PSP™

Project Casper

Preliminary Design 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

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Construction Team Lead

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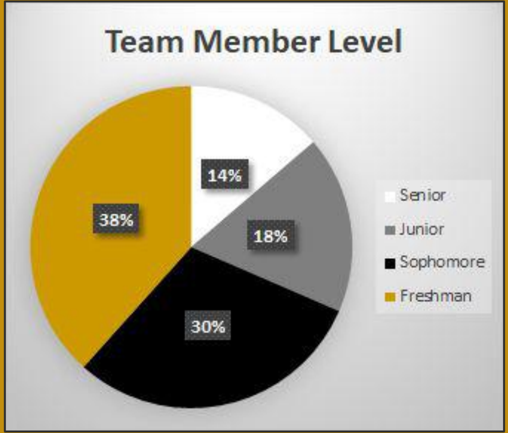
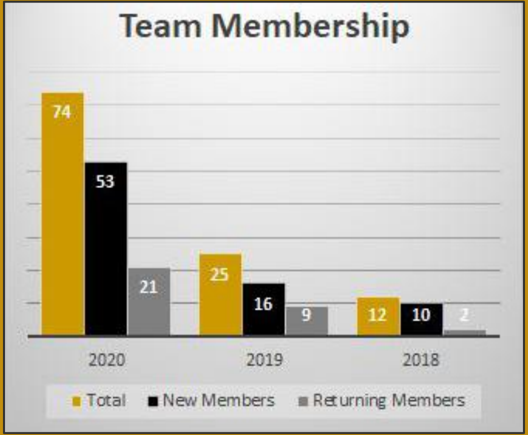
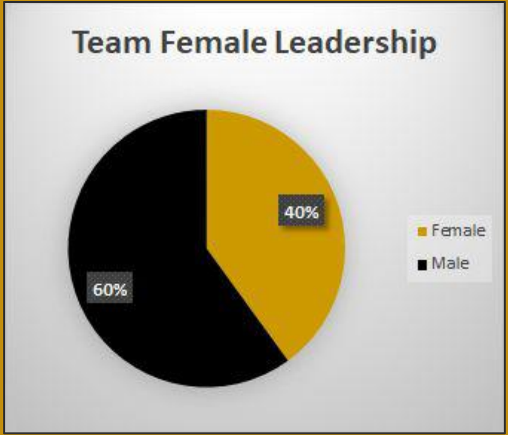
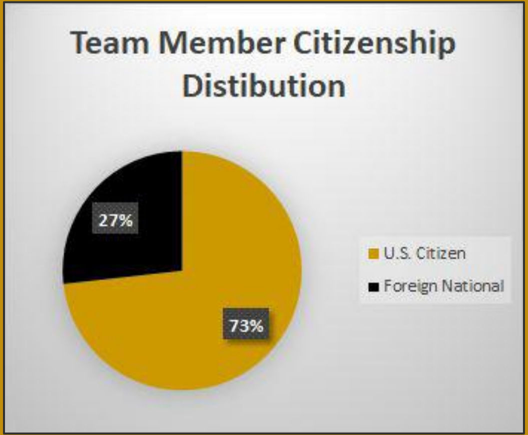
Construction Team Mentor

Team Diversity









Derived Requirements

NASA Derived Requirements

Requirement ID: 4.3.7.2 **Description:** The retention system will be robust enough to successfully endure flight forces experienced during both typical and atypical flights.	**Verification Plan:** The retention system will be tested to validate a robust design and construction, and any structurally critical components will be designed with a safety factor of at least 2.
	Comments: N/A
Status: *Incomplete*	**Verification Test ID:** PT_03

Inspection	**Demonstration**
Analysis	**Test**

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Team Derived Requirements

Requirement ID: T5.1 **Description:** Every team member must have a Pocket Safety Document on their person for all launch day, construction, assembly, or test operation.	**Verification Plan:** Team members will be asked to display Pocket Safety Documents before applicable operations occur. **Comments:** Separate pocket safety documents will be written for the operations of testing, machining, construction, and launch days.
Status: *Incomplete*	**Verification Test ID:** N/A

Inspection	**Demonstration**
Analysis	**Test**

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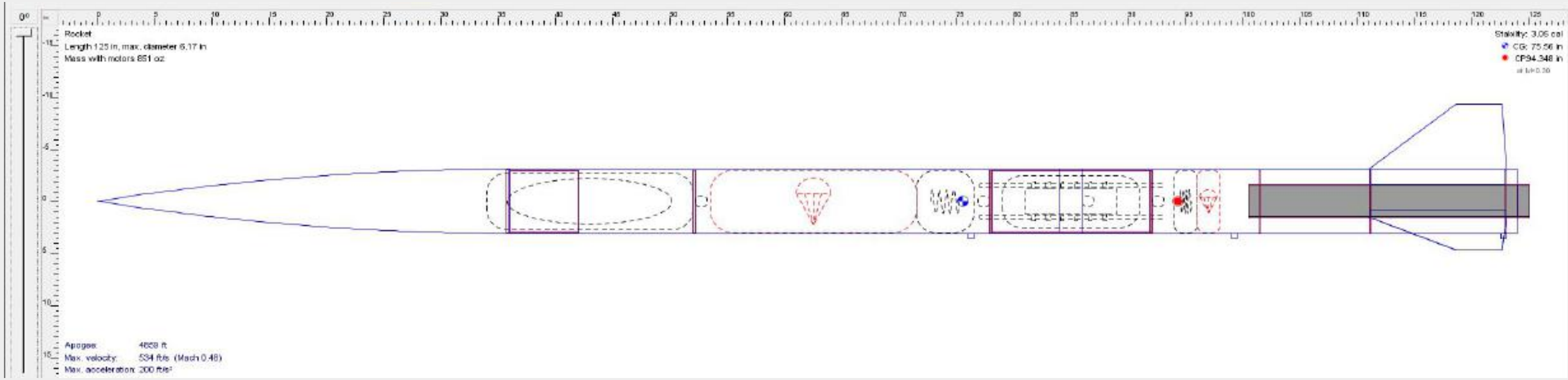
Construction Team

Launch Vehicle Overview

- 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	125”
Body Tube Inner Diameter	6”
Estimated Weight	53.2 lbm
Estimated Average Launch Pad Stability	3.05 cal



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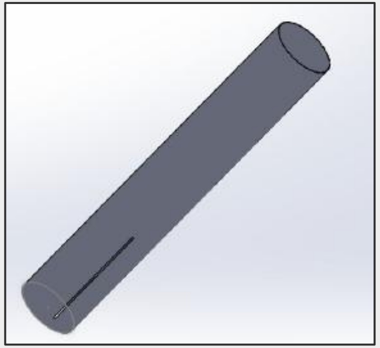
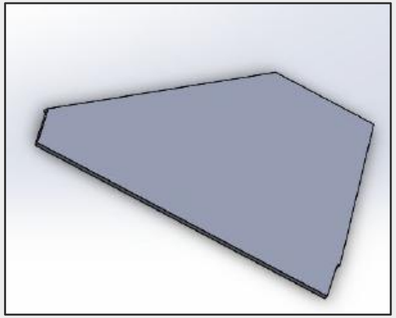
Lower Airframe

- 8 lbm estimated weight
- 38” in length
- Designed to interface with the mid airframe coupler tube
- Transfers thrust loads from the retained motor to the airframe
- Provides aerodynamic stability



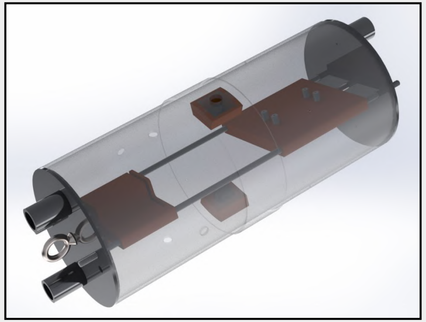
Fins

- 3 lbm estimated total weight
- Max height of 6.25” from the exterior of the rocket
- Trapezoidal in shape
- Each has a tip chord of 4”, a root chord of 12”, and a fin sweep angle of 50.5°



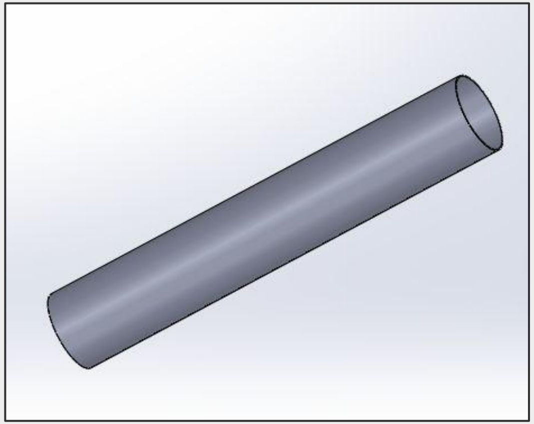
Avionics Bay

- Houses primary and redundant altimeters and corresponding batteries on a custom 3D printed sled
- Primary and redundant ejection charges are mounted to the bulkheads on either end of the bay, as are the both parachutes



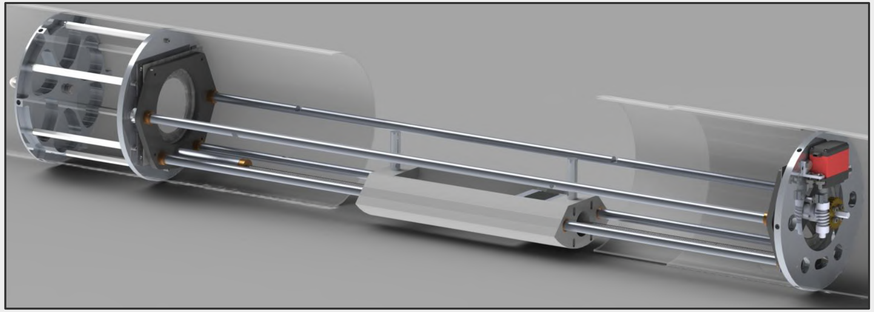
Upper Airframe

- 27 lbm estimated weight
- 43.5” in length
- Designed to hold main recovery gear and to interface with the payload and avionics bay



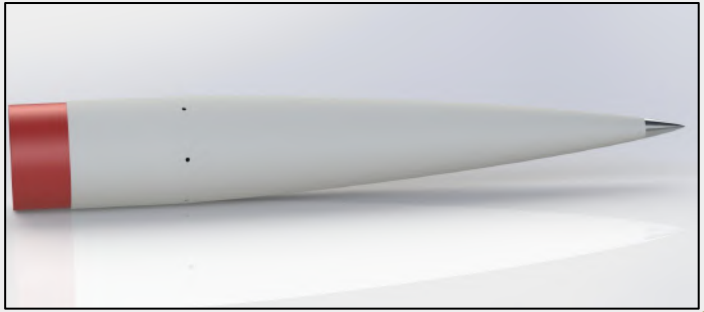
Payload Bay

- 12.5 lbm estimated weight
- 18” in length (2” of which extends into nose cone)
- 5.775” outer diameter
- Designed to hold the payload UAS and its retention and deployment system



Nose cone

- 2 lbm estimated weight
- 30” in length
- Designed to reduce drag, features an increased interior volume for future payloads or electronics, and interfaces with upper payload coupler



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Solid Rocket Motor (SRM) Choices

Solid Rocket Motor	Cost	Pros	Cons
AeroTech (AT) L1420	$280	-75mm motors preferred over 98mm due to increased stability -Lowest cost	-Lowest total impulse -75mm motors are longer than 98mm motors, increasing lower airframe length and weight
AeroTech (AT) L1500	$305	-Highest total impulse (98mm)	-98mm diameter motors concentrate weight in the lower airframe, decreasing stability
Cesaroni (CTI) L1115	$293	-75mm motors preferred over 98mm due to increased stability -Highest total impulse (75mm) -Long burn time/lower average thrust minimizes losses to drag	-75mm motors are longer than 98mm motors, increasing lower airframe length and weight
Cesaroni (CTI) L3150	$344	-Shortest length, trims lower airframe length/weight	-98mm diameter motors concentrate weight in the lower airframe, decreasing stability -Highest cost -Short burn time

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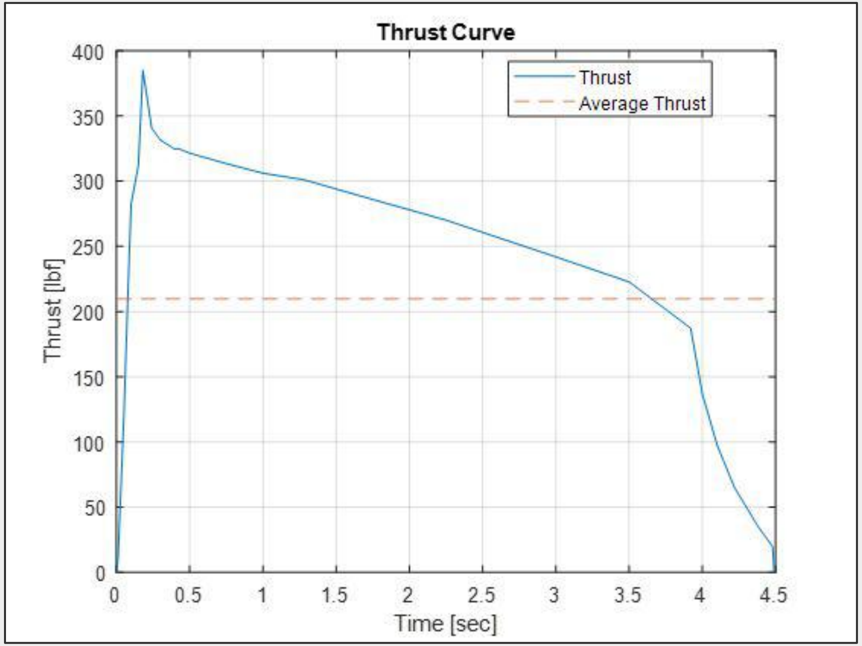
Preliminary Motor Choice → L1115

Motor Criteria	Value
Total Impulse [lbf-sec]	1127.42
Max Thrust [lbf]	385.17
Average Thrust [lbf]	251.56
Liftoff Thrust [lbf]	324.46
Burn Time [sec]	4.48
Propellant Mass [lbm]	5.28
Loaded Mass [lbm]	9.71
Dimensions [in]	2.95 (76 mm) x 24.45



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T/W Ratio and Rail Exit Velocity

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

Altitude Prediction Theory

Percent Likelihood [%]	Test Case		Theoretical Apogee [ft]				Test Case Altitude Averages [ft]
	Launch Angle [deg]	Pad Wind Speed [mph]	+0lbm Mass Margin	+1.5lbm Mass Margin	+2lbm Mass Margin	+3lbm Mass Margin	
10 (Ideal)	0	0	4867	4670	4606	4479	4655.5
30 (Less Realistic)	5	5	4744	4555	4494	4367	4540
40 (Reasonably Realistic)	5	10	4647	4481	4416	4295	4459.75
40 (Reasonably Realistic)	10	5	4542	4358	4299	4180	4344.75
60 (Significantly More Realistic)	10	10	4431	4237	4190	4073	4232.75
5 (Worst Case)	15	20	3844	3662	3596	3479	3645.25
Altitude Weighted Averages			4540	4358.66	4301.66	4182.66	

	Averages Across All Test Cases [ft]	Averages Across All Mass Margins [ft]
	4655.5	4540
	4540	4358.66
	4459.75	4301.66
	4344.75	4182.66
	4232.75	-
	3645.25	-
Average of Averages [ft]	4313	4345.75
Overall System Average [ft]	4329.375	

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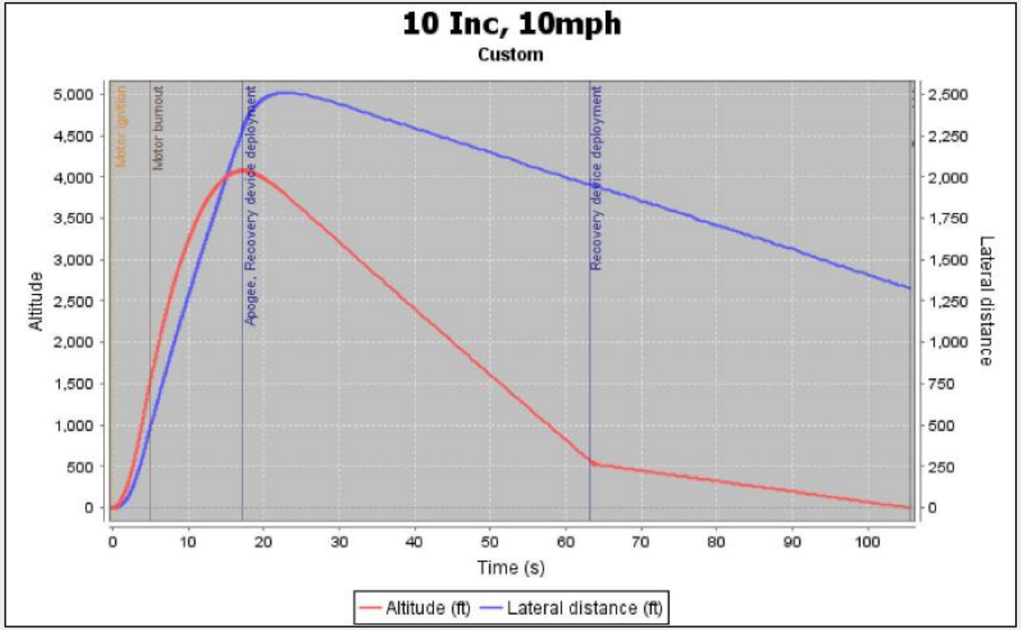
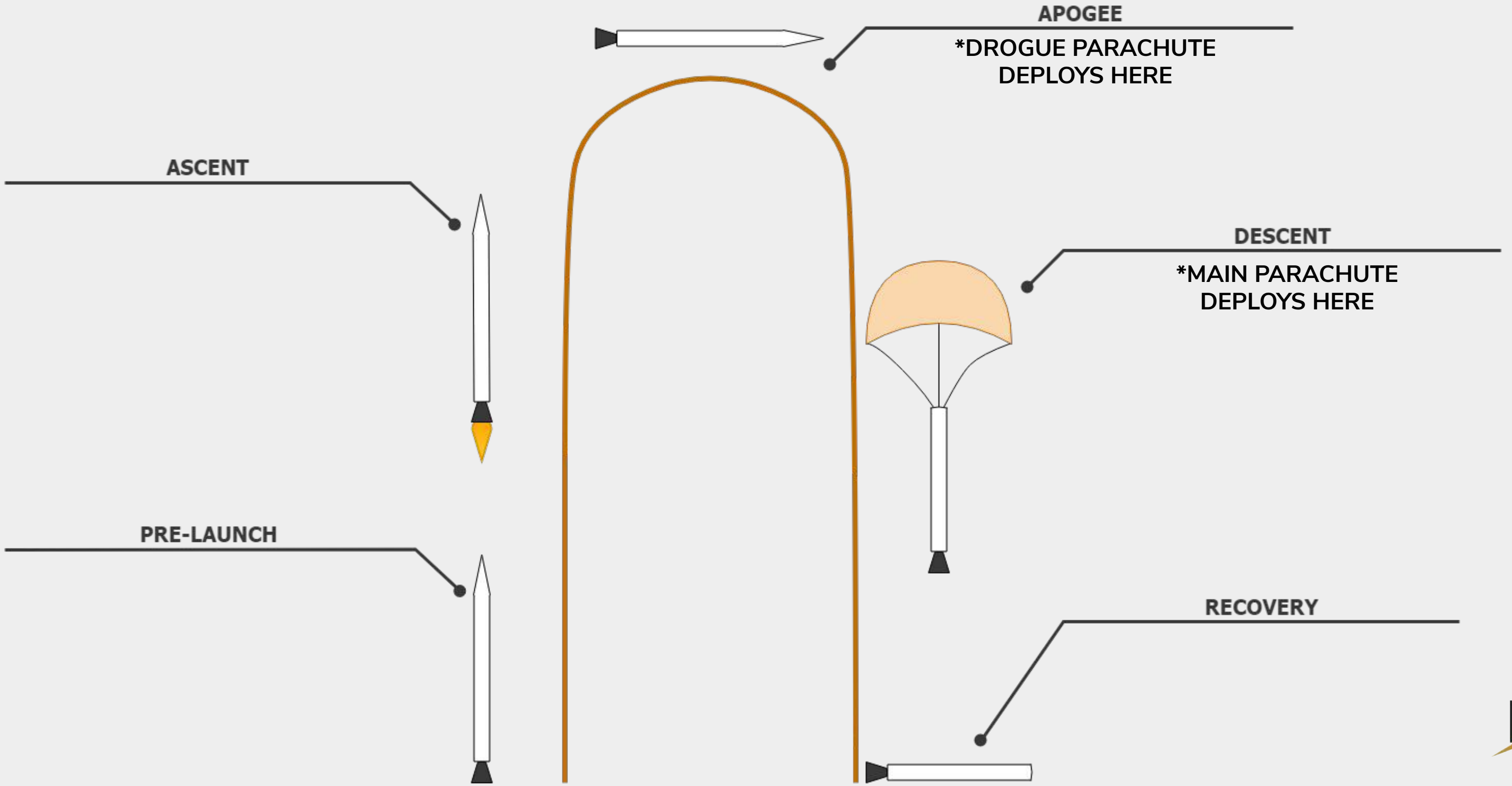
Drift Predictions / Calculations

Drift Distance (Simulated)	1335 ft
Descent Time (20 mph case)	88.8 sec
Drift Distance (Hand-Calc)	2605 ft
Drift Distance = Descent Time * 20 mph (29.33ft/s)	



Avionics & Recovery Team

Recovery Overview



Shock Cord

- Drogue parachute
  - ½” tubular nylon
  - 2’ long
- Main parachute
  - ½” tubular nylon
  - 40’ 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 Choices

Drogue Parachute	Cost	Pros	Cons
Rocketman Standard (24”)	$28.50	Light, low packing volume, cheap	Low drag coefficient, low carrying capacity
Rocketman Standard (36”)	$40.50	Light, low packing volume, high carrying capacity	Large
Fruity Chutes Classic Elliptical (24”)	$64.00	Light, low packing volume, high drag coefficient	Expensive, moderate carrying capacity
SkyAngle Cert-3 Drogue (24”)	$27.50	Cheap, was successfully used last year	Heavy, low carrying capacity, low drag coefficient

Also Considered: Rocketman Pro Experimental (24”), Rocketman Pro Experimental (36”), Giant Leap Rocketry TAC-1 (24”), Top Flight Recovery Crossfire (24”), and Dino Chutes Octagon (24”)

Main Parachute Choices

Main Parachute	Cost	Pros	Cons
Rocketman Standard (144”)	$155.00	Light, high carrying capacity, cheap	Very large, high packing volume, low drag coefficient
Fruity Chutes Iris Ultra Standard (84”)	$296.96	Small, light, low packing volume, high drag coefficient	Low carrying capacity, expensive
Fruity Chutes Iris Ultra Standard (96”)	$348.15	High carrying capacity, high drag coefficient	High packing volume, very expensive
SkyAngle Cert-3 XL (100”)	$189.00	High carrying capacity, high drag coefficient, was successful with it last year	Heavy
SkyAngle Cert-3 XXL (120”)	$239.00	Very high carrying capacity, high drag coefficient	Large, heavy, expensive

Also Considered: Rocketman Standard (120”), Giant Leap Rocketry TAC-1 (84”), and Top Flight Recovery Crossfire (120”)

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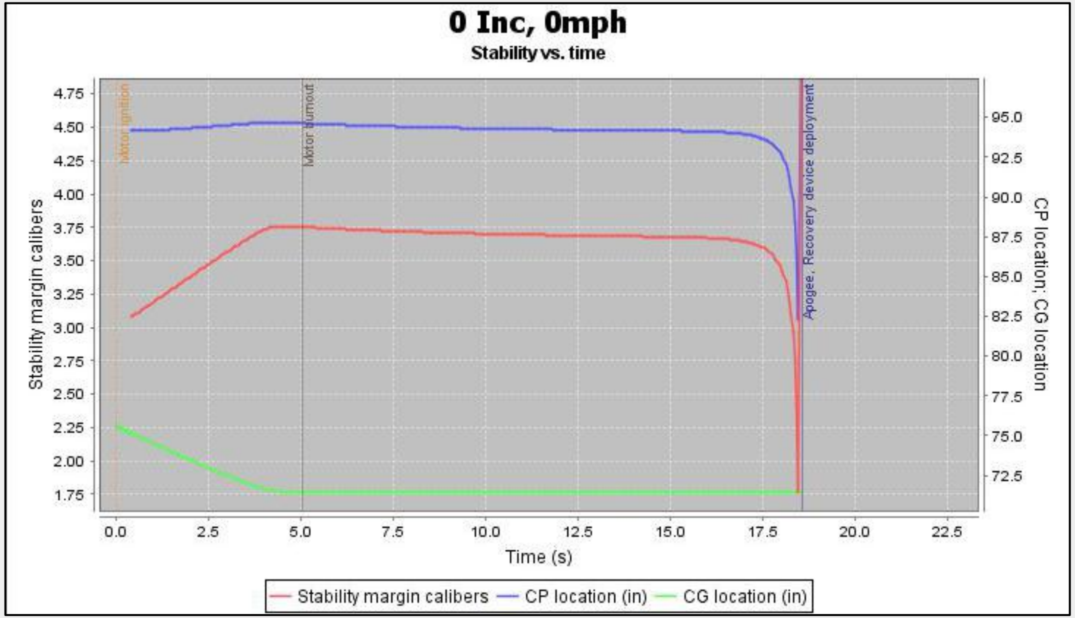
Drogue Parachute

- **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 slow our heavy launch vehicle down enough to maintain a low kinetic energy upon landing

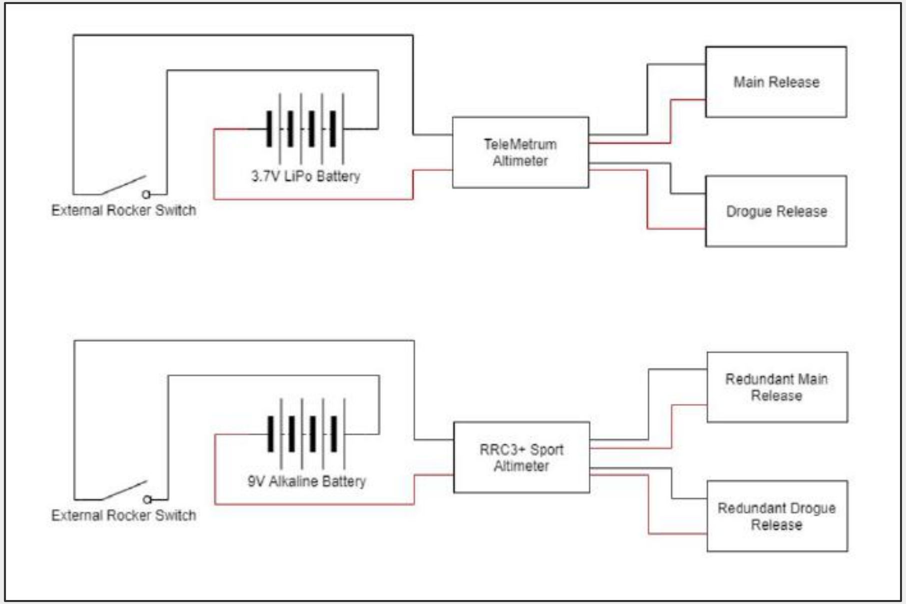
Stability and Landing Energy Predictions



Section	Landing Kinetic Energy [ft-lbf]
Total Landing Energy	101.2
Lower Airframe	31.8
Avionics Bay	15.1
Upper Airframe	54.3

Ejection Charges and Wiring Diagram

Avionics Wiring Diagram:



Ejection Charge Type: FFFFG black powder

- Primary Drogue: 3 grams
- Backup Drogue: 4 grams
- Primary Main: 4 grams
- Backup Main: 5 grams

Altimeter Choices

Decision Criteria:

Cost, voltage requirements, altitude, efficiency, size, operating system, and reliability

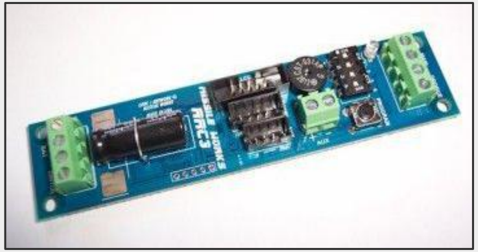
Altimeter	Cost	Pros	Cons	Corresponding Battery
Missile Works RRC2+	$45	Cheap, small, efficient	No GPS or telemetry capabilities	9V Alkaline
Missile Works RRC3+ Sport	$90	Cheap, stores a large amount of flight data, was successfully used last year	Large	9V Alkaline
Eggtimer TRS	$140	Stores a large amount of flight data	Low efficiency, large, heavy	7.4V LiPo
Altus Metrum Telemetrum	$300	Small, efficient, was successfully used last year	Expensive	3.7V LiPo

Primary Altimeter

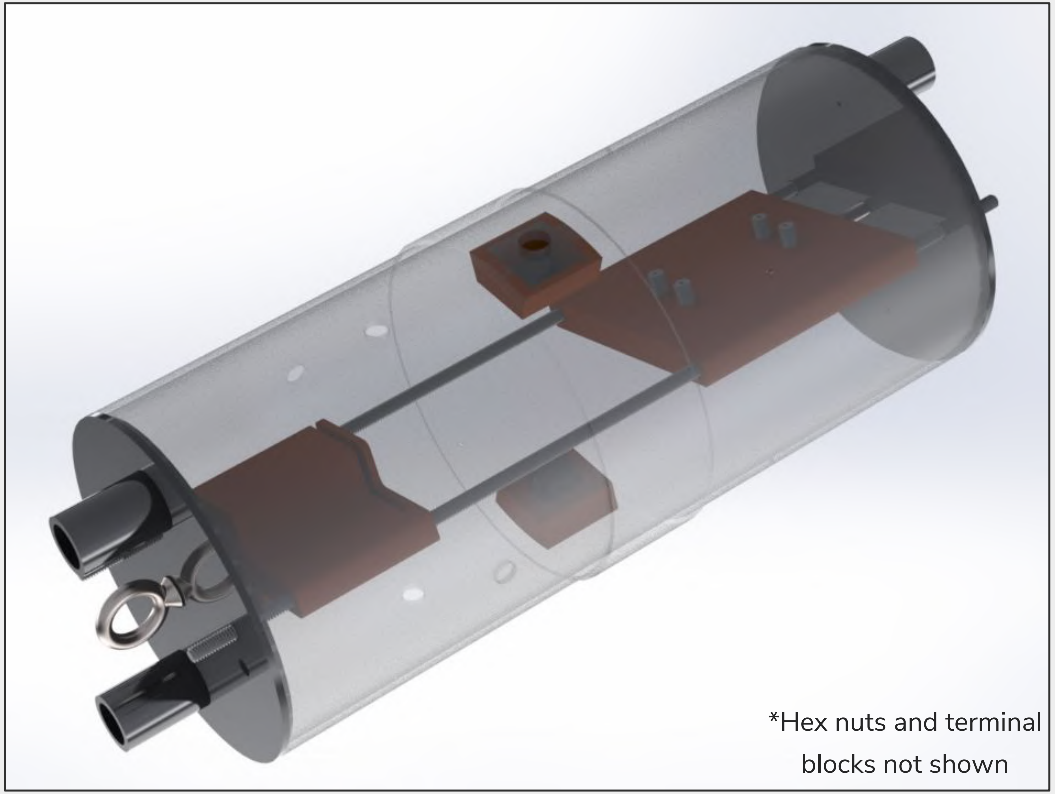
- **Make:** Altus Metrum
- **Model:** Telemetrum
- **Battery:** 3.7V LiPo
- Also used as rocket locator
- **Why it was chosen:** Has proven to be reliable in many past launches, is small and efficient

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



Preliminary Avionics Setup & CAD



*Hex nuts and terminal blocks not shown

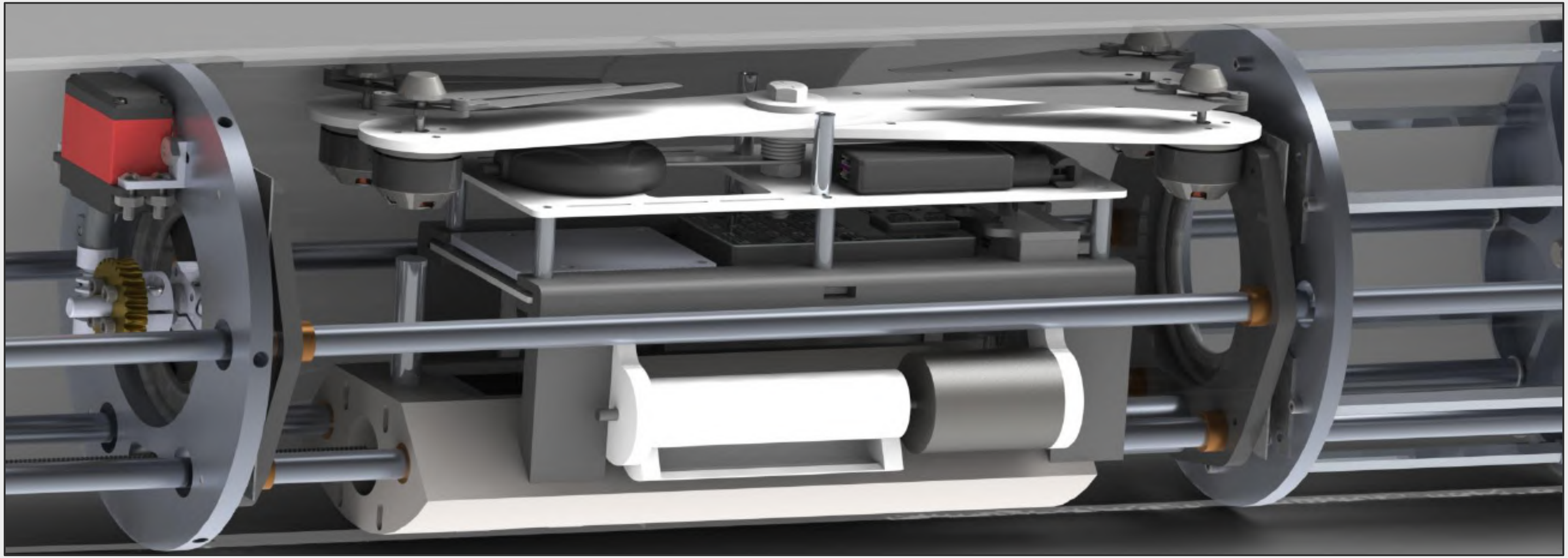
Overall Weight [lbm]	6.3
Communication Methods	Laptop, TeleBT, TeleDongle, Yagi Arrow 3 Element Antenna
Switch Type	Rocker
Drogue Deployment Altitude [ft AGL]	Apogee
Main Deployment Altitude [ft AGL]	800
Backup Ejection Time Delay [sec]	1

Payload Team

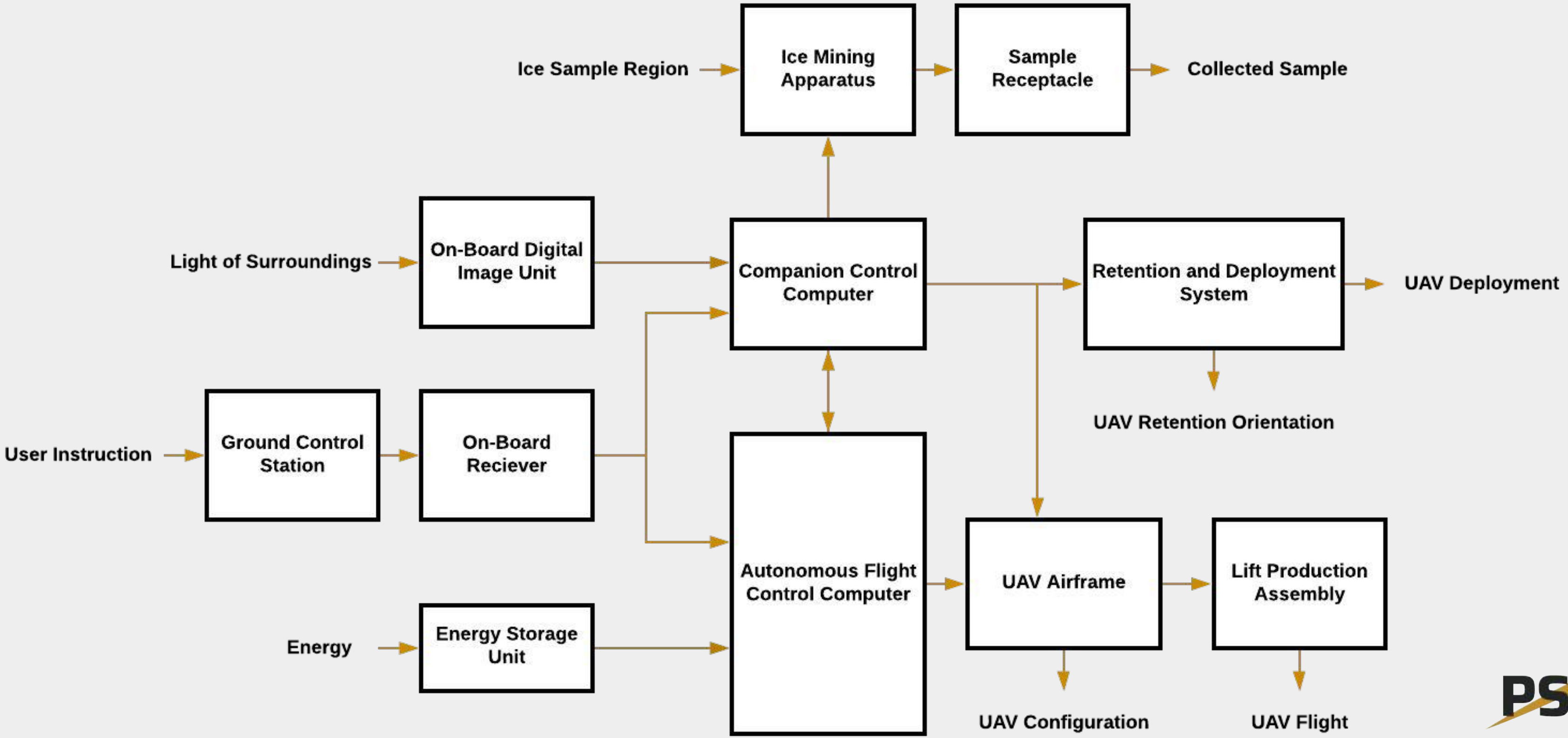
Payload System Overview

- “The Friendly Ghost” - Autonomous Unmanned Aerial System
  - Autonomous UAV with integrated lunar ice mining system accompanied by a ground control station
  - Sophisticated retention and deployment system for securing and orienting the UAV
- Functional Requirements
  - UAV must be able to navigate to an “ice mining” site and collect a 10mL sample
  - Bay must be able to retain and deploy the UAV after the flight

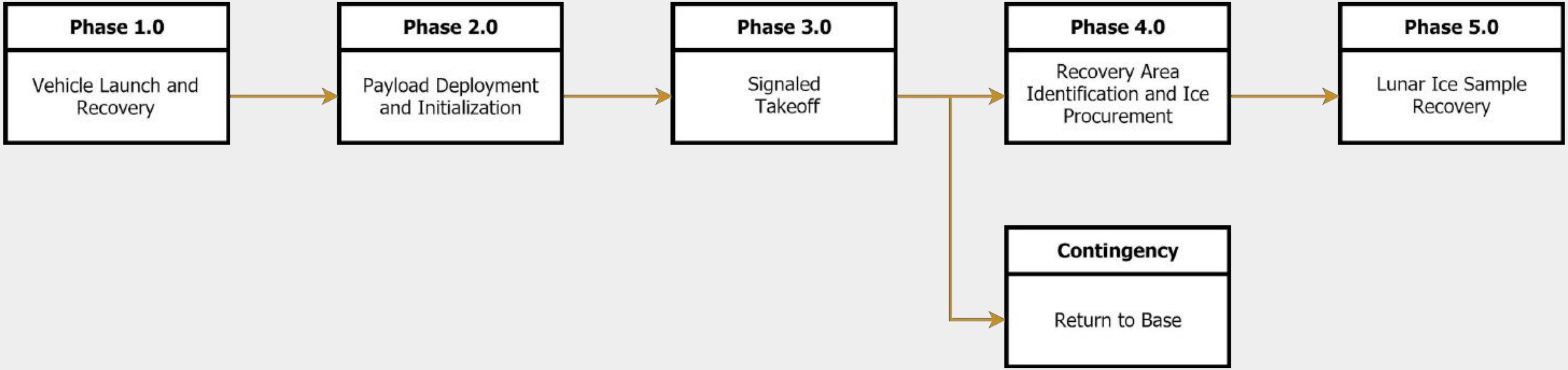
Payload System Overview



Payload System Overview

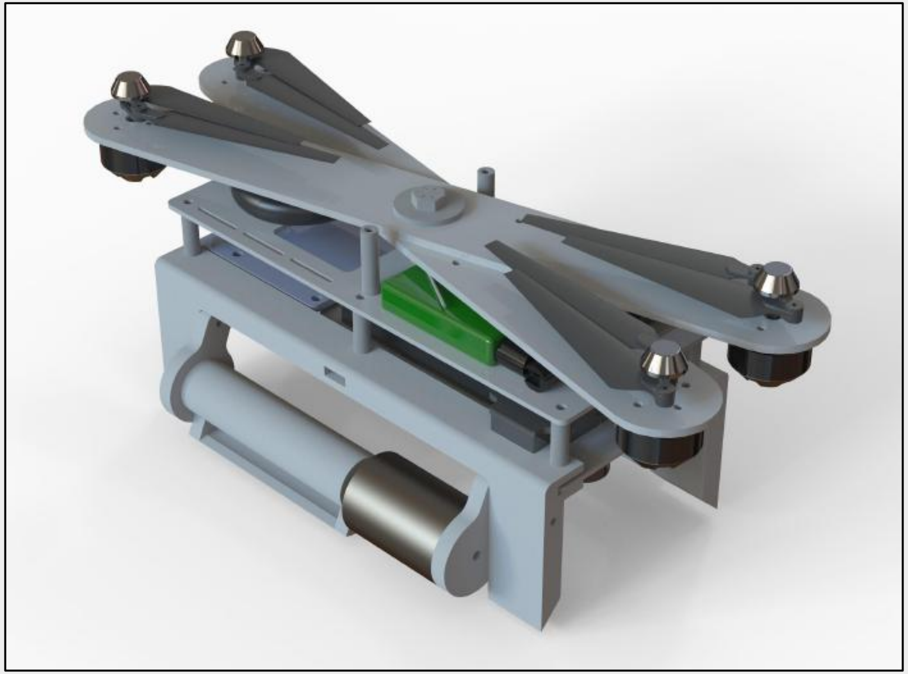


Mission Breakdown



UAV Airframe

- Quad-rotor design
- Opening mechanism for fitting in airframe
- Ice mining mechanism slung under for immediate sampling access upon landing
- Nylon-6 construction
- Estimated weight: 2.38 lbm



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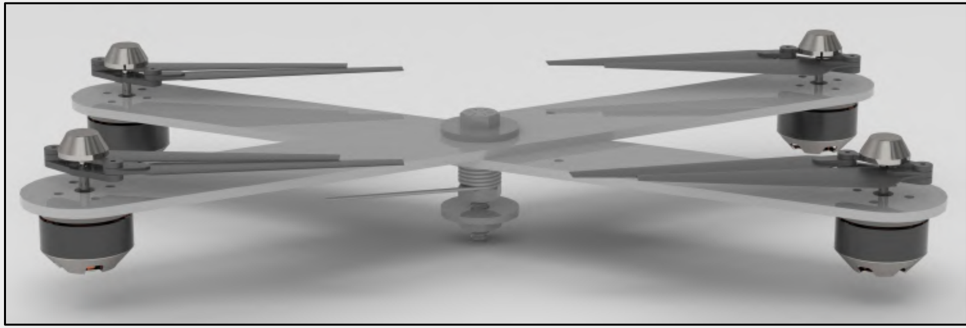
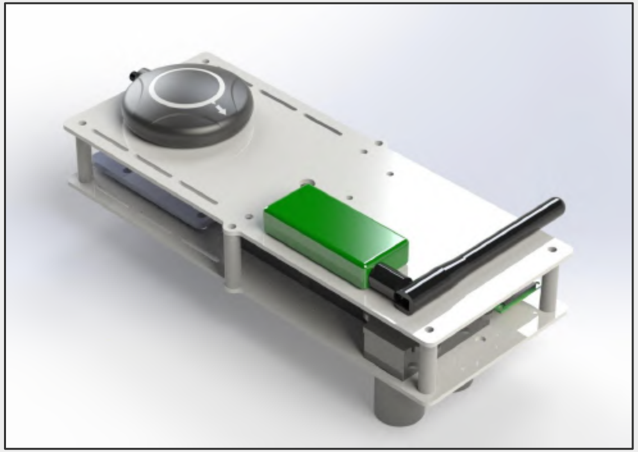
UAV Airframe

- X-Mechanism armatures
    - Passive, torsion spring-based design
    - <30° closed configuration to 90° flight configuration
- Propellers unfold as rotors spin up
- Plate-based design makes room for electronics while providing protection

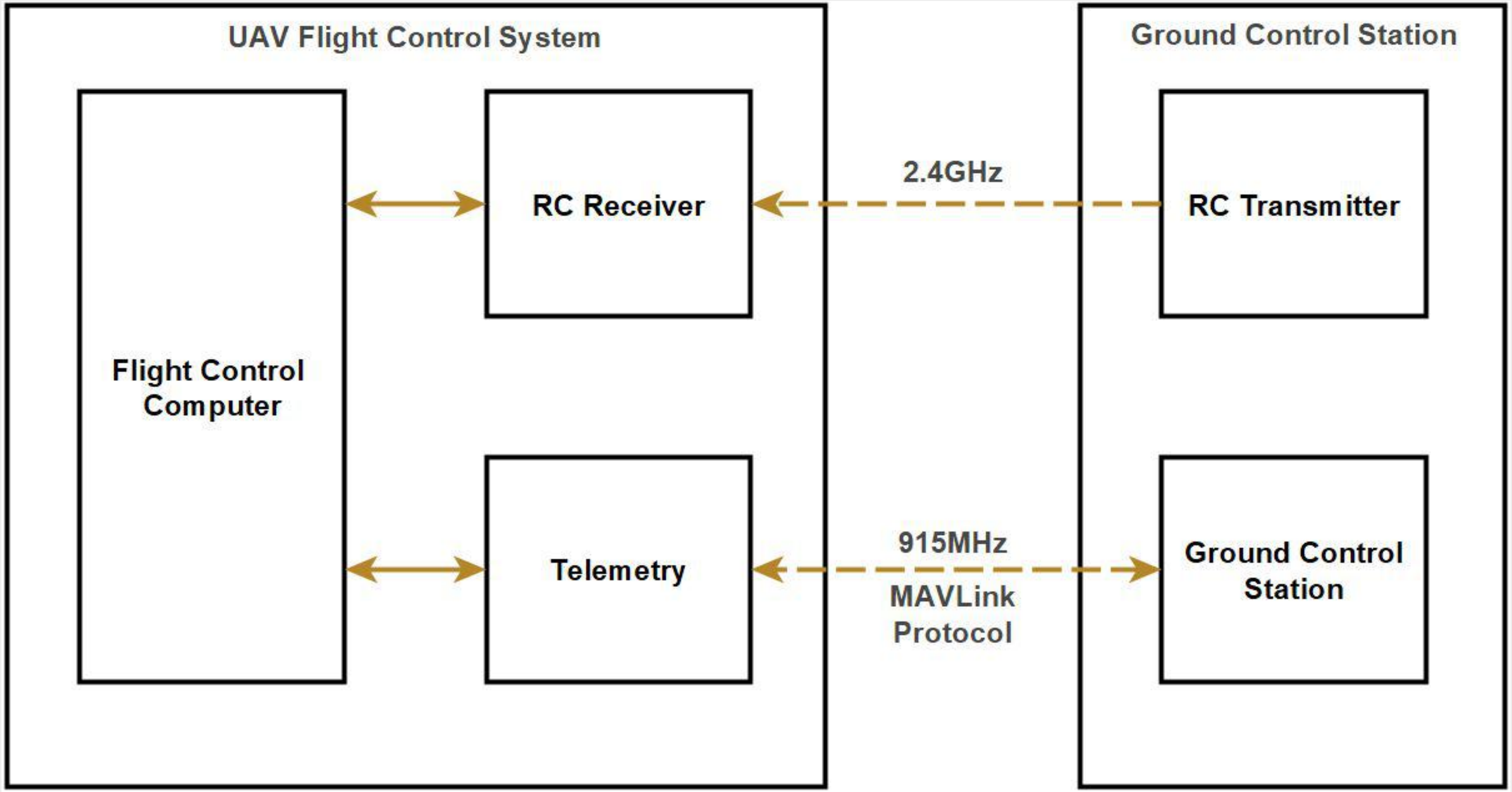




Electronics and Control

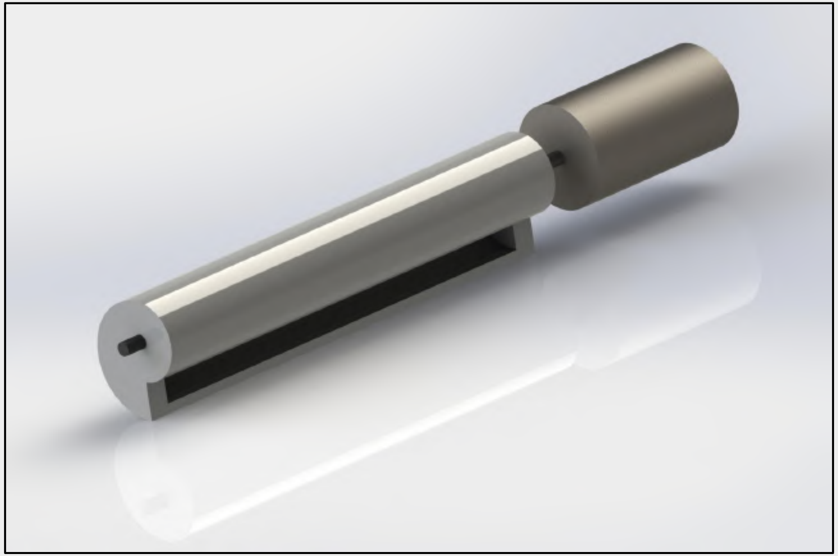
- Primary E&C Components:
  - Pixhawk 4 - Flight Computer
  - Raspberry Pi Zero - Mission Control computer
  - Power electronics - Brushless DC motors, motor drivers, etc.
  - Raspberry Pi Camera - Computer Vision System
  - 11.1V LiPo battery
- Ground Control Station (GCS)
  - Full mission control capability
  - Real-time telemetry data

Electronics and Control



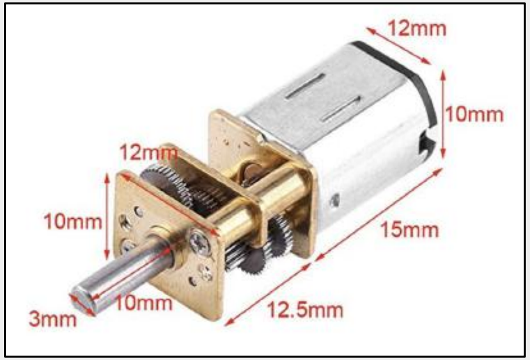
Ice Mining and Procurement System

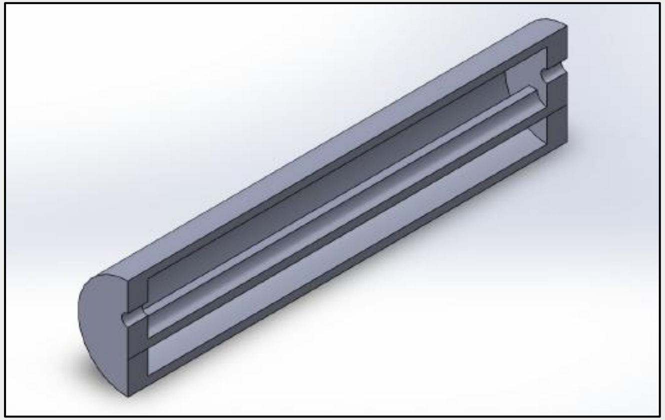
- Objective: Collect at least 10mL of lunar ice
- Design constraints:
    - Ice sample geometry
    - UAV geometry
    - Actuation
- Design alternatives:
    - Rotating scoop(s)
    - Auger



Ice Mining and Procurement System

- 2 x cylindrical scoops on either side of UAV
- Internal containment shelf for retaining ice samples
- Actuated by small 5V DC motors
- Grid-based search algorithm
- OpenCV for recovery area identification





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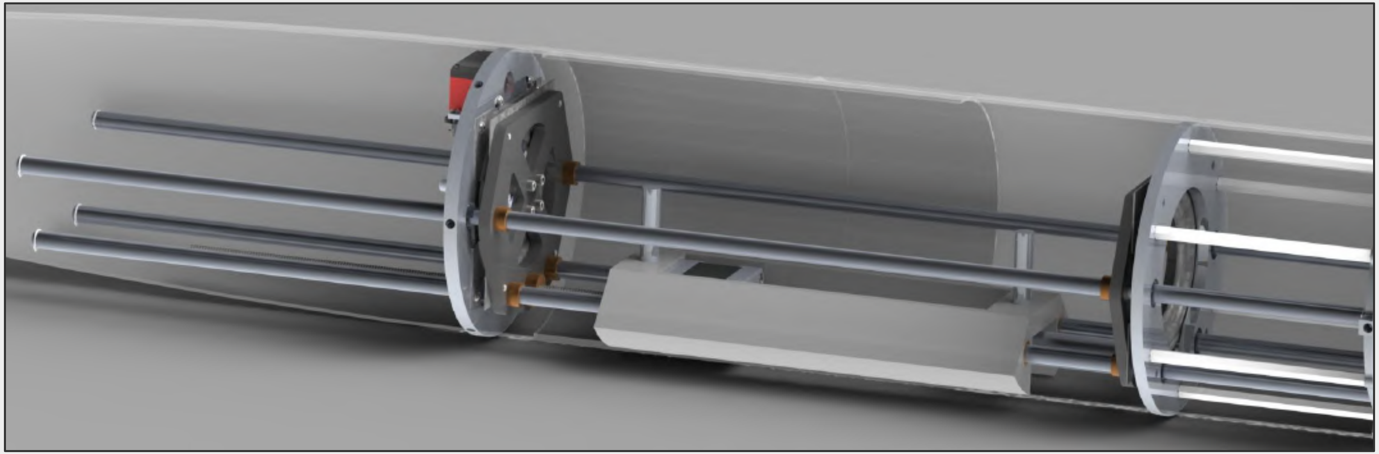
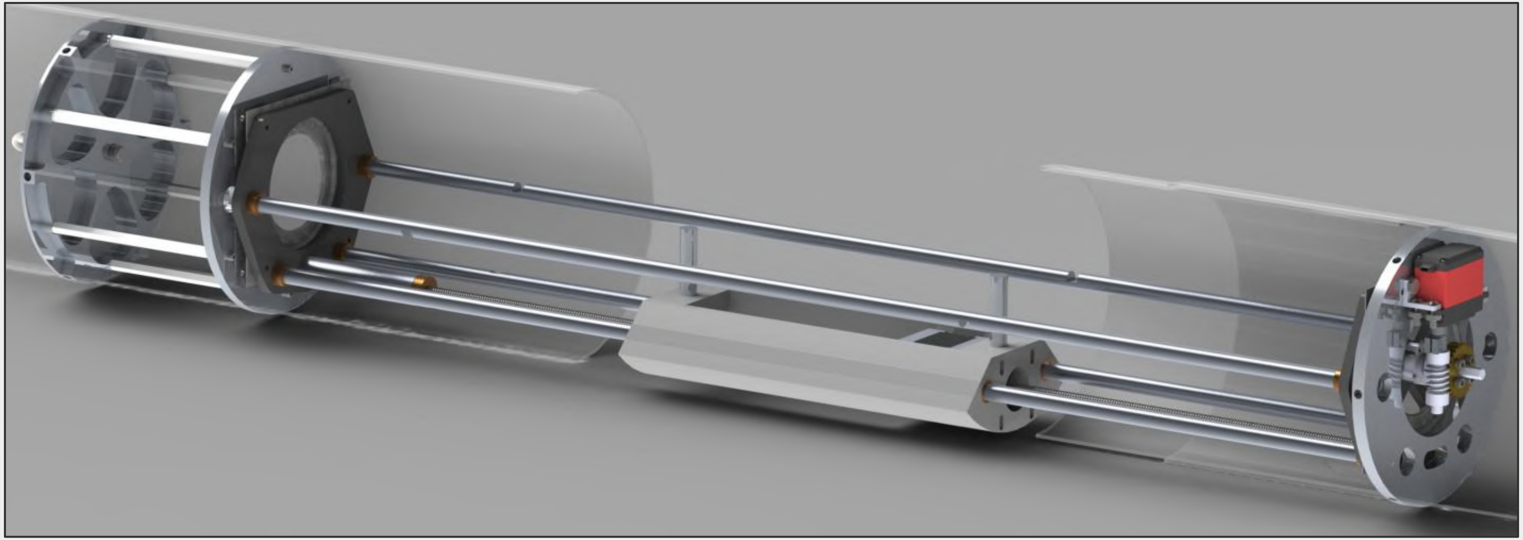
Retention and Deployment

- Robust system for controlling safe retention and deployment of UAV
  - UAS interface and retention
  - Axial motion restriction
  - Orientation control
  - Safe and remote deployment

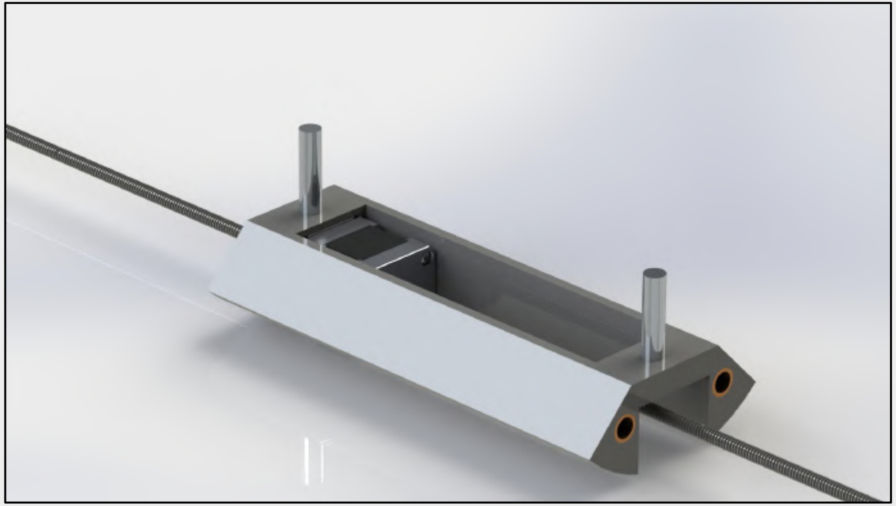


Retention and Deployment

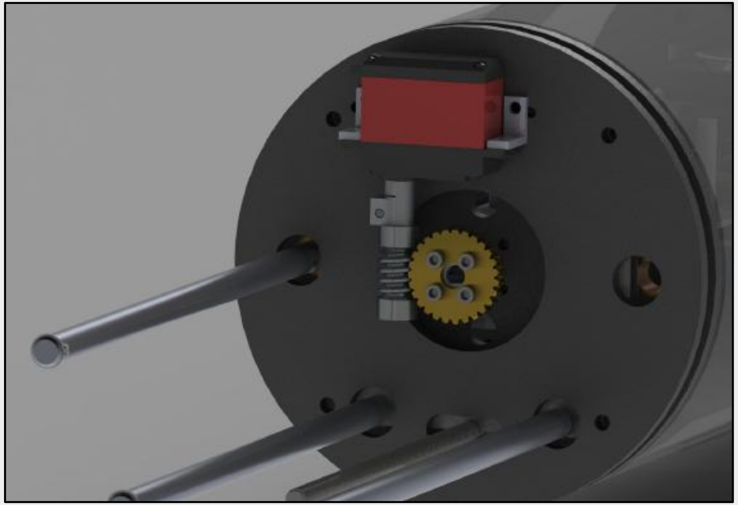


- Nose cone separation
- "Bi-Lead Screw" approach
- Provides clear space for UAV egress

Retention and Deployment



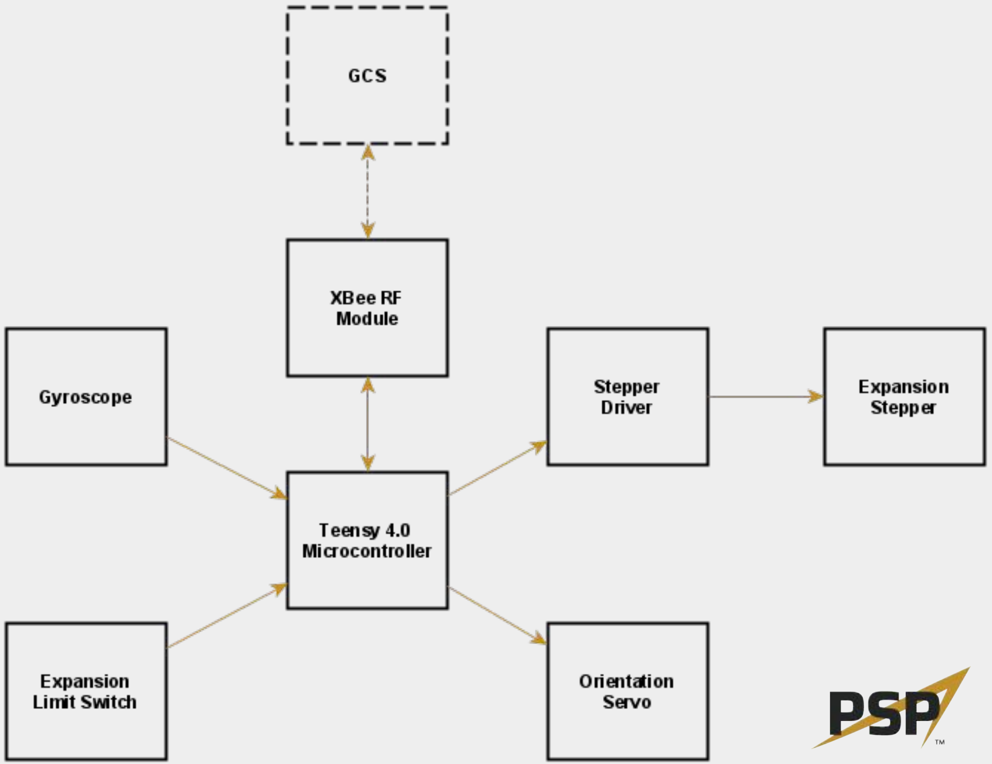
- Sled retains UAV throughout flight
- UAV constrained on all axes
- Sled houses expansion stepper motor



- Servo motor controls payload bay orientation via 6-DOF IMU
- Locking mechanism for structural integrity

Retention and Deployment

- Teensy 4.0 microcontroller
- XBee RF module for link to GCS
- Stepper motor driver
- 6-DOF IMU
- 12V 1800mAh Li-ion Battery



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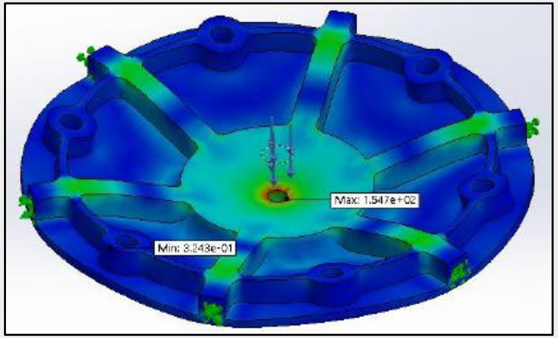
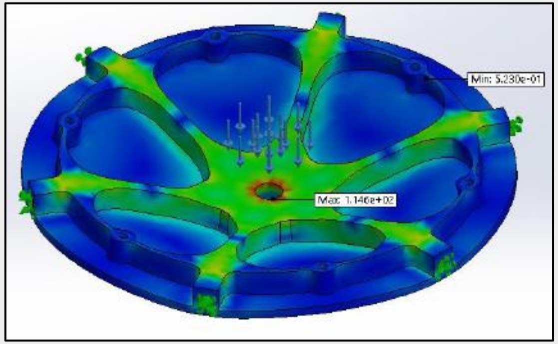
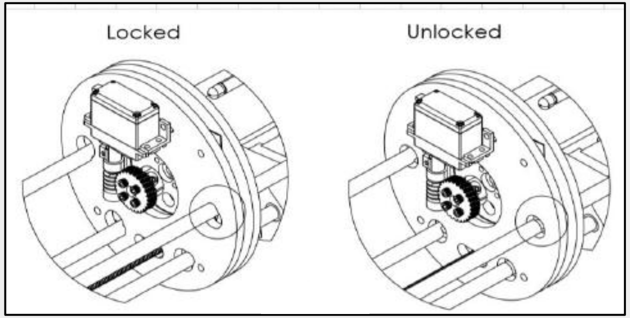
Retention and Deployment

- Integrity
  - Locked and unlocked position for flight
  - By locking the rods, movement of the nose cone is prevented
- FEA on Bulkplate
  - Bulkplate attaches main parachute to airframe
  - Manual topology optimized for weight and FOS > 2
  - 1000 lbm instantaneous load







FOS:

Safety Team

Safety Officer Role and Expectations

- The Safety Officer for the PSP-SL team participating in the 2019 competition will be **Noah Stover**
- Some of the Safety Officer's most important duties are as follows:
    - Enforcing all safety plans and procedures set by the team
    - Enforcing all laws and regulations set for the team by authorities and governing bodies
    - Ensuring that all team members are properly trained and supervised to be carrying out their current task
    - Ensure all team members have signed and agree to the team safety statement

Team Mentor - Victor Barlow

- Level 3 certified, TRA TAP, NAR L3CC
- 50+ Level 1 launches
- 100+ Level 2 launches
- 35+ Level 3 launches
- Team mentor since 2010 competition
- Founding member of Tripoli Indiana

Team Resources

Resource	Safety Rules Known	Required Personnel	Safety Precaution
Zucrow Propulsion Laboratory (ZL)	Yes	PSP- SL Project Manager and Safety Officer	Team members must be briefed on proper safety precautions for using the ASL's equipment by the safety officer before being allowed to use the building's resources. PPE in the form of earplugs and safety glasses is available on-site
Aerospace Sciences Laboratory (ASL)	Yes	PSP-SL Project Manager for access, Safety Officer	Limited access through Scott Meyer, climate controlled environment, and secured areas
Bechtel Innovation and Design Center (BIDC)	Yes	Teaching assistant supervisor or Purdue-employed machinist	TAs or employed machinists must always be present when using machines, team members must take quizzes and undergo training before using machines
Purdue BoilerMAKER Lab	Yes	Lab assistants, part designer	Lab assistants will handle the machinery and parts during production to avoid burns to the team members and will oversee the machines to ensure no problems arise

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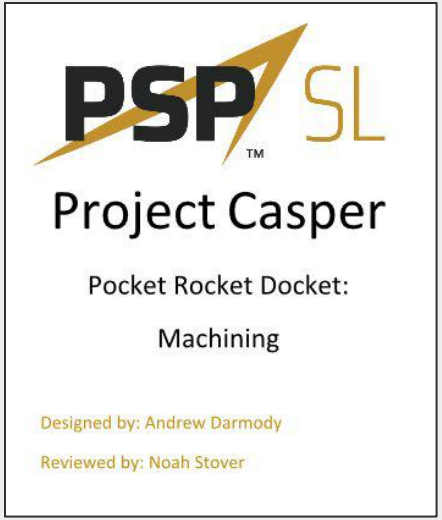
Project Risks - Walkthrough

Hazard	Likelihood (Cause)	Severity (Effect)	Risk	Mitigation	Verification	Post Mitigation Risk
Unintended Black Powder Ignition	3 (Accidental exposure to flame or sufficient electric charge)	5 (Possible severe hearing damage or other personal injury)	15, High	Label containers storing black powder, one may only handle the black powder if he/she possesses a low-explosives user permit.	Have check in/out form to confirm only those permitted to handle materials are the only ones handling the material.	5, Low
Premature Ejection	2 (Altimeter programming, poor venting)	5 (Zippering, loss of stability, possible destruction of rocket)	10, Medium	Check altimeter settings prior to flight and use appropriate vent holes. Test altimeter in similar conditions to those to be experienced at launch.	Include checking altimeter settings to pre launch checklist to verify that this task is complete. Altimeter testing before launch.	5, Low
Pollution From Vehicle	2 (Loss of components from vehicle)	3 (Slow material degradation, 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
Improper Funding	3 (Lack of revenue)	5 (Inability to purchase parts)	15, High	Create and execute a detailed funding plan properly, minimize excessive spending by having multiple members check the necessity of purchases.	Have each team verify purchases with team lead to ensure the team is still within their given budget.	5, Low

Additional Safety Work

- Pocket Safety Documentation
  - To be kept on hand during construction, testing, and launches
  - Contains information on first aid, PPE, emergency contacts, MSDS, launch checklists
- Checklists prepared
  - Provide consistency for launch day operations
  - Minimize likelihood of incidents
  - Provide contingency for catastrophic events or failures


PSP SL

Project Casper

Pocket Rocket Docket:

Machining

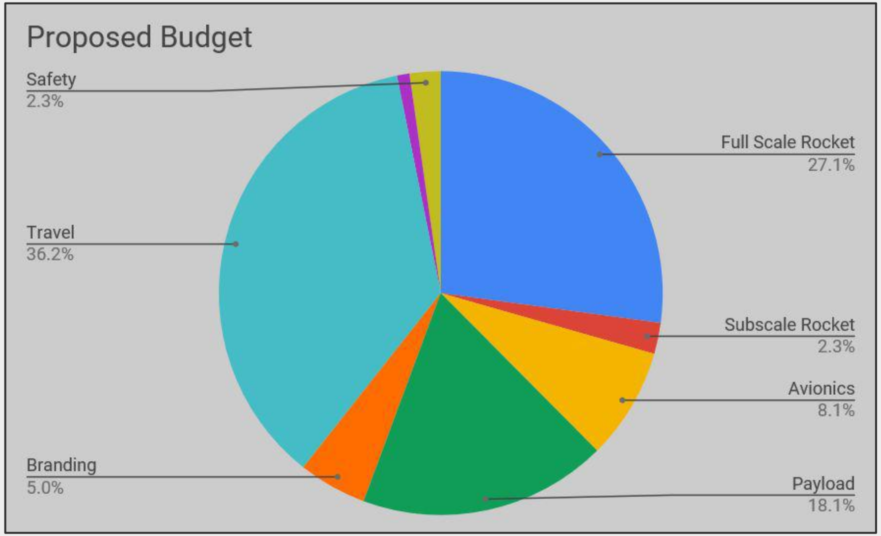
Designed by: Andrew Darmody

Reviewed by: Noah Stover

Business Team

Subteam Cost Estimates

Subteam	Total Subteam Cost
Construction	$3250
Avionics	$900
Payload	$2000
Safety	$250
Social/Outreach	$650
Business	$4000
Total	$11,050



Team Funding Sources and Budget

- Currently at 75.8% of our budget
    - 27.1% from department heads
    - 34.1% from crowdfunding
    - 14.5% from grant applications
- Three primary sources
    - Engineering department heads
    - Crowdfunding campaign
    - Grant applications

Social & Outreach Team

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Current Educational Outreach Events

Purdue Space Day Ambassadors
Foam Rockets & Crater Impact Testing

- Taught homeschool children of various ages about energy and rocket propulsion through the construction of foam rockets
- The students also learned about what creates craters and what variables affect their shape and size
- 46 children, who were as young as four and as old as thirteen, attended alongside approximately 30 adults

PSP™

Current Educational Outreach Events

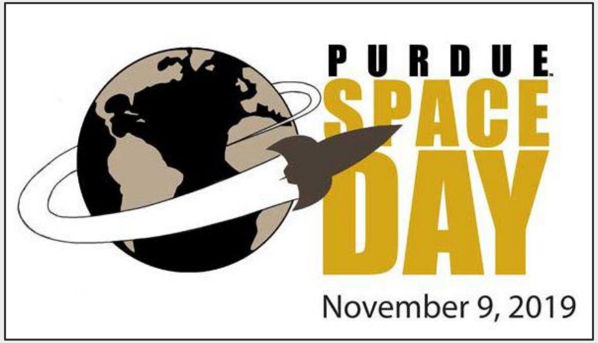
College Mentors for Kids

Foam Rockets

- Once again taught homeschool children about energy and rocket propulsion through the construction of foam rockets
- 27 children, who were in third and fourth grade, attended alongside approximately 27 college students who were their mentors

Future Educational Outreach Events

- **Purdue Space Day:**
    - Annual event taking place on Saturday, November 9th, which will put team members in charge of running activities for multiple groups of 30-50 students between 3rd and 8th grade
    - Team members will help guide the children through space-related projects including model rockets, astronaut arms, solar sails, and more
- More College Mentors for Kids and Purdue Space Day Ambassadors events
- Guidance session for the Boy Scouts Of America’s space exploration merit badge



Questions & Answers

purdueseds.space/student-launch/

@psp.studentlaunch