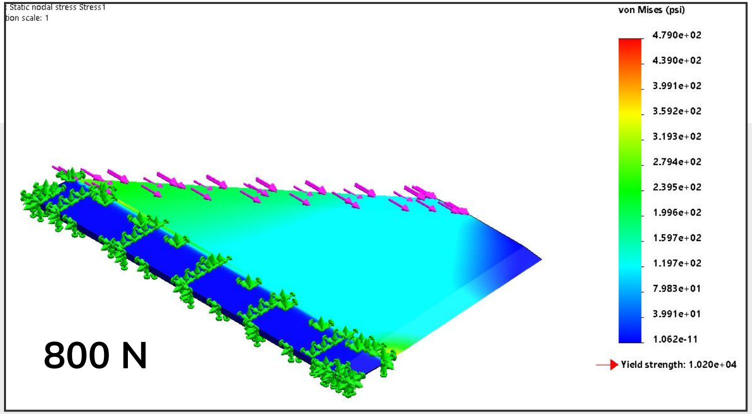
Updated Fin FEA

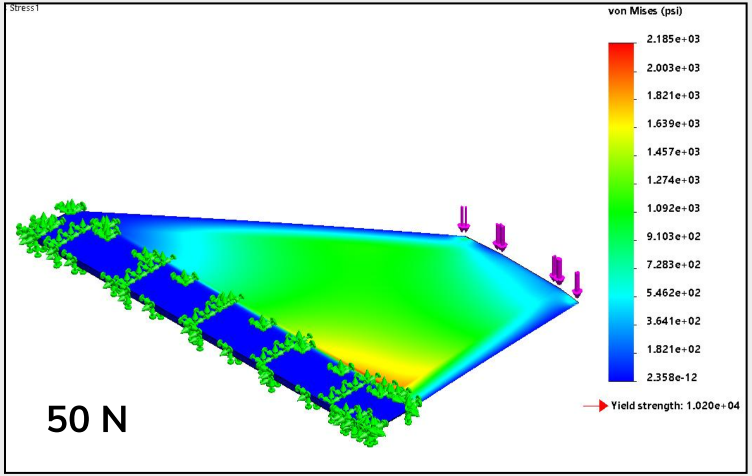
Goal: Understand whether the updated fin design would survive the flight conditions

Assumptions: 1.5” fin tab area fixed

Results: Yield stress was not exceeded by an order of magnitude. Forces were larger than expected from OpenRocket simulations.

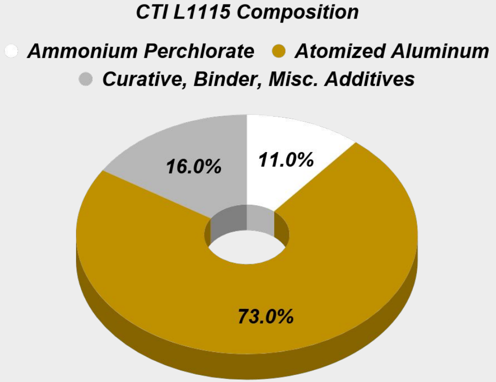
Yield Strength	1.02e+04psi
Forward Max von Mises	2.19e+03psi
Axial Max von Mises	4.79e+02psi

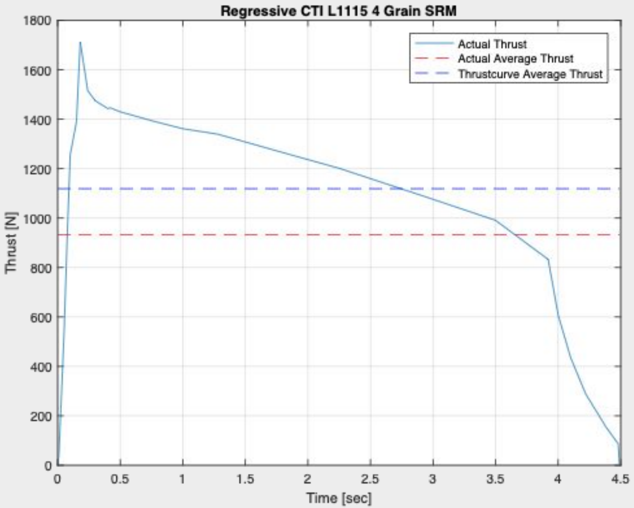


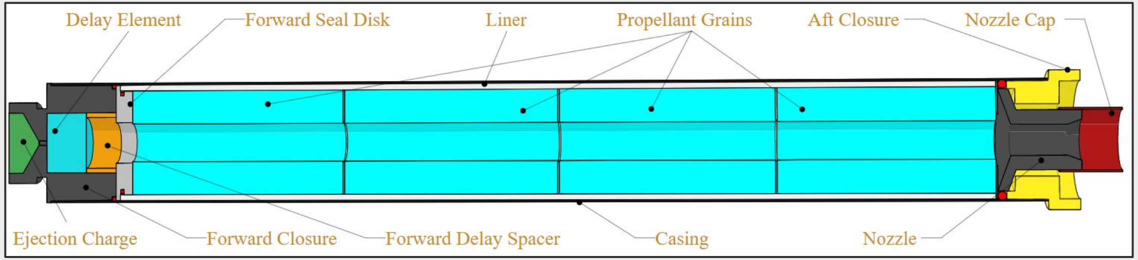


Final Motor Choice → CTI 75 mm L1115

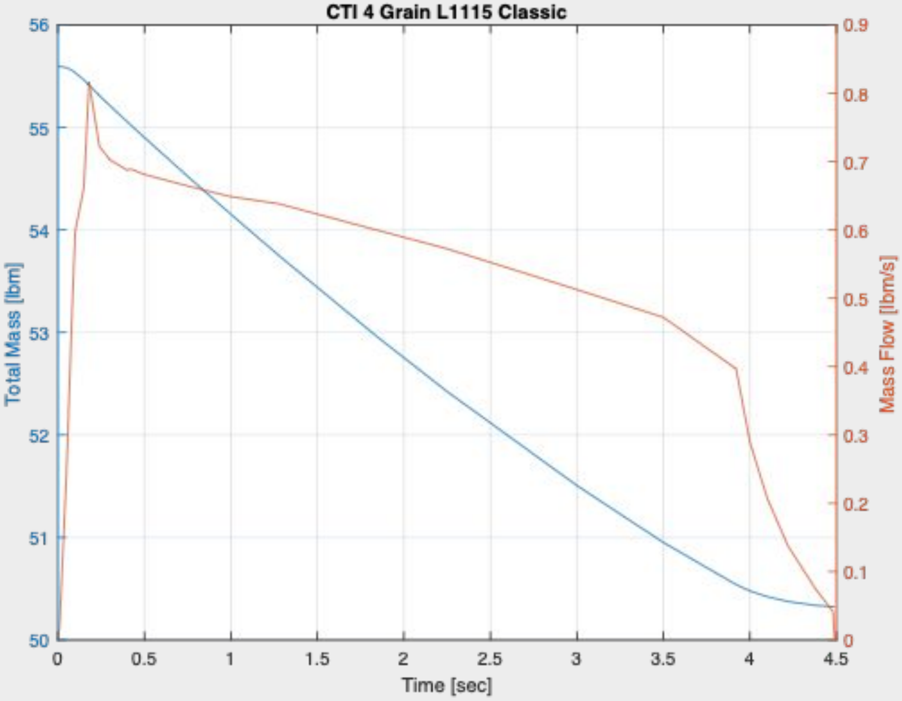
Vehicle Criteria	Value
Oxidizer	Atomized Aluminum, Al
Fuel	Ammonium Perchlorate, NH_4ClO_4
Max Thrust	385.17lbf
Burn Time	4.48lbm
Propellant Mass	5.28lbm
Loaded Mass	9.71lbm
Igniter Type	Pyrotechnic Ignition
Motor Dimensions	2.95" (76mm) x 24.45"







Vehicle and SRM Characteristics



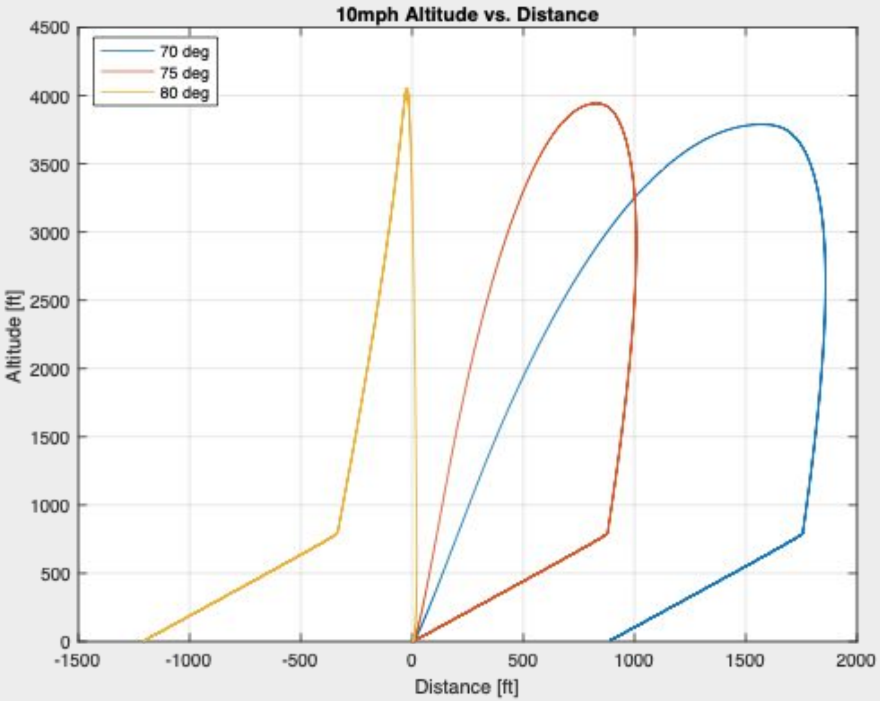
Vehicle Criteria	Value
Thrust-to-Weight Ratio	324.46lbf / 56.2lbf ≈ 5.77
Maximum Acceleration	188ft/s^2
Maximum Velocity	502ft/s (Mach 0.45)
Maximum Dynamic Pressure	0.5 * 0.0023769slug/ft^3 * (502ft/s)^2 ≈ 299lbf/ft^2
Rail Exit Velocity	63.5ft/s

Drift Predictions / Calculations

Crosswinds	Hand-Calc Drift	OpenRocket Drift
0mph	0’	9’
5mph	648’	685’
10mph	1340’	1400’
15mph	1995’	2200’
20mph	2605’	2625’

Note: Above case is using 0deg launch angle

$$\text{Drift} = \text{Descent Time} * V_{\infty}$$



Note: Above case is PSP-SL trajectory code using 10mph headwinds, 70-80deg (90 is normal to the ground)

Vehicle Mass Margin

Section	Estimated Weight	Current Weight
Motor	9.71lbm	9.71lbm
Lower Airframe	10.2lbm	9.96lbm
Avionics Bay	6.0lbm	6.34lbm
Upper Airframe	5.61lbm	5.61lbm
Payload	12.5lbm	11.7lbm
Nosecone	2.8lbm	2.8lbm
Recovery	5.0lbm	4.375lbm
Ballast	0lbm	3.75lbm*
Paint	~0lbm	~2.00lbm
Total	**55.6lbm***	**55.0lbm**

Current weight is based off the values provided in OpenRocket with an applied safety factor of 1.15

Reasons for these values to change:

- Epoxy weight
- Stickers and Final Paint
- Variations in mass for small objects such as washers and nuts
- More/Less hardware needed
- Non-uniform fiberglass weight due to manufacturing process
- Addition of holes where necessary

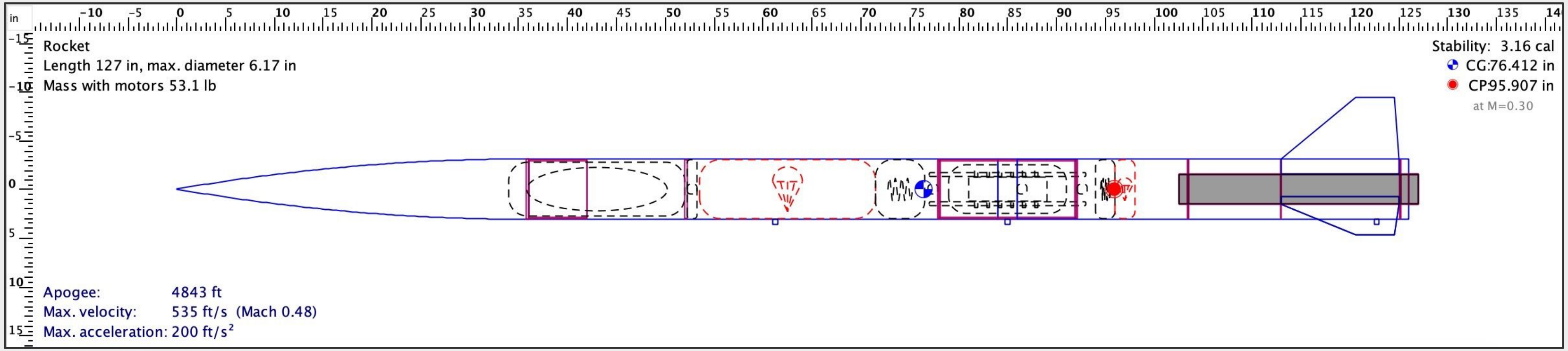
This weight is expected to be within 8% of the final launch weight

PSP™

Vehicle / Payload Demonstration Flight

Reviewing Safety

Folding Main Parachute

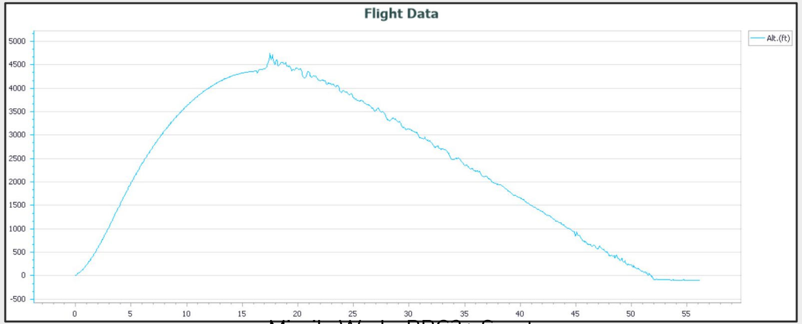


VDF / PDF Overview

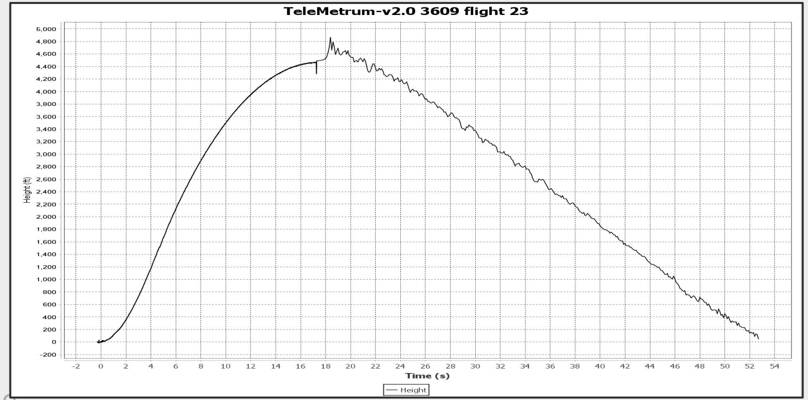
Launch Date	02/15/2020
Final Vehicle Design	Yes (minus paint)
Final Payload Flown	Yes
Safety Brief	Conducted
RSO Approval	Yes
Temperature	36F
Elevation	698’
Cloud Coverage	Mostly Cloudy
Launch Wind Speed	~14mph from SSW
Launch Location	North of Pence, IN

PSP™

Vehicle Demonstration Flight Results



Missile Works RRC3+ Sport



Al;tus Metrum Telemetrum

- Nosecone* / Upper Airframe / Payload* / Avionics* attached together - **ballistic**
- Lower Airframe* - **ballistic**
- ~$3,000 of parts destroyed / lost
- >>1,000 work hours lost
- **Cause:** Shock cord / quick-link connection error
- **Future Mitigation:** Discussed in safety

Desired Apogee	4325’
Telemetrum Reported Apogee	4488’
RRC3+ Sport Reported Apogee	4688’
Flight Time	52.69s
Flight Status	Unsuccessful

*Denotes component(s) either destroyed or lost

Vehicle Demonstration Flight Results cont.

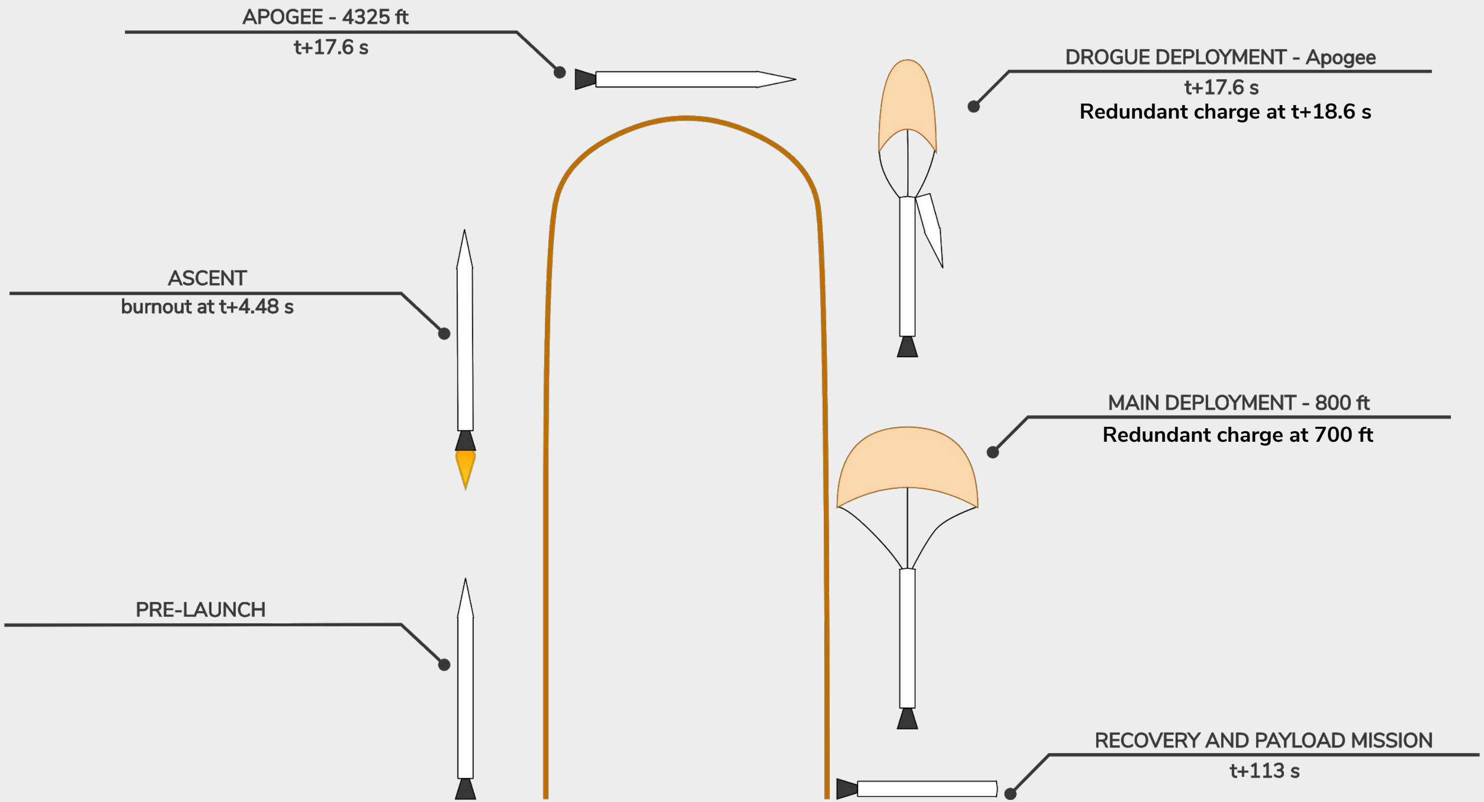
Flight Payload Results

- Most of payload was destroyed due to ballistic descent of launch vehicle
  - Drone encountered heavy damages
  - R&D encountered substantial damages
- Current update: Payload has been completely rebuilt

Avionics & Recovery Team

Team Lead: Katelin Zichittella
Team Members: Brady Beck | Pratik Dogra | Smrithi Pranatharthi Haran | Samvit Valluri

Recovery Topology



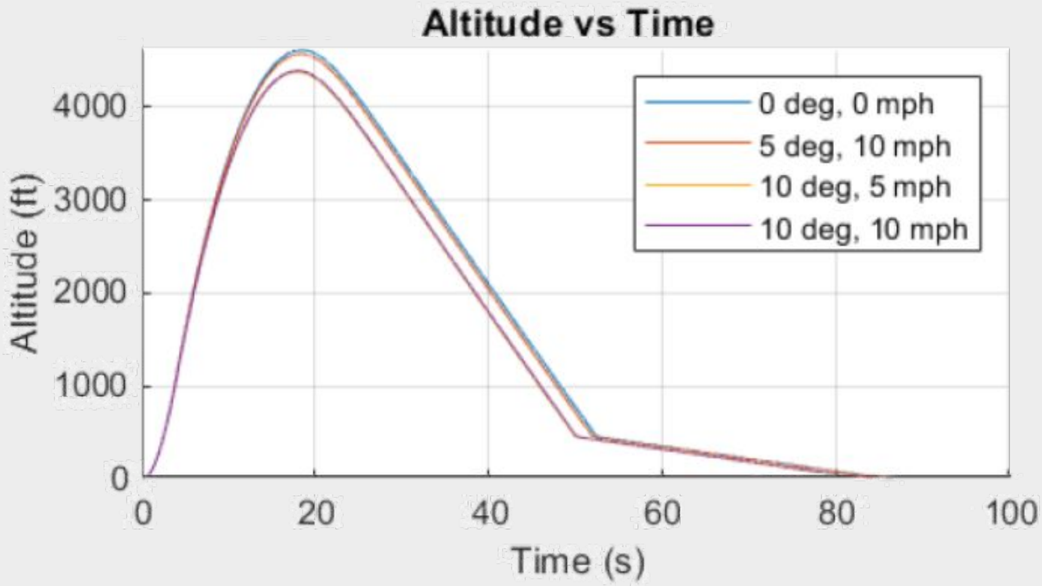
Team Trajectory Verification with MATLAB

Capabilities: Predicts apogee, range, drift

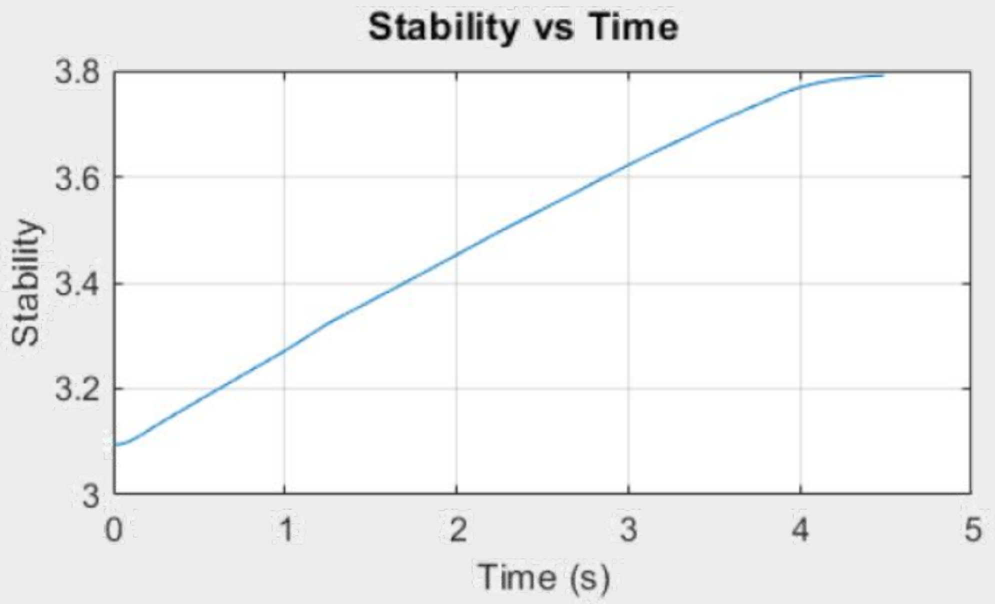
Inputs: C_D (vehicle), C_D (main/drogue), all component masses, wind speed, launch angle, motor characteristics

	Trajectory Code Estimates	OpenRocket Estimates
Apogee [ft]	4611.7	4865.5
Max Velocity [ft/s]	506.2	534.8
Burnout Velocity [ft/s]	501.3	506.2
Flight Time [s]	117.7	119.0
Descent Time [s]	99.3**	100.5**

Note: Above case is using 0 deg launch angle and 0 mph crosswind



Stability and Landing Energy Predictions



Note: This is to study stability from ignition until motor burnout

Section	Landing Kinetic Energy [ft-lbf]
Total Launch Vehicle	142.9
Lower Airframe	39.1
Avionics Bay	17.8
Upper Airframe	65.4

Descent Under	Descent Velocity [ft/s]
Drogue	93.9
Main	13.5

Note: Above case is using 0 deg launch angle and 0 mph crosswind

Main Parachute Opening Force Study

The calculations for the tension force consider the tension acting on the bulkheads by two bodies. The calculations and diagrams for each body are as follows:

Body 1 – Vehicle and Drogue

*Tension= $(M_{Total}$*Acceleration$)$-Drag +F_g*

M_{Total} = 53.2-(4) = 49.20 lbm

Drag =

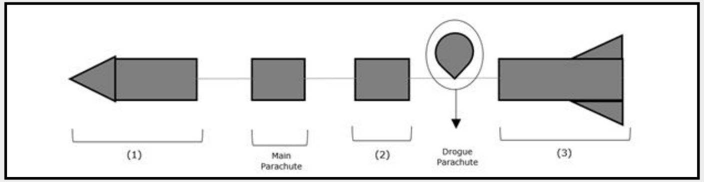
*coeff$_{Drag}$*0.5*0.002387*41.27^2*Area*

$Drag_{Total} = D_1+D_2+D_3+D_{drogue}$ = 340.97lbf

*F_g = 32.2*Mass$_{Total}$ = 1582.96 lbf*

In both cases, body acceleration before the parachute opens: ≈0ft/s^2

Tension 1 = 1241.99lbf



Body 2 – Main Parachute

*Tension= Drag-$(M_{Total}$*Acceleration$)$-F_g*

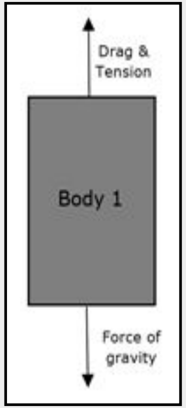
M_{Total} = 53.2-(0.1375+1.5) = 51.56lbm

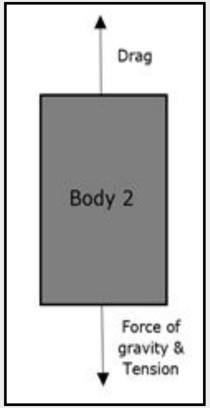
*Drag = coeff$_{Drag}$*0.5*0.002387*41.27^2*Area*

$Drag_{Total} = Drag_{Main}+D_1+D_2+D_3$ = 24730.76lbf

*F_g = 32.2*Mass$_{Total}$ = 1658.97lbf*

Tension 2 = 230.72lbf





Therefore, the total tension force acting on the bulkhead:
Tension 1 + Tension 2 = ***1472.71lbf***

Ejection Charges and Airframe Pressurization

Black Powder Grain	FFFFg
Drogue Primary	2g
Drogue Redundant	3g
Main Primary	5g
Main Redundant	6g

$Area_{Pin} = \pi R^2 = 0.009852in^2$

$Force_{Pin, Failure} = Area_{Pin} * T_{Nylon} = 98.52lbf$

$4 * Force_{Pin, Failure} = 394.1lbf$

$Area_{Bulkhead} = \pi R^2 = 28.27in^2$

$P_{Bulkhead} = (4 * F_{Pin, Failure}) / (Area_{Bulkhead}) = 13.94psi$

Drogue

$G = Mass_{BP} = C_P * D^2 * L * 1.2 = 1.037$ grams ≈ **2 grams** of BP

Main

$G = Mass_{BP} = 4.406$ grams ≈ **5 grams** of BP

PSP™

Shock Cord

- Drogue parachute
  - ⅜” tubular kevlar
  - 30’ long
- Main parachute
  - ⅜” tubular kevlar
  - 60’ long
- Harness/airframe interfaces
  - 1/4" SS quick link through looped tether ends
  - 1/4" SS I-bolt through bulkheads

Heat Shielding

- Nomex blankets
  - Square, 18” side
  - One wraps around the drogue parachute and one wraps around the main parachute
  - Serve as protection from hot ejection charge gases

Drogue Parachute

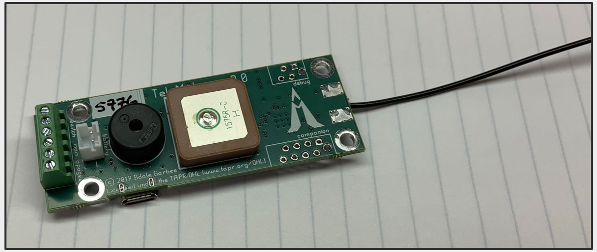
- **Make:** Fruity Chutes
- **Model:** Classic Elliptical
- **Size:** 24”
- **Cd:** 1.5-1.6
- **Materials:** 1.1 oz rip-stop, 220 lb nylon shroud lines, 1000 lb swivel
- **Why it was chosen:** Very low weight and packing volume, higher drag coefficient more suitable for our heavy launch vehicle

Main Parachute

- **Make:** SkyAngle
- **Model:** Cert-3 XXL
- **Size:** 120”
- **Cd:** 2.92
- **Materials:** Zero-porosity 1.9 oz balloon cloth, 2250 lb mil-spec suspension lines, 1500 lb swivel
- **Why it was chosen:** High drag coefficient, large enough to bring vehicle down under landing energy requirement of 75ft-lbf, already in hand

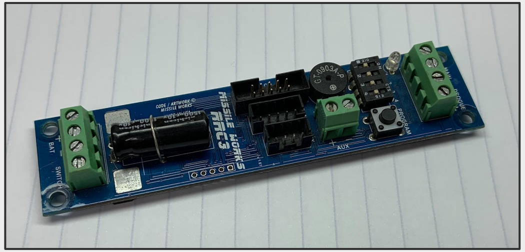
Primary Altimeter

- **Make:** Altus Metrum
- **Model:** Telemetrum
- **Battery:** 3.7V LiPo
- Also used as rocket locator
- **Why it was chosen:** Has proven to be reliable in many past launches, is small and efficient, already in hand



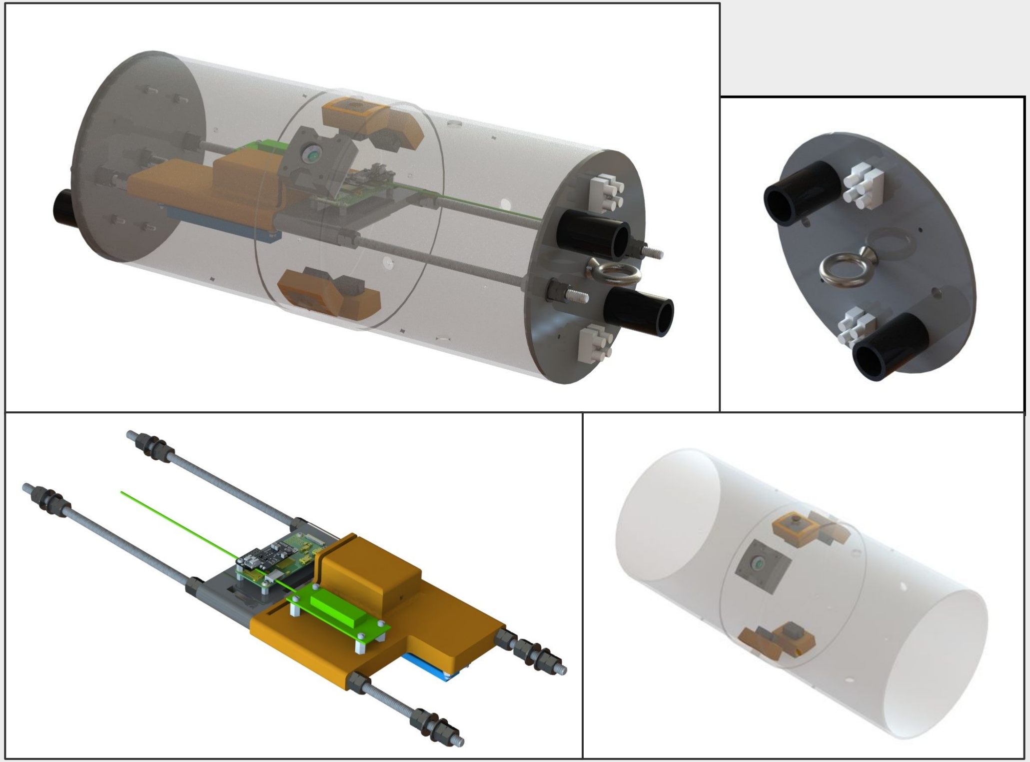
Redundant Altimeter

- **Make:** Missile Works
- **Model:** RRC3+ Sport
- **Battery:** 9V Alkaline
- **Why it was chosen:** Is cheap, has proven to be reliable in many past launches, is a different make/model than the primary altimeter, already in hand



PSP™

Avionics Setup & CAD



Overall Weight [lbm]	6.3
Switch Type	Rocker
Drogue Deployment Altitude	Apogee
Main Deployment Altitude	800 ft AGL
Backup Ejection Time Delay	+1 sec
Communication Methods	Laptop, TeleBT, TeleDongle, Yagi Arrow 3 Element Antenna

Avionics Test Phases and Milestones

Req. ID	Test ID	Test	SUT	DT/OT	Status
3.12.2, T3.5	A_01	Altimeter Continuity Test	Altimeters	OT	Complete**
3.1.1, T3.4, T3.4.1, T3.4.2, T3.4.3	A_02	Altimeter Ejection Vacuum Test	Altimeters	OT	Complete**
3.2, T3.3	A_03	Avionics Ejection Black Powder Test	Ejection System	DT	Complete
3.12.2, T3.2	A_04	Avionics Battery Drain Test	Altimeter Batteries	OT	Complete
3.3, T3.1	A_05	Parachute Drop Test	Parachutes	OT	Complete

Note: DT = Developmental Test and OT = Operational Test

**These tests will be redone prior to the reflight

PSP™

Avionics Testing - Altimeter Ejection Vacuum Test - A_02

Objective: The objective of this test was to ensure that both the Telemetrum and RRC3+ Sport altimeters ignite the drogue ejection charge at apogee (or one second after apogee for the RRC3+ Sport) and the main ejection charge at the correct altitude during descent (800’) (or 700’ for the RRC3+ Sport).

Procedure:

1. To test one altimeter, a lighter was connected to each the drogue and main outputs, and a battery and switch were also connected. This system (along with the Altimeter One turned on and set to Real Time mode) was placed in the glass bowl.
2. A larger ring of plumbers’ putty was placed around the rim of the bowl, over the lighters and switch wires. The prepared sheet of plexiglass was then placed over the bowl and pressed down until there was a uniform seal around the entire perimeter. Extra plumbers’ putty was placed around the exposed wires as needed.
3. A small piece of plumbers’ putty was used to seal the pressure release hole, then the altimeter was switched on and allowed to complete its initialization routine.
4. The wine bottle air remover pump was then used to remove air through the stopper. Once the process of removing air was halted at the expected apogee altitude (the digital display of the Altimeter One indicated when this was), the drogue lighter was expected to ignite (or one second after apogee for the RRC3+ Sport).
5. Finally, the small piece of plumbers’ putty was very slightly lifted away from the plexiglass to slowly allow air back inside it, causing the altitude to decrease according to the Altimeter One. The main lighter was expected to ignite at pressures corresponding to an altitude of 800’ (or 700’ for the RRC3+ Sport).

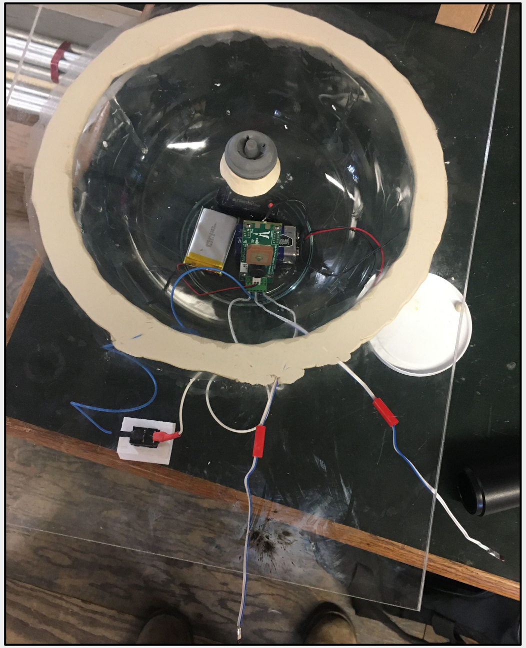
Avionics Testing - Altimeter Ejection Vacuum Test - A_02

Procedure, Continued:

6. The flight data was downloaded onto a laptop for analysis.
7. The procedure was repeated two more times for a total of three trials, then three more times with the other altimeter.

Success Criteria: The Telemetrum altimeter passed this test if the magnitude of the difference between the apogee altitude and the altitude the drogue lighter ignited at was less than 500’ and the altitude the main lighter ignited at was between 800 ± 50’ for all three trials. The RRC3+ Sport altimeter passed this test if the drogue delay (the time between apogee and ignition of the drogue lighter) was between 0.75s and 1.75s (as it is programmed to be 1s) and the altitude the main lighter ignited at was between 700 ± 50’ for all three trials.

Results: This test was conducted on the 20th of January. Initial tests with the RRC3+ Sport altimeter failed, but after retesting it was determined that these failures were largely due to deficiencies in the test setup. Both altimeters have therefore met the success criteria outlined above and have **passed** this test.

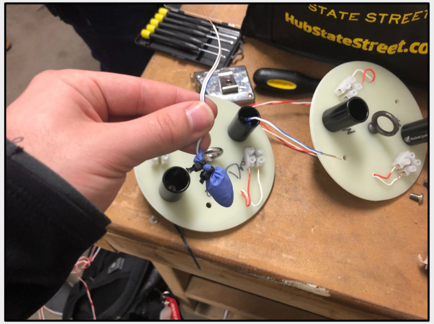


Avionics Testing - Avionics Ejection Black Powder Test - A_03

Objective: The objective of this test was to verify that the calculated amount of black powder in each canister results in a successful separation, or to determine a new value if necessary.

Procedure:

1. The primary black powder canister on the upper airframe side of the avionics bay was filled with 5g of black powder.
2. After assembly of the vehicle, a remote detonator was connected to an extension wire, which was connected to a lighter in the black powder.
3. The person conducting the test stood 40’ away from the system and set off the remote detonator. The ejection charges were then expected to ignite and result in separation of the two components. If they did indeed separate, the distance between them was measured in feet using a tape measure.
4. If the success criteria outlined in the next slide were not met, the procedure was repeated using increasing amounts of black powder (in 1g increments) until 6’ of separation was achieved. This last amount of black powder was then recorded as the ideal amount of black powder.
5. The procedure was also repeated for the black powder canister on the lower airframe side of the avionics bay, with 2g of black powder.



Avionics Testing - Avionics Ejection Black Powder Test - A_03

Success Criteria: Each black powder canister passed this test if its ignition resulted in at least 6' of separation of the avionics bay from the corresponding airframe for at least one amount of black powder equal to or greater than 5g for the upper airframe canisters and 2g for the lower airframe canisters.

Results: This test was conducted on the 26th of January. Both the upper airframe side and lower airframe side black powder canisters resulted in well over 6' of separation between the airframe and the avionics bay. Therefore, both black powder canisters have met the success criteria outline above and have **passed** this test.

Payload Team

Team Leads: Josh Binion | Hicham Belhseine
Team Members: Julian Petrillo | Bret Reser | Luke Hecht | Cooper Slack | Matthew Rumple | Morgan Harris | Natalie Keefer | Skyler Harlow | Wellington Froelich | William Graber

The Friendly Ghost - Autonomous UAS

- Autonomous UAV with integrated lunar ice mining system
- Sophisticated retention and deployment system for actively securing and orienting the UAV
- Ground control station with full mission control capability and ability to receive avionics telemetry

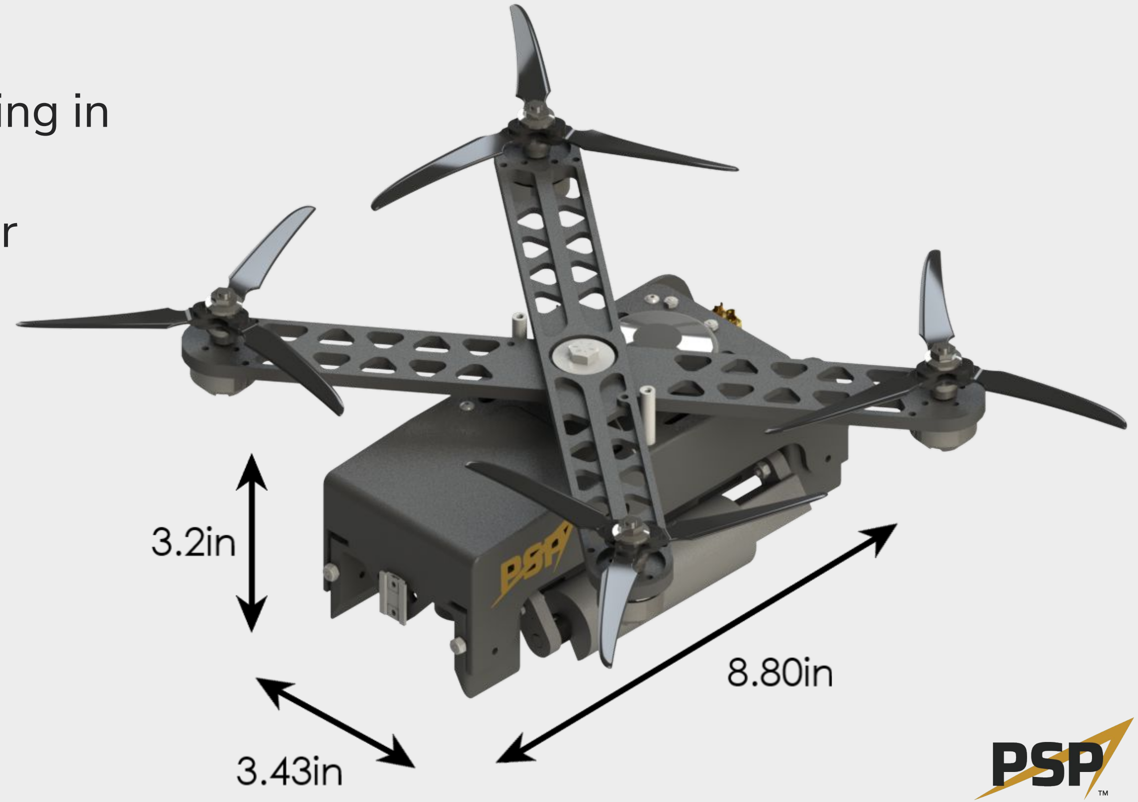
Key Metrics	
Estimated System Weight	10.5lbm
Estimated UAV Weight	2.4lbm
Estimated Flight Time	10.1min (606s)

PSP™

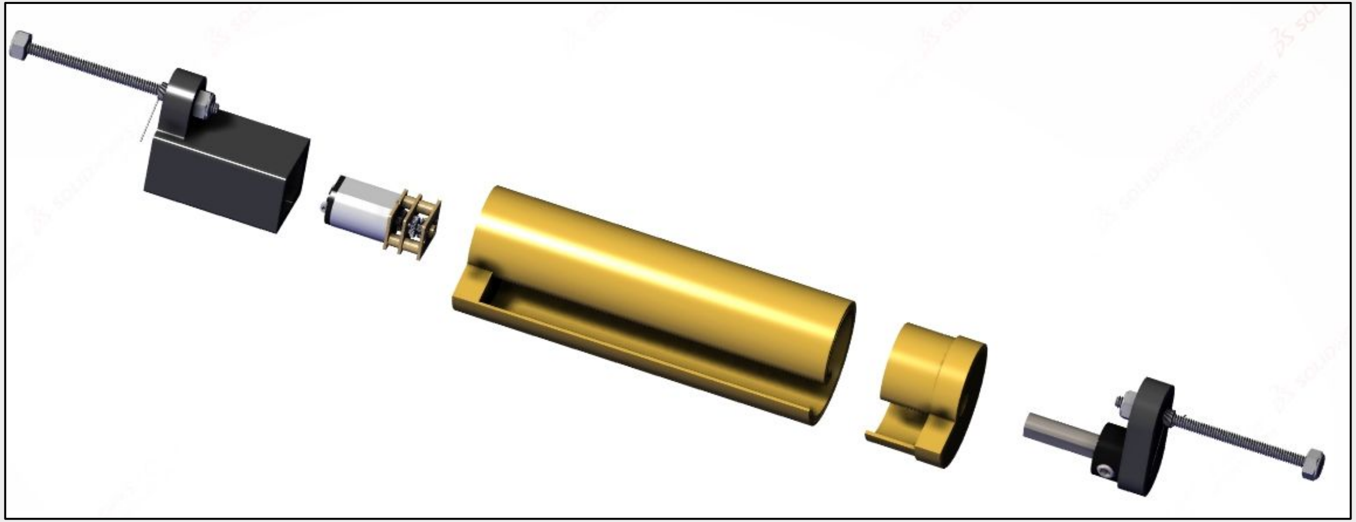
Payload System Overview

UAV Airframe

- Quad-rotor design
- Opening mechanism for fitting in airframe
- Plate-based construction for electronic components
- Nylon-6 construction



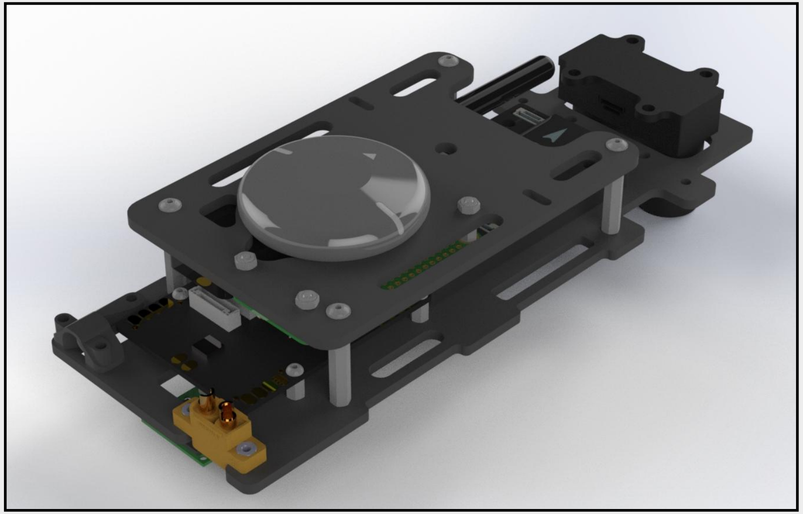
Ice Mining System - Overview

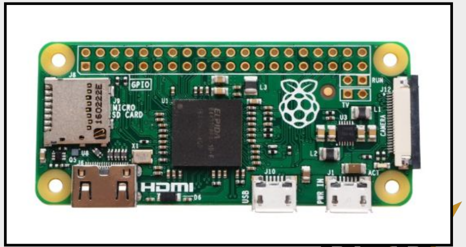


- Rotating scoop-based design
- Designed to minimize space and weight on-board the UAV
- Electronics redesigned after CDR for robustness and reliability

Flight Control and Mission Management

- Primary E&C Components:
  - Pixhawk 4 - Flight Computer
  - Raspberry Pi Zero - Mission Control computer
  - Raspberry Pi Camera - Computer Vision System
  - GPS/Compass Module
- Raspberry Pi manages high-level vehicle control and image processing
- Navigation based on known GPS coordinates and recovery site image detection





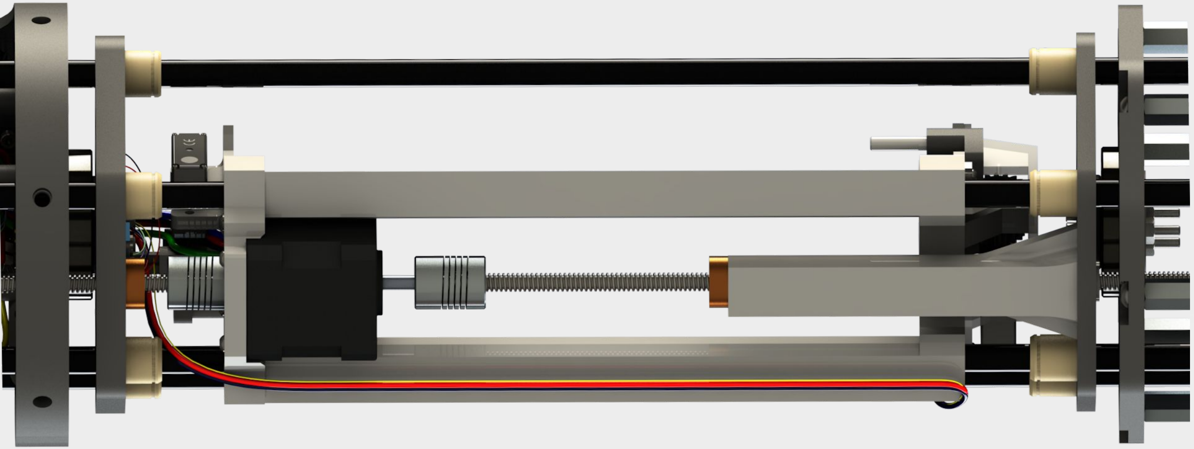
Ground Control Station

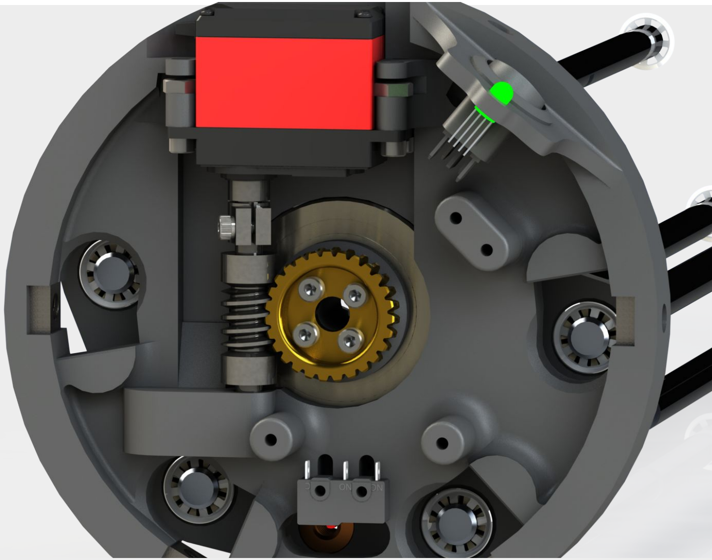
- Physical interface between payload personnel and UAV
- Functionality:
  - UAV telemetry monitoring
  - Viewing image data
  - Autonomous mission planning
  - Monitoring mission status
  - Flight mode switching
  - Avionics telemetry monitoring
- Buttons, switches, and indicators give user control and feedback throughout the mission

Retention and Deployment - Overview

- Robust system for controlling safe retention and deployment of UAV
- UAV retention, axial motion restriction, orientation control, and remote deployment

R&D - Mechanical Design

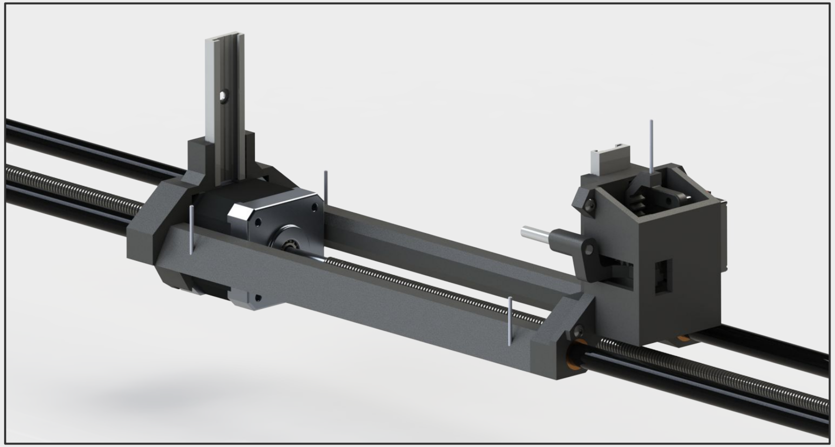




- Stepper motor (pictured left) for separation of nose cone and upper-airframe
- Servo and worm-gear system (pictured right) for locking and orientation control

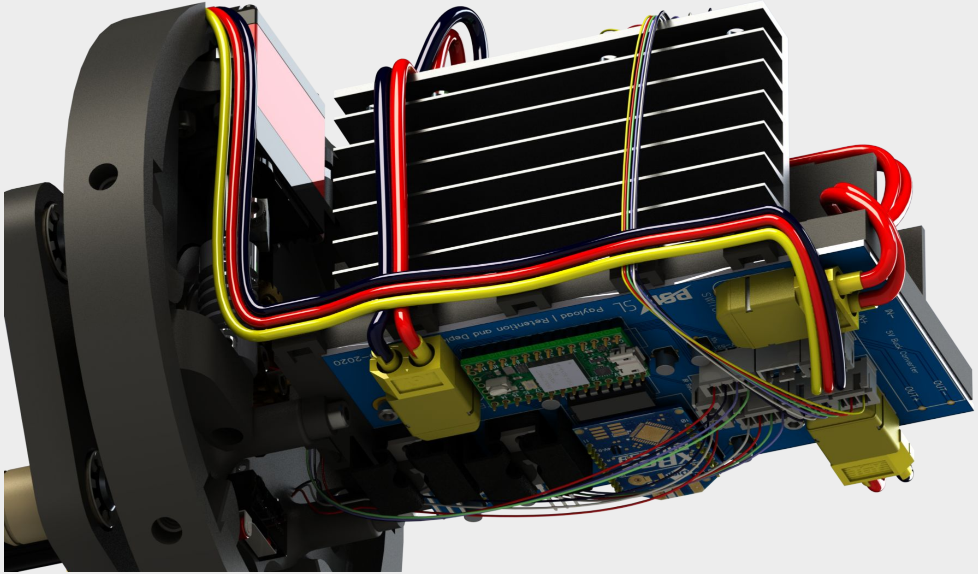
R&D - UAV Active Retention

- Servo-actuated rack and pinion sled that retains the UAV
- Prevents motion in any axis and isolates power to the flight computer
- Holds passive X-Wing Mechanism together
- Guide rails and dowel pins guide the UAV through a vertical takeoff



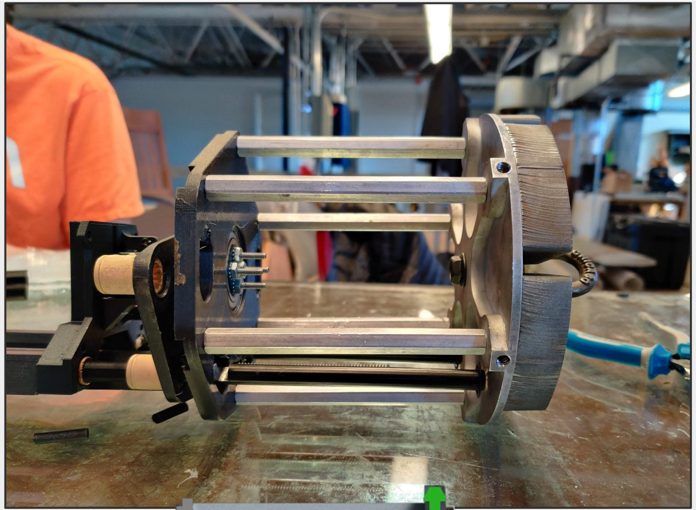
R&D - Electrical Design

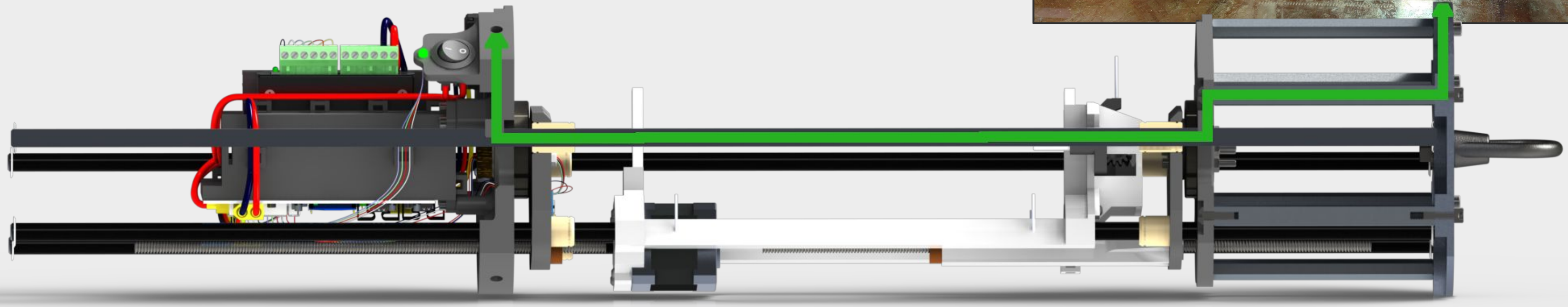
- Custom electronics developed for controlling R&D hardware
- XBee-based wireless communication system
- System has been thoroughly tested to ensure flight reliability



Launch Vehicle Interface and Integration

- Aluminum bulkplate directly bolted through side of airframe
- Locking mechanism provides failsafe means of securing nosecone to upper-airframe
- LEDs and push buttons accessible through the airframe provide electronic status and control





Payload Test Phases and Milestones

Req. ID	Test ID	Test	SUT	DT/OT	Status
4.3.2	PT_01.1	IMPS Stand Test	UAV	DT	Complete
	PT_01.2	Onboard Ice Mining Test	UAV	OT	In Progress
PR_2.6	PT_02.1	Variable Pitch Orientation Test	UAV/R&D	DT	Complete
	PT_02.2	Variable Roll Orientation Test	UAV/R&D	DT	Complete
PR_2.7	PT_03.1	Flight Controller Tuning	UAV	DT	In Progress
PR_2.8	PT_04.1	SITL Ice Recovery Testing	UAV/GCS	DT	In Progress
	PT_04.2	Recovery Area Identification Testing	UAV/GCS	OT	Incomplete
PR_2.9	PT_05.1	RF Comms Testing	All	DT	Incomplete
PR_2.10	PT_06.1	XWing Structural Testing	UAV	DT	Complete
PR_2.11	PT_07.1	Battery Drain and Power Testing	All	DT	In Progress

Note: DT = Developmental Test and OT = Operational Test

Variable Pitch Orientation Test

Trial	Pitch Angle	Result
1	0°	Pass
2	-5°	Pass
3	-10°	Fail
4	-8°	Fail
5	-7°	Pass
6	2°	Pass
7	5°	Pass
8	7°	Fail
9	6°	Fail

Objective: Determine maximum pitch at which UAV can deploy from launch vehicle
Results: The UAV can successfully take off at angles between -7 and 5 degrees

IMPS Stand Test

Objective: Verify that the ice mining system can collect the required sample volume

Results: The system consistently collects the required amount of material

- System must end in correct orientation to retain the material

Trial	Number of Rotations	Amount Collected
1	1	11.5 mL
2	2	12.5 mL
3	1.5	7.5 mL
4	1.75	2.5 mL
5	2	13 mL

PSP™

Safety Team

Team Lead: Noah Stover
Team Members: Andrew Darmody | Reid Trafelet

PSP™

Project Risks

Hazard	Likelihood (Cause)	Severity (Effect)	Risk	Mitigation	Verification	Post Mitigation Risk
Hypothermia	3 (Low temperatures on launch day)	3 (Sickness and possible hospitalization)	9, Medium	Wear clothing appropriate to the weather, ensure all members have access to a warm area to rest at launch.	Team members must have adequate clothing, Safety team will report violators to the project lead to decide if the violator should be dismissed to a warmer area.	6, Low
Loss of Parachute	3 (Poor attachment or improper materials used)	5 (Partial or total destruction of vehicle)	15, High	Use appropriate materials and high strength building methods. Parachute attachment will be witnessed, orange tape will be used to show connected quicklink	Quick link attachment of parachute will be witnessed by 1+ additional team members and completed with orange tape around quick link.	5, Low
Pollution From Vehicle	2 (Loss of components from vehicle)	3 (Possible harm to wildlife or water contamination)	6, Low	Properly fasten all components. Scavenge for fallen parts after launch is completed.	Inspect the securements of components before launch. Have designated clean up team for each launch.	3, Low
Damage During Transit	2 (Mishandling during transportation)	5 (Inability to fly launch vehicle)	10, Medium	Protect all launch vehicle components during transit.	Ensure launch vehicle safety secured by testing.	5, Low

Pre-Launch Safety Presentation

- Pre-launch safety presentation
  - Explain general launch procedure
  - List needed PPE
  - Explicitly state critical safety concerns
    - Minimum personnel distance, workspace crowding, etc
  - Give overview of the quality witness process

Pocket Rocket Docket

- Pocket Rocket Docket
  - Used through the launch and reconstruction
  - Launch docket includes:
    - Overview of procedures
    - Launch specific first aid
    - Troubleshooting quick reference
    - Launch safety considerations

Pre-Launch Checklist

General Safety:

- ☐ Ensure that a trained Range Safety Officer is present
- ☐ Have first aid equipment and at least one phone available for use nearby
- ☐ Designate a "rapid response" person or persons to be the one(s) to perform duties such as administering first aid in the case of an emergency
- ☐ Designate spotters to keep track of the launch vehicle's descent
- ☐ Have adequate fire suppression equipment available for use nearby
- ☐ A fire blanket has been placed under the pad if conditions at launch are dry enough to require it

3

In the case of a misfire:

- ☐ Wait a minimum of three minutes
- ☐ Send ONLY Luke, Mike, Vic , Noah, and anyone they deem necessary to launch pad
- ☐ Disarm launch controller
- ☐ Remove failed igniter and motor
- ☐ Disarm avionics ONLY if fixing misfire will take an extended period of time
- ☐ Remove vehicle from launch rail

In the case of ballistic trajectory:

- ☐ Should the launch vehicle enter freefall without any indication of parachute ejection, issue "Scatter" command
- ☐ All in attendance of the launch are to immediately turn away from the direction of the launch vehicle and run for a minimum of 30 seconds

11

PSP SL ™

Project Casper

Fullscale Launch

Designed by: Andrew Darmody

Reviewed by: Noah Stover, Luke Perrin

Launch Checklist Improvements

- Checklist Improvements
  - Completely overhauled launch checklists
  - Improved quality witness procedures
    - More witness steps
    - Better defined failure criteria
  - New launch clearance procedure
    - Quality witnesses confirm completion of assembly milestones
    - All witnesses must confirm before launch

PSP™

Quality Witness Example

- QUALITY WITNESS: Inspect **UAV preparation** for the following. If any of the following are missing or damaged, halt launch procedures and direct attention to the appropriate authority. NOTE: Appropriate response to any irregularities will be determined by team leads
    - Inspect for presence of:
        - Ice mining assembly
        - LiPo battery
        - Electronic component
        - FCC
        - MCU
        - Inspect all electrical connections for exposed wire or loose connections
    - Inspect X-Wing assembly for visible or tactile cracks, scratches, or irregularities
    - Inspect propellers for visual or tactile cracks, scratches or irregularities. Ensure propeller nuts are tightened.
        - Inspect airframe mechanical and electrical connections

PSP™

Business Team

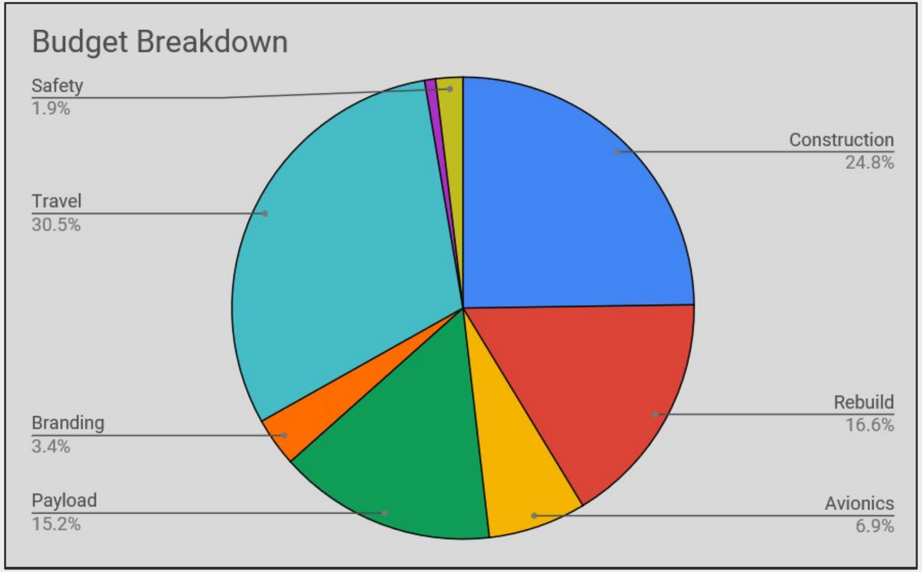
Team Lead: Natalie Keefer

Team Funding Sources

Source	Estimated Cost
Aerojet Rocketdyne Grant	$1600
Purdue Propulsion	$1315.02
Crowdfunding	$5266.96
Purdue ECE Department	$2000.00
Purdue ME Department	$1000.00
Purdue AAE Department	$2000.00
Money From Apparel Sales	$157.00
Total Raised	$13338.98
Total Remaining to be Fundraised	$78.89
Total Remaining in Bank Account	$7104.54

Team Budget Breakdown

Section	Estimated Cost
Construction	$3000.00
Avionics	$900.00
Payload	$2000.00
Outreach	$100.00
Safety	$250.00
Branding	$450.00
Travel	$4000.00
Rebuild	$2717.87
Total	$13417.87



Social & Outreach Team

Team Lead: Skyler Harlow

Educational Outreach Events Since CDR

Purdue Space Day Ambassadors (1/24/20)-Straw Rockets

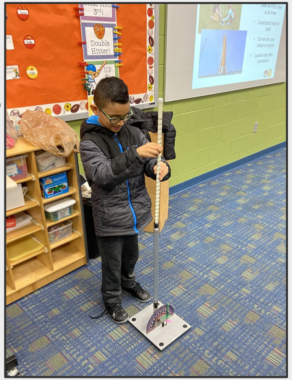
- Reached 50 students and 2 educators

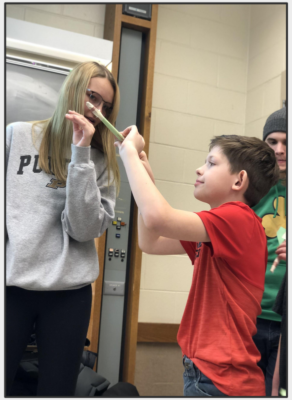
College Mentors for Kids (2/26/20)-Strawkets

- Reached 12 students and 12 university students

Imagination Station (3/1/20)-Foam Rockets

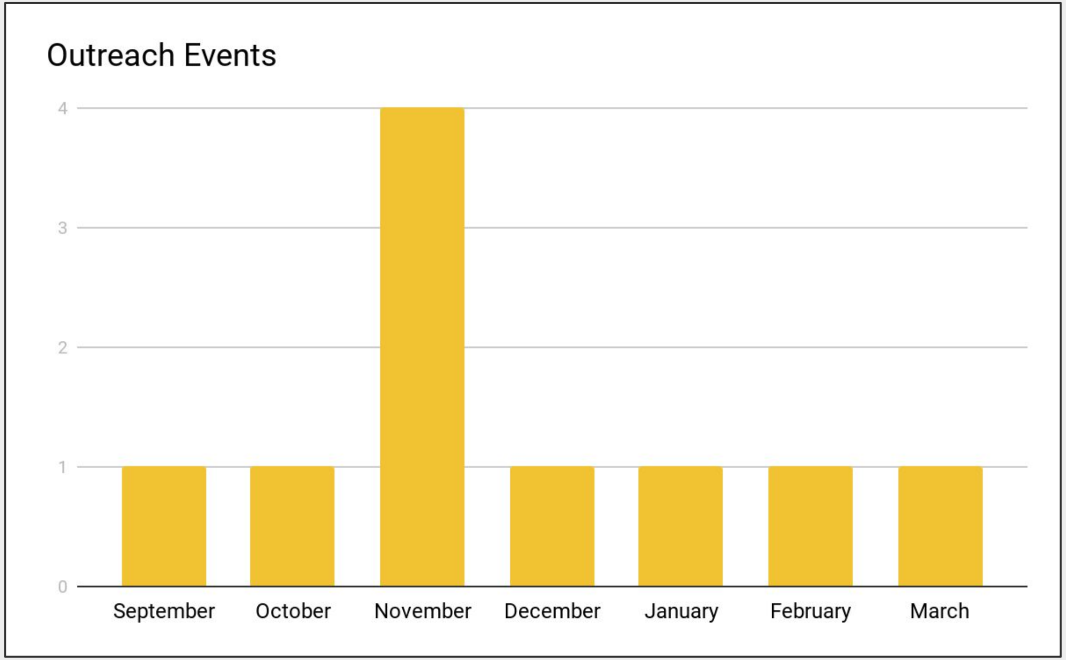
- Reached 9 students and 5 adults






Outreach per Month

- For FRR the team was able to reach a total of 83 direct interactions and 7 indirect interactions.
- Throughout the entire competition the team has 1,219 direct interactions and 282 indirect interactions.



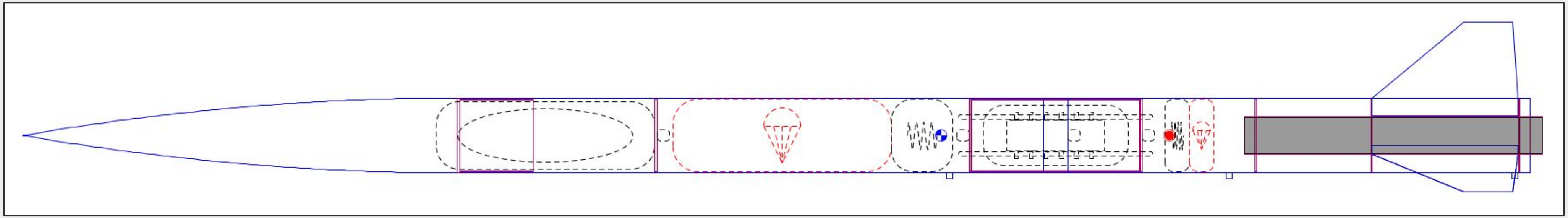
Questions & Answers

purdueseds.space/student-launch/

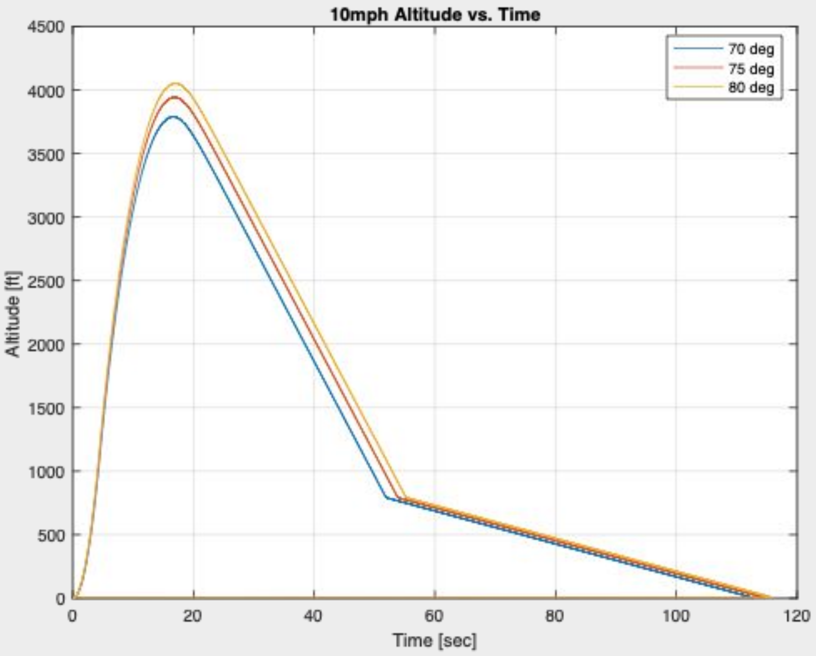
@psp.studentlaunch @pstudentlaunch @purduesl

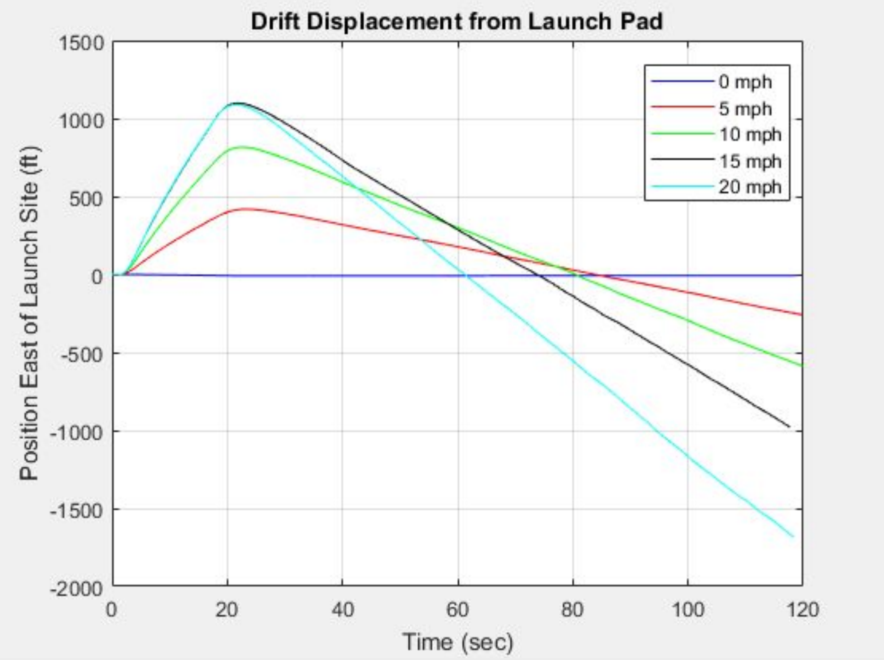
Backup Slides

OpenRocket Design



PSP-SL MATLAB Trajectory Script





Upper Airframe Ballast

- 5x ¾lbm steel wedges
- Cut with waterjet
- Asymmetrical to counteract imbalanced payload system.
- Attached to Main Parachute Bulkplate