Rocket Team at UCSC

NASA Student Launch
2019-2020 Proposal
September 18th, 2019

1 General Information

1.1 School Information and Project Title

School:	University of California, Santa Cruz
Organization:	Rocket Team at UCSC
Location:	University of California, Santa Cruz 1156 High St. Santa Cruz, CA 95064
Project Title:	Titan-bound
Date:	September 18th, 2019

1.2 Team Mentors and Advisors

Team Mentor: David Raimondi
Email: d.raimondi@sbcglobal.net
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NAR Number: #82676 NAR Section #534
President of Livermore Unit NAR (LUNAR)

Faculty Mentor: Ian Garrick-Bethell
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Earth and Planetary Sciences
Assistant Professor

1.3 Team Leadership

Judah Luberto

Administrative Lead & Co-Captain

Judah is entering his second year at UCSC, pursuing a BS in Physics. For Judah, the Rocket Team has both further cultured his passion for hands-on work and engineering and been ample excuse to not do schoolwork.

Duncan Bark

Technical Lead & Co-Captain

Duncan is a third year student at UCSC currently pursuing a BS in Computer Science. This is Duncan's third year on the team and his second being a team lead. Duncan, since joining the Rocket Team, has grown a strong interest in rockets and engineering and hopes to one day work at an aerospace company.

Brandon Erickson

Safety Officer

Brandon, a third year student at UCSC, is pursuing a BS in Computer Engineering with a Systems Programming concentration. Brandon has been involved with the team since last year, and this is his first year as Safety Officer. Brandon takes great interest in software development, and since joining the team he has become fascinated with applying the concepts of software engineering to rocketry.

Andrew Zarzar

Finance Lead

Andrew is a fourth year Biomolecular Engineering student at UCSC. This is Andrew's third year on the team and first year being a team lead. Joining the team has inspired him to pursue personal rocketry projects and he is currently building his NAR L1 Certification rocket. After graduation, Andrew hopes to attend medical school and specialize in aerospace medicine.

1.4 Team Membership and Organization

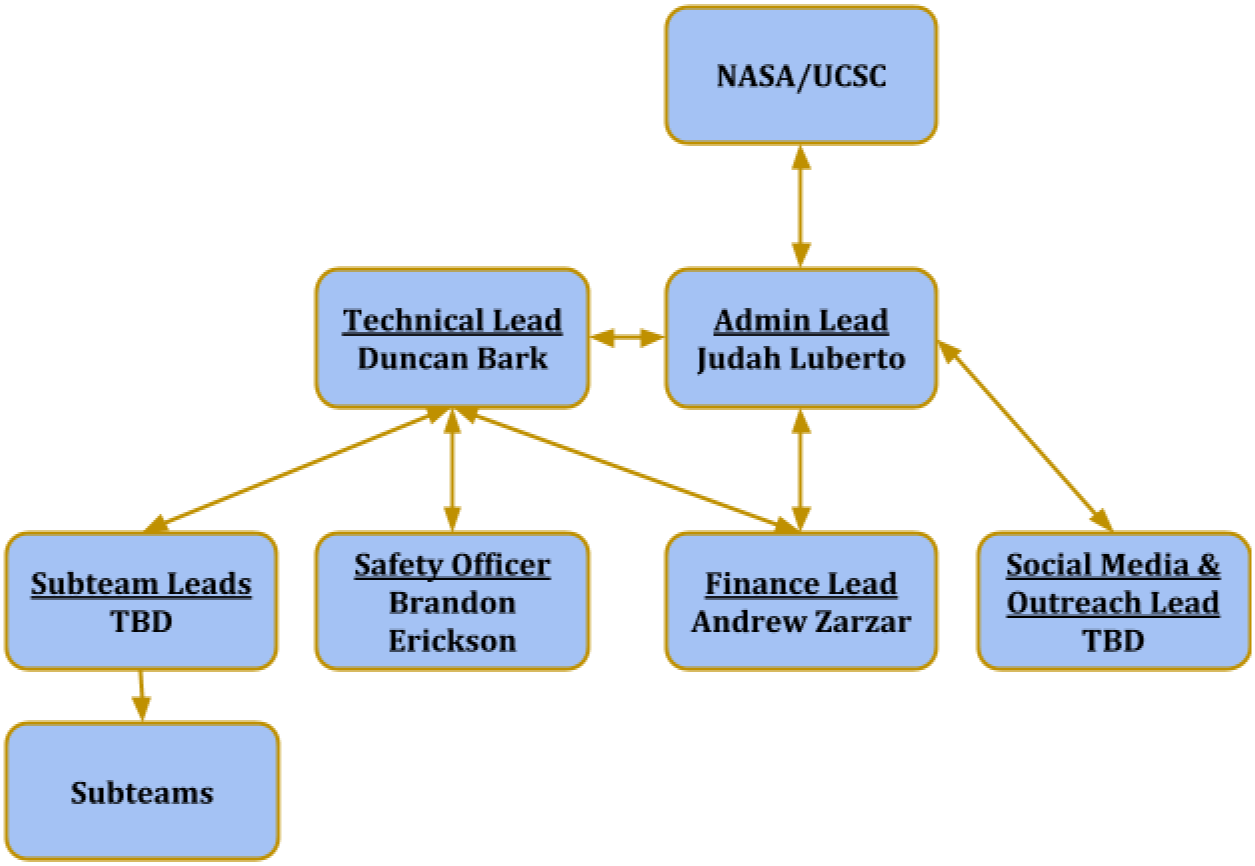


Figure 1.4.1 Team Organization Chart

The Rocket Team at UCSC will consist of approximately 30 students, from a variety of backgrounds and majors. The group responsible for constructing the final vehicle is divided into various sub-teams, each with their own sub-team lead, as well as team-wide executive leadership known as the Leads. This is done in order to partition and complete required tasks efficiently. An election will be held early in the school year to determine these sub-team leads based on students applicable skills to those respective fields. A look at how the team is composed can be seen in Figure 1.4.1. The sub-teams and the leadership positions and their responsibilities are listed below.

Payload Team -- Designs, constructs, and tests the chosen payload challenge. Completes documentation related to the payload.

Airframe Team -- Responsible for the design and modelling (CAD and flight tests) and construction of the vehicle capable of carrying the subsystems. Completes documentation related to the vehicle as a whole.

Adaptive Aerobraking System (ADAS) Team -- Designs, constructs, and tests an adaptive aerobraking system to guide the vehicle to chosen apogee. Completes documentation related to the subsystem.

Recovery Team -- Designs, constructs, and tests the vehicles recovery system. This includes parachute allocation, recovery electronics (altimeters and GPS), and the procedures for recovery of the vehicle. Completes documentation related to recovery.

Admin(istrative) Lead -- The Administrative Lead is responsible for team organization, logistics, and outside communication. This includes, but is not limited to, organizing and leading team meetings, organize logistics for meetings and launches, make announcements to the team as needed, and facilitate communication between the team and various outside organizations.

Tech(nical)/Project Lead -- The Technical/Project Lead is responsible for leading the technical aspects of the project and the team. This includes, but is not limited to, assisting the subteams with designing, testing, building and launching the project, providing technical guidance, having knowledge of machinery, tools, and general engineering concepts, and knowledge of CAD and other software.

Safety Officer -- The Safety Officer is responsible for the team's safety and adherence to rules and laws. This includes, but is not limited to, creating or maintaining a safety manual, verifying all members have the necessary trainings, verifying all activities are conducted in a safe manner, verifying the team follows all rules and regulations set forth by NASA, the FAA, UCSC and any other official bodies.

Finance Lead -- The Finance Lead is responsible for the financial wellbeing of the team. This includes, but is not limited to, creating a budget, creating a funding plan, organize the requisition of funds, monitor and facilitate the purchase of parts and other items and create and maintain a project timeline.

Social Media & Outreach Lead -- The Social Media & Outreach Lead is responsible for creating and maintaining the team's social media presence, as well as organizing and conducting outreach events in the local community. Responsibilities include, but are not limited to, creating social media posts on the team's social media pages, updating the team on local events, organizing and conducting outreach events in the local community, and facilitate on-campus events to recruit new members.

2 Facilities and Equipment

2.1 Workspaces

The Rocket Team at UCSC is involved with the on-campus Sustainability Lab organization that provides lab space and equipment for student led groups focused on sustainability. The Rocket Team, being a member of the Sustainability Lab, has been granted a main workspace in Thimann Labs Room 376, a 3D-Printing and computer lab in Thimann Labs Room 373, a workspace in Thimann Labs Room 372 containing heavy machinery including a CNC Mill, Drill Press, lathe and bandsaw, and storage space in Thimann Labs Room 149a.

Entrance to the lab requires one of the three key-holding leads to be present to open the doors. With this key limitation, there will always be a lead present during use of the space. This helps to ensure that all operations run smoothly, members are all following the correct and safe procedures of the lab.

To be permitted within the lab space the Sustainability Lab requires all members to complete a number of necessary safety trainings. The team's Safety Officer will help new members and guide them through the trainings before they are allowed to work in the lab. Refer to section 3.5 for information related to the required trainings and use of the lab space.

2.1.1 Thimann Labs Room 376

Thimann Labs Room 376 is the main work and storage space for the Rocket Team at UCSC. This room contains multiple computers for use by team members, subteam specific storage as well as general supplies and merchandise. The room also houses two fume hoods, where all necessary procedures will occur. The room is shared between the Rocket Team at UCSC and Slugbotics, allowing for collaboration and sharing of materials.

Figure 2.1.1 Thimann Labs Room 376

2.1.2 Thimann Labs Room 373

Thimann Labs Room 373 houses all the 3D and 2D printers available to the team to use. These printers are all shared by groups affiliated the S-Lab. There are various 3D printers that each offer different benefits and characteristics such as material selection and print quality allowing the team to choose the right material for the situation. This room is only accessible by team leads, but team members may use this space if needed.

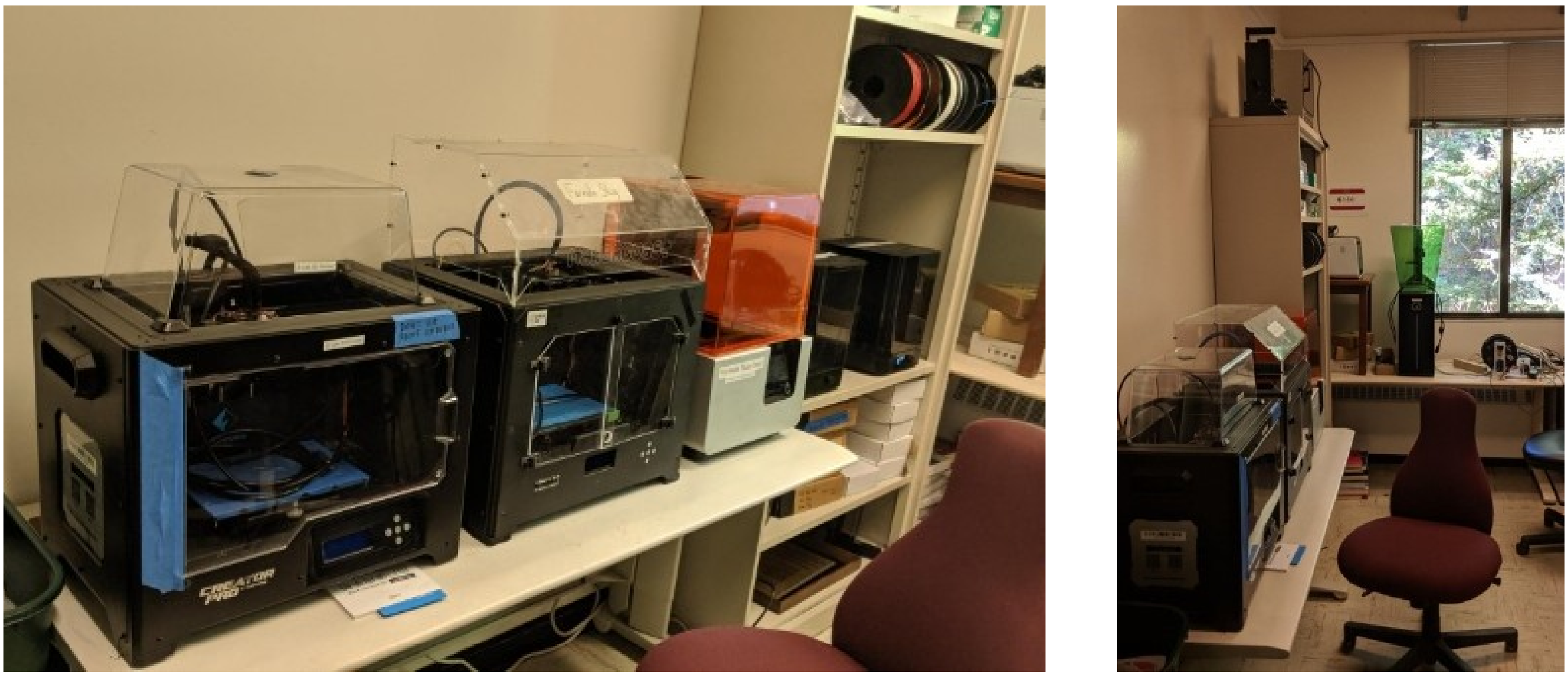


Figure 2.1.2 Thimann Labs Room 373

2.1.3 Thimann Labs Room 372

Thimann Labs Room 372 houses all the heavy machinery provided by the S-Lab. Machines include band-saws, drill presses, a lathe, a CNC Router, a CNC Mill, sanders and various hand tools. This room can only be accessed by team leads, but all members with the proper trainings completed will be allowed to use the machinery in the room.

Figure 2.1.3 Thimann Labs Room 372

2.1.4 Thimann Labs Room 149a

Thimann Labs Room 149a is the primary large storage space for groups affiliated with the S-Lab. Currently this room houses the Rocket Team's previous rockets and bulk materials. This room is only accessible using keys given to the S-Lab.

2.1.5 Engineering 2 Room 581

Engineering 2 Room 581 is a computer lab available for use of S-Lab groups and other senior design groups on campus. Each of the 12 computers has SolidWorks, the Adobe Suite, and various other programs installed. The door is unlocked using an electronic lock connected to a student's ID card. As a result, anyone can request access to the room, however anyone can use the room if granted access.

2.2 Launch Sites

The Rocket Team at UCSC will primarily be utilizing the launch site provided by our mentor's NAR chapter, LUNAR. This launch site is located just east of Stockton, CA which takes approximately three hours to travel to and allows for flights up 15,000 ft with motors no larger than class 'M'. The launch site also provides numerous launch rails including 1010 and 1515 rails of various lengths, allowing the team to use a competition permitted rail. The team will also be able to purchase any necessary AeroTech motors, parachutes, or other supplies at the launch site should it be necessary.

Should the LUNAR launch site be closed, the team will utilize the Friend of Amateur Rocketry (FAR) launch site outside Mojave, CA. During the 2019 SLI Competition, the team used this site during multiple launches due to poor weather at LUNAR's launch site. This launch site offers multiple facilities for testing, launching, or anything related to rocketry. The team will be using a launch rail provided by our mentor for any launch completed at the FAR site.

2.3 Materials

The majority of the materials necessary for the project will be sourced from online retailers including McMaster-Carr for hardware, Apogee Rocketry for general rocketry supplies, and Amazon for various other electronics and general supplies. The team can also utilize local hardware stores include the Home Depot and ACE Hardware for rapid acquisition of hardware and supplies.

Motors and other specialized rocketry parts will be purchased in-person either by our mentor David Raimondi, or from a vendor at the LUNAR launch site. The final competition motor will be purchased and shipped from Bay Area Rocketry. This is done in order to avoid unqualified team members to purchase or handle energetics, to prevent storage of energetics on campus, and to ensure all rules and regulations are followed.

2.4 Software

The Rocket Team at UCSC will be utilizing various programs and resources in the design, construction and testing of the launch vehicle and its subsystems. Vehicle design will be done using the SolidWorks and Fusion 360 CAD programs, and GrabCAD will be used to better facilitate collaborative design and work. Modelling of the rocket, its flight, and other characteristics will be done using OpenRocket as well as a team made flight modeling script made in Python. Both will be used in conjunction to verify their results.

To facilitate communication and collaborative work, the team will be using Slack to discuss, make announcements and share work. The team will also use a team Google Drive to store all documents, team information and necessary resources. Along with Google Drive, the team will utilize GitHub to easily share and collaboratively work on code for the vehicles subsystems. Lastly, the team will use Trello to organize tasks for each subteam to better plan out designing and building the system.

2.5 Website and Remote Conferencing

The Rocket Team at UCSC will be using ucscrocketry.org to host documentation, photos, team contact information, event calendar, subteam descriptions, and team members. The website is designed, built and maintained by team members with modifications done throughout the year as necessary. The website is made to represent the team in a clean, informative and inspiring manner, and to show the public what the team does, who is apart of the team, and what the team stands for.

Remote conferencing, necessary for document presentations and Q&A sessions, will be completed on campus in a reserved room in the McHenry library. The library offers many small and private study rooms available for students to reserve. The reserving of the room will be done as soon as available and a time for the presentation is chosen. From these rooms, the team will have knowledgeable members present the documents, explain necessary details, and answer any questions. The team will be utilizing a team member's laptop with webcam, and cell phone in order to conduct these conferences.

3 Safety

3.1 Safety Officer's Plan

Brandon Erickson will fulfill the Safety Officer position for the Rocket Team at UCSC for the 2019-2020 SLI competition. He will ensure that all personnel constructing and launching rockets will be safe from injury, that laws regarding rocketry are followed at all times, and that unwanted damage to the rocket will be prevented where possible. Safety is of the utmost importance to the team and will not be treated lightly. If the Safety Officer becomes unable to complete their duties due to personal or unforeseen reasons, an immediate replacement must be made to fill the vacancy.

The specific responsibilities and requirements of the Safety Officer are as follows:

- Be fully competent in the known laws and regulations of NAR/TRA, the FAA, the state of California, and UC Santa Cruz regarding the building and launching of the vehicle and payload.
- Ensure the team's compliance with local, state, and federal law.
- Provide the team with safety information, hazard and risk assessment and analysis, failure mode analysis, PPE requirements, materials safety data sheets, and emergency procedures.
- Oversee the design, construction, and testing of the rockets and subsystems.
- Create and enforce checklists for each launch of the vehicle that meet safety and operation standards as per launch needs.
- Attend the following activities such that checklist requirements are met, safety protocol is followed, and guests are educated on the procedures involved:

  -- Building sessions
  -- Launch tests
  -- Ground testing of the vehicle and payload
  -- Recovery activities, including design and installation of recovery components

-- Educational/Outreach events
-- Logistical meetings with the rest of the Board

- Provide a Safety Manual detailing the necessary steps to gain access to lab workspaces, handle tools and materials, understand the laws and regulations in rocketry, and identify risks.
- Provide a Safety Acknowledgement Form that members must read and sign to certify completion of all deliverables in the Safety Manual and have met lab access requirements.
- Maintain a list of all students and their contact information who have signed the Safety Acknowledgement Form.
- Cooperate with the team's NAR mentor, David Raimondi, to safely handle and prepare electric matches, charges, ignitors, and the motors used on the launch vehicles.

3.2 Risk Assessment

3.2.1 Risk Assessment Matrix

To quantify the magnitude of certain hazards that may occur for the team during the project, a risk assessment matrix must be created. With this matrix, the Safety Officer may identify, prioritize, and mitigate potential hazards. Each hazard is studied and analyzed by its impact on human health, environmental damage, and importance to the launch vehicle and payload.

In the risk assessment matrix, the risk of each hazard is measured by two factors: severity and probability. Hazards are assigned a severity value between 1 and 4, with 1 being ranked most severe and 4 least severe. This value gauges how devastating the effects of an incident would emerge on the team's goals. Table 3-1 describes the severity levels and details. Hazards are also assigned a probability value designated by capital letters A-E, where A represents events that will most likely or most frequently occur. Table 3-2 describes the probability levels and details. The severity and probability values combined form a Risk Assessment Code (RAC) which can rank the dangers jeopardizing the team's participation in the competition, from direct physical harm to monetary losses. Tables 3-3 and 3-4 break down the RAC and each risk level's color legend and the associated penalties.

Description	Value	Properties
Catastrophic	1	May cause life-threatening injury or death, irreversible damage to the environment, and/or complete loss of onboard systems. Violates at least one major law or regulation, and fails the entirety of the mission.

Critical	2	May result in serious injury, major but reversible environmental damage, and/or major damage to onboard systems. Violates at least one law or regulation, and most of the mission is severely impacted.
Marginal	3	May result in minor injuries, minor damage to the environment, and minor damage to onboard systems. Does not violate a law or regulation, and does not critically impact the mission.
Negligible	4	May result in little to no injuries, minimal damage to the environment, and at most partial damage to a non-critical onboard system. Does not violate any law or regulation, and has little to no noticeable impact on the mission.

Table 3.2.1 Hazard Severity Levels and Criteria.

Description	**Code**	**Properties**
Frequent	A	Expected to occur with greater than 90 percent probability; happens almost immediately or very soon.
Common	B	Expected to occur with 50 to 90 percent probability; usually happens in the near future, if not more than once over a set period of time
Occasional	C	Expected to occur with 10 to 50 percent probability; possible to happen once over an extended period of time.
Unlikely	D	Expected to occur with 1 to 10 percent probability; has a remote chance to occur at some point over an extended period of time
Improbable	E	Expected to occur with less than 1 percent probability; almost certainly will never happen and will not be expected at any time

Table 3.2.2 Hazard Probability Levels and Criteria.

Probability	**Severity**			
	Catastrophic (1)	**Critical (2)**	**Marginal (3)**	**Negligible (4)**
Frequent (A)	1A	2A	3A	4A
Common (B)	1B	2B	3B	4B
Occasional (C)	1C	2C	3C	4C
Unlikely (D)	1D	2D	3D	4D
Improbable (E)	1E	2E	3E	4E

Table 3.2.3 Risk Assessment Codes (RAC).

Risk Level	**Penalties/Response**
Extreme	Unacceptable. Will cause complete project failure. Immediate mitigation required.
Moderate	Undesirable. Will cause major loss in competition points and project status. Mitigation required soon.
Low	Acceptable. Will cause minor loss in points and project completion. Mitigation needed on case-by-case basis.

Table 3.2.4 Risk Level Color Codes.

3.2.2 Hazard Analysis

Some team-identified hazards, including potential causes, effects, and mitigation tactics, are outlined below using the RAC designation outlined in Section 3.2.1. Hazards posed by launches and tests are analyzed in Table 3-5, and the risks involved with building the rocket are investigated in Table 3-6 These hazards do not encompass all possible events, and more issues may be identified and addressed in future documentation as time progresses with the project.

Hazard	**Cause**	**Effect**	**RAC**	**Mitigation**
Motor	1. Catastrophe at	Injury or death of	1D	Motor will be

detonation	Take-Off (CATO) 2. Improper installation 3. Damaged motor canister	personnel, loss of vehicle and on-board systems		purchased from reputable vendors, strict oversight will occur at the launch pad, and NAR or other qualified personnel may help with installation, as well as there being strict zoning limits at takeoff.
Recovery system	1. E-match and/or black powder charges fail to deploy 2. Parachutes not ejected from detonation due to being stuck in vehicle 3. Parachutes become entangled while vehicle descends	Injury or death of personnel, loss of vehicle and on-board systems	1C	Trained personnel will ensure that cords and risers are not tangled during installation, e-matches and electronics will be tested for continuity, and sizing of parachutes will come from numerous tests before launch
Pyrotechnic charges	1. Stray voltage 2. Installation of e-match while battery on 3. Altimeter powered on ground	Severe burns, electric shock, limb damage, death, loss of recovery system hardware	1C	Installation of pyrotechnics restricted to Safety Officer and launch personnel; batteries and altimeters will be powered off when charges placed
Unstable rocket trajectory	1. Unexpected winds 2. ADAS deploys too early in flight 3. Damaged or improperly prepared motor housing	Personnel and bystanders injured or killed by high velocity impact from rocket, loss of vehicle and on-board systems, rocket may not reach intended	1D	1. Range safety officer has final say of when to launch, and team may cancel if winds are stronger than expected on launch pad 2. Rigorous tests will be performed such that ADAS will

		apogee		remain idle while in the burn phase and its deployment will not harm flight path if opening early 3. All couplers and motor retainers will be inspected and tested thoroughly before installation
Extended exposure to RF signals	Use of radio antennas for RF communications on rover deployment and GPS tracking	High frequency electromagnetic waves may cause cancer or other disease	2D	Any use of antennas or testing of telemetry systems will be done in short periods of time to avoid over exposure
Ground testing	1. Falling objects from vehicle or its systems 2. Drone/rover colliding with personnel during operation	Minor cuts and bruises	3D	Personnel will be held accountable for injuries and accidents that could be avoided by being reprimanded; team will be told to watch out for others' health and safety

Table 3.2.5 Launch and Test Conditions Hazard Analysis

Hazard	Cause	Effect	RAC	Mitigation
Electric Shock	Exposed wiring, improper connecting of batteries	Severe burns, electrocution, damage to equipment	2D	All personnel who must work with high voltage equipment must be trained on the lab's materials and design, and will ground themselves when appropriate
Power and hand tools (sander, hammer, drill,	Improper training or handling	Cuts, bruises, damage to equipment,	2C	Team members are required to watch and learn how to

dremel, etc.)		damage to vehicle components		operate tools before being used on the vehicle, and verify their expertise with the Safety Officer
Shop tools and machines (automatic saws, grinders, CNC, drill press, etc.)	Improper training, improper use of PPE	Severe cuts, limb damage, death, damage to equipment and components worked on	1D	More specialized machinery will require operation by certified personnel who must demonstrate their ability to the Safety Officer, and no operation of such devices will happen if the Safety Officer is directly unavailable
Soldering iron	Improper training, improper use of PPE, distracted from task	Severe burns, damage to equipment and work environment, inhalation of toxic solder/circuit fumes	2B	Soldering tutorials will be presented to untrained personnel, and they will be required to verify their understanding with demonstration to the Safety Officer
Liquid or solid chemical reactions (epoxy, glass hardener, cutting fluid, motors, etc.)	Improper training or handling, improper use of PPE	Burns, skin damage or irritation, inhalation leading to respiratory problems like congestion or lung damage	2B	All volatile compounds will be stored in secure locations in the lab, and only certified personnel may handle the compounds in a controlled environment with proper attire
Carbon fiber/ fiberglass	Involuntary inhalation while sanding or fabricating vehicle	Congestion, lung damage, cuts	2C	Team members will be required to wear breathing masks and other PPE to avoid inhalation of toxic

				materials
Rechargeable batteries (LiPo, Li-Ion, etc.)	Improper training or handling	Electric shock, severe burns, damage to components	2B	No sharp or hot object will be allowed within close proximity of batteries, and they will be handled according to product specifications
Non-affiliate personnel working near team members and components	The on-campus lab space is shared by other engineering teams performing their own potentially hazardous tasks, and may not inform or warn our team about their actions.	Team members may encounter non-team students operating machinery unsafely, or otherwise might be hurt by non-personnel actions beyond Safety Officer control.	1C	All team members will be required to cooperate with non-team students and plan ahead for building work, as well as reporting hazardous interactions with the Safety Officer or Project Lead immediately

Table 3.2.6 Lab and Workshop Hazard Analysis

3.2.3 Hazardous Materials

The hazardous materials that may be used in the construction of rockets and their payloads are listed in Table 3.2.7, which is also included in the team's Safety Manual as a reference. All of the following items pose potential threats to team safety if handled improperly. Each item is given a description, its intended purpose within the team, the hazards it may pose, mitigation methods, and advised PPE.

Material	**Description**	**Use**	**Hazard**	**Mitigation**	**PPE**
Batteries	Up to 18V, LiPo, Li-ion, NiMH, etc.	Powers on-board electronics	Electric shock, burns	Check for faulty equipment	N/A
Black Powder	Pyrotechnic charge	Separates rocket body,	Highly flammable,	Stored in secure and	N/A

		ejects parachutes	explosive	low-temps, restricted to certified personnel	
Epoxy	Polymer resin	Structural adhesive	Corrosive, toxic, irritant	Use in well-ventilated area	Nitrile gloves
Fiberglass Resin	Polyester resin	Structural adhesive	Corrosive, flammable, toxic, irritant	Use in well-ventilated area	Nitrile gloves
Liquid Hardener	Polyester resin	Resin casting and curing	Corrosive, flammable, toxic, irritant	Use in well-ventilated area	Nitrile gloves
Solder	Low-melting alloy, usually made of tin, lead, etc.	Electrical connections, join fusible metals	Severe burns, irritant	Use at a soldering station, well-ventilated area	Safety glasses, breathing mask
Superglue and Hot Glue	Thermo-plastic, Cyano-acrylate	Basic adhesives	Severe burns, irritant	Use in well-ventilated area	Nitrile gloves

Table 3.2.7 Hazardous Material Analysis

3.3 NAR/TRA Personnel Duties

3.3.1 NAR Code Compliance

The NAR High Powered Rocket Safety Code will be adhered to throughout the project in regards to rocket development and launches. Each requirement laid out in the code has been complied with by the team as seen in Table 3-7.

NAR Code	Team Compliance
1. **Certification**. I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.	David Raimondi, the team mentor, or other certified members will be the only persons allowed to purchase and handle motors.
2. **Materials**. I will use only lightweight materials such as paper, wood, rubber,	The rocket and its subsystems will only use the materials allowed, with the only

plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.	addition to the list potentially being carbon fiber, but it is lightweight and composite.
3. **Motors**. I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.	All motors will be purchased from commercially available vendors, with David Raimondi doing the purchase and handling for the majority of the time. Other personnel will maintain Safety Manual standards in regards to the motors should they be nearby.
4. **Ignition System**. I will launch my rockets with an electrical launch system and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the “off” position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.	Only on the launchpad at NAR/TRA certified events will the electronic ignition system be installed onto the vehicles. Onboard recovery altimeter systems will be inhibited from activation while the vehicle is on the launch pad. The Range Safety Officer will also communicate any concerns and requirements to safety issues at these events.
5. **Misfires**. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher’s safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.	The Range Safety Officer and the team’s Safety Officer will be responsible for communicating any issues before, during, and after a misfire. In the case where one occurs, the defined procedure will be followed.
6. **Launch Safety**. I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and	All pre-launch procedures will be followed and carried out by the officials at the NAR/TRA events or by the team if necessary. Further requirements set for by the Range Safety Officer or team mentor will also be adhered to.

those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.	
7. **Launcher**. I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.	Sufficient testing of the launch vehicle will occur before any launch event. This will ensure the supplied rails at the NAR/TRA launchpad are capable of handling the team's design.
8. **Size**. My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.	The team will not build a vehicle that surpasses allowed weight, nor will it select motors that exceed the specified threshold.
9. **Flight Safety**. I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if	These guidelines, as well as those determined by the Range Safety Officer and team mentor, will be carried out at the launch events. FAA waivers and other advisory notices will also be checked for by the team mentor.

wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.	
10. **Launch Site**. I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).	All launches will occur at events and locations approved by NAR/TRA and the team mentor.
11. **Launcher Location**. My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.	The team will ensure the location being used at any launch site will fulfill this requirement, as well as any advisement from the Range Safety Officer.
12. **Recovery System**. I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.	A recovery subsystem will be designed and tested by the Recovery subteam that meets these guidelines. In addition, a recovery checklist will be followed throughout the event to ensure the compliance in preparing the recovery methods is met.
13. **Recovery Safety**. I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it	All team members and persons at the event will adhere to this rule. The Range Safety Officer can also declare unsafe conditions for retrieval as necessary, and their guidelines will also be followed. Professional third-parties may be contacted

approaches the ground.	in order to recover the item(s).

Table 3.3.1 NAR High Power Rocket Safety Code and Rocket Team at UCSC Compliance to the Code

3.3.2 Motor and Pyrotechnical Safety

David Raimondi, the team's mentor, will be responsible for the purchase, storage, transportation (by car), and general handling of any and all motors to be used on launch vehicles. Any team members who have achieved a Level 2 High Power Rocketry Certification will also be able to assist in motor responsibility if possible. Mr. Raimondi will also be responsible for ignition charges, electric matches, and any other pyrotechnical items necessary to launch and recover the vehicle.

3.4 Law and Regulation Compliance

3.4.1 National Laws

The Safety Officer and all team members who have signed the Safety Acknowledgement Form will be able to understand and abide by the relevant federal laws regarding high-powered rockets, specifically the ones listed here:

- Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C; Amateur Rockets. The team will adhere to information requirements prior to any launch and consult with Range Safety Officers (RSOs) to ensure that launch conditions fall within the operating limitations imposed by this law.
- Code of Federal Regulation 27 Part 55: Commerce in Explosives; and Fire Prevention.
- NFPA 1127 "Code for High Power Rocket Motors". The team will comply with NAR safety codes as outlined in Section 3.3 and Table 3.3.1.

3.4.2 Launch Sites

All launches will occur at NAR/TRA approved sites, likely around California (Stockton or San Diego) and the surrounding areas (Reno, NV or Phoenix, AZ). Mr. Raimondi will handle correspondence with the coordinators at these locations to arrange for the team to launch from these sites, as well as being present to assist in matters relating to the pyrotechnics and logistics at these events for the team. He will also be capable of informing the FAA (via Notice to All Airmen), United States Air Force, and local airports to notify them of any potential launches in the relative air spaces. Launches will only occur if weather conditions and the FAA permit, with the ultimate choice being left to the Range Safety Officer (RSO). The RSO dictates whether the vehicle may launch or not, and thus communication with the RSO is of critical importance. Pre-launch checklists will be used to ensure the plans and requirements of the rocket and subsystems are met before being placed on the launchpad, and another set of checklists will ensure proper handling while on the launchpad. Any changes to the checklists or plans in flying will be immediately brought to the attention of the RSO.

3.4.3 Written Safety Compliance Agreement

The team is aware of and understands the regulations put forth by NASA in their guidelines and rules. As per requirements, the Rocket Team at UCSC acknowledges the following NASA safety regulations and will incorporate them as part of the Safety Manual and Safety Acknowledgement Form:

1. Range safety inspections will be conducted on each rocket before it is flown. Each team shall comply with the determination of the safety inspection or may be removed from the program.
2. The Range Safety Officer has the final say on all rocket safety issues. Therefore, the Range Safety Officer has the right to deny the launch of any rocket for safety reasons.
3. The team mentor is ultimately responsible for the safe flight and recovery of the team's rocket. Therefore, a team will not fly a rocket until the mentor has reviewed the design, examined the build and is satisfied the rocket meets established amateur rocketry design and safety guidelines.
4. Any team that does not comply with the safety requirements will not be allowed to launch their rocket.

3.5 Team Safety Measures

3.5.1 Required Training

All students and team members who wish to help directly build rockets must successfully complete lab safety courses as designated by lab safety training courses. These activities are online and free, with the only stipulation being the student set up a necessary account with the UC Learning Center (http://learningcenter.ucsc.edu/). Once the student has an account, they will take five mandatory courses to gain access to the on-campus labs and workspaces:

- Laboratory Safety for Research Personnel
- Hazardous Waste Management
- Electrical Safety for Research Personnel
- Hand and Power Tool Safety
- PPE: Eye and Face Protection

In addition to these deliverables, students who intend to charge batteries or work with open flames, flammable liquids or other flammable chemicals must complete fire extinguisher training available at http://fireextinguishertraining.com and answer all questions correctly on a quiz provided by the Sustainability Lab.

After completing the above trainings, students will be required to attend a walkthrough of the labs with the Safety Officer, completing a Lab Specific Safety Checklist which informs personnel of the locations of fire alarm pull stations and fire extinguishers, safety showers and eye washes, evacuation routes, facilities systems, fume hoods, biosafety cabinets, and storage of hazardous materials, including rechargeable batteries, spray paint, and epoxy, within the Sustainability Lab.

After registration with the Sustainability Lab is complete, students must also complete the Rocket Team Lab Hazard Assessment Tool (LHAT) and associated quiz on the UC Safety website and verify completion with the Safety Officer.

The Safety Officer will also personally help students on equipment they are not familiar with until they feel comfortable with the devices involved. Briefings will be carried out periodically, usually before launches and at the beginning of the academic year to ensure all team members are aware of their duties when around the rocket and its materials.

3.5.2 Lab Safety Equipment

Any Personal Protective Equipment (PPE) necessary for fabrication will be available in the lab space of Thimann 376 and the storage space of Thimann 149A. These include safety glasses/goggles, lab coats, and gloves. In addition to PPE, the lab space is outfitted with labeling of potentially hazardous materials using standard lab symbols and labeling as found in the Globally Harmonized System of Classification and Labeling of Chemicals (GHS) Hazard Labels, which students should be able to clearly identify and understand based on their training. Team members will be required to wear appropriate attire going into the lab for work, specifically closed-toed shoes, properly fitted clothing, and no loose hair or accessories.

3.5.3 Lab Space Usage

The rooms allotted to the team in Thimann Labs are only accessible through keys which are designated to the Project Lead, Duncan Bark, and the Safety Officer, Brandon Erickson. Additional keys to Thimann Labs may be purchased and distributed to other Board members at the discretion of Sustainability Lab managers. However, since the space is considered part of the Sustainability Lab program, more than just the team leaders will have access to Room 376, where the launch vehicles and payload is stored. As such, team-designated shelving and storage areas will be marked and labeled, allowing lab visitors to easily identify the team’s presence. Outside of this room and down the hall is Room 343 which houses the heavier machinery and tools, such as band saws and routers.

This space is also limited to properly authorized Sustainability Lab personnel, but is considered freely to use by any of the program members, so the team will not keep any hardware outside of Room 376 cabinet spaces.

Also on campus that the team may potentially use, though unlikely, is the Arts Department and its facilities. Should the team ever require access to the equipment there, the proper faculty and administration will be notified in advance and all protocols will be followed to be allowed entry and usage.

Off campus, the team may also potentially use lab space provided by Idea Fab Labs.. For this facility, any team members going will be aware of the rules and protocols as needed there, and will not be allowed to leave parts there once finished with their visit. Transportation can be arranged to go from campus to the city with the use of members and their cars, or through the convenience of the city of Santa Cruz's metro bus system.

It should also be noted that the access to on-campus spaces through the Sustainability Lab is a privilege, and that the team act respectfully and collaborate alongside the other student groups who use the spaces in Thimann Labs. Should members fail to adhere to lab policies, or otherwise disrupt the community, the program may remove access and storage space for the entire team. Therefore, it will be important that all students unfamiliar with the Sustainability Lab be briefed in the Safety Manual and in person when necessary.

3.5.4 Safety Acknowledgement

Once a student has completed all necessary training and preparation to begin working in the lab spaces on the rockets, they are required to read and sign a form stating that they understand all the risks associated with the team's work environment and can act responsibly. A copy of this Safety Acknowledgement Form can be found in Appendix A.

If a student cannot comply with the rules and regulations regarding any level of the project, or be the direct cause cause of an accident which results in damage to a person(s) or property, their lab access privileges may be revoked for an indefinite amount of time based on the severity of the incident and at the Safety Officer's discretion.

4 Technical Design

4.1 General Vehicle Design

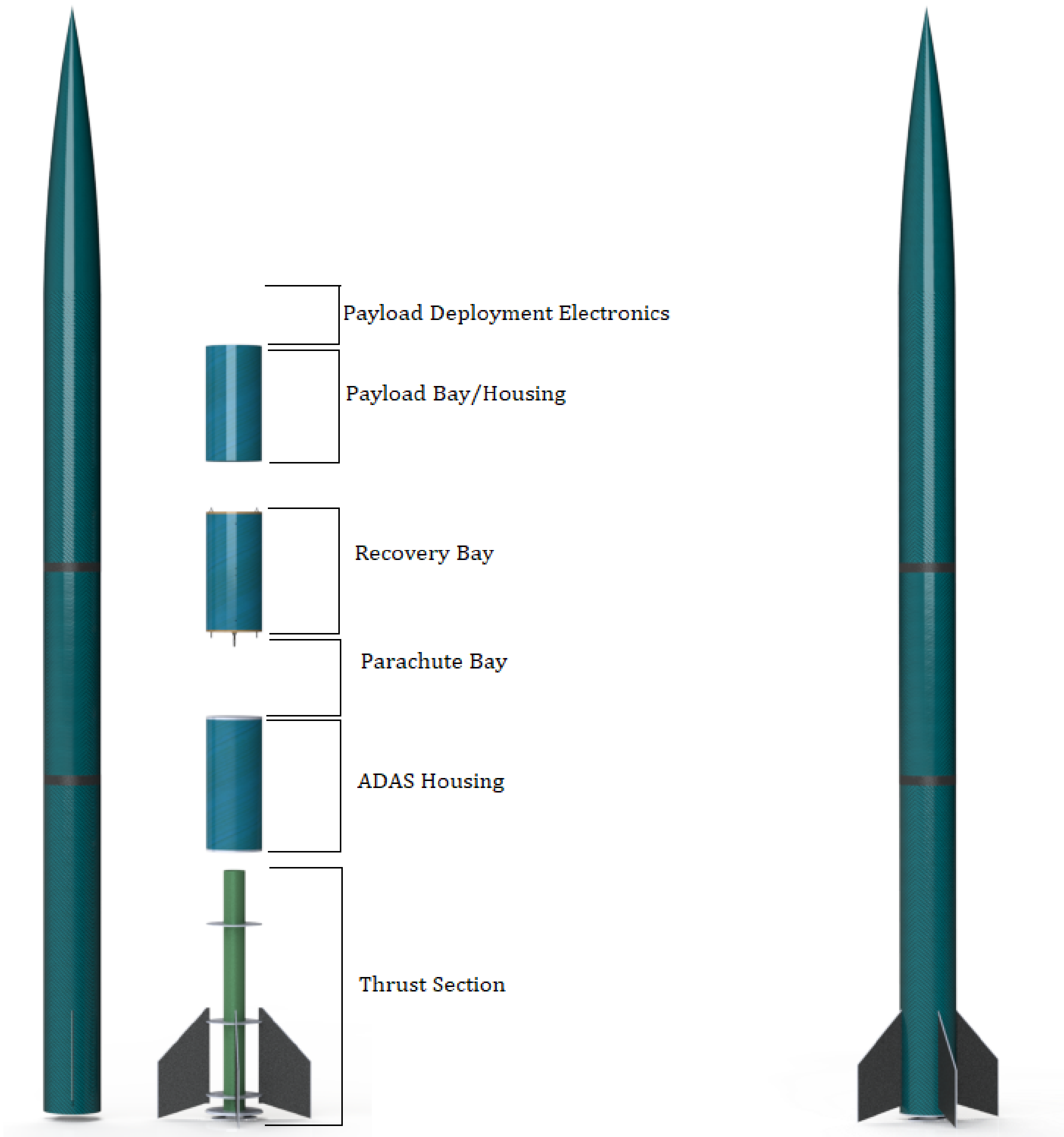


Figure 4.1.1 The Titan-bound II Rocket

This year the vehicle's design is based on previous years' successes, failures, and experiences. As a result of looking over the previous years, the team has decided on a few key design aspects for the designing and building of the vehicle. Firstly, each subsystem will be designed and built within specific constraints. For example, the payload subsystem will be constructed within the following design constraints: 6" diameter, 16" length (including deployment electronics), and a maximum mass of 5 lbs. These numbers were decided on from previous years experience and current design choices. The maximums, when applied to each subsystem, will provide a concrete base for modelling the vehicle to verify flight characteristics. With a maximum mass, the vehicle will always be the same mass each launch because each subsystem will be brought up to maximum mass with ballast. This prevents last year's problem of the vehicles mass constantly changing resulting in the final vehicle's flight characteristics to be sub-nominal and unplanned. Finally, this set mass system will eliminate the need for a removable fin system, making assembly and design simpler and flights more reliable.

4.1.1 General Dimensions

Length (inches)	**Diameter (inches)**		**Wet mass (lbs)**	**Motor Selection**	**Recovery System (inches)**		**Target Altitude (feet)**	**Vehicle Material**	**Wet CG (in, nose)**	**Wet CP (in, nose)**	**Rail Size**
	Outer	*Inner*			*Drogue*	*Main*					
115	6.00	5.82	9.8	1000L	18	60	4000	Carbon Fiber	71.69	87.23	10ft 10-10

Figure 4.1.2 General Vehicle Characteristics

	Payload	**Recovery**	**ADAS**
Length	16"	12"	13.5"
Mass	5 lbs	3 lbs	4.5 lbs

Figure 4.1.3 Sub-system Design Constraints

4.1.2 Material Selections

The body of the rocket will be carbon fiber based on the success of last year's carbon fiber body. The strength of the carbon fiber will allow for the rocket to withstand any forces experienced in-flight while minimizing the weight of the rocket. This decrease in weight of the rocket in comparison to other materials like fiberglass gives the sections more mass while keeping the same stability during the flight.

The couplers to connect the sections of the rocket will be Blue Tube. It is a material that is light, cheap, and sturdy enough to warrant its use. It has weakness when lateral force is applied, but the carbon fiber outer layers will cover any weaknesses on that end. Blue Tube is also relatively easy to drill and tap through. This is the primary use of the Blue Tube and is helpful in the rocket's construction.

The fins will be ⅛" fiberglass fins. These were chosen to limit, if not eliminate, wobbling from the fins. Last year's design was equipped with non-fiberglass fins and had potential to wobble during flight, creating a flight risk. Using fiberglass fins this year -- especially with a heavier rocket -- will add much needed safety.

The nose cone of the rocket will be a COTS fiberglass nose cone. Other materials like carbon fiber increase cost and are not needed at speeds experienced for the competition. They also add a difficulty and unreliability during construction. The fiberglass nose cone will be sturdy, cost-effective, and reliable.

4.1.3 Construction Methods

The carbon fiber body of the rocket will be constructed in much the same manner as last year. However, construction methods learned last year will be used this year with added confidence the process will be successful. This involves wrapping the carbon fiber around a mandrel, applying epoxy, waiting until the epoxy dries, and removing the carbon fiber from the mandrel. What results is a fully-formed section.

Connecting each section seems difficult at first, but they all follow certain rules: each coupler depends on the diameter of the rocket and each section needs a secure connection to the couplers. Then it is simple to connect each section. The carbon fiber and couplers are tapped and connected using semi-permanent bolts. This is so the rocket may be disassembled in transportation and gives access to last minute changes that will be needed.

4.2 Projected Altitude

Using the AeroTech L1000 motor, we expect an apogee of 4195 feet under ideal conditions, and an apogee of 4114 feet in 20 mph winds. Because we are aiming for an apogee of 4000 feet, we expect to be able to meet our target altitude, even in poor weather conditions. This overshooting of our target altitude allows for ADAS to deploy the drag fins and guide the vehicle to exactly 4000 feet.

4.3 Recovery System

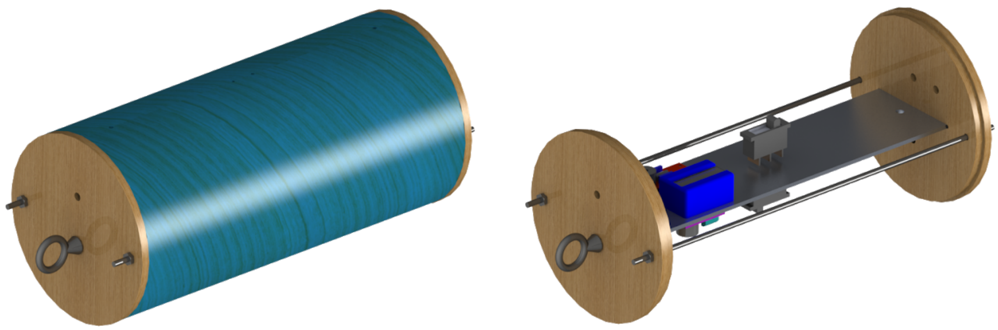


Figure 4.3.1 Avionics Bay

The rocket will perform a two stage recovery, separating into two tethered sections. At apogee, an 18in drogue parachute will be deployed, along with an encased 60in main parachute. Deployment is done with two black powder charges from two separate altimeters to ensure reliability and redundancy. The first will be fired at apogee by an EasyMini Altimeter, with the second being using as a, larger, redundant charge and will be fired shortly after apogee by a StratologgerCF Altimeter. During descent, the main parachute will be located inline with the drogue parachute, but wrapped with two Jolly Logic Chute releases in series, ensuring redundancy and reliability. The Jolly Logic Chute Release system has a dedicated altimeter to detect the given deployment altitude. The main parachute will be released at a height of 500 feet in order to minimize drift.

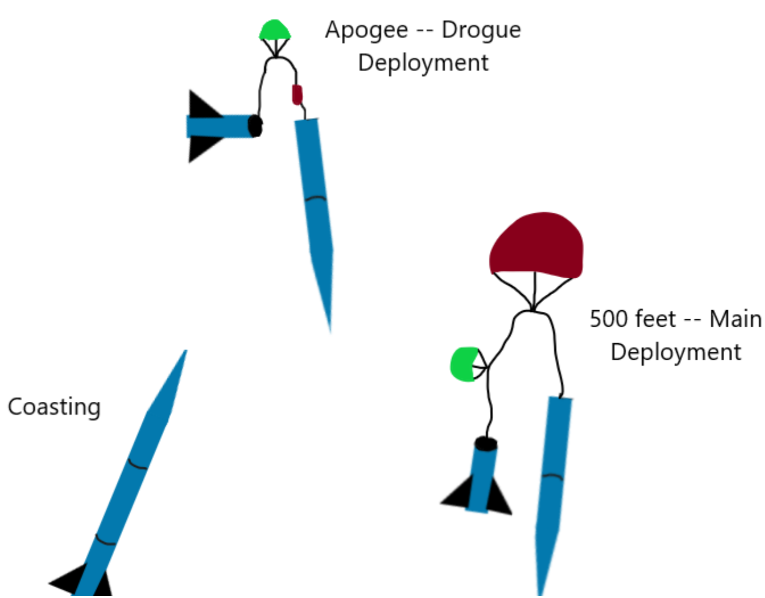


Figure 4.3.1 Recovery Diagram

The parachutes will be protected from the blast of the black powder charges by a large fire resistant parachute protector and kevlar shock cord. This is done to ensure the safety of the parachutes and cords during the blast.

Requirement 3.3 in the Student Launch handbook stipulates that each independent section of the vehicle must not exceed a kinetic energy of 75 ft-lbf at landing. The kinetic energy of an object is given by the equation:

$$KE = \frac{1}{2}mv^2$$

The total vehicle mass is 26.65 lbs (dry mass with empty motor mass), with the mass for the upper section being 12.95 lbs and the mass for the lower section being 11.7 lbs. This allows for a maximum landing velocity of 19.29 ft/s, or 5.88 m/s. The terminal velocity of a falling object is given by the equation:

$$v_{terminal} = \sqrt{\frac{2mg}{\rho_{air} C_d A_{parachute}}}$$

Because the drogue parachute is much smaller than our main parachute, we will ignore it when calculating the terminal velocity. Using the value 1.225 kg/m^3 for the density of air and a value of 1.55 for the drag coefficient of our parachute. With a main parachute diameter of 60 in, we get an area of 2827.4 in^2, giving a final landing velocity of 18.9 ft/s. The largest independent section of the rocket has a mass of 12.95 lbs, so this velocity gives a kinetic energy of 71.89 ft-lbf at landing, which is within the energy requirement.

4.4 Motor Designation

Using the AeroTech L1000 motor, the vehicle is expected to have a velocity off the rod of 75.6 ft/s and a maximum velocity of 562 ft/s. This satisfies requirement 2.16 which states the the vehicle must have a velocity of at least 52 ft/s at rail exit. With the L1000, the vehicle has a minimum static stability of 2.59, satisfying requirement 2.14. Finally the L1000 motor has a total impulse of 2714.0Ns, thereby satisfying the maximum of 5120.0Ns set by requirement 2.12.

4.5 Payload

4.5.1 Payload System Overview

The team has chosen to build a UAV to fulfill the payload experiment. The UAV design is an RC quadcopter. The body of the UAV will be 3 in. in length, with a 1.5 in. height and 1.5 in. width. In addition to housing the UAV, the Payload system will also house a mount for the UAV, deployment parachutes, and a retention tether. Deployment electronics and charges will be housed in the nose cone. The payload section will be 12 inches long, with a maximum mass of 5 lbs.

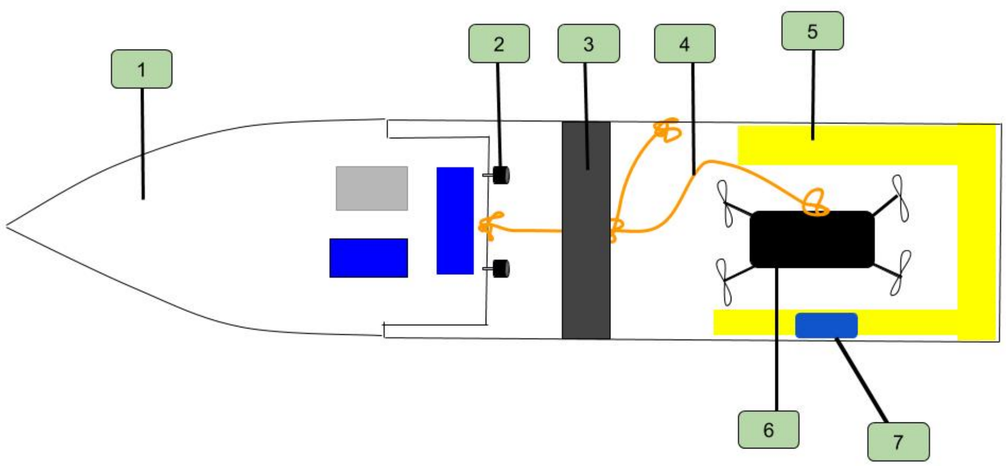


Figure 4.5.1.1 Design overview of Payload section

The section labeled 1 in Figure 4.5.1.1 represents the nose cone, which houses the radio and necessary batteries. Section 2 represents the black powder charges, followed by section 3: the door to protect the UAV from the black powder upon detonation. Section 4 is the tether that connects the nose cone, airframe, door (to be pulled off during blast), and the UAV. Section 5 is the housing that contains the UAV (labeled as 6), and 7, the external battery source.

The following engineering design matrix helped the team decide that a UAV will be utilized for the lunar ice sample recovery challenge:

		UAV	***Rover***

Selection Criteria	Weight (1-5)	Score (1-5)	Weighted Score	Score (1-5)	Weighted score
Retainment	4	3	12	3	12
Deployment	5	2	10	4	20
Reliability	5	3	15	3	15
Maneuverability	5	5	25	1	5
Cost	3	2	6	4	12
Mass	4	5	20	4	16
Total Score		**88**		**80**	

Weight: 1 (non-concern) - 5 (major concern)

Score: 1 (hard/complex) - 5 (easy/simple)

4.5.2 Vehicle Design

4.5.2.1 UAV body

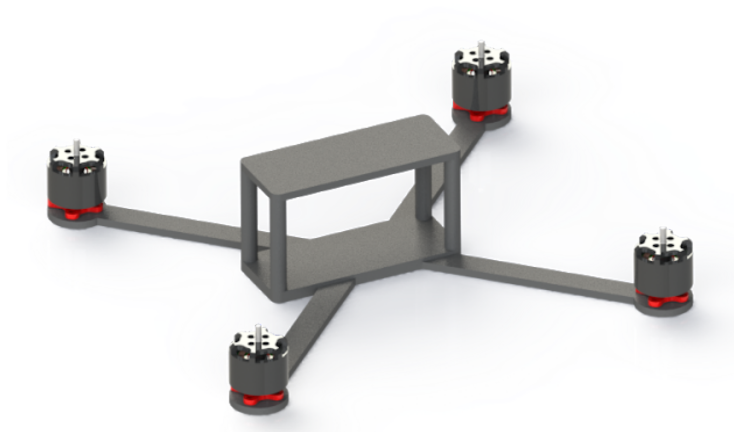


Figure 4.5.2.1 Preliminary design of the UAV frame

The UAV will be a quadcopter, with a custom 3D-printed ABS or PETG frame. It features a compact body (3 x 1.5 x 1.5") to fit into the 6" diameter airframe. The top and bottom plates of the UAV will be accompanied by four screw connectors in order to adjust the height if necessary.

4.5.2.2 Electronics

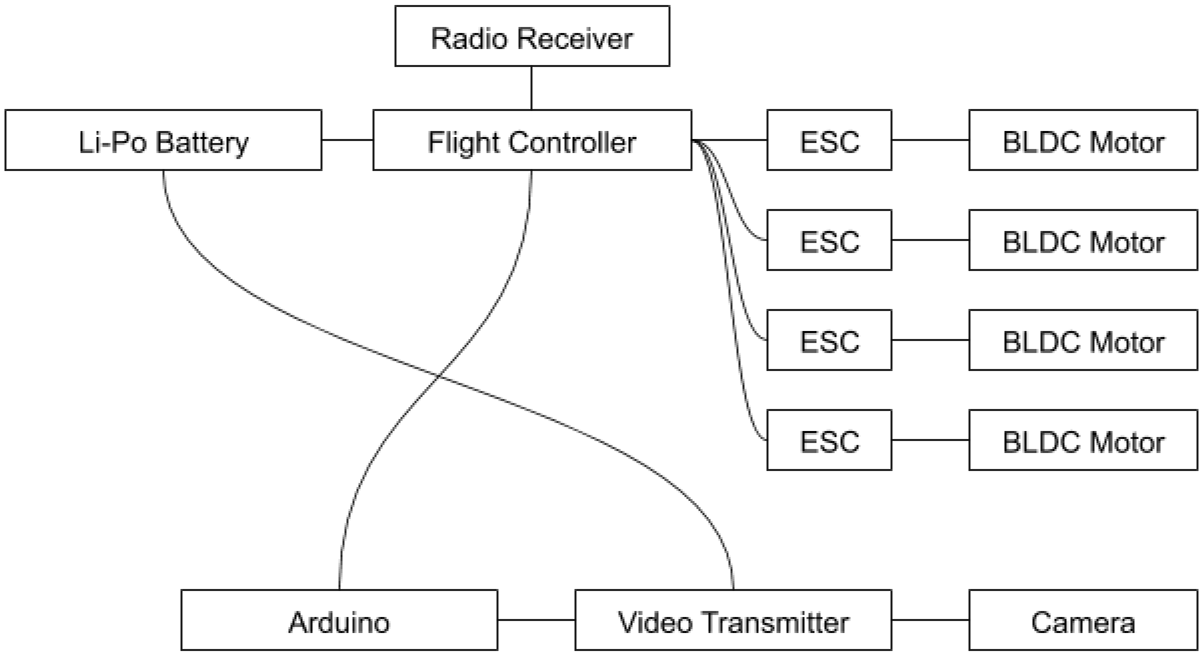


Figure 4.5.2.2 System interconnection diagram for payload electronics

The UAV will be controlled by radio on the 915 Mhz band, using the FrSky R9 Mini Receiver and X-lite radio controller. It will be powered by a 850mAh 3s LiPo battery at 11.1 volts. It uses four 4500KV brushless DC motors for propulsion, with two rotating clockwise and the other two rotating counterclockwise so their torques cancel out. These are controlled using ESCs (electronic speed controllers) by a Lumenier LUX V2 flight controller, which gets its input from the FrSky R9 receiver. In order to stream video back to the ground from the UAV, the UAV will use a 400mW Unify Pro32 transmitter on the 5.8GHz band, coupled with a compact wide angle camera that can be powered directly from the transmitter. In order to conserve power, the video transmitter will remain off while the payload is stowed and will be powered on and configured by an Arduino Micro once the UAV has been deployed. The Arduino will be powered from the 5 volt regulator built into the flight controller.

4.5.2.3 Soil Collection

In order to collect the ice sample, the UAV will use a clear plastic tube with a flexible rubber membrane on the end. There is a slit in the membrane that only opens when a sufficient force is applied to it. The UAV will push the collection mechanism against the sample area, opening the membrane, and forcing the ice sample into the tube. The weight of the collected sample is not able to provide enough force to re-open the membrane, so when the UAV lifts off of the sample area, it will not fall out. Incremental markings on the side of the tube allow the volume of ice collected to easily be determined. The benefit of this mechanism design over a scoop or claw is its simplicity; there are no electronics and only one moving part.

4.5.3 Housing and Vehicle Retainment

4.5.3.1 Primary Retainment (UAV Inflight Housing)

During flight, the UAV will be housed below the nose cone, which will be affixed by shear pins. The vehicle will be securely mounted to a 3D-printed PLA stand by a normally closed solenoid until landing. Once the rocket has safely landed, and permission from the RSO is received to deploy, a radio signal will trigger the microcontroller to open the solenoid.

4.5.3.2 Secondary Retainment (Tether)

The drone will be connected to both the nose cone and the airframe by a kevlar shock cord tether, until it is released by radio signal. This secondary retainment mechanism will ensure no unattached parts fall, in the unexpected event that the nosecone separates from the airframe prematurely (for example, in a premature black powder detonation). This mechanism also ensures that the UAV is connected to the airframe, until given permission to deploy by the RSO.

4.5.4 Payload Deployment

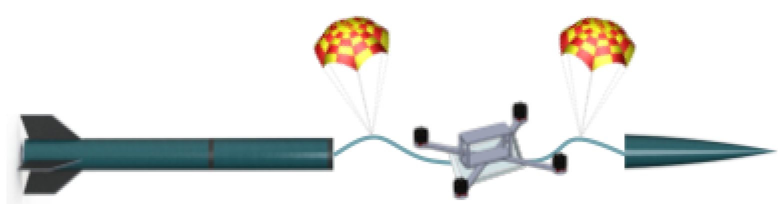


Figure 4.5.4.1 Payload post-deployment design with retention tether

4.5.4.1 Mechanical design

The UAV will be ejected by black powder charges upon descent, separating the nosecone from the payload section. The charge will be triggered manually via radio (or other wireless communication) signal, after the team has received permission to deploy, and after the main parachute has been deployed. After this charge is activated, releasing the

UAV, the tether will keep the Payload electronics and UAV attached to the airframe, and also contain two parachutes to ensure that the vehicle 1) lands safely and 2) is oriented correctly to begin its flight. The drone will be flown manually via a wireless transmitter to collect the ice sample.

4.5.4.2 Electrical design

The signal to detonate the black powder charges is sent and received by paired Digi XBee wireless communication modules. The sender module is attached to a laptop with software that allows the deployment signal to be sent, while the receiver module is mounted inside the rocket's fiberglass nosecone, which allows for more reliable wireless connection than the carbon fiber body. Because the voltage of the signal output by the receiver module is too low to detonate the black powder charge on its own, a microcontroller is connected between the receiver module and other components of the deployment circuit. Upon receiving the activation signal, the microprocessor transmits a 5V signal to the gate of an nMOS transistor whose source is connected to a 9V power supply and the e-match that detonates the black powder charge.

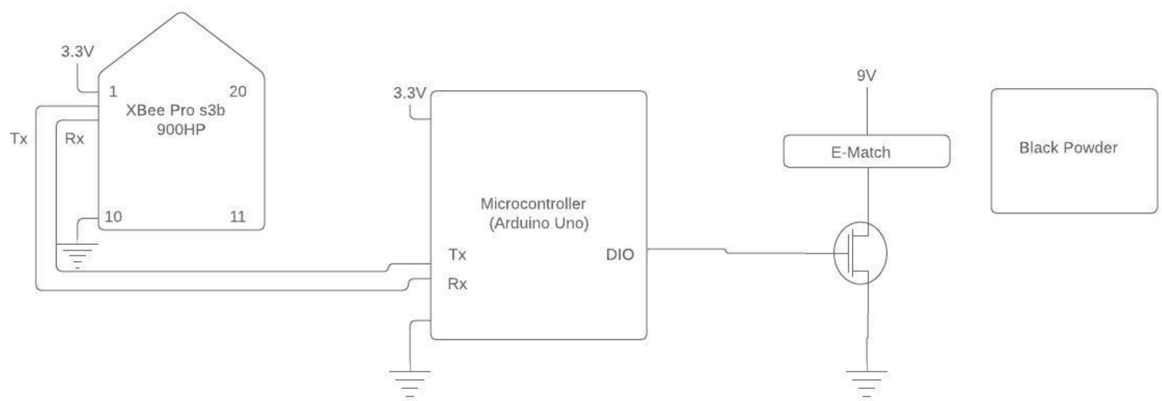


Figure 4.5.1 Block diagram of payload deployment circuit

4.6 Requirement Verification

4.6.1 SLI Requirements

The NASA Student Launch provides five major sets of requirements that each team is expected to recognize and fulfill:

1. General Requirements
2. Vehicle Requirements
3. Recovery System Requirements

4. Payload Experiment Requirements
5. Safety Requirements

Table 4.6.1 to Table 4.6.5 describe how the team will comply with these stipulations, using the following four methods of verification:

- **Inspection (Look)** -- Examination of the object or system using the senses and tools available to the team. This method is very unobtrusive and does not require much interaction or modification of the object or system being examined. This includes administrative items such as documentation and deliverables.
- **Demonstration (Do)** -- Making the system or object perform its intended purpose under scrutiny to ensure that it functions as desired.
- **Analysis (Compute)** -- Verification that the system or object performs as intended through a set of calculations, models, and simulations. Also includes post-flight data analysis to verify expected outcomes and operation.
- **Test** -- Verification of the system or objects by means of controlled inputs, and comparison of output to the intended output of the object or system.

Each requirement is also given a current status. A requirement's status can be one of the four following statuses:

- **Not Started** -- Work towards the completion of the requirement has not been started for reasons listed in the details section.
- **Incomplete** -- Requirement verification is not complete and work towards the completion of the requirement is not occuring.
- **In Progress** -- Work towards the completion of the requirement is ongoing.
- **Completed** -- Requirement and verification has been completed.

General Requirements

#	Requirement Description	Method of Verification	Description of Verification	Status	Details
1.1	Students on the team will do 100% of the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder or any variant of ejection charges, or	Inspection	The team will exclusively submit documentation that is their own, citing data from outside sources when necessary. All other project requirements, excluding the handling of motors or explosives, will be	**In Progress**	The team will continue to submit original and new work in the foreseeable future.

	preparing and installing electric matches (to be done by the team's mentor). Teams will submit new work. Excessive use of past work will merit penalties.		conducted by students on the team.		
1.2	The team will provide and maintain a project plan to include, but not limited to the following items: project milestones, budget and community support, checklists, personnel assignments, STEM engagement events, and risks and mitigations.	Inspection	The team will include a detailed project plan on all documents that are turned in. In addition, individual subteams will maintain their own plans.	**In Progress**	The team has designated the Finance Lead to take the lead in creating and maintaining project plans, both for the whole team and for subteams.
1.3	Foreign National (FN) team members must be identified by the Preliminary Design Review (PDR) and may or may not have access to certain activities during launch week due to security restrictions. In addition, FN's may be separated from their team during certain activities on site at Marshall Space Flight Center.	Inspection	All Foreign National team members, who are interested in attending launch week, will be identified by PDR. All contact information will be passed along to the designated NASA crew member.	**Not Started**	Work towards completion of this requirement has not yet begun due to the school year not yet beginning.
1.4	The team must identify all team members attending launch week activities by the Critical Design Review (CDR). Team	Inspection	Team members attending launch week activities will be identified in the CDR, and will include one mentor	**Not Started**	Work towards the completion of this requirement has not yet

	members will include: 1.4.1. Students actively engaged in the project throughout the entire year. 1.4.2. One mentor (see requirement 1.13). 1.4.3. No more than two adult educators.		and no more than two adult educators.		begun due to the team roster not being fully known
1.5	The team will engage a minimum of 200 participants in educational, hands-on science, technology, engineering, and mathematics (STEM) activities, as defined in the STEM Engagement Activity Report, by FRR. To satisfy this requirement, all events must occur between project acceptance and the FRR due date and the STEM Engagement Activity Report must be submitted via email within two weeks of the completion of the event. A sample of the STEM Engagement Activity Report is on page 35.	Inspection	Accurate outreach engagement forms will be completed and turned in soon after the completion of each outreach events. The Outreach lead will handle all outreach events and outreach documentation. This year the team will continue to work at local schools, the community, and on campus.	**Not Started**	Work towards completing this requirement has not yet begun due to the competition not yet starting.
1.6	The team will establish a social media presence to inform the public about team activities.	Inspection	The team has already established a social media presence.	**Completed**	The team will continue to update all social media outlets throughout the year.
1.7	Teams will email all	Inspection	The team will email	**In Progress**	The team will

	deliverables to the NASA project management team by the deadline specified in the handbook for each milestone. In the event that a deliverable is too large to attach to an email, inclusion of a link to download the file will be sufficient.		the NASA project development team all required deliverables prior to specified deadlines.		continue to submit deliverables on time following this proposal.
1.8	All deliverables must be in PDF format.	Inspection	All deliverables will be downloaded as PDFs and will be verified prior to turn in.	**In Progress**	The team member responsible for turning in documents will verify each document is in PDF format.
1.9	In every report, teams will provide a table of contents including major sections and their respective sub-sections.	Inspection	A table of contents will be included following the title page of every document. A team member will verify that it matches with the document.	**In Progress**	Each document will be verified to have a table of contents.
1.10	In every report, the team will include the page number at the bottom of the page.	Inspection	All reports thus far have page numbers included at the bottom of the page.	**In Progress**	Future reports will continue to include page numbers at the bottom of the page.
1.11	The team will provide any computer equipment necessary to perform a video	Demonstratio n	A team member with the necessary equipment will be present during all	**Not Started**	Work towards completion of this requirement

	teleconference with the review panel. This includes, but is not limited to, a computer system, video camera, speaker telephone, and a sufficient Internet connection. Cellular phones should be used for speakerphone capability only as a last resort.		video teleconferences and will prepare all necessary items at least 15 prior to any conference. Conferences will be conducted in the McHenry Library at UCSC.		has not begun due to the competition not yet starting.
1.12	All teams will be required to use the launch pads provided by Student Launch's launch services provider. No custom pads will be permitted on the launch field. At launch, 8-foot 1010 rails and 12-foot 1515 rails will be provided. The launch rails will be canted 5 to 10 degrees away from the crowd on launch day. The exact cant will depend on launch day wind conditions.	Inspection	The team will use the provided launch pads and refrain from using custom launch pads.	**Not Started**	Work towards completion of this requirement has not begun due to the competition not yet starting.
1.13	Each team must identify a "mentor." A mentor is defined as an adult who is included as a team member, who will be supporting the team (or multiple teams) throughout the project year, and may or may not be affiliated with the	Inspection	David Raimondi has been identified as the team mentor.	**Complete**	David Raimondi will continue to be the team mentor throughout the competition.

	school, institution, or organization. The mentor must maintain a current certification, and be in good standing, through the National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) for the motor impulse of the launch vehicle and must have flown and successfully recovered (using electronic, staged recovery) a minimum of 2 flights in this or a higher impulse class, prior to PDR. The mentor is designated as the individual owner of the rocket for liability purposes and must travel with the team to launch week. One travel stipend will be provided per mentor regardless of the number of teams he or she supports. The stipend will only be provided if the team passes FRR and the team and mentor attend launch week in April.				

Table 4.6.1 Student Launch General Requirements Verification

Vehicle Requirements

#	Requirement Description	Method of Verification	Description of Verification	Status	Details

2.1	The vehicle will deliver the payload to an apogee altitude between 3,500 and 5,500 feet above ground level (AGL). Teams flying below 3,000 feet or above 6,000 feet on Launch Day will be disqualified and receive zero altitude points towards their overall project score.	Demonstration	The vehicle will be designed to reach an apogee of at least 3,500 feet in worst cases. This will be proven during multiple test flights of the vehicle and simulations.	**In Progress**	The vehicle is currently designed to reach an apogee of 4100 feet in poor conditions. This will be verified through test flights.
2.2	Teams shall identify their target altitude goal at the PDR milestone. The declared target altitude will be used to determine the team's altitude score during Launch Week.	Inspection	A final target altitude will be identified on the PDR, based on simulations and models.	**Incomplete**	A target altitude of 4000 feet has been chosen, but a final target altitude will be decided by PDR.
2.3	The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the Altitude Award winner. The Altitude Award will be given to the team with the smallest difference between their measured apogee and their official target altitude on launch day. This altimeter may also be used for deployment purposes (see Requirement 3.4)	Inspection	The avionics bay will feature two commercially but different barometric altimeters, one being the StratologgerCF which "beeps" out the maximum altitude upon landing.	**Incomplete**	The team has chosen two commercially available barometric altimeters, however the final vehicle has not yet been built.

2.4	The launch vehicle will be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.	Demonstration & Inspection	All systems are designed to be reusable and recoverable, without any damage to the vehicle and its subsystems.	**Complete**	Design of the vehicle is currently recoverable and reusable, and any future design will be the same.
2.5	The launch vehicle will have a maximum of four (4) independent sections. An independent section is defined as a section that is either tethered to the main vehicle or is recovered separately from the main vehicle using its own parachute.	Inspection	The vehicle is, and will always be, designed to not exceed four independent sections. Currently it is designed to be four sections: thrust, recovery, payload, and the nose cone.	**Incomplete**	Design of the vehicle is completed, however flights have not occurred to verify this requirement.
2.5.1	Coupler/airframe shoulders which are located at in-flight separation points will be at least 1 body diameter in length.	Inspection	All couplers at separation points will be at least one body diameter in length.	**Incomplete**	Design of the vehicle is complete, however construction has not yet begun.
2.5.2	Nosecone shoulders which are located at in-flight separation points will be at least ½ body diameter in length.	Inspection	The nose cone shoulder will be at least ½ body diameter in length (3 in).	**Incomplete**	Design of the vehicle is complete, however construction has not yet begun.
2.6	The launch vehicle will be capable of being prepared for flight at the launch site within 2 hours of	Demonstration	All necessary assembly steps and tests will be completed in under two hours prior to	**Not started**	This requirement will be verified through

	the time the Federal Aviation Administration flight waiver opens		launch. This will be done multiple times to verify this requirement.		mock assemblies and during test flights.
2.7	The launch vehicle and payload will be capable of remaining in launch-ready configuration on the pad for a minimum of 2 hours without losing the functionality of any critical on-board components, although the capability to withstand longer delays is highly encouraged.	Demonstration & Analysis	All critical systems and the payload will be designed to be in their launch-ready configuration for a minimum of two hours. This will be done by low power modes and addition batteries.	**Incomplete**	Design of the systems have been completed and are expected to satisfy this requirement, however tests are necessary to prove this.
2.8	The launch vehicle will be capable of being launched by a standard 12-volt direct current firing system. The firing system will be provided by the NASA-designated launch services provider.	Demonstration	The vehicle will be designed to be launched using a standard 12-volt DC firing system.	**Incomplete**	The vehicle is currently designed to support the firing system, however test flights will prove this.
2.9	The launch vehicle will require no external circuitry or special ground support equipment to initiate launch (other than what is provided by the launch services provider).	Demonstration	The vehicle is designed to require no external circuitry or equipment to function.	**Incomplete**	Design of the vehicle satisfies this requirement, however test flights will prove this.
2.10	The launch vehicle will use a	Inspection	The vehicle is designed to fit	**Incomplete**	All motors will be

	commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR).		54mm COTS motors. The current motor is the AeroTech L1000, which satisfies this requirement. All future motors will be verified to satisfy this requirement.		verified to satisfy this requirement. Motors used will only be COTS.
2.10.1	Final motor choices will be declared by the Critical Design Review (CDR) milestone.	Inspection	A final motor will be listed and declared on the CDR.	**Not Started**	A final motor has not yet been chosen, only a preliminary motor.
2.10.2	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.	Inspection	Should the motor listed on the CDR result in poor safety margins, the team will request a motor change at the cost of a points penalty.	**Not Started**	The team does not foresee the need to change motors, however the competition has not yet started so this requirement cannot be verified.
2.11	The launch vehicle will be limited to a single stage.	Inspection & Demonstration	The vehicle is currently, and will always be designed to be a single stage.	**Incomplete**	Assembly of the vehicle and test flights will

					verify this requirement.
2.12	The total impulse provided by a College or University launch vehicle will not exceed 5,120 Newton-seconds (L-class). The total impulse provided by a High School or Middle School launch vehicle will not exceed 2,560 Newton-seconds (K-class).	Inspection	The chosen motor will be verified to not exceed 5120Ns.	**Incomplete**	The current motor does not exceed 5120Ns, and any future motor will be verified to satisfy this requirement.
2.13	Pressure vessels on the vehicle will be approved by the RSO and will meet the following criteria:	Inspection	All pressure vehicles will meet the following criteria and will be approved by the RSO.	**Not Started**	The vehicle currently is not designed to have any pressure vessels.
2.13.1	The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) will be 4:1 with supporting design documentation included in all milestone reviews.	Inspection	Design documentation for the pressure vehicle will be included in all documents and listed out in a description of the parts.	**Not Started**	The vehicle currently is not designed to have any pressure vessels.
2.13.2	Each pressure vessel will include a pressure relief valve that sees the full pressure of the tank and is capable of withstanding the maximum pressure and flow rate of the tank.	Inspection	Each pressure vessel will be verified to have a pressure relief valve that functions correctly.	**Not Started**	The vehicle currently is not designed to have any pressure vessels.

2.13.3	The full pedigree of the tank will be described, including the application for which the tank was designed and the history of the tank. This will include the number of pressure cycles put on the tank, the dates of pressurization/depressurization, and the name of the person or entity administering each pressure event.	Inspection	A history of the pressure vessel will be provided on all documents in order to gain an understanding of the quality and safety of the pressure vessel.	**Not Started**	The vehicle currently is not designed to have any pressure vessels.
2.14	The launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit. Rail exit is defined at the point where the forward rail button loses contact with the rail.	Analysis	The vehicle will be verified to have a minimum stability margin of 2.0. This will be done through modelling software and post-flight analysis.	**Complete**	The vehicle is currently designed to have a stability margin of at least 2.
2.15	Any structural protuberance on the rocket will be located aft of the burnout center of gravity.	Inspection	ADAS is designed to exist aft of the center of gravity in order to maintain stability.	**Complete**	ADAS is on the only protuberance and is located aft of the center of gravity.
2.16	The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.	Analysis & Demonstration	The vehicle is currently designed to excess 52 fps upon rail exit.	**Incomplete**	Simulations have verified this requirement, however test launches are necessary to further prove this.

2.17	All teams will successfully launch and recover a subscale model of their rocket prior to CDR. Subscales are not required to be high power rockets.	Inspection & Demonstration	A subscale vehicle will be designed, built, and launched prior to the CDR deadline.	**Not Started**	Design and work on the subscale has not yet started.
2.17.1	The subscale model should resemble and perform as similarly as possible to the full-scale model, however, the full-scale will not be used as the subscale model.	Inspection & Demonstration	The subscale vehicle will be scaled down version of the fullscale, will similar functions and features.	**Not Started**	Design and work on the subscale has not yet started.
2.17.2	The subscale model will carry an altimeter capable of recording the model's apogee altitude.	Inspection	The subscale will contain two COTS barometric altimeters that can record the vehicles apogee.	**Not Started**	Design and work on the subscale has not yet started.
2.17.3	The subscale rocket must be a newly constructed rocket, designed and built specifically for this year's project.	Inspection	The subscale will be designed and built from scratch for this year's competition.	**Not Started**	Design and work on the subscale has not yet started.
2.17.4	Proof of a successful flight shall be supplied in the CDR report. Altimeter data output may be used to meet this requirement.	Inspection	Altimeter data and photos will be provided on the CDR to verify the success of the subscale flight.	**Not Started**	Design and work on the subscale has not yet started.
2.18	All teams will complete demonstration flights as outlined below.	Inspection	All demonstration flights will be completed successfully and on time.	**Not Started**	Work towards completion of this requirement

					has not begun due to the competition not yet starting.
2.18.1	Vehicle Demonstration Flight - All teams will successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown must be the same rocket to be flown on launch day. The purpose of the Vehicle Demonstration Flight is to validate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for flight. A successful flight is defined as a launch in which all hardware is functioning properly (i.e. drogue chute at apogee, main chute at the intended lower altitude, functioning tracking devices, etc.). The following criteria must be met during the full-scale demonstration flight:	Demonstration & Inspection	The vehicle demonstration flight will be completed successfully and on time. This flight will prove the vehicle's stability, strength, and ability to perform satisfactorily.	**Not Started**	Work towards completion of this requirement has not begun due to the competition not yet starting.
2.18.1.1	The vehicle and	Inspection &	The vehicle's	**Not Started**	The vehicle

	recovery system will have functioned as designed.	Analysis	recovery system will be verified following the flight.		has not yet flown.
2.18.1.2	The full-scale rocket must be a newly constructed rocket, designed and built specifically for this year's project.	Inspection	The full-scale will be designed and built from scratch for this year's competition.	**Incomplete**	The full-scale has not yet been built, however the design is complete.
2.18.1.3	The payload does not have to be flown during the full-scale Vehicle Demonstration Flight. The following requirements still apply:	Inspection	The team will make sure the payload is flown during some full-scale flight.	**Not Started**	The vehicle has not yet flown.
2.18.1.3.1	If the payload is not flown, mass simulators will be used to simulate the payload mass.	Inspection	Should the payload not fly during the vehicle demonstration flight, mass simulations will be used.	**Not Started**	The vehicle has not yet flown.
2.18.1.3.2	The mass simulators will be located in the same approximate location on the rocket as the missing payload mass.	Inspection	Mass simulations used during a vehicle demonstration flight will be accurate to the actual payload.	**Not Started**	The vehicle has not yet flown.
2.18.1.4	If the payload changes the external surfaces of the rocket (such as with camera housings or external probes) or manages the total energy of the vehicle, those systems will be active during the	Inspection	Any system that changes the external surface of the rocket will be present during the vehicle demonstration flight.	**Not Started**	The vehicle has not yet flown and the payload is not designed to change the external surface of the vehicle.

	full-scale Vehicle Demonstration Flight.				
2.18.1.5	Teams shall fly the launch day motor for the Vehicle Demonstration Flight. The team may request a waiver for the use of an alternative motor in advance if the home launch field cannot support the full impulse of the launch day motor or in other Extenuating circumstances (such as weather).	Inspection	The same motor will be used during the competition flight as used for the vehicle demonstration flights.	**Not Started**	The vehicle has not yet flown.
2.18.1.6	The vehicle must be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the same amount of ballast that will be flown during the launch day flight. Additional ballast may not be added without a re-flight of the full-scale launch vehicle.	Inspection	The vehicle is designed to always fly in its fully ballasted configuration as a result of the design constraint system.	**Not Started**	The vehicle has not yet flown, however it is designed to always fly in its fully ballasted configuration.
2.18.1.7	After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components will not be modified without the concurrence of the NASA Range Safety	Inspection	The team will not modify the vehicle or its contents after the full-scale demonstration flight without agreement with the NASA RSO.	**Not Started**	Work towards completion of this requirement has not begun due to the competition not yet

	Officer (RSO).				starting.
2.18.1.8	Proof of a successful flight shall be supplied in the FRR report. Altimeter data output is required to meet this requirement.	Inspection	The team will provide proof of a successful flight in the FRR report, including altimeter data output	**Not Started**	Work towards completion of this requirement has not begun due to vehicle implementati-on and testing not yet starting.
2.18.1.9	Vehicle Demonstration flights must be completed by the FRR submission deadline. No exceptions will be made. If the Student Launch office determines that a Vehicle Demonstration Re-flight is necessary, then an extension may be granted. THIS EXTENSION IS ONLY VALID FOR RE-FLIGHTS, NOT FIRST TIME FLIGHTS. Teams completing a required re-flight must submit an FRR Addendum by the FRR Addendum deadline.	Inspection	The team will complete a Vehicle Demonstration flight before the FRR submission deadline, and will conduct a Vehicle Demonstration Re-flight if necessary, communicating results on an FRR Addendum by the FRR Addendum deadline.	**Not Started**	Work towards completion of this requirement has not begun due to vehicle implementati-on and testing not yet starting.
2.18.2	Payload Demonstration Flight - All teams will successfully launch and recover their	Inspection & Demonstration	Prior the competition launch, the payload will be launched in its final form with the	**Not Started**	The payload and vehicle have not yet flown.

	full-scale rocket containing the completed payload prior to the Payload Demonstration Flight deadline. The rocket flown must be the same rocket to be flown on launch day. The purpose of the Payload Demonstration Flight is to prove the launch vehicle's ability to safely retain the constructed payload during flight and to show that all aspects of the payload perform as designed. A successful flight is defined as a launch in which the rocket experiences stable ascent and the payload is fully retained until it is deployed (if applicable) as designed. The following criteria must be met during the Payload Demonstration Flight:		payload performing successfully and as expected.		
2.18.2.1	The payload must be fully retained until the intended point of deployment (if applicable), all retention mechanisms must function as designed, and the retention mechanism	Inspection & Demonstration	The payload will be retained securely until the RSO has given permission to deploy it. The retention system will not sustain damage requiring repair after	**Not Started**	The payload and vehicle have not yet flown.

	must not sustain damage requiring repair.		deployment.		
2.18.2.2	The payload flown must be the final, active version.	Inspection	The payload used will be its final version and the same flown during launch week.	**Not Started**	The payload has not yet flown.
2.18.2.3	If the above criteria are met during the original Vehicle Demonstration Flight, occurring prior to the FRR deadline and the information is included in the FRR package, the additional flight and FRR Addendum are not required.	Inspection	Documentation of the flight will be included on the FRR should all flights occur prior to then.	**Not Started**	Vehicle and payload have not yet flown.
2.18.2.4	Payload Demonstration Flights must be completed by the FRR Addendum deadline. NO EXTENSIONS WILL BE GRANTED.	Inspection	The payload demonstration flight will be planned to occur prior to the FRR addendum deadline.	**Not Started**	Payload has not yet flown.
2.19	An FRR Addendum will be required for any team completing a Payload Demonstration Flight or NASA required Vehicle Demonstration Re-flight after the submission of the FRR Report.	Inspection	The team will submit an FRR Addendum for any Payload Demonstration Flight or NASA required Vehicle Demonstration Re-flight after the submission of the FRR Report.	**Not Started**	The vehicle and payload have not yet flown. No Demonstrati o-n Flight or Re-flight is scheduled after the submission of the FRR Report at this time.

2.19.1	Teams required to complete a Vehicle Demonstration Re-Flight and failing to submit the FRR Addendum by the deadline will not be permitted to fly the vehicle at launch week.	Inspection	Should the Vehicle Demonstration Re-Flight not be completed prior to the FRR Addendum deadline, the team will not fly during launch week.	**Not Started**	Vehicle has not yet flown and should it be necessary, ther FRR Addendum will be turned in on time.
2.19.2	Teams who successfully complete a Vehicle Demonstration Flight but fail to qualify the payload by satisfactorily completing the Payload Demonstration Flight requirement will not be permitted to fly the payload at launch week.	Inspection	Should the payload not fly successfully during either the vehicle demonstration flight or payload demonstration flight, the payload will not fly during launch week.	**Not Started**	The payload has not yet flown.
2.19.3	Teams who complete a Payload Demonstration Flight which is not fully successful may petition the NASA RSO for permission to fly the payload at launch week. Permission will not be granted if the RSO or the Review Panel have any safety concerns.	Inspection	Should the Payload Demonstration Flight be not fully successful, the team will petition the NASA RSO for permission to fly the payload at launch week, and will abide by decisions made by the RSO or Review Panel.	**Not Started**	The vehicle and payload have not yet flown.
2.20	The team's name and launch day contact information shall be in or on the rocket airframe as well as in	Inspection	The teams contact information will present on the main airframe and payload. The	**Not Started**	Construction of the vehicle has not yet been started. Once it does,

	or on any section of the vehicle that separates during flight and is not tethered to the main airframe. This information shall be included in a manner that allows the information to be retrieved without the need to open or separate the vehicle.		payload is the only section of the vehicle that will be untethered to the main airframe.		the contact info will be verified to be on the specified sections.
2.21	All Lithium Polymer batteries will be sufficiently protected from impact with the ground and will be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other payload hardware.	Inspection & Demonstration	Lithium Polymer batteries will be handled and marked correctly as per safety requirements.	**Not Started**	The vehicle and payload have not yet flown.
2.22	Vehicle Prohibitions				
2.22.1	The launch vehicle will not utilize forward canards. Camera housings will be exempted, provided the team can show that the housing(s) causes minimal aerodynamic effect on the rocket's stability.	Inspection & Analysis	No forward canards will be present on the vehicle's body. ADAS produces protuberances, but behind the center of gravity in order to minimize effects on the vehicle's stability.	**Incomplete**	Preliminary design of the vehicle does not feature forward canards, however the vehicle has not been constructed to verify this requirement.
2.22.2	The launch vehicle will not utilize forward firing motors.	Inspection	The team will not utilize forward firing motors in design or	**Incomplete**	Preliminary vehicle design does not include

			construction.		motors of this type. The vehicle has not yet been constructed or flown.
2.22.3	The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.)	Inspection & Demonstration	The team will not utilize motors that expel titanium sponges in vehicle design or construction.	**Incomplete**	Preliminary vehicle design does not include motors of this type. The vehicle has not yet been constructed or flown.
2.22.4	The launch vehicle will not utilize hybrid motors.	Inspection & Demonstration	The team will not utilize hybrid motors in vehicle design or construction.	**Incomplete**	Preliminary vehicle design does not include motors of this type. The vehicle has not yet been constructed or flown.
2.22.5	The launch vehicle will not utilize a cluster of motors.	Inspection	The team will not utilize a cluster of motors in vehicle design or construction.	**Incomplete**	Preliminary vehicle design does not include motors of this type. The vehicle has not yet been constructed or flown.
2.22.6	The launch vehicle will not utilize friction fitting for motors.	Inspection	The vehicle will not use friction to secure the motor.	**Incomplete**	The vehicle has designed a system of bolts and plates to

					secure the motor. The vehicle has not yet been built or flown.
2.22.7	The launch vehicle will not exceed Mach 1 at any point during flight.	Demonstration & Analysis	The vehicle will not exceed Mach 1 at any point during flight.	**Incomplete**	The vehicle is currently designed not to exceed Mach 1, but the vehicle has not yet flown.
2.22.8	Vehicle ballast will not exceed 10% of the total unballasted weight of the rocket as it would sit on the pad (i.e. a rocket with an unballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast).	Inspection & Analysis	All ballast used during the vehicle's flights will be calculated to be a maximum of 10% of the vehicle's weight.	**Not Started**	The vehicle has not yet been built so a final weight or ballast weight has not been determined.
2.22.9	Transmissions from onboard transmitters will not exceed 250 mW of power (per transmitter).	Inspection & Analysis	All transmitters used within the rocket will not exceed 250 mW of power.	**Incomplete**	The vehicle has not yet been built, and transmitters to be used onboard have not yet been finalized.
2.22.10	Transmitters will not create excessive interference. Teams will utilize unique frequencies, handshake/passcode systems, or other	Inspection & Analysis	The team will use unique frequencies or other means to mitigate transmitter interference.	**Incomplete**	Preliminary design involves XBee radio transmitters, which automatically

	means to mitigate interference caused to or received from other teams				search for an open range of frequencies to communicate .
2.22.11	Excessive and/or dense metal will not be utilized in the construction of the vehicle. Use of lightweight metal will be permitted but limited to the amount necessary to ensure structural integrity of the airframe under the expected operating stresses.	Inspection & Analysis	The vehicle will not contain excessive material or dense metal. All materials will be chosen based on weight and strength and will be verified to satisfy this requirement.	Incomplete	Preliminary design of the vehicle does not feature any excessive and/or dense metal, however the vehicle has not yet been constructed.

Table 4.6.2 Vehicle Requirements Verification

Recovery System Requirements

#	Requirement Description	Method of Verification	Description of Verification	Status	Details
3.1	The launch vehicle will stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee, and a main parachute is deployed at a lower altitude. Tumble or streamer recovery from apogee to main parachute deployment is also permissible, provided that the kinetic energy during drogue stage descent is reasonable, as deemed by the RSO.	Inspection & Demonstratio n	The vehicle will utilize a dual deployment system using a drogue parachute at apogee and main at a lower altitude.	Incomplete	The preliminary design of the vehicle has been completed and is similar to previous year’s designs, however the vehicle has not yet been built or flown.

3.1.1	The main parachute shall be deployed no lower than 500 feet.	Demonstration & Analysis	The Jolly Logic's will be set to an altitude higher than 500 feet.	**Incomplete**	The system is designed to deploy at 500 feet, however the vehicle has not yet been built or flown.
3.1.2	The apogee event may contain a delay of no more than 2 seconds.	Demonstration & Analysis	The delay for the apogee event will be set to a time less than 2 seconds.	**Incomplete**	The system is designed with a delay of 2 sections, however the vehicle has yet been built or flown.
3.1.3	Motor ejection is not a permissible form of primary or secondary deployment.	Inspection	The team will not utilize motor ejection as primary or secondary deployment in design or construction of the vehicle.	**Incomplete**	The preliminary design of the vehicle recovery system does not utilize motor deployment, but the vehicle has not yet been constructed or flown.
3.2	Each team must perform a successful ground ejection test for both the drogue and main parachutes. This must be done prior to the initial subscale and full-scale launches.	Demonstration & Test	Prior to every launch, the team will conduct a ground deployment test to ensure the successful deployment of the parachutes.	**Not Started**	The vehicle has not yet undergone any ground deployment test.

3.3	Each independent section of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf at landing.	Analysis	Prior to any launch, the team will conduct simulation to ensure all sections of the launch vehicle will not exceed 75 ft-lbf of kinetic energy at landing.	**Not Started**	The vehicle has not yet undergone any testing or simulation.
3.4	The recovery system will contain redundant, commercially available altimeters. The term “altimeters” includes both simple altimeters and more sophisticated flight computers.	Inspection	The recovery system is designed to have two barometric altimeters from different manufacturers to ensure reliability and redundancy.	**Completed**	The chosen altimeters are the same from the previous years which have proved their reliability.
3.5	Each altimeter will have a dedicated power supply, and all recovery electronics will be powered by commercially available batteries.	Inspection	The current design features multiple COTS 9V batteries for each altimeter. This is a similar design to previous years.	**Incomplete**	Design of the system is complete, however the vehicle has not yet been built.
3.6	Each altimeter will be armed by a dedicated mechanical arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.	Inspection & Demonstration	A screw switch, accessible from the exterior of the vehicle, will be present for each altimeter.	**Incomplete**	Design of the system is complete, however the vehicles has not yet been flown.
3.7	Each arming switch will be capable of being locked in the ON position for launch	Demonstration & Test	A screw switch present for each altimeter, has been flight tested and	**Incomplete**	Design of the system is complete, however the

	(i.e. cannot be disarmed due to flight forces).		proven to not be disarmed due to flight forces. The switch is also oriented in such a way that flight forces will not disarm it.		vehicles has not yet been flown.
3.8	The recovery system electrical circuits will be completely independent of any payload electrical circuits.	Inspection	The team will design and construct the recovery system to be independent of any payload electrical circuits.	**In Progress**	The preliminary design of the recovery system circuits is separate from any payload electrical circuits.
3.9	Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.	Inspection	The team will use removable shear pins in the design and construction of the main parachute compartment and drogue parachute compartment.	**Incomplete**	The preliminary design of the recovery system includes shear pins for the main and drogue parachute compartmen t-s, but the vehicle has not yet been constructed or flown.
3.10	The recovery area will be limited to a 2,500 ft. radius from the launch pads.	Demonstratio n & Analysis	Drift calculations will be completed along with simulation results to verify this requirement.	**Incomplete**	The vehicle has not yet been flown, however simulations have verified this

					requirement.
3.11	Descent time will be limited to 90 seconds (apogee to touch down).	Demonstration & Analysis	The descent time of the vehicle will be verified through simulations and post-flight analysis to not excess 90 sections.	**Incomplete**	The vehicle has not yet been flown, however simulations have verified this requirement.
3.12	An electronic tracking device will be installed in the launch vehicle and will transmit the position of the tethered vehicle or any independent section to a ground receiver.	Inspection	A tracking device will present on all independent section of the vehicle to ensure they are not lost.	**Incomplete**	The preliminary design of the vehicle has been completed, but the vehicle has not yet been built.
3.12.1	Any rocket section or payload component, which lands untethered to the launch vehicle, will contain an active electronic tracking device.	Inspection	The team will include an active electronic tracking device for any component jettisoned during recovery.	**Not Started**	The vehicle and payload components have not yet been constructed.
3.12.2	The electronic tracking device(s) will be fully functional during the official flight on launch day.	Inspection & Demonstration	The team will ensure that all required electronic tracking devices are fully functional prior to the official flight on launch day	**Not Started**	The competition has not yet started.
3.13	The recovery system electronics will not be adversely affected by any other on-board electronic devices	Demonstration & Test	The recovery system will be shielded from any other on-board electronic devices	**Incomplete**	Design of the vehicle's electronics is complete and believed

	during flight (from launch until landing).		during launch. This will be verified through tests and flights.		to satisfy this requirement but flights and tests will verify this.
3.13.1	The recovery system altimeters will be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device.	Inspection	The recovery electronics have been designed to be in their own, enclosed container, isolated from any other electronics.	**Incomplete**	Design of the vehicle has been completed, however the vehicle has not yet been flown.
3.13.2	The recovery system electronics will be shielded from all onboard transmitting devices to avoid inadvertent excitation of the recovery system electronics.	Inspection	The recovery system will be shielded from any other on-board electronic devices during launch. This will be verified through tests and flights.	**Incomplete**	Design of the vehicle's electronics is complete and believed to satisfy this requirement but flights and tests will verify this.
3.13.3	The recovery system electronics will be shielded from all onboard devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system.	Inspection	The recovery system will be shielded from any other on-board electronic devices during launch. This will be verified through tests and flights.	**Incomplete**	Design of the vehicle's electronics is complete and believed to satisfy this requirement but flights and tests will verify this.
3.13.4	The recovery system electronics will be shielded from any other onboard devices which may adversely	Inspection	The recovery system will be shielded from any other on-board electronic devices	**Incomplete**	Design of the vehicle's electronics is complete and believed

	affect the proper operation of the recovery system electronics.		during launch. This will be verified through tests and flights.		to satisfy this requirement but flights and tests will verify this.

Table 4.6.3 Recovery System Requirement Verification

Payload Experiment Requirements

#	Requirement Description	Method of Verification	Description of Verification	Status	Details
4.1	High School/Middle School Division – Teams may design their own science or engineering experiment or may choose to complete the College/University Division mission. Data from the science or engineering experiment will be collected, analyzed, and reported by the team following the scientific method.	N/A	This requirement does not apply to us as a college team.	N/A	This requirement does not apply to us as a college team.
4.2	College/University Division – Teams will design a system capable of being launched in a high power rocket, landing safely, and recovering simulated lunar ice from one of several locations on the surface of the launch field. The method(s)/design(s) utilized will be at the teams' discretion and	Inspection, Demonstratio n & Test	The team will design a payload to be housed securely in the rocket, to be deployed safely, and to be capable of conducting the required lunar ice sample collection. No additional experiments will be flown.	**In Progress**	Initial design of the payload and its integration into the rocket are described in Section 4.5.

	will be permitted so long as the designs are deemed safe, obey FAA and legal requirements, and adhere to the intent of the challenge. An additional experiment (limit of 1) is allowed, and may be flown, but will not contribute to scoring. If the team chooses to fly an additional experiment, they will provide the appropriate documentation in all design reports so the experiment may be reviewed for flight safety.				
4.3	Lunar Ice Sample Recovery Mission Requirements				
4.3.1	The launch vehicle will be launched from the NASA-designated launch area using the provided Launch pad. All hardware utilized at the recovery site must launch on or within the launch vehicle.	Inspection & Demonstration	The team will launch the vehicle containing all hardware required for the project from the designated launch area.	**Incomplete**	The team's initial design of the vehicle contains all hardware used in the project within the rocket. Other requirements have not yet been fulfilled due to the competition not yet starting.
4.3.2	Five recovery areas	Demonstratio	The team will	**Not Started**	Work towards

	will be located on the surface of the launch field. Teams may recover a sample from any of the recovery areas. Each recovery site will be at least 3 feet in diameter and contain sample material extending from ground level to at least 2 inches below the surface.	n	design a payload capable of navigating to one of the lunar ice recovery sites to collect an ice sample.		completion of this requirement has not begun due to the competition not yet starting.
4.3.3	The recovered ice sample will be a minimum of 10 milliliters (mL).	Inspection	The sample collection mechanism of the payload will be able to store a minimum of 10 mL	**In Progress**	Preliminary design of the payload includes a soil collection mechanism that can hold 10 mL of soil.
4.3.4	Once the sample is recovered, it must be stored and transported at least 10 linear feet from the recovery area.	Inspection	The payload will secure the soil sample and travel a minimum of 10 linear feet from the recovery area.	**Not Started**	Work towards completion of this requirement has not begun due to the competition not yet starting.
4.3.5	Teams must abide by all FAA and NAR rules and regulations.	Demonstration	The Safety Officer and team members are responsible for respecting and following FAA and NAR rules and regulations.	**Not Started**	Work towards completion of this requirement has not begun due to vehicle implementation and testing not yet starting.
4.3.6	Black Powder and/or	Inspection &	The payload will	**In Progress**	The

	similar energetics are only permitted for deployment of in-flight recovery systems. Any ground deployments must utilize mechanical systems.	Demonstration	deploy during descent, allowing for the usage of Black Powder charges in deployment.		preliminary design of the payload's deployment mechanism adheres to this requirement.
4.3.7	Any part of the payload or vehicle that is designed to be deployed, whether on the ground or in the air, must be fully retained until it is deployed as designed.	Inspection & Demonstration	The payload will be retained securely inside the vehicle until after the signal to deploy is sent.	**In Progress**	The preliminary design of the payload's housing mechanism adheres to this requirement.
4.3.7.1	A mechanical retention system will be designed to prohibit premature deployment.	Inspection & Test	The payload will be retained within its housing with both a mount and a tether.	**In Progress**	The preliminary design of the payload's housing mechanism includes a retention system that adheres to this requirement.
4.3.7.2	The retention system will be robust enough to successfully endure flight forces experienced during both typical and atypical flights.	Demonstration & Test	The housing retention system will be tested with simulated typical and atypical flight forces.	**Incomplete**	Under the preliminary design and without specifications on the retention system, analysis on the strength of the system cannot be conducted.
4.3.7.3	The designed system will be fail-safe.	Test	The integrity of the payload housing and	**Incomplete**	Integrity of the payload and its surrounding

			deployment will be tested through ground tests and full-scale launch tests.		systems cannot be tested or analyzed without a complete design.
4.3.7.4	Exclusive use of shear pins will not meet this requirement.	Inspection	The team will not exclusively use shear pins to retain the payload.	**In Progress**	The preliminary design of the payload avoids exclusive or excessive use of shear pins in its housing.
4.4	Special Requirements for UAVs and Jettisoned Payloads				
4.4.1	Any experiment element that is jettisoned during the recovery phase will receive real-time RSO permission prior to initiating the jettison event.	Demonstration	The jettison event will only be initiated after real-time RSO permission.	**Not Started**	Work towards completion of this requirement has not begun due to launch testing of the vehicle and payload not yet starting.
4.4.2	Unmanned aerial vehicle (UAV) payloads, if designed to be deployed during descent, will be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given permission to release the UAV.	Demonstration	The payload housing will include a tether which will connect the payload to the vehicle until the RSO has given permission to release the UAV	**In Progress**	The housing retention system includes a tether which may be used to fulfill this requirement.
4.4.3	Teams flying UAVs will	Demonstratio	The team will	**Not Started**	Work towards

	abide by all applicable FAA regulations, including the FAA's Special Rule for Model Aircraft (Public Law 112-95 Section 336; see https://www.faa.gov/uas/faqs).	n	abide by all applicable FAA regulations during the launch mission and testing		completion of this requirement has not begun due to launch testing of the vehicle and payload not yet starting.
4.4.4	Any UAV weighing more than .55 lbs. will be registered with the FAA and the registration number marked on the vehicle.	Inspection	Since the estimated weight of the team's UAV is 5 lbs., it will be registered with the FAA and the registration number will be marked on the vehicle	**Not Started**	Work towards completion of this requirement has not begun due to the UAV not being fully developed.

Table 4.6.4 Payload Experiment Requirement Verifications

Safety Requirements

#	Requirement Description	Method of Verification	Description of Verification	Status	Details
5.1	Each team will use a launch and safety checklist. The final checklists will be included in the FRR report and used during the Launch Readiness Review (LRR) and any launch day operations.	Inspection & Demonstration	Final checklists will be included in the FRR and demonstrated to Range Safety Officers or other safety officials if/when required. The team will adhere to launch and safety checklists during the LRR and launch day operations.	**Not Started**	This year's rocket is in the early stages of design; as such, a launch and safety checklist has not yet been drafted.

5.2	Each team must identify a student safety officer who will be responsible for all items in section 5.3.	Inspection	Brandon Erickson has been identified as the team's Safety Officer.	**Complete**	Brandon Erickson is the team's Safety Officer. If the Safety Officer cannot fulfill their duties due to any unforeseen circumstances , an immediate replacement will be made.
5.3	The role and responsibilities of the safety officer will include, but are not limited to:				
5.3.1	Monitor team activities with an emphasis on safety during:				
5.3.1.1	Design of vehicle and payload	Inspection	The Safety Officer will monitor vehicle and payload design, ensuring that design accounts for safety hazards.	**In progress**	The team Safety Officer will monitor team activities throughout the ongoing design process.
5.3.1.2	Construction of vehicle and payload components	Inspection	The Safety Officer will monitor vehicle and payload construction, ensuring that personnel understand and follow safety conduct in their lab space or	**In progress**	The team Safety Officer will monitor team activities throughout the construction process and ensure that students involved

			workspace.		complete required safety training.
5.3.1.3	Assembly of vehicle and payload	Inspection	The Safety Officer will monitor vehicle and payload assembly, ensuring that personnel understand and follow safety conduct in their lab space or workspace.	**In progress**	The team Safety Officer will monitor team activities throughout the assembly process and ensure that students involved complete required safety training.
5.3.1.4	Ground testing of vehicle and payload	Inspection & Demonstration	The Safety Officer will monitor vehicle and payload ground testing, ensuring that the team follows safety protocol appropriate for ground tests.	**Incomplete**	Prior to ground testing being conducted, the Safety Officer and/or other safety officials will establish protocol specific to the test which the Safety Officer will enforce.
5.3.1.5	Subscale launch test(s)	Inspection	The Safety Officer will monitor subscale launch test(s) and cooperate with Range Safety Officers (RSOs) to establish and enforce protocol that ensures	**Incomplete**	The Safety Officer will consult with the RSO and create safety checklists to establish and monitor safety protocol for all launches

			team safety, minimizes environmental impact, and protects any materials involved in the launch.		
5.3.1.6	Full-scale launch test(s)	Inspection	The Safety Officer will monitor full-scale launch test(s) and cooperate with RSOs to establish and enforce protocol that ensures team safety, minimizes environmental impact, and protects any materials involved in the launch.	**Incomplete**	The Safety Officer will consult with the RSO and create safety checklists to establish and monitor safety protocol for all launches
5.3.1.7	Launch day	Inspection	The Safety Officer will monitor the launching of the rocket during launch day and cooperate with RSOs and other safety officials to establish and enforce protocol that ensures team safety, minimizes environmental impact, and protects any materials	**Incomplete**	The Safety Officer will consult with the RSO and create safety checklists to establish and monitor safety protocol for all launches

			involved in the launch.		
5.3.1.8	Recovery activities	Inspection	The Safety Officer will monitor all recovery activities and ensure that safety protocol is understood and followed during such activities.	**Incomplete**	The Safety Officer will attend and enforce safety regulations for recovery activities, ensuring that personnel involved are appropriately trained.
5.3.1.9	STEM Engagement Activities	Inspection	The Safety Officer will monitor any activities requiring the implementation and enforcement of safety protocol.	**Incomplete**	Future outreach activities will be monitored by the Safety Officer to ensure the safety of all parties involved
5.3.2	Implement procedures developed by the team for construction, assembly, launch, and recovery activities.	Inspection	Procedures for construction, assembly, launch, and recovery activities will be implemented and enforced by the team and Safety Officer.	**Incomplete**	Procedures are in the process of official implementation, and will be applied to all team activities.
5.3.3	Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical	Inspection	Current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical	**In progress**	The Safety Officer is currently involved in the development of documentation

	inventory data.		inventory data are shared with team leadership.		n regarding hazard analyses, failure modes analyses, and procedures.
5.3.4	Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.	Inspection	The Safety Officer's involvement in maintaining hazard/failure mode analysis and procedures will be verified through edit history, etc.	**In progress**	The Safety Officer is currently involved in the development of documentatio n regarding hazard analyses, failure modes analyses, and procedures.
5.4	During test flights, teams will abide by the rules and guidance of the local rocketry club's RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch does not give explicit or implicit authority for teams to fly those vehicle configurations and/or payloads at other club launches. Teams should communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.	Inspection	RSOs will verify the team's abidance of their respective rules and guidance, as well as communication of the team's planned attendance of any NAR or TRA launch.	**In progress**	Prior to any launch testing, the team's Administrativ e Lead will communicate intention to launch to the local club's President or Prefect and RSO. The Safety Officer will communicate and enforce any rules or guidance established by the RSO.
5.5	Teams will abide by all	Inspection	The Safety	**In progress**	The Safety

	rules set forth by the FAA.		Officer will ensure that the team understands and follows all rules set forth by the FAA.		Officer will assist the team in conducting procedures that adhere to any rules set forth by the FAA.

Table 4.6.5 Safety Requirement Verification

4.6.2 Team Derived Requirements

In addition to the requirements listed in Tables 4.6.1 to 4.6.5, the team has created its own requirements to be met throughout project completion. They may be categorized as follows:

1. General Requirements
2. Vehicle Requirements
3. Recovery Requirements
4. Payload Requirements
5. ADAS Requirements
6. Safety Requirements

Table 4.6.6 to Table 4.6.11 describe these requirements in detail and how the team will verify they have been met, applying the previously described methods of verification.

Team Derived General Requirements

#	Requirement Description	Method of Verification	Description of Verification
1.1	The team will arrange a regular time to hold general team meetings and board meetings.	Inspection/ Demonstration	Rooms and hardware will be reserved every Friday and announcements will be made for the meeting.
1.2	Slack will be used for all intra-team communication.	Inspection/ Demonstration	All members will be added onto the Team Slack and is assisted with joining channels or anything else needed.
1.3	All code will be uploaded to a team GitHub.	Inspection/ Demonstration	The members interested in contributing code will be given

			access team or subteam GitHub repositories.
1.4	Any documents relative to the team will posted for all on the Team Google Drive.	Inspection/ Demonstration	All members will be added to the team Google Drive.

Table 4.6.6 Team Derived General Requirements

Team Derived Vehicle Requirements

#	Requirement Description	Method of Verification	Description of Verification
2.1	Vehicle will feature an adaptive air-braking system (ADAS).	Inspection	ADAS will be inspected and tested for functionality.
2.2	ADAS will regulate drag with the help of two retractable fins.	Inspection	ADAS fins will be inspected to fit inside the launch vehicle frame and to have a minimum and maximum protrusion that allows for adequate drag control during flight.
2.3	The ADAS fins will be able to withstand the maximum forces during flight.	Analysis	The team will perform visual and structural inspections of the ADAS component after launch tests.
2.4	ADAS will deploy the fins to the correct range.	Demonstration	The team will inspect the position of fin deployment with optical sensor feedback.
2.5	ADAS will stop the rocket to an apogee within 50 feet of the target.	Demonstration	The team will apply cross verification of onboard altimeter sensors to verify we reached an actual apogee within 50 feet of the target.
2.6	ADAS will have an accurate flight curve profile.	Inspection	The team will compare calculated flight envelope for none and maximum ADAS deployment to physical launch

			results.
2.7	ADAS will follow the flight curve within an error margin of 15%.	Demonstration	The team will record sensor metric data and calculate deviation.
2.8	ADAS will adjust itself at a frequency of 20Hz.	Inspection	The team will set time measurement between beginning of algorithm calculation and motor movement signal.
2.9	The airframe of the rocket must be hand-wound carbon fiber and made to specifications required from the subteams. The carbon fiber itself must have enough structural integrity to not bend or break from any forces during flight.	Inspection & Demonstration	The team will utilize hand-wound carbon fiber with sufficient structural integrity to withstand flight forces in the construction of the rocket's airframe.

Table 4.6.7 Team Derived Vehicle Requirements

Team Derived Recovery Requirements

#	Requirement Description	Method of Verification	Description of Verification
3.1	Packed parachute size of less than 5.5 in.	Inspection	Inspect the packaging of the purchased parachutes
3.2	Landing energy less than 70 lbs.	Analysis, Test	Analyze using mathematical calculations and sensor information recorded during launch tests
3.3	Motor that gets the	Inspection,	View the details of the motor

	apogee 10% above a mile	Analysis, Test	being purchased, and test to verify
3.4	Data recording capabilities are less than 20 Hz	Inspection	Verify with the product details
3.5	Data storage is more than 2GB minutes	Inspection	Verify with the product details

Table 4.6.8 Team Derived Recovery Requirements

Team Derived Payload Requirements

#	Requirement Description	Method of Verification	Description of Verification
4.1	Payload will be deployed/jettisoned during descent of the rocket, after permission to deploy is given by the Range Safety Officer (RSO).	Inspection, Demonstration	The team will design the deployment mechanism to be activated during descent, with real-time activation authorized by the RSO.
4.2	Payload deployment circuit will be located in the nosecone of the rocket.	Inspection	The team will house the wireless transmitter and deployment circuit inside the nose cone in design, construction, and assembly of the rocket
4.3	Black powder charge will eject the payload and nose cone sections, allowing the payload to exit.	Test	The team will conduct ground testing to ensure that the nose cone can be removed by the powder charge.
4.4	Payload will be durable enough to withstand the flight and ejection.	Test	The team will ground test the ejection, checking that no damage to the rover occured.
4.5	Drone will fit inside the 5.82” inner diameter rocket	Analysis, Inspection	Analysis: before building the rover, CAD analysis will be done to ensure the drone will fit inside the rocket

			Inspection: The drone will be measured and inserted inside the rocket to ensure it fits.
4.6	Drone will be able to reliably navigate to the recovery site and at least 10 linear feet from the recovery site after obtaining the lunar ice sample.	Test	The team will test the navigation capabilities of the UAV through ground testing.
4.7	Drone will be able to reliably pick up and seal over 10 mL of dirt of different types and moisture levels.	Test	The team will test soil collection method on different soil types (hard and soft, wet and dry). Ensure soil collection method design can penetrate even hard clay.
4.8	Drone soil container will be able to retain at least 10mL of soil.	Demonstration	The selected or designed container will have a volume large enough to contain a minimum of 10mL of soil.

Table 4.6.9 Team Derived Payload Requirements

Team Derived ADAS Requirements

#	Requirement Description	Method of Verification	Description of Verification
5.1	ADAS will stop the rocket to an apogee within 50 feet of the target.	Demonstration	Cross verification of onboard altimeter sensors to verify we reached an actual apogee within 50 of the target.
5.2	ADAS will deploy the fins to the correct range.	Demonstration	Optical sensor feedback look reading position of fin deployment.
5.3	ADAS will adjust itself at a frequency of 20Hz.	Inspection	Set time measurement between beginning of algorithm calculation and motor movement signal.

5.4	ADAS will have an accurate flight curve profile.	Analysis	Calculate flight envelope for none and maximum ADAS deployment and compare to physical launch.
5.5	ADAS will follow the flight curve within an error margin of 15%.	Analysis	Record sensor metric data and calculate deviation.

Table 4.6.10 Team Derived ADAS Requirements

Team Derived Safety Requirements

#	Requirement Description	Method of Verification	Description of Verification
6.1	All team members must take required safety training from UC Santa Cruz to gain permission to enter and use lab equipment, and must sign the Safety Acknowledgement Form before being allowed entrance or privileges	Demonstration	The Safety Officer will maintain a list of students who have completed the trainings and signed all needed forms.
6.2	Personnel will wear appropriate attire and PPE when in lab and work spaces.	Inspection	All members will be responsible for ensuring a safe work environment by wearing and reminding others to wear appropriate PPE.
6.3	Hazardous chemicals will be stored and handled with proper technique and rules as laid out in training.	Inspection	The Safety Officer and team members will ensure that materials are used appropriately, and the team mentor will handle pyrotechnic and explosive devices for the team at launch sites.
6.4	Material safety data sheets will be reviewed before use of said chemicals.	Demonstration	Personnel will show their trained ability to the Safety Officer prior to independent work. MSDS and electronic components are available on the team website and online.

6.5	Launches will involve cross-checking and referencing between the Safety Officer and involved personnel.	Demonstration	The Safety Officer will coordinate with numerous team personnel at launch events and facilitate a safe area for bystanders.
6.5.1	All e-matches and igniters will be tested, with the mentor and other critical personnel, for continuity prior to installation, and the failed components will not be used.	Test	Necessary testing equipment will be brought by the team for system testing at all levels of the launches, including recovery devices.
6.5.2	Parachutes and other delicate installation materials will be handled by the proper sub-team personnel with oversight by the Safety Officer.	Analysis	The recovery sub-team will ensure the proper parachute folding will be performed, and other sub-teams will inspect for their own issues. The Safety Officer ultimately determines if some part of the vehicle is unfit for flight.
6.5.3	Multiple team personnel will ensure the systems and checklists are in agreement with proper procedures for launching.	Demonstration	A collaborative setup will occur at launch sites such that sub-team leads discuss any concerns with the Safety Officer throughout the events to ensure complete safety.
6.6	Misconduct and violations of the safety manual will be dealt with by the Safety Officer.	Demonstration	It is expected of all personnel to report incidents involving unsafe actions, and of the Safety Officer to patrol the workspaces as needed. Personnel caught in unsafe behavior will be reprimanded appropriately.
6.7	Injured personnel must notify emergency services or the Safety Officer as conveniently needed.	Demonstration	The Safety Officer will be listed as an emergency contact, and all personnel are expected to know nearby showers, and of course to call 911.
6.8	Wireless circuit components responsible for detonating black powder charges must require	Demonstration & Test	The Safety Officer will collaborate with team members responsible for the payload

	multiple sent signals or user inputs to activate to prevent accidental or premature detonation.		deployment design to develop preventative measures against unintended detonation.

Table 4.6.11 Team Derived Safety Requirement Verification

4.7 Major Technical Challenges and Solutions

4.7.1 Adaptive Aerobraking System (ADAS)

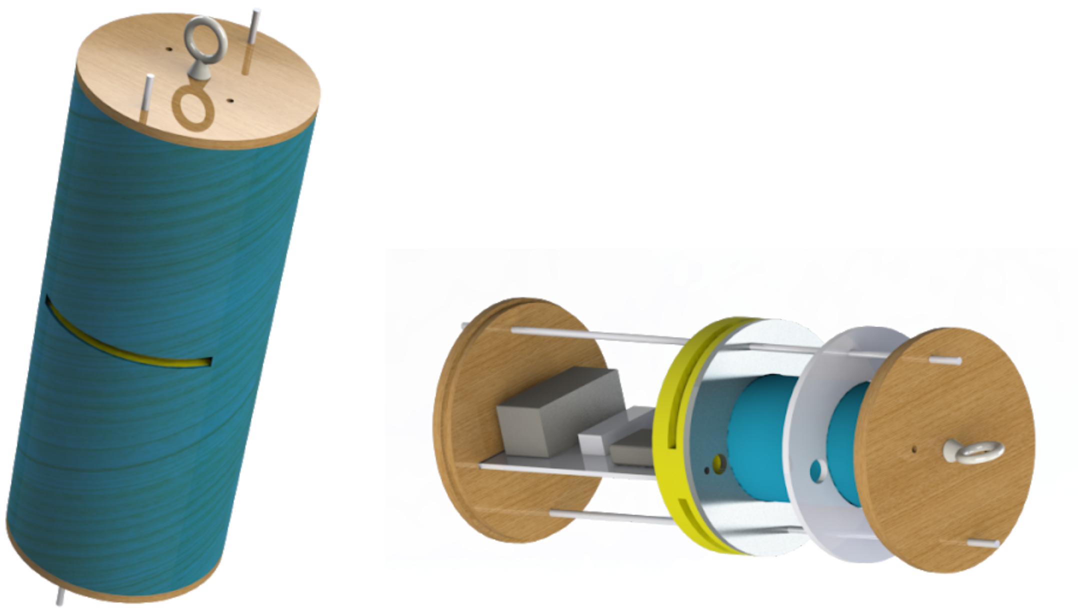


Figure 4.7.1 ADAS Bay

The Adaptive Aerobraking System (ADAS) is a fully autonomous system with the sole purpose of intelligently controlling drag force on our rocket. It was developed with the intention of reaching our target apogee of 4000 feet with arbitrary precision. Altitude control will be accomplished through passive drag adjustment using our 2 adjustable fins. What the component controls is force and does so by acting on the rocket in the form of drag. Since the fins and therefore drag is adjustable, this will give us flight envelope of our rocket with max apogee from fully retracted fins to minimum apogee from maximum deployment.The system uses a central gear to rotate two semi-circular aerobraking fins from inside the vehicle to increase drag. When this system is implemented with the proper PID control algorithm, it will make corrections to the vehicle's trajectory mid-flight.

The fins will only be activated after detection of MECO through multiple onboard sensors including a gyroscope, accelerometer, timing system, and barometric altimeter. By ensuring deployment after active propulsion, all forces on the rocket will be deceleration in the form of drag, and no intentional change in trajectory will occur during powered flight. This mitigates the risk of a targeting projectile.

Extensive research and work has gone into the control theory of ADAS over the previous year's work. ADAS has not been successfully flown due to various reasons, however the general design of the component will follow previously tried and true methods. To ensure a robust system with high chances of success, the team will focus on the following design principles:

1. Modularity of the system through the compartmentalization of specific tasks (e.g. separate units and team members will be responsible for single tasks such as drivetrain, algorithm, sensors, etc…)
2. Simplification of design focused on building an autonomous system to control drag force according to an algorithm, no more no less
3. Standardized requirements and restraints in compliance with the rest of the team

The CAD model of the fin assembly is presented in the following figure as well as a design schematic of the previous years component.

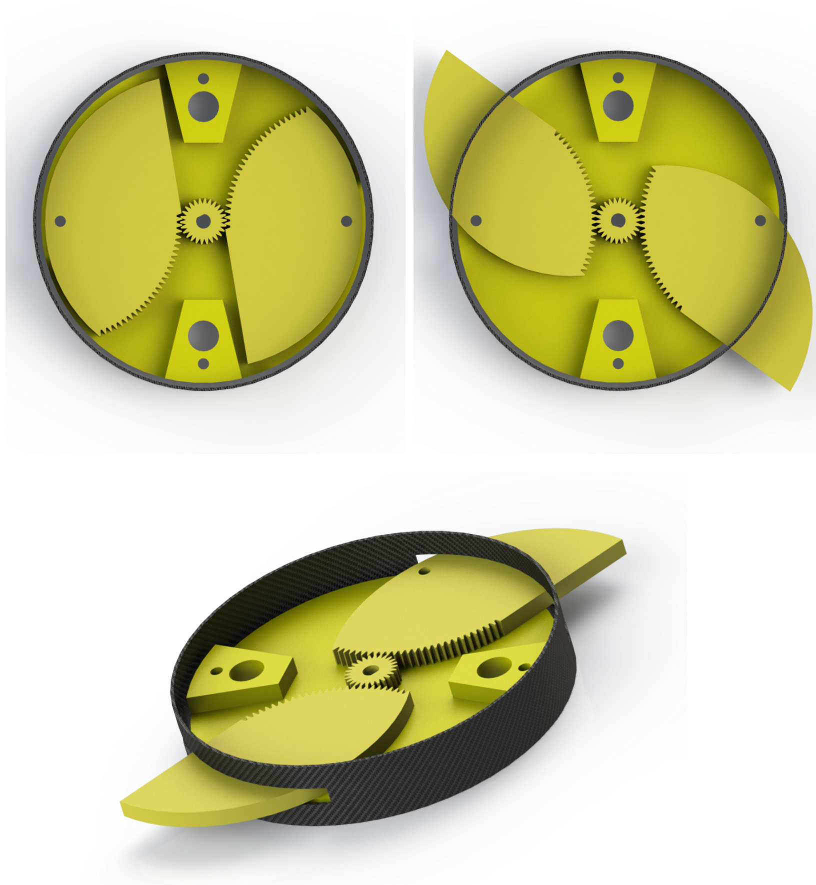


Figure 4.7.2 Fin Assembly

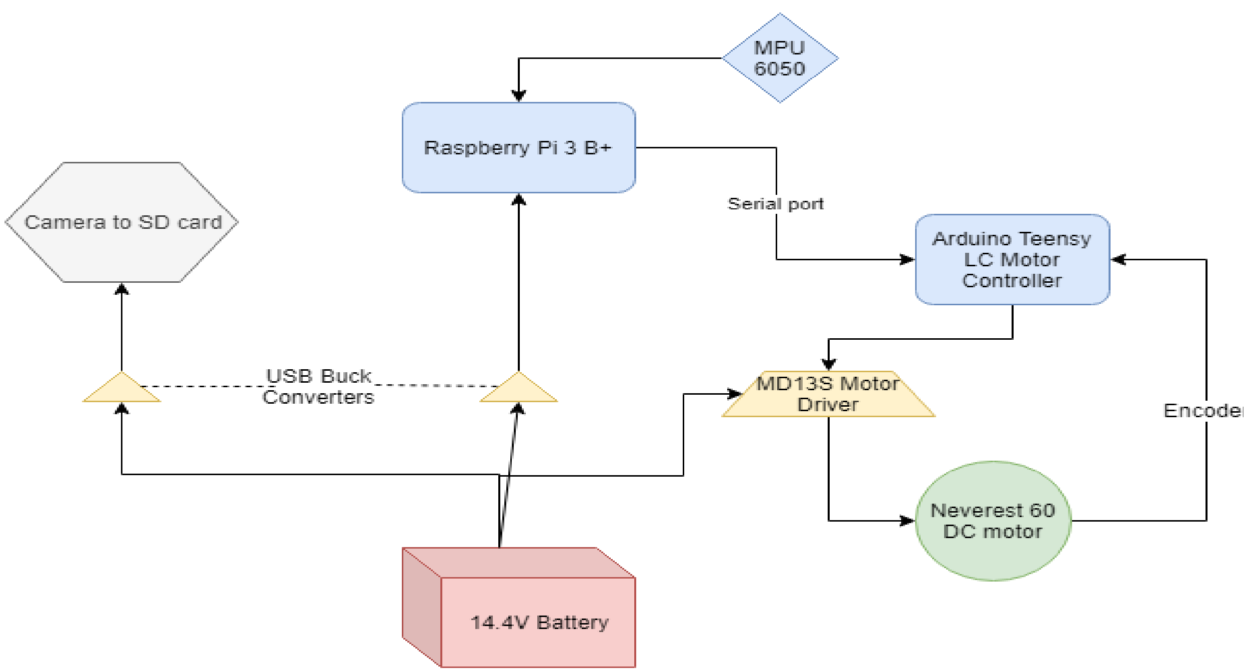


Figure 4.7.3 2018-2019 ADAS design

Learning from last years challenges the current design attempted to adhere to the 3 main goals previously outlined.

Pros

1. Centering all computations on Raspberry Pi allowed access to a full OS and simpler development by individual team members
2. Isolating power to individual components aided in the protection of more expensive hardware
3. Having dedicated hardware and defining clear separation between functionalities for specific tasks made development simpler

In retrospect of the previous system following design changes will help to ensure a more reliable ADAS system

Improvements

1. Tighter integration of drivetrain and simplification of overall deployment mechanism
2. Clear and short list of defined system characteristics needed by component
3. Modularized code base with sample test input harness
4. Minimal hardware use while maintaining redundancy

This years design will build off of previous designs to build a system that can achieve the goal set before it. In moments of uncertainty the subteam will work together to develop a plan to address concerns, and will contact the previous year's team if needed.

5 Education and Community Engagement

5.1 Past

Last year the team hosted 15+ outreach events in the local community with a total outreach of over 200 kids and community members.

The team's outreach events consisted of a brief introductory lecture style lesson on rockets and then a hands on component in which the students made their own paper rockets and launched them using a modified bike pump launcher.

The team primarily held outreach events at Monarch Elementary School where almost every week the team would work a new group of students. The students were all very interested and inspired seeing the team's rockets, a team member's LEGO Saturn V rocket, and seeing their own rocket soar into the sky.

Figure 5.1.1 Student's rockets next to the Rocket Team's rocket

Figure 5.1.2 Students watching their rockets launch and students holding their rockets.

5.2 Planned

In order to promote STEM education and contribute to the further inspiration of the developing youth in Santa Cruz, the Rocket Team at UCSC will continue to host numerous educational engagement activities target at a broad range of students. The team has already developed strong relationships with local schools and a local Girl Scout troop. The team plans for outreach events at Branciforte Small Schools, the Central Coast YMCA, the local chapter of the Boys and Girls Club, and a local Girl Scouts troop.

Currently the team offers a fun and engaging activity for all ages. The activity starts with a presentation that introduces rockets and rocket science. The team asks many questions and makes sure that the children are following along. Then the team assist the students with constructing and launching their very own paper rockets. These paper rockets are launched using compressed air (usually from a bike pump) and can reach heights of a few hundred feet. This activity helps to inspire students to look into STEM opportunities and to just have fun.

Following experiences from previous years' outreach events, the team hopes to expand both the activities that are done, and the amount of kids and community members the team engages with.

5.3 Social Media Presence

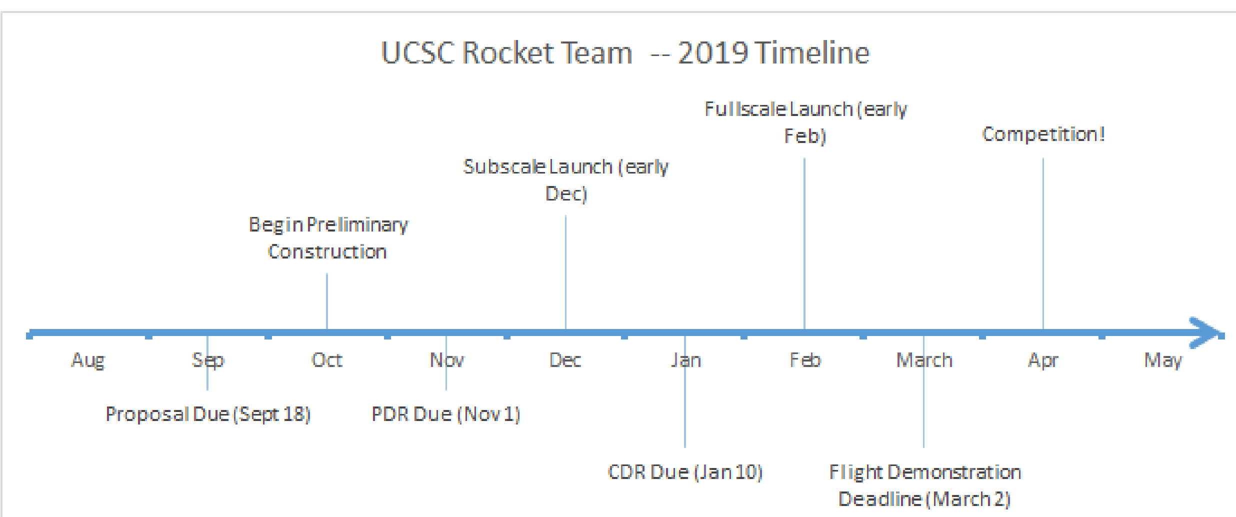
Last year, the team had great success using both Instagram and Facebook to announce meetings, special events, updates on what the team us doing, and team member spotlights. This year the team hopes to continue this strong social media presence by continuing what was done before and adding new, fun posts to keep those interested aware of the team is doing. The team also hopes that through a strong social media presence more people will be willing to join the team or even donate to keep it going. The team aims to post a minimum of once a week once the school year starts. These posts include progress pictures of the rockets, information on our team and SLI, photos and plans of outreach events, and team member spotlights.

6 Project Plan

6.1 Timeline

During the completion year, the team will require each subteam to keep an updated timeline of all activities in order to keep true to all deadlines. The finance lead is in charge of maintaining a general timeline, as well as communicating with subteams for their timelines. In the past, the team has had poor quality timelines which has lead to many last minute changes and work. This year the team hopes to prevent this through keeping the subteams to a higher standard when it comes to timelines and plans.

6.1.1 Build Schedule



6.2 Project Budget

For this year's budget, the Rocket Team at UCSC has allocated $3,000 to be used for the entirety of the NASA SLI competition (not including travel). In the event that the project goes over budget, the team can allocate additional funding as needed (up to $2,000). The team will attempt to avoid this scenario by requiring members to submit trade studies and go through multiple design phases before items are requested. Each item requested (within reason) will have to be approved by the finance officer and discussion regarding the necessity of a purchase will be had before approval is granted.

6.2.1 Planned Expenditures

This budget has not yet been finalized and is subject to change. Some items are not listed, and generalizations are made based on current observations and past experiences.

6.2.1.1 Project Expenses

Airframe				Comments			
Total Expenses:			$464.53	A large portion of the carbon fiber needed is either donated or already owned.			
Item	**Part Number / Link**	**Vendor**	**Quantity**	**Price per Unit**	**Shipping**	**Tax**	**Total Cost**
Blue Tube Coupler		Apogee	2	71.64	0	0	$143.28
Epoxy		ACE	3	20	0	0	$60
General Epoxy		ACE	4	6	0	0	$24
Nose cone		Apogee	1	113.03	0	0	$113.03
Fiberglass Sheets		Apogee	2 sqft	28.08/sqft	0	0	$56.16
Motor tube		Apogee	1	68.06	0	0	$68.06

Recovery				Comments
Total Expenses:			$126.35	Many items required for this year's competition have already been purchased over previous years.

Item	Part Number / Link	Vendor	Quantity	Price per Unit	Shipping	Tax	Total Cost
Blue Tube Coupler		Apogee	1	21.35	0	0	$21.35
End cap material		ACE	1 sqft	10/sqft	0	0	$10
9V Batteries		Amazon	16	10 per 8	0	0	$20
Miscellaneous							$75

Payload

Total Expenses: $278.7

Comments

Some items have not yet been finalized so a general price will be given to account for this. This includes the body material and miscellaneous items.

Item	Part Number / Link	Vendor	Quantity	Price per Unit	Shipping	Tax	Total Cost
Motor	Emax RS1106	GetFPV	4	12.99	0	0	$51.96
ESC	Lumenier 30a	GetFPV	4	12.99	0	0	$51.96
Video Transmitter	Unify pro32	GetFPV	1	29.95	0	0	$29.95
Camera	TBS tiny camera	Team Blacksheep	1	17.95	0	0	$17.95
Propeller		GetFPV	1	1.89	0	0	$1.89
Flight Controller	Lumenier lux v2	GetFPV	1	24.99	0	0	$24.99
Miscellaneous							$100

ADAS

Total Expenses: $81.35

Comments

Many items required for this year's competition have already been purchased over previous years.

Item	Part Number / Link	Vendor	Quantity	Price per Unit	Shipping	Tax	Total Cost
Blue Tube Coupler		Apogee	1	21.35	0	0	$21.35
End cap material		ACE	1 sqft	10/sqft	0	0	$10
Miscellaneous							$50

Outreach				Comments			
Total Expenses:			$200	Items listed are those necessary for planned outreach events. New events may require items not listed and are accounted for in miscellaneous items.			
Item	**Part Number / Link**	**Vendor**	**Quantity**	**Price per Unit**	**Shipping**	**Tax**	**Total Cost**
Printer paper		Bay Tree	4	5	0	0	$20
PVC Pipe		ACE	10ft	2/ft	0	0	$20
Masking Tape		ACE	20	3	0	0	$60
Miscellaneous							$100

Other Costs				Comments			
Total Expenses:			$850	Other costs include items that are not directly involved with individual subteams.			
Item	**Part Number / Link**	**Vendor**	**Quantity**	**Price per Unit**	**Shipping**	**Tax**	**Total Cost**
AeroTech Motor	L1000	BAR	3	240	0	0	$720
AeroTech Motor	TBD (Subscale)	BAR	1	80	0	0	$80
Launch site use			3	50	0	0	$50

Total Project Expenses:	$2000.93

6.2.1.2 Travel Expenses

The Rocket Team at UCSC is committed to giving all contributing members the chance to attend the NASA Student Launch Initiative Competition in Huntsville. The team is strongly against preventing members from attending the competition due to an inability to fund their own travel costs. All members should be able to attend, regardless of their financial situation.

Throughout the year the team will attempt to raise money for any competition travel expenses. In the past the team has done multiple fundraising events, and the team plans to continue this for this year's competition. The team will work with multiple local businesses for fundraisers, host fundraising sales on campus, and use online crowdfunding platforms. The team will subsidies travel expenses based on how much is raised.

Travel Costs				Comments	
Total Expenses:			$7500	Price per person is $500.	
Item	Vendor	Quantity	Price (tax included)	Total Cost	
Flights (Round Trip)		15	$300	$4500	
Housing (5 nights)		15	$130	$1950	
Rental Cars (6 days)		3	$350	$1050	

6.3 Funding

All the money (not including travel) to fund the team for the competition has already been secured and is available for use. There are many options the team can pursue to obtain funding, and any fundraising efforts throughout the year will be primarily focused on raising money for future team projects and travel costs associated with this years competition.

6.3.1 General Funding

6.3.1.1 UCSC Giving Day

In February of 2019 the team was able to raise over $5,000 through the university's yearly online fundraising drive. This currently comprises the bulk of the team's financial resources and as such, the team is flexible in where this money can be spent.

6.3.1.2 Student Services Funding Request

The team's university accepts grant proposals to its Student Fee Advisory Committee. This committee supports services and programs offered to students that are not a part of the core academic mission of the university. Last year the committee had $996,000 to fund proposals and the team was able to gain $2,500 from this fund to help last year's SLI expenses. The team plans to submit a more robust proposal this year to fund other projects as the team expands and takes on increasingly complicated endeavours.

6.3.1.3 Corporate Sponsorships

Last year the team did not have much luck obtaining corporate sponsors. This year, the team has already begun a more aggressive strategy for obtaining sponsors. With these sponsorships the team hopes to obtain either material or monetary support in order to support team activities.

6.3.2 Travel Funding

6.3.2.1 Food Sales

Similar to what the team has done in previous years, the team will continue to host fundraisers on campus through food and drink sales. The team hopes to make $1,000 - $1,500 through 3 - 4 sales. The sales not only provide funding, but allows the team to be exposed to the campus community. As a relatively new group on campus, these events help make the teams presence known.

6.3.2.2 Local Business Fundraisers

The team plans to work with restaurants and other shops as have been done in the past in order to gain a percentage of profits on the given fundraising day.

6.3.2.3 UCSC School of Engineering Travel Reimbursements

The team's School of Engineering provides travel reimbursements for students traveling to competitions or conferences. For last year's expenses the team was able to obtain a partial travel reimbursement of $1,600. The team plans to submit a travel reimbursement for this year's competition as well.

6.4 Sustainability

6.4.1 Partnerships/Funding Sustainability

The team has already begun discussing potential partnership opportunities with several local and non-local businesses, specifically for providing materials or funds. This is a part of a widespread effort to further engrain the team within the local community and on campus to ensure the team's success in years to come. The team's primary goal is to form partnerships with companies willing to provide capital funding in exchange for promotion. This will allow the team to further expand its operations and influence in the community.

6.4.2 Student Engagement/Recruitment

The team, following experiences from previous years, continues to recruit team members through planned outreach events including UCSC's CORNUCOPIA, a large gathering of on campus groups and teams, and other tabling events at various locations on campus. CORNUCOPIA is the team's largest and primary source for new members, with tabling and outreach bringing in fewer members. In addition to planned events, the team has had great success with recruiting members through personal outreach in classes, social groups, and extracurricular activities, which helps to bring in members already interested in STEM enrichment activities.

Close relationships with other S-Lab groups has also proved fruitful for student recruitment. Due to the proximity, both physically and administratively, of all the groups and teams affiliated with the S-Lab, team members are able to work with each team and find their niche in the diverse set of projects the S-Lab hosts.

6.4.3 STEM Engagement

For STEM Engagement, the team has planned several outreach events at local schools, social clubs and school-sponsored events. This includes activities with specific classes in local elementary schools, Girl Scout Troops, and on campus events. Through all of these activities, the team will engage students at the university level, as well as students in elementary and middle school programs. The team's goal is to inspire a diverse group of individuals from a variety of intellectual, ethnica and economic backgrounds.