UC Berkeley Space Technologies and Rocketry
NASA Student Launch Proposal
Project Arktos

432 Eshleman Hall, MC 4500

Berkeley, CA 94720-4500

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Contents

1 General Team Information

We are the University of California, Berkeley (Cal) Space Technologies And Rocketry team (CalSTAR).

1.1 Key Contacts

Faculty Advisor	Carlos Fernandez-Pello
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Team Mentor	David Raimondi
	President, Livermore Unit of the National Association of Rocketry
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Student Team Leader	Carly Pritchett
	President, Space Technologies and Rocketry
	College of Engineering, UC Berkeley
	BS Engineering Physics,
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Safety Officer	Grant Posner
	College of Letters & Sciences, UC Berkeley
	BA Computer Science & BA Mathematics,
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1.2 Project Organization

There are approximately 70 members of STAR currently working on the NASA Student Launch. Members are broken into 8 separate sub-teams, with many serving on multiple teams. The approximate number of members on each sub-team (including double) counting are: Airframe - 17, Budget - 5, Electrical - 20, Outreach - 7, Payload - 17, Recovery - 9, Reports - 4, Safety - 3. The team officers and sub-team leads are as follows:

President	Carly
Vice President	Brunston
Logistics	Aaron
Outreach	Adam
Treasurer	Jia
Historian/Webmaster	Sean
Airframe	Tushar
Budget	Jun
Electrical	Jacob
Payload	Brunston and Carly
Recovery	Allen
Reports	Ryan
Safety	Grant

1.3 NAR/TRA Sections

Livermore Unit of the National Association of Rocketry NAR Section #534.

2 Facilities/Equiptment

Etcheverry Mechanical Engineering Machine Shop

Will be used for majority of our machining, especially that of the airframe and rover and will be the primary storage location of our materials.

- Hours: Mo-Th 8AM-11PM, Fr 8AM-4:30PM, Sa-Su 11AM-5PM

- Multiple team members already have access, and more will receive required training this (Fall) semester, and the following (Spring) semester.

- Relevant Equipment:

  - Band Saw
  - Horizontal Band Saw
  - Mill
  - Lathe
  - Waterjet Cutter
  - CNC Mill

Jacobs Institute for Design Innovation

Will be used for manufacturing parts on laser cutters and 3D printers, in addition to electrical work.

- Hours: Mo-Fr 8:30AM-11PM, Sa 12PM-7PM

- Multiple team members have keycard access and training on relevant machines and tools.

- Relevant Equipment:

  - 3D Printers
  - Vacuum Former
  - Laser Cutters

Moffitt MakerSpace

Will be used for general construction, assembly, etc. that does not require specialized machines. Also used for higher quality 3D prints.

- Hours: Mo-Th 8AM-2AM, Fr 8AM-10PM, Sa 9AM-10PM, Su 1PM-2AM

- Open to all students.

- Relevant Equipment:

  - 3D Printers

Berkeley Global Campus at Richmond Bay (BGC)

We recently acquired an official room at BGC. We will use this space for any lay-ups or manufacturing that would be a hazard to perform on campus, and for out door tests (especially propulsion tests).

- Hours: 24/7

- Relevant Equipment:

  - Indoor construction space
  - Outdoor testing space
  - Storage

3 Safety

The utmost concern of the team is safety during all aspects of launch vehicle construction, assembly, testing, and launch. The team's Safety Officer, Grant Posner, will ensure that team operations and procedures are carried out safely according to codes and regulations.

3.1 Risk Assessment

The safety team considers the following items to be some of the most likely or worrisome risks to the completion of the project:

Risk	Effect	Severity & Likelihood	Mitigation
Improper use of power tools	Injury to team members	2C	Require team members to read all relevant safety documents of Jacobs Hall/Etcheverry machine shop before use of equipment; furthermore, experienced team members will supervise less-experienced members to make sure that construction is carried out safely.
Improper handling of hazardous materials/-chemicals	Explosion or fire, personal injury (burns, loss of eyesight, cuts, etc.)	2C	Experienced team members/team mentor should supervise all handling of hazardous materials, or the team mentor should handle materials him/herself. Also, use of Personal Protective Equipment and applying lab safety standards can help: wearing safety goggles, lab coats, closed-toed shoes, having minimal exposed skin, wearing gloves, etc.

Risk	Effect	Severity & Likelihood	Mitigation
Transportation: forgetting equipment/-parts	Launch Vehicle may lack a part that is required for safe flight	2D	The team will maintain a list of all launch vehicle components and required equipment, and each item will have a specified team member who shall ensure that the item is accounted for before transportation.
Launch safety: not covering all items on a checklist	Launch Vehicle may be improperly or unsafely set up, launching mechanism could fail, team could fail to abide by regulations (such as the NAR HPRSC)	3B	Call-and-response system for completing a checklist: one team member calls out each checklist item, and a separate member completes the item and verifies it is complete out loud. If there is any confusion, the checklist item should be clarified by the member calling out the items.
Flight testing	Launch vehicle failure or damage; injury to team members and/or spectators	2D	All flight tests will abide by NAR/-TRA safety codes, along with applicable federal, state, and local regulations. Checklists will be used (as described above), and all present team members will be briefed on hazard and accident avoidance. Ground tests will be used to ensure stability of the launch vehicle before flight.

Project Risks & Mitigations

3.2   Facilities Safety

The team plans to use Jacobs Hall, the Etcheverry machine shop, the Richmond Field Station, the MakerSpace in Moffitt Library, and occasionally team members' residences for design and construction. All the university-owned buildings have safety information and codes, and use of several of these spaces require university training. Team members will read, know, and abide by the facilities' rules, and shall also consider safety briefings by the Safety Officer, in order to maximize safety when working on the launch vehicle at any of the listed locations. The planned use of the facilities is described in section 2. Team members will have access to PPE at each facility: at some facilities we will store PPE for easy accessibility, and team members are required to bring PPE to facilities which do not have stored PPE already available.

3.3   NAR Member Procedures

Our NAR team mentor will purchase all launch vehicle motors and any energetic devices that the team requires, and also transport, store, and install these devices, or will delegate these tasks to another NAR/TRA-certified member. Our mentor will perform all hazardous materials handling and hazardous operations, or will delegate to a certified and experienced person to perform hazardous operations. Members of the team will never handle a motor or energetic devices, and will not handle hazardous materials. The team will maintain safety by leaving hazardous operations to experienced, certified people.

At each launch the team's Safety Officer will confirm with the team's mentor that all the requirements of the NAR high power safety code are followed, so that our experienced mentor can supervise operations and ensure that all operations are safe. In particular, the Safety Officer and team mentor will ensure that all safe minimum distances are observed, and that all launch mechanisms (ignition system, motor, launch pad and rod) are safe and abide by codes and regulations.

3.4   Safety and Pre-Launch Briefings

The safety team will present safety briefings to the rest of the team, and each briefing will be relevant to particular sub-teams. These safety briefings include any new safety tips or advisories, as well as any new hazard analyses or modifications to old hazard analyses, so that the entire team is up-to-date with information about hazardous materials, procedures, or actions. Furthermore, the safety team will give a presentation to relevant team members on hazard recognition and accident avoidance prior to launch vehicle construction, and before any launch, to maintain team awareness of proper safety protocols. This presentation will cover such topics as construction safety, in particular proper use of machine shop equipment, construction accident avoidance, and proper use of hazardous materials and chemicals; proper use of personal protective equipment; launch safety codes; and any other topics that will improve team safety.

Before every launch the Safety Officer will give a pre-launch briefing to the members of the team. This briefing shall include the above briefings on hazard and accident avoidance, and will also include discussion of relevant launch codes and regulations, in particular the NAR high power safety launch code, and will include any pertinent information on local weather conditions, possible failures, launch vehicle recovery plans, and any location-specific hazards.

3.5   Caution Statements and Documentation

Necessary caution statements will be placed in all plans, procedures, and other working documents that pertain to any operation or procedure with risks involved, such as, for example, airframe construction with composite materials. These caution statements will include information on proper use of Personal Protective Equipment, in particular the proper use of safety goggles, closed-toed shoes, and any specialized safety equipment relating to specific tasks such as (for example) the use of respirators while constructing with composite

materials and the use of gloves while handling epoxies and glues. Furthermore, these caution statements will reference relevant MSDS and procedure-specific safety codes and regulations.

Documents for risky (even low-risk) procedures will always be easily accessible to team members observing the procedures. For example, MSDS will be physically accessible to team members working with chemicals or other materials, and documentation on PPE will be physically accessible close to construction equipment.

3.6   Complying with Applicable Laws

The team will comply with all applicable laws when constructing and launching rockets. Specific plans for federal regulations are as follows:

Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C: Amateur Rockets

We comply with §101.23 (General operating limitations). The team shall make calculations and simulations for the rocket of operation to ensure that it is launched in a suborbital trajectory, not launched into foreign territory or launched into any hazardous environments (such as buildings, urban areas, or aquatic landmarks). The rocket will not be launched into any government property, aircraft, or aircraft territory of any sort. Absolutely no live animal or such organisms will be launched in, or attached to, any part of the rocket. The rocket will not ever be launched at a target. The rocket will only be launched vertically, perpendicular to the ground, towards the sky. We further comply with §101.25 (Operating limitations for Class 2-High Power Rockets and Class 3-Advanced High Power Rockets). The team shall be extremely cautious when planning to launch any rocket. If any of the following conditions are met, the rocket shall not be launched: launch into any clouds or vision restriction hazards of more than half of the flight, before sunrise or after sunset, or within 5 miles of any airport or airspace range. All members should be excluded from the appropriate range when launching the rocket, for safety reasons. A member of the safety team shall bring a fire extinguisher to any rocket launch. The team will provide the necessary information to the nearest FAA ATC facility when planning on launching a rocket if the rocketry club does not.

Code of Federal Regulation 27 Part 55: Commerce in Explosives

The team's NAR mentor will handle all motors and energetic devices legally and safely.

NFPA 1127: Code for High Power Rocket Motors

The team's rocket shall be inspected by a Range Safety Officer before launch, and if the rocket does not pass the inspection, then the rocket shall not be launched. Furthermore, the rocket will be designed to be stable in expected operating conditions, and will have a recovery system designed to safely deliver all parts of the rocket to the ground after launch.

NFPA 1127 is largely based on the NAR high power rocket safety code, which the team shall abide by.

3.7   Testing

Testing will be used as much as possible to ensure that the final launch vehicle is stable and safe, and that all the components of the launch vehicle meet design requirements. Sub-scale tests will be used to verify that integration of various components works as planned, and wind tunnels may be used to ensure aerodynamic stability of the launch vehicle.

All tests will be carried out while following all applicable safety codes and regulations, in particular for sub-scale launches.

Before each major test, the safety team will compile a checklist of operations for the test, with feedback from relevant team members. No such test will be executed without a checklist, which will include a section on failure modes for the test.

At minimum, we expect to have a sub-scale launch test, a full-scale parachute deployment test, rover deployment tests.

3.8   Launch Vehicle Deployment & Recovery

First and foremost, our safety priority is the team itself, which implies that in the situation of unintentional black powder ignition, shock cord snap, bulkhead deformity, or deployment failure, our main objective is to protect the crew from any injuries by removing every individual from harm's way.

Our second safety concern is the use of black powder and electronic matches. We will have our mentor purchase both the electronic matches and black powder. They will install both the electronic matches and black powder before all ground tests and launches. While the electronic matches and black powder are being handled, all members of the team will wear protective glasses. Our safety officer will make sure that there are no open flames or substantially hot objects nearby. The members of the recovery team will make sure that the altimeters are off and that no wires are live. During any ground tests, the members of both safety and recovery teams will clear the immediate vicinity of testing and check that all other team members are wearing their protective glasses.

Our third, but also extremely important priority, is the launch vehicle itself. A single perturbation that distorts the performance and ability of the shock cords/bulkheads can jeopardize not only the structure of the launch vehicle, but the success of the competition itself. Thus, any and all aberrations in the designing and testing phase for the implementation of the shock cords and bulkheads must be addressed and fixed. More specifically, our most hazardous situations involving a defective shock cord or bulkhead include, but are not limited to, entanglement of the shock cords during parachute deployment, which would inhibit the lift-off and/or landing of the launch vehicle; busted bulkhead from impact of black powder that might damage the performance of the avionics bay's equipment; and others. Thus, CalSTAR is taking the initiative to invest in equipment that would counteract both of those potential issues. For the entanglement dilemma, investing in swivels and possibly a slider parachute would streamline deployment, allowing a greater degree in deployment flexibility while simultaneously improving the consistency of deployment. For the bulkheads, the primary method of counteraction would be investing in a sturdy enough bulkhead, sealed with gaskets and secured firmly with our center rod and U-bolts, in order to minimize possible damage from a high temperature/pressure explosion. With the right equipment and mental-

ity, CalSTAR will ensure that failures in the shock cords and bulkheads will not jeopardize the mission or the life of its members.

Our fourth, and most important, safety concern with recovery is deployment failure. In the case that a parachute deploys prematurely during ascent, we will warn all of those around the site of launch and keep a close watch of the launch vehicle so that team members and spectators can safely clear the area before crash landing. In the case that one or multiple parachutes fail to deploy, we will again warn all of those in the vicinity and keep watch of the launch vehicle in order to clear the area where it may crash. In order to minimize these risks, we will use two altimeters. One altimeter will be the main one, and the other will be in place for redundancy in the case that the first does not work. We will also perform multiple ground test to be sure that we are using the correct amount of black powder to break our shear pins and deploy the parachutes.

3.9   Safety Agreement

The team agrees to abide by the following requirements, along with other safety rules:

1. Range safety inspections of 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. Any team that does not comply with the safety requirements will not be allowed to launch their rocket.

See Appendix A: "Safety Agreement" for a list of safety rules and evidence of team member agreement to the rules.

4   Airframe

4.1   General Dimensions

The overall length of the proposed vehicle is 96.427". The diameter of the nose cone and front partition is 6", and the diameter of the booster section is 4". The booster is 25" in length. It houses an Aerotech L1150P motor, an avionics bay, the drogue parachute, and the main parachute. The reduced diameter of the booster section serves to reduce the rockets drag and wake, increasing aerodynamic stability. Three clipped delta fins of widths of 4.75" are attached to the rear portion of the booster section. The booster is connected to the upper section by a 3" conical transition that increases the launch vehicle's diameter to 6". The payload section houses the Deployable Rover as its experiment. The payload will consist of a cylindrical-bodied two-wheeled rover that maximizes the use of space within the airframe while eliminating the need for ballast. It will provide protection to its solar panels and is a rugged design meant to traverse uneven terrain. It will be deployed using a redundant, safe ejection method using a free-floating secondary bulkhead and a black powder separation event. Trade studies were used to determine the rover design selection as well

as the deployment systems, and a detailed design is described in the payload section of this report. This section is 13" in length. Above, the ogive nose cone is 22" in length, with aerodynamically favorable proportions. The center of gravity of the launch vehicle is located 42.781" from the rear of the rocket. The center of pressure is located 30.778" from the rear. The launch vehicle's static stability margin is 2.0 cal.
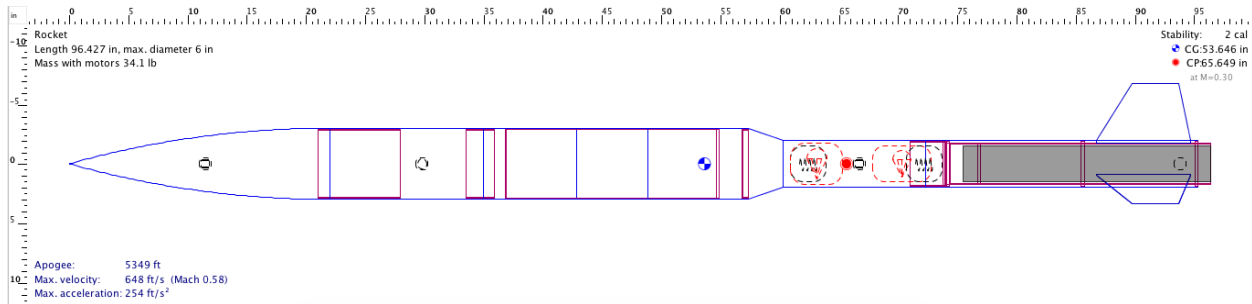
2D Side View of the Rocket

3D Model of Rocket with Internal Features
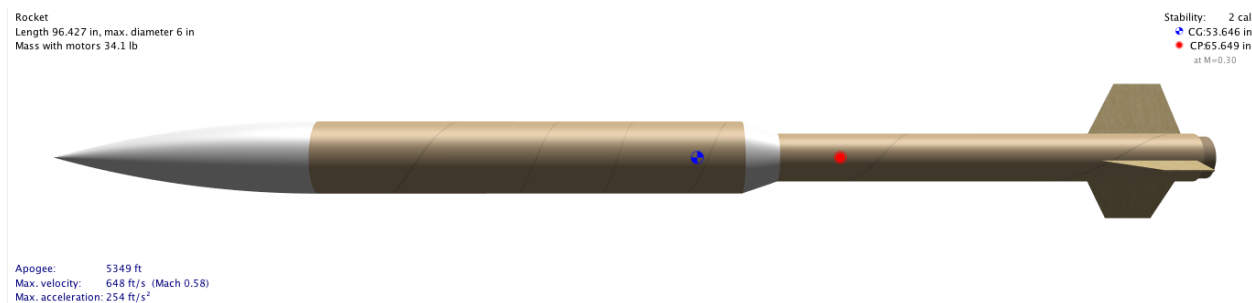
3D Model of Rocket Exterior

4.2 Material Selection and Justification

The main body of the launch vehicle will be constructed from Blue Tube. It is strong enough (with peak stress at 5000psi) to withstand high-impact landings, as well as high G-forces experienced during takeoff. It is also much more shatterproof than materials like phenolic, as long as not painted. Its heat resistance is high enough to survive the temperatures of the motors exhaust. Additionally, Blue Tube has a density of approximately 0.871oz per cubic inch, which is fairly low when compared with those of other materials such as fiberglass or phenolic. It is much easier to work with, too, than materials such as fiberglass are, which

often require water jet cutting that is much slower than laser cutting for Blue Tubes. These reasons, coupled with its relatively low price at $67 per 48, make Blue Tube an appealing choice for our main airframe. The nosecone and the fins, the parts undertaking highest stress, will be constructed from fiberglass because of its high compressive strength of over 20300psi and flexibility, which make it worthy of its high density of 1.069oz per cubic inch and toxicity. The motor will be mounted in an inner tube made of phenolic, a material with very good heat resistance and a reasonable density of 0.844oz per cubic inch. The motor tube is carefully protected by centering rings inside the main body, so its brittleness can be spared. Centering rings for the inner tubes will be constructed from plywood and cut on a laser-cutter. Albeit a traditional material, it is ductile and holds in any oscillation.

4.3   Construction

Beginning from the top, the team has designed the launch vehicle with fiberglass cone of base 6" OD and 6" OD blue tube for payload and recovery. Next, the team has researched fabricating a 4" to 6" fiberglass transition to cut weight; if the transition is used, the rest of the body will be made from 4" OD blue tube. If not, 6" OD blue tube will be used instead. At the booster section of the launch vehicle, we plan on using between 1.5' to 2' length phenolic tubing to house the motor. Throughout the rocket we will be using birch plywood for centering rings and bulkheads.

4.4   Projected Altitude

The current apogee estimate is 5349 feet. This value was calculated by inputting the current rocket design into the OpenRocket software and running a simulation of the rocket's flight. The current apogee is above the desired goal, but, at this point in planning and development, we are taking into account possible unforeseen mass growth and additional drag which would lower the apogee.

4.5   Motor

We currently plan to use a reloadable AeroTech L1150 with a total impulse of 3489 Ns. This motor fits best with our current vehicle design and will allow us to get closer to the desired apogee than any other motor.

4.6   Vehicle Requirements

1. *The vehicle will deliver the payload to an apogee altitude of 5,280 feet above ground level (AGL).* Our current predicted apogee is 5,349 feet, which is likely to change slightly based on actual payload mass. In case it does not change, we will correct by adding extra mass as ballast.

2. *The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the altitude award winner. Teams will receive the maximum number of altitude points (5,280) if the official scoring altimeter reads*

a value of exactly 5280 feet AGL. The team will lose one point for every foot above or below the required altitude. We will use a Perfectflite Stratologger CF for scoring and a Missileworks RRC3 altimeter for redundancy.

3. *Each altimeter will be armed by a dedicated arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.* We plan to have holes in the avionics section of the airframe for rotary altimeter switches. The are able to be armed at the launch pad with a flat-head screw driver.

4. *Each altimeter will have a dedicated power supply.* Both altimeters will be powered by a separate Duracell battery.

5. *Each arming switch will be capable of being locked in the ON position for launch (i.e. cannot be disarmed due to flight forces).* The rotary switches will not be able to b disarmed by any flight forces.

6. *The launch vehicle will be designed to be recoverable and reusable.* All airframe materials were chosen to be able to easily withstand any foreseen impact upon landing (not including crash landings).

7. *The launch vehicle will have a maximum of four (4) independent sections.* The vehicle has 2 independent sections, 3 if the rover is included as a independent section.

8. *The launch vehicle will be limited to a single stage.* The vehicle has one motor and one stage.

9. *The launch vehicle will be capable of being prepared for flight at the launch site within 3 hours of the time the Federal Aviation Administration flight waiver opens.* Members critical to pre-launch procedure will practice preparation before launch dates. Preparation is expected to take significantly less than 3 hours.

10. *The launch vehicle will be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any critical on-board components.* Electronics will be designed so that they have sufficient power to function for well over an hour. No part of the functionality of our mechanical design will be affected by the passing of 1 hour.

11. *The launch vehicle will be capable of being launched by a standard 12-volt direct current firing system.* The motor we selected is ignitable by standard systems, and nothing in the design requires any additional or unique circuitry or equipment.

12. *The launch vehicle will use a 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).* We will use an AeroTech L1150 motor using APCP, certified by all above associations.

13. *Pressure vessels on the vehicle will be approved by the RSO and will meet certain stated criteria.* The design does not incorporate pressure vessels.

14. *The total impulse provided by a College and/or University launch vehicle will not exceed 5,120 Newton-seconds (L-class).* The motor has a maximum impulse of 3489 Newton-seconds.

15. *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.* The vehicles static stability margin is 2.0, as calculated by OpenRocket.

16. *The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.* At rail exit, our velocity is 70 fps.

17. *Any structural protuberance on the rocket will be located aft of the burnout center of gravity.* No structural protuberances are required in the rocket design.

18. *All teams will successfully launch and recover a subscale model of their rocket prior to CDR.* We plan to launch the sub-scale model at LUNAR on December 2nd.

19. *All teams will successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration.* We plan to launch the full-scale model at LUNAR on February 3rd.

20. *Vehicle Prohibitions* The launch vehicle does not utilize any of the materials or features explicitly prohibited in section 2.21 of the NSL Handbook.

Challenges	Solutions
Creating Transition Pieces: We have decided to use two different diameters for our rocket. This allows us to cut down on mass where and when we dont need it. However, it generates the problem of transitioning between these two diameters.	The transition piece will be either created by using a filament winder or will be custom ordered from a developed contractor.
Strength of Transition Piece: Bonds, in this case, transition pieces, can be the weakest part of a section.	The transition piece will undergo Finite Element Analysis in the design phase and then rigorous testing after it has been constructed and will be made of stronger material if necessary.
Fin Placement: It is imperative that the fins are placed correctly at exactly 120 °apart.	A custom, 3-D printed jig will be made that is constructed to the exact specifications required to properly align the fins and can be placed on the rocket to ensure no slippage.
Launching off the Rail: With two different diameters, launching off the rail poses a problem because the buttons cannot be aligned.	There will be either an extension from the smaller diameter to the rail or there will be removable buttons that disengage with the rocket after liftoff.
Motor Insulation: By using a very high powered motor such as the Aerotech L1150, insulation becomes a major factor.	The material used will be kraft phenolic which is a very good insulator and will protect the rest of the rocket from any significant temperatures.

5   Recovery

5.1   Technical Design

The STAR recovery system is composed of two primary components: 1) the avionics bay and 2) the deployment systems and parachutes.

5.1.1   Avionics Bay Design

- Dimensions: 18" in height (6" of airframe in the middle and 6" of protruding coupler above and below), 4" in diameter. Door is 3" tall and 1/3 of airframe circumference long. One bulkhead will be mounted flush with the top coupler, while another bulkhead will be located 6 in. from the bottom bulkhead. This will result in an internal length of 12 inches for the recovery electronics.

- Materials: BlueTube is used for the airframe and coupler. The rails will likely be steel. The honeycomb will be made out of a composite material yet to be decided. It will

most likely be similar to a carbonfiber hexagonal crystalline structure.

- Construction Methods: The BlueTube will be cut using a horizontal bandsaw, while the door will most likely be cut with a dremel. The metal components will most likely be fabricated in the student access machine shop, while the wood materials will be cut using a laser cutter in the Jacobs Hall Makerspace. Furthermore, the honeycomb composites will need to fabricated at the Richmond Field Station in a ventilated compartment.

The avionics bay design was driven by two primary factors: 1) ease of accessibility and 2) minimize airframe protrusions to optimize aerodynamics. The avionics bay will incorporate a sled that is able to sit on rails and be removed from the avionics bay through a small door connecting the internal avionics bay to the outer airframe. This would allow the altimeters and other electronics to be very easily accessible, not only during assembly, but also on the launch pad, where disassembly of the rocket would cause significant time delays. On the other hand, the door would be very small since the sled will be oriented perpendicular to the flight path of the launch vehicle. Thus, this satisfies both the "ease of accessibility" and the "minimize drag" requirements. Upon analyzing the design, it was noted that the sled would experience the most load in the axial direction during liftoff and recovery. Thus, a sheet of honeycomb composite core will be placed above and below the sled to absorb the load experienced by the launch vehicle. Above and below these would be a 1/4-inch plywood bulkhead to secure the honeycomb in place. Through the bulkheads, honeycomb composites, and sled are two 1/4-inch threaded aluminum rods that run the length of the entire avionics bay. The aft end of the avionics bay consists of a bulkhead contains a U-Bolt that will be connected to the deployment system of the rocket.

5.1.2 Sled Design

- Dimensions: The sled is approximately 4.5" wide and 5" length and 0.5" in thickness

- Materials: High Density 3D printed composites

- Construction Methods: The sled will most likely be 3D printed in the machine shop. This will require CAD modelling in Solidworks.

Counter to conventional sled designs, STAR's design strives to minimize empty volume by orienting the sled to be parallel with the axial cross-section of the rocket. The sled would be in two components joined together by a rail. One component would be stationary, fixed in place with the rods, while the other would be removable through a small door. One justification for this particular sled orientation is that it minimizes the amount of airframe cut, which would potentially minimize the amount of drag created by such an incision. The sled would sit inside the airframe such that it would be constrained in all six degrees of freedom, ensuring that it would not move around. However, it is understood that such constraints may cause the sled to shatter more easily, in which case, a breakable sled must be designed.

5.1.3 Parachute System Design

The deployment system will utilize a single-side dual deployment tactic, releasing drogue chute at apogee and main chute at 700 ft. agl. The parachutes will be released between the avionics bay and the booster+ portions of the rocket, and will incorporate a delayed deployment system utilizing two L2 Tender Descenders in series. A 72" toroidal main chute and 36" elliptical drogue chute are used. Justification for using these parachutes is in the following section. The parachutes will be deployed using a redundant system of altimeters (Perfectflite Stratologger CF and Missleworks RRC3), which will send a 1.5A current to ignite an e-match that would ignite a small vial of black powder. The parachutes will be protected in the parachute bag during the black powder explosion. Once the force necessary to break the shear pins is known, the following equations can be used:

$$P = \frac{F}{A}$$

The internal volume of the parachute bay is

$$V = \pi r^2 L,$$

where r is the radius of the launch vehicle and L is the internal length between bulkheads. From the ideal gas law $PV = NRT$ we get

$$N = \frac{PV}{RT},$$

where $R = 266 \text{ in lbf/lbm}$ and $T = 3307° \text{ R}$. Thus

$$N = \frac{F}{\pi r^2} \cdot \frac{\pi r^2 L}{(266 \text{ in lbf/lbm})(3307° \text{ R})} \cdot (454 \text{ g/lbf})$$
$$= 5.161 \cdot 10^{-4} \text{ FL}$$

The above equation will give the necessary black powder in grams.
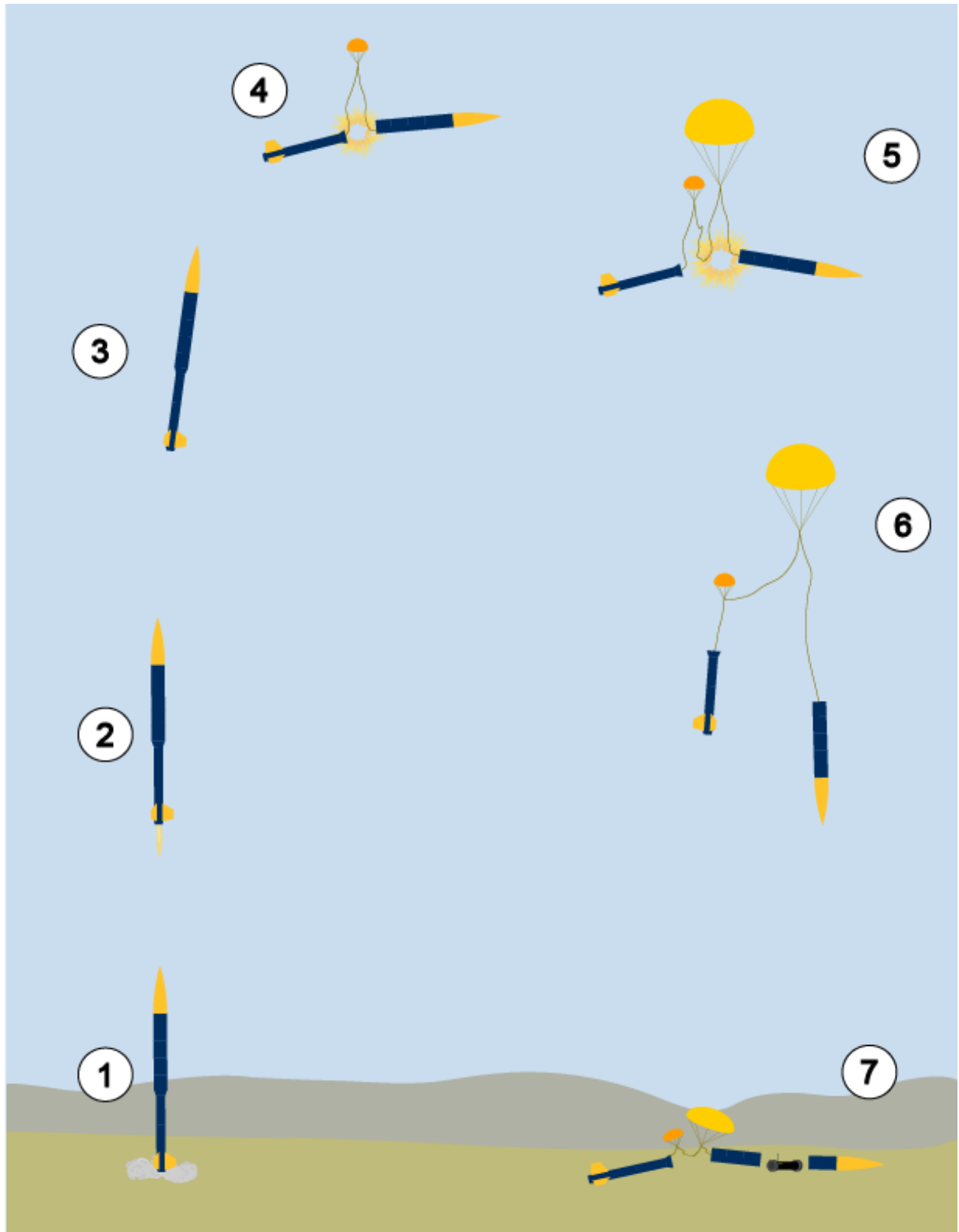
Phase   Event

Phase	Event
1	Ignition.
2	Powered flight.
3	Coasting.
4	Drogue parachute deployed at an apogee of 5418 ft. AGL
5	Main parachute deployed at an altitude of 700 ft. AGL
6	Launch vehicle descends under main and drogue chute.
7	All sections of the rocket land with a KE under 75 ft-lbf. The rover is deployed.

5.1.4 Kinetic Energy and Drag Equations

See the figure below for a drawing of the forces described in this section. The following equations are used to calculate the sizes of parachutes necessary to land each part with a kinetic energy less than 75 ft-lbf:

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

$$F_D = \frac{1}{2}\rho C_d A v^2$$

Since there are both the drogue and main parachutes, these are the two drag forces:

$$F_1 = \frac{1}{2}\rho C_1 A_1 v^2 \text{ and } F_2 = \frac{1}{2}\rho C_2 A_2 v^2.$$
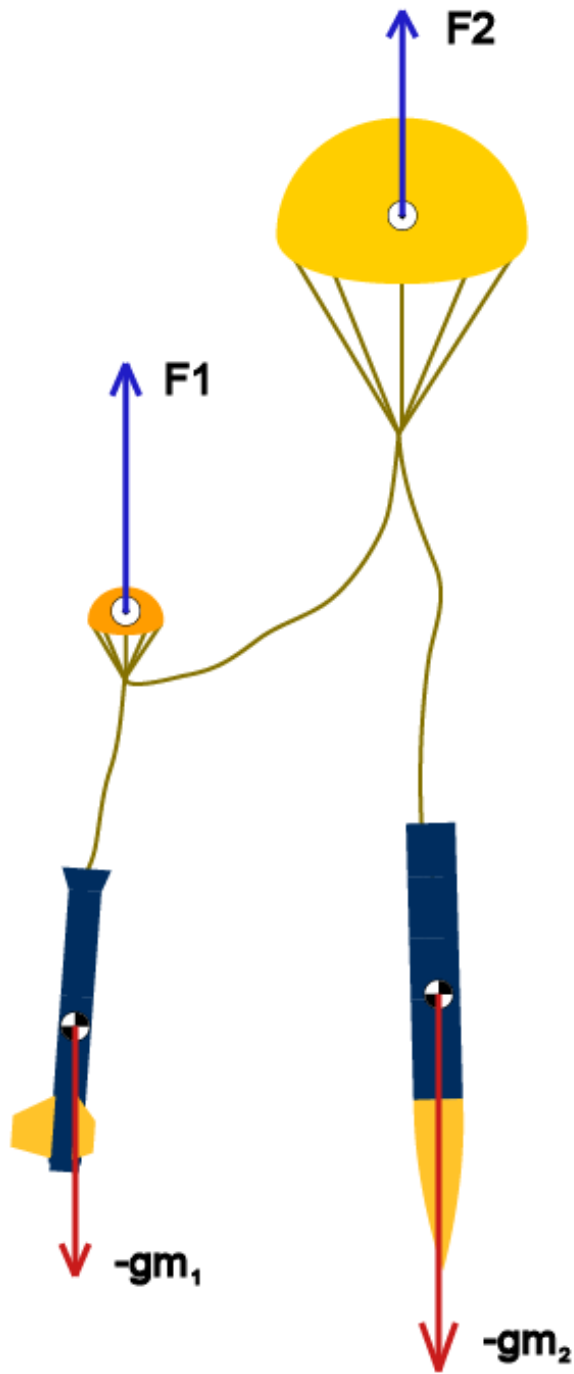
All pieces are connected, so their velocities will be the same; thus to determine the maximum velocity, only the kinetic energy of the heaviest section (m_2) must be considered,

because the other sections are lighter and will have less kinetic energy:

$$v_{max} = \sqrt{\frac{2 \cdot 75 \text{ ft} \cdot \text{lbf}}{m_2}} \cdot \sqrt{\frac{32.174049 \text{ lbm} \cdot \text{ft}}{1 \text{ lbf} \cdot \text{s}^2}}$$

The total mass of the launch vehicle is found to be:

$$m_1 + m_2 = m_{total}$$

Terminal velocity will be the maximum velocity, attained when the gravitational and drag forces are equal:

$$m_{total}g = \frac{1}{2}\rho v_{max}^2 C_1 A_1 + \frac{1}{2}\rho v_{max}^2 C_2 A_2,$$

$$v_{max}^2 \leq \frac{150 \cdot 32.174049 \text{ lbm} \cdot \text{ft}^2}{m_2 \cdot \text{s}^2},$$

So then we have the following restriction on parachute areas:

$$C_1 A_1 + C_2 A_2 = \frac{m_{total}g}{(0.5)v_{max}^2 \rho}$$

Velocity can be lower (thus $\geq$) and we can substitute the value of v_{max}^2:

$$C_1 A_1 + C_2 A_2 \geq \frac{m_{total}g m_2}{75 \text{ ft}^2 \cdot \text{lbm/s}^2 \cdot (32.174049)\rho}$$

In order to land with a KE less than 75 ft-lbf the two parachutes' coefficients of drag and area must fit the inequality above.

Size Calculations:

- $m_1 : 8.27 lbm$

- $m_2 : 17.30 lbm$

Drogue Chute Size:

Optimally the main parachute deploys at a speed less than 50 mph or 73 ft/s. The drogue parachute will be slowing the descent of the entire launch vehicle so the total mass for the equations is $m_{total} = 25.57$ lbm. Terminal velocity will be

$$v_t = \sqrt{\frac{2m_{total}g}{\rho C_1 A_1}},$$

which gives the inequality

$$73.333 \text{ ft/s} \geq \sqrt{\frac{2m_{total}g}{\rho C_1 A_1}}$$

Given the values $g = 32.174$ ft/s^2, $m_{total} = 25.57$ lbm, $\rho = 0.0765$ lbm/ft^3, and $C_1 = 1.5$, we then have

$$C_1 A_1 \geq 3.999 \text{ ft}^2$$

$$A_1 \geq 2.666 \text{ ft}^2$$

$$\pi r_1^2 \geq 2.666 \text{ ft}^2$$

$$r_1 \geq 0.921 \text{ ft}$$

$$d_1 \geq 1.842 \text{ ft} = 22.11 \text{ in}$$

A drogue parachute of 24 in. with $C_1 = 1.5$ and $A_1 = 3.14 \text{ ft}^2$ has $A_1 C_1 = 4.71 \text{ ft}^2$ and will allow for a descent rate slower than 73.33 ft/s. A 24-inch Elliptical Parachute from Fruity Chutes will be used as the drogue parachute.

Main Chute Size (based on 24in. drogue chute):

With the previous equations and the coefficient of drag and area for the drogue chute, the necessary size of the main chute can be calculated with the following equation.

$$C_1 A_1 + C_2 A_2 \geq \frac{m_{total} g m_2}{75 \text{ ft}^2 \text{ lbm/s}^2 \cdot (32.174049) \rho}.$$

With the heaviest component being 17.30 lbm, the maximum velocity required to have every component land with less than 75 ft-lbf is 16.70 fps.

$$C_1 A_1 + C_2 A_2 = \frac{m_{total} g}{(0.5) v_{max}^2 \rho}$$

Given the values $g = 32.174 \text{ ft/s}^2$, $m_{total} = 25.57 \text{ lbm}$, $m_2 = 17.30 \text{ lbm}$, $\rho = 0.0765 \text{ lbm/ft}^3$, $C_1 A_1 = 4.71 \text{ ft}$, and $C_2 = 2.2$, along with the inequality $C_2 A_2 \geq 72.41 \text{ ft}^2$, the inequality is

$$\pi r_2^2 \geq 32.91 \text{ ft}^2$$

$$r_2^2 \geq 10.47 \text{ ft}^2$$

$$r_2 \geq 3.23 \text{ ft}$$

$$d_2 \geq 6.47 \text{ ft} = 77.68 \text{ in}$$

Thus, a parachute with a diameter of at least 77.68 inches is required for every part of the rocket to land with a Kinetic Energy less than 75 ft-lbf). In order to land with a safe kinetic energy, an Iris Ultra 84-inch Compact Parachute from Fruity Chutes will be used as the main parachute.

Final Kinetic Energy:

The launch vehicle, given the 24-inch drogue parachute and the 84-inch main parachute, will land with velocity given by the following equation:

$$v_{max}^2 = \frac{m_{total} g}{(0.5)(C_1 A_1 + C_2 A_2) \rho}.$$

Given $C_1 A_1 = (1.5)(3.14 \text{ ft}^2) = 4.71 \text{ ft}^2$ and $C_2 A_2 = (2.2)(38.48 \text{ ft}^2) = 84.67 \text{ ft}^2$, the maximum velocity is

$$v_{max} = 15.51 \text{ ft/s}.$$

The kinetic energy of each component at landing is

$$KE = \frac{0.5 m v^2}{32.174049}.$$

Thus, the following kinetic energies at landing are:

- $m_1 : 8.27 lbm, KE = 30.92 ft - lbf$

- $m_2 : 17.30 lbm, KE = 64.67 ft - lbf$

5.1.5 Deployment System Design

The launch vehicle utilizes a same-side dual-deployment system, incorporating a unique and redundant system of Tender Descenders, shock cords, parachutes, and black powder. This implies that both the drogue and main parachutes will be deployed from the same opening in the launch vehicle (between the avionics bay and the booster+). The drogue chute will first be deployed at apogee, initiated by a pulse from the redundant altimeter system, which ignites an e-match to ignite the black powder charge stored in the booster+ section of the launch vehicle. The impact will separate the two primary components of the launch vehicle initially joined with two 4-40 shear pins. The drogue chute, initially wrapped in a parachute blanket, is thus pulled out and catches air. As the launch vehicle drifts to approximately 700 ft AGL, the altimeters will emit the second pulse, igniting black powder in the two tender descenders attached between the avionics bay bulkhead and the main chute. The two tender descenders are set up in series such that the main chute will have deployment regardless if only one or both of the tender descenders are triggered. Once the tender descenders are initiated, the drogue chute drags the main chute out of the parachute bag, and is thus, successfully deployed.

This deployment system is not only unique, but is also heritage; it was flight-proven for five successful launches in the 2016-17 competition year. Thus, this system is not only simple, but it is also consistently successful.

5.2 Recovery System Requirements

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 kinetic energy during drogue-stage descent is reasonable, as deemed by the RSO.* See flight plan in subsubsection 5.1.3.

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.* Ground tests will be performed for both the subscale and full-scale launch vehicle on their respective launch dates at the Snow Ranch Launch Site. See project schedule in subsection 8.1.

3. *At landing, each independent sections of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf.* See kinetic energy and drag equations in subsubsection 5.1.4.

4. *The recovery system electrical circuits will be completely independent of any payload electrical circuits.* The altimeters will be placed in the avionics bay, separate from the payload electrical circuits.

5. *All recovery electronics will be powered by commercially available batteries.* 9V Duracell batteries will be used to power all recovery electronics.

6. *The recovery system will contain redundant, commercially available altimeters. The term altimeters includes both simple altimeters and more sophisticated flight computers.* The main altimeter used is the PerfectFlite Stratologger CF. The backup altimeter used will be the Missile Works RRC3.

7. *Motor ejection is not a permissible form of primary or secondary deployment.* Both parachutes will not be deployed using motor ejection, see **??** for deployment system.

8. *Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.* The main and drogue chute will be deployed from the same section of tubing. The avionics bay will attached to the parachute compartment will removable shear pins.

9. *Recovery area will be limited to a 2500 ft. radius from the launch pads.* Simulations will be performed to ensure that the rocket does not drift beyond 2500 ft.

10. *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.* A TeleGPS transmitter module will be used to transmit the position of the launch vehicle. All sections of the launch vehicle will remain tethered together.

11. *The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing).* The recovery system electronics will physically be located in a separate section of the avionics bay than the GPS. Furthermore, the recovery system electronics will be shielded from onboard transmitting devices and any other devices that may adversely affect their operation.

5.3 Technical Challenges and Solutions

Challenges	Solutions
Accessibility of Altimeters: In the event that a last-minute adjustment to the altimeter system needs to be made on the launch field, it is critical to have ease of accessibility in the avionics bay from outside of the airframe.	Rather than removing one of the bulkheads below the avionics bay in order to access and fix the altimeters and batteries, a removable door system was implemented so that the altimeters can be accessed with greater ease on the field. The altimeters will slide out on a rail through the door for quick fixes.

GPS Tracking: In order to continue using the launch vehicle, recovery of all components is critical.	In order to successfully recover all components of the launch vehicle, a GPS will be included in the tethered components of the launch vehicle can be found in case of drift. Suitable parachute sizes will be chosen based on calculation and simulation so that all components land safely. Two commercially available altimeters will be used to be certain both parachutes are deployed. Ground tests of all recovery mechanisms will be performed to be certain that black powder charges are correctly sized.
Altimeter Misreadings: It is imperative to prevent false readings on altimeters from excess air flow over avionics bay door.	In order to prevent false readings on the altimeters, as well as failed deployment of parachutes, a gasket will be on the door of the avionics bay to make the door air-tight. Screws will tightly hold the door in place.
Structural Integrity: There exists a loss of structural support when removing section of airframe and replacing it with door.	To be certain that structural support of the avionics bay isn't compromised with the removal of part of the airframe, the area around the door will be reinforced with fiberglass. Simulations will be made to ensure that the avionics bay will be structurally sound.
Electrical Interference: Since the avionics bay houses both the altimeters and GPS systems, there exists the possibility of signal interference.	In order to prevent the possibility of interference between the GPS and altimeter systems, there will be primarily be physical separation of the two systems with 0.5 inch thick plywood. However, to mitigate the impact of magnetic fields generated by travelling currents, the wires leading from the altimeter to the ejection charges will be wrapped in a coil to direct the magnetic field in a straight line. It is recognized that this might produce some latency in the passing of the current. Thus, this will be accounted for in the altimeter code and will undergo extensive ground tests.

5.4 Recovery Safety Precautions

Safety is a priority to the recovery system. Thus, to ensure the safety of all the members, the following precautions must be followed.

5.4.1 Precaution with Materials

- Black Powder: While black powder is technically a low explosive material as it does not produce a shockwave during ignition, all necessary measures should be taken to avoid ignition before deployment of parachutes to ensure safety. In this case, black powder should be treated as a highly explosive material and handled with utmost care. Black powder should be loaded last into the launch vehicle after all other parts have been checked for integrity. When handling black powder, all non essential personnel must vacate the area in case of an accident. Likewise, no high heat material or tools should be within a 30 foot radius of the black powder. The black powder will be loaded into vials that will be checked for full closure before launch. Ensure there are no high heat materials near black powder during setup.

- Fiberglass: Given that fiberglass is a highly brittle and flaky material, it is imperative that the necessary precautions are made. While dealing with fiberglass, all users must wear a full-body suit and respirator to prevent the inhalation of and exposure to fiberglass debris. If the full body suit is unavailable, users must wear a face mask, long-sleeved shirt, long pants, safety goggles, and gloves.

5.4.2 Precaution with Tools

- Dremel: Given high kickback possibility and spark potential, users should secure object with a vise or secure clamp while using the dremel. The material should be kept away from flammable objects, and the user should wear gloves and safety goggles in order to protect themselves from the possibility of fragments breaking off the material.

- Power Drill: While operating a power drill, wear safety goggles to protect eyes from shavings or dust and work gloves to protect hands from possible high temperature and intense vibrations. Avoid baggy clothing and also keep hair restrained because a spinning drill can easily catch any loose items. Secure the working piece using a clamp to prevent shifting. Make sure that the drill bit is properly tightened and remember to turned off the power before switching the drill bit. Use correct drill bits for different jobs and do not apply excessive pressure.

- Razor Blade: While utilizing a razor blade, wear long sleeves to avoid having exposed skin. The razor blade should never be pulled towards the user.

5.4.3 Hazard Recognition

In order to maintain a safe workspace, materials and tools must not be left lying out on surfaces following use. Users must ensure that tools are unplugged and all dangerous or

ignitable materials are safely placed away. All materials also must be labeled so that later users are aware what is inside a given container.

6 Payload

6.1 NASA Payload Requirements

4.5.1. Teams will design a custom rover that will deploy from the internal structure of the launch vehicle.

4.5.2. At landing, the team will remotely activate a trigger to deploy the rover from the rocket.

4.5.3. After deployment, the rover will autonomously move at least 5 ft. (in any direction) from the launch vehicle.

4.5.4. Once the rover has reached its final destination, it will deploy a set of foldable solar cell panels.

6.2 Summary

The STAR payload will consist of a cylindrical-bodied two-wheeled rover that maximizes the use of space within the airframe and additionally provides protection to its solar panels and is a rugged design meant for uneven terrain. It will be deployed using a redundant, safe ejection method using a free-floating secondary bulkhead and a black powder separation event. Trade studies were used to determine the rover design selection as well as the deployment systems.

6.3 Trade Studies

STAR considered multiple designs for the rover and its deployment, taking into consideration a number of factors. Our trade studies are summarized below.

STAR considered several overarching rover types when designing the payload. A traditional wheeled rover design which would consist of either four or six wheels provides the advantage of thorough documentation and design familiarity. However, due to the small diameter of the airframe, the rover would have to be considerably scaled down which would cause manufacturing and maneuverability issues later on. Additionally, the orientation-dependent nature of traditional rovers was a disadvantage when designing the necessary rover deployment mechanisms from the airframe. Another type of rover considered was a spherical rover. This spherical design allows for easy deployment from the airframe considering its shape and the fact that it is orientation independent. However, mounting and deploying foldable solar panels onto a moving sphere posed a significant design challenge. Additionally, a spherical rover presents a high risk of becoming stuck in rough terrain.

STAR also considered multiple designs for rover deployment mechanisms. Initial designs consisted of a door on the airframe which would be locked during launch vehicle travel and only unlatch and open after landing. However, imperfections in the airframe caused by the door raised strong aerodynamic concerns. Furthermore, the infeasibility of landing the launch vehicle in a specific orientation required for this design proved to be a major

disadvantage. Another mechanism discussed was deploying the rover through the nose cone of the rocket. Upon landing, the nose cone would unlatch and open on a hinge where the rover would then be pushed out of the nose cone for deployment. This design raised the same concerns over aerodynamics and orientation as the airframe door design. Additionally, the robustness of the nose cone connection to the payload airframe during flight raised safety concerns.

Design Factor	Criteria Weighting (Out of 5)	Traditionally Wheeled Rover	Spherical Rover	Cylindrical Rover
Mobility	5	5	2	4
Reliability	3	4	2	3
Robustness to Environment	4	2	3	3
Space Efficiency	3	2	4	5
Ease of Deployment	5	2	2	3
Manufacturability	3	4	2	4
Axisymmetric weight (lower required ballast = higher score)	4	2	5	5
Cost (lower cost= higher score)	2	4	2	2
Total	N/A	89	85	107

Design Factor	Criteria Weighting (Out of 5)	Airframe Door	Nose Cone	Black powder, no bulkhead	Black powder, removable bulkhead
Aerodynamics	5	2	3	5	5
Weight (lower weight = higher score)	2	3	3	4	4
Manufacturability	4	2	2	5	4
Robustness in Flight	5	3	2	3	4
Ease of Activation	4	1	1	5	5
Shock to Payload (less shock = higher score)	4	4	4	1	3
Cost (lower cost= higher score)	3	2	3	5	3
Total	N/A	65	68	107	110

6.4   Downselect

As a result of performing analyses that are summarized in the design matrices and discussing and sketching various solutions to payload development, we concluded that the following detailed design best matches the conditions the rover will experience during flight and after deployment. It will provide the best margin of success while remaining low-cost and rapidly iterable. An in-depth design description is below.

6.5   Detailed Description
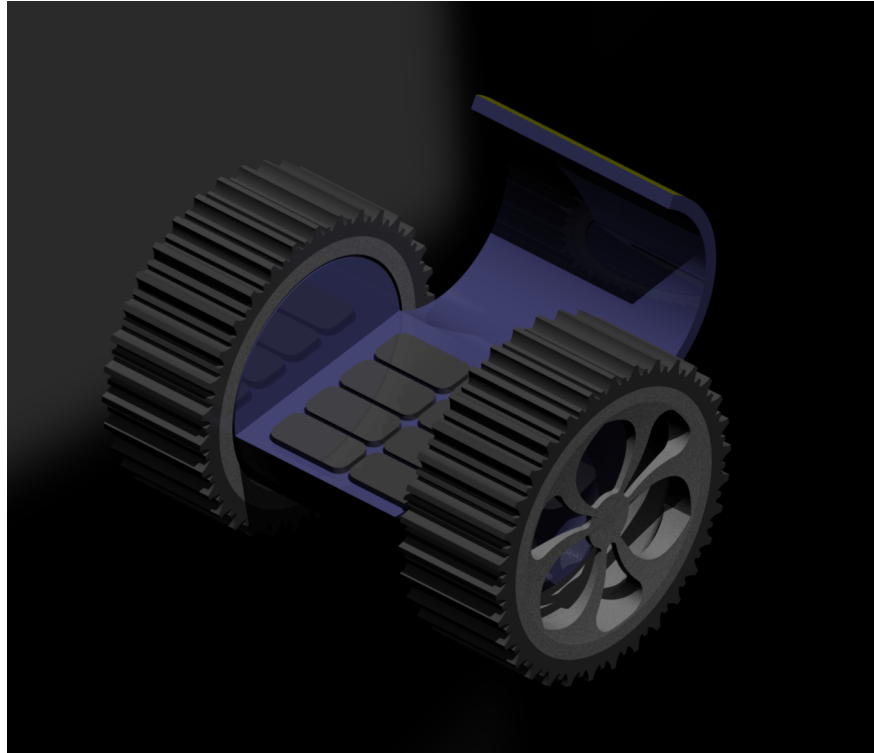
6.5.1   Rover

The STAR rover payload is a cylindrical design where the body of the rover is in line with its two large-diameter wheels. This design maximizes the use of space within the payload section of the rocket, simplifies deployment, and requires no ballast to ensure that the weight distribution is axisymmetric and about the center axis of the rocket.

The wheels will be 5.5 inches in diameter, with 1 inch width, and the body will be 4 inches in diameter with a 6 inch width. A half-shell on the body of the rover will deploy upon ejection of the rover from the airframe, creating a skid which will prevent the rotation of the cylindrical rover body when the wheels are rotated. A flat surface on the inside (originally covered up by the half-shell) will house the electronics and a folded-flat solar panel, which will be deployed on a servo once the rover has moved outside the 5 foot radius.

6.5.2   Rover Electronics

The rover will use a microcontroller to control the wheels and deployment of the solar panels. Detection of its ejection from the vehicle will occur using photoresistors, at which point an autonomous program will drive the rover away from the airframe and deploy its solar panels once it has determined the rover is greater than 5 feet away from the airframe.

In order to determine distance from the vehicle, we will use an encoder on each wheel as well as an accelerometer to determine progress. This system does not take into account small bumps in the terrain or wheel slippage - to mitigate this shortcoming, we will calibrate the software by using the terrain of the launch site by driving the rover for a short distance and finding the ratio of calculated distance to actual distance. For example, if the microcontroller calculates that the wheel has traveled 5 feet but the rover only moved 4 feet, we would apply a scaling factor of 1.25 and drive the rover 6.25 feet during launch. To ensure the rover travels in a straight line, we will use a combination of wheel encoders and an on-board gyroscope to track turning.

6.5.3   Deployment

(not to scale)
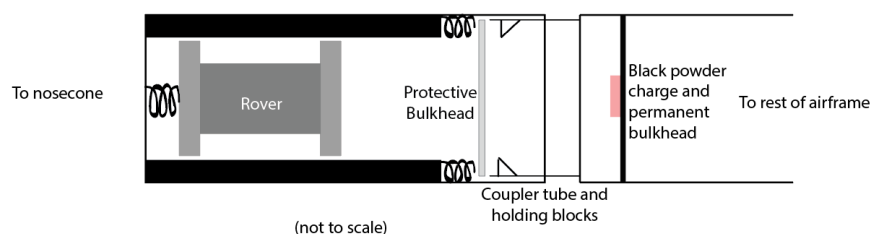
There is a protective bulkhead which rests on holding blocks connected to the coupler tube. When the black powder charge on the permanent bulkhead activates, the force will break the shear pins connecting the payload section to the airframe, and will compress the springs behind the protective bulkhead. The resulting energy transfer will cause the protective bulkhead to be ejected from the opening on the bottom of the payload section, allowing the rover to be pushed out.

The rover ejection will occur following the removal of the protective bulkhead by means of a large spring forcing the rover out of the airframe.

6.5.4   Deployment Electronics

On the airframe, there will be a microcontroller that waits for a signal to be received by radio link from the ground station before activating the black powder charge that separates the payload section from the rest of the rocket. This circuit will contain an altimeter in series such that the black powder charge cannot be activated unless it is on the ground (the inertial measurement unit determines there has been no movement for a predetermined amount of time, and the altimeter is in the post-recovery deployment state).

Challenges	Solutions

Design rover capable of maneuvering rough terrain	In terms of packaging, the cylindrical rover design allows for the largest possible wheels. These large wheels allow for higher ground clearance for increased all terrain mobility.
Prevent separation charges from triggering anytime before vehicle landing	The separation charges will only be triggered from a signal sent from the teams ground station. For redundancy, the signal can only activate the separation charges if 1) an altimeter determines that there has been no movement of the payload for a certain amount of time and 2) the altimeter is in the post-recovery deployment state.
Airframe aerodynamic defects due to rover deployment mechanism	By designing a mechanism where the rover exits through the bottom end of the payload airframe tube, as described in the payload deployment description. There are no additional irregularities in the airframe besides the standard shear pins.
Provide robust packaging to protect solar panels	The solar panels will be protected with padding within the body of the rover. Additionally, our packaging design dictates that the only part of the rover in contact with the airframe is the wheels. Since the solar panels are within the main body of the rover which is connected to the wheels with shocks, the solar panels should be protected from vibrations.
Ensure correct rover orientation after ejection from the airframe	The torsion springs on the skid will have enough force to deploy regardless of the rover orientation. After the deployment, conservation of angular momentum will ensure that the rover body will rotate into the correct position prior to moving forwards.
Guarantee rover ejection from payload section	The wheels will be 3D printed plastic with a tread pattern incorporated into the wheel. The payload section interior will be coated with a thin plastic film. As the linear spring pushes the rover of of the airframe, the plastic wheels will slide smoothly along the plastic film and thereby minimize friction.
Autonomously measure 5 ft distance from the rocket	An encoder on both wheels to measure distance traveled. To ensure the distance is not less than 5 feet, wheel slip tests can be run to determine the worst-case performance of the wheels over different terrains, slopes, and wheel materials. In addition, a factor of safety can be applied, making the rover travel significantly more than 5 feet.

Achieve 5 ft distance despite untraversable obstacles	The rover will be programmed to detect when its not moving forward and then determine another suitable path to avoid that obstacle. It will also rely on accelerometer and encoder wheel data to correct for uneven terrain

7 Outreach & Educational Engagement

7.1 Goals

STAR's outreach mission is to make strong connections with educational programs(Schools, Libraries, Museums), partner with various UC Berkeley aerospace clubs, and engage and inspire as many students as possible. STAR is also working to engage UC Berkeley students in science and engineering and collaborating with its sponsors, the Space Sciences Laboratory, other student groups, and the School of Engineering to create an Aerospace Major.

7.2 Projects

7.2.1 Past/Ongoing

CalDay 2017

CalDay 2017 (April 22, 2017) was the first official event STAR participated in after the 2016-2017 NASA SL Competition. STAR had a table where the team talked to prospective incoming students, current students, other student organizations, and faculty about the NASA SL Competition and the club as a whole.

CubCon

During Cal Hacks' CubCon (April 23, 2017) STAR gave a short presentation about the club and demoed the electronics from the 2016-2017 NASA SL Competition Payload.

Jacobs Spring Design Showcase

STAR held a booth at the Jacobs Spring Design Showcase (May 4, 2017) where the team talked to students, community members, and Jacobs Hall Staff about the club and the NASA SL competition.

Maker Faire 2017

STAR manned a booth at Maker Faire (May 19-21, 2017) where team members talked to attendees about the club and answered technical questions about the 2016-2017 NASA SL

rocket. Additionally, STAR provided a hands-on activity for children where they designed and built their own capsule and parachute structure to protect a water balloon. Their design was then tested by dropping it from a height of 12 feet.

Student Organizations Fair During Golden Bear Orientation

The Student Organizations Fair (August 21, 2017) was an opportunity for newly admitted engineering students to talk to the different organizations on campus. STAR had two tables and talked with students about the club and the competitions it would be participating in.

Calapalooza Fall 2017

At Calapalooza (August 31, 2017) STAR held a booth and talked to UC Berkeley students of all years and majors about the club and how to join.

Turn the Tables Fair

Turn the Tables Fair (September 11, 2017) is an opportunity for student groups to "turn the table" and recruit potential partners and sponsors. STAR made connections with General Motors, Northrop Grumman, and Belmont Village.

7.2.2 Planned

Ohlone College Night of Science

The Ohlone College Night of Science (October 7, 2017) is an annual event at Ohlone College where various groups provide science demonstrations and activities to the general public. STAR will have three classrooms at the event; one classroom as a general display where the public can learn more about NASA SL and the team, one classroom with a K-4 grade level activity, and another classroom with a 5-9 level activity.

Space Day

Space Day (TBD) is an event that STAR is currently planning. The event would be a day of space related activities that students from around the bay area would be able to attend for free. Other student groups on campus would be able to sign up and host their own activities during the event. STAR would provide lunches for all students and volunteers.

7.3 Evaluation Criteria

7.3.1 Interaction Count

At each event the amount of students, educators, and community members will be directly counted. At larger events, stamp cards will be given out to avoid overcounting and to determine what type(s) of interaction occurred.

7.3.2 Interaction Quality

Participants will be asked to gauge the quality of the event they attended either by filling out a Google Form or a short survey on the back of the stamp card they receive at the event. The satisfaction form can be found at https://goo.gl/forms/uxNRAeGVvGRPJFg32.

7.3.3 Maintained Interaction

Participants who leave their information on the survey or the stamp card will be notified about future STAR events.

8 Project Plan

8.1 Project Schedule/Timeline

Below will be a schedule based of the key external dates of the Proposal, Announcement of awarded proposals, PDR, CDR, FRR, and Launch week. How the team plans to progress with the project between each of these dates will be detailed.

9-20-17 Proposal Due

- Hold workshops (Solidworks, Eagle CAD, LaTeX, etc.) for new team members

- First internal design review

- Rocket Stand mini-project for new members

- Move into new Richmond Field Station space Begin first use of CFD for vehicle design

10-6-17 Awarded Proposals Announced

- **10-7-17 Ohlone Science Night: outreach event with 3000+ attendees**

- Payload and electronics provide updated weight estimates for airframe and recovery

- Prototypes for payload

- Chute calculations done

- More thorough computer analysis done to calculate drag and projected altitude

- Internal Preliminary Design Review

11-3-17 PDR Due

- **11-4-17 Sub-scale launch at LUNAR**

- Sub-scale flight analyzed, evaluated

- Necessary changes to airframe, recovery, motor made

- Preliminary Rover manufactured and tested performing tasks

- Internal Critical Design Review 12-2-17 Back-up Sub-scale launch at LUNAR

1-12-18 CDR Due

- Rover completed and integrated into payload section of rocket

- **2-3-17 Full-scale launch at LUNAR**

- Full-scale flight analyzed, evaluated

- Full payload tests conducted (with-out launch)

- 3-3-17 Back-up Full-scale launch at LUNAR (last chance before FRR)

3-5-18 FRR Due
4-4-18 - 4-8-18 Launch Week

8.2   Budget & Funding

This year, our team has grown in size from approximately 20 members, to over 80. To better handle the large amount of members, our team is divided into nine sub teams that handle various parts of the competition. As of the time of writing, we have $9,455.00 in our accounts. This money is split into two main sections, Allocated Funds and Discretionary Funds. $6,790 in Allocated Funds are split amongst the subteams as listed in the attached allocation sheet. The remaining $2,665 is put aside as Discretionary Funds. This money will be used in the event an unforeseeable event pushes a subteam over budget, or if a purchase does not fall under any one sub team.

Our sources of funding include a successful crowdfunding campaign, donations from Northrop Grumman and Boeing, and various school funds, like the Student Opportunity Fund, and the Student Technology fund. We are also going to be participating in another school sponsored crowdfunding campaign. We are currently working on securing a few more corporate sponsorships as well.

The following page contains the detailed budget sheet for the upcoming year.

Budget Sheet 2017-2018

Allocation of Current Funds (August 2017)

Subteam	Percentage	Amount	2016-2017 Allocation	Net Change		
Propulsion	16.2%	$ 1,100.00	$ -	$ 1,100.00	**Allocated Amount**	
Airframe	15.9%	$ 1,080.00	$ 2,022.53	$ (942.53)	$	6,790.00
Payload	14.0%	$ 950.00	$ 713.73	$ 236.27		
Recovery	13.3%	$ 900.00	$ 1,321.00	$ (421.00)	**Discretionary Fund**	
Electronics	11.6%	$ 790.00	$ 703.69	$ 86.31	$	2,665.00
Safety	11.0%	$ 750.00	$ 39.50	$ 710.50		
Outreach	10.6%	$ 720.00	$ 150.00	$ 570.00	**Total Initial Budget**	
Logistics	5.9%	$ 400.00	$ -	$ 400.00	$	9,455.00
Reports	1.5%	$ 100.00	$ -	$ 100.00		

Preliminary Allocation of Projected Funds (December 2017)

Subteam	Percentage	Amount	Previous Allocation	Net Change		
Propulsion	19.0%	$ 2,000.00	$ 1,100.00	$ 900.00	**Allocated Amount**	
Airframe	18.1%	$ 1,900.00	$ 1,080.00	$ 820.00	$	10,500.00
Payload	14.3%	$ 1,500.00	$ 950.00	$ 550.00		
Recovery	14.3%	$ 1,500.00	$ 900.00	$ 600.00	**Discretionary Fund**	
Electronics	11.4%	$ 1,200.00	$ 790.00	$ 410.00	$	4,500.00
Safety	8.8%	$ 925.00	$ 750.00	$ 175.00		
Outreach	8.8%	$ 925.00	$ 720.00	$ 205.00	**Total Projected Budget**	
Logistics	3.8%	$ 400.00	$ 400.00	$ -	$	15,000.00
Reports	1.4%	$ 150.00	$ 100.00	$ 50.00		

Preliminary Allocation of Projected Funds (February 2018)

Subteam	Percentage	Amount	Previous Allocation	Net Change		
Propulsion	18.0%	$ 2,250.00	$ 2,000.00	$ 250.00	**Allocated Amount**	
Airframe	17.2%	$ 2,150.00	$ 1,900.00	$ 250.00	$	12,500.00
Payload	13.6%	$ 1,700.00	$ 1,500.00	$ 200.00		
Recovery	13.6%	$ 1,700.00	$ 1,500.00	$ 200.00	**Discretionary Fund**	
Electronics	12.8%	$ 1,600.00	$ 1,200.00	$ 400.00	$	5,500.00
Safety	10.4%	$ 1,300.00	$ 925.00	$ 375.00		
Outreach	9.6%	$ 1,200.00	$ 925.00	$ 275.00	**Total Projected Budget**	
Logistics	3.2%	$ 400.00	$ 400.00	$ -	$	18,000.00
Reports	1.6%	$ 200.00	$ 150.00	$ 50.00		
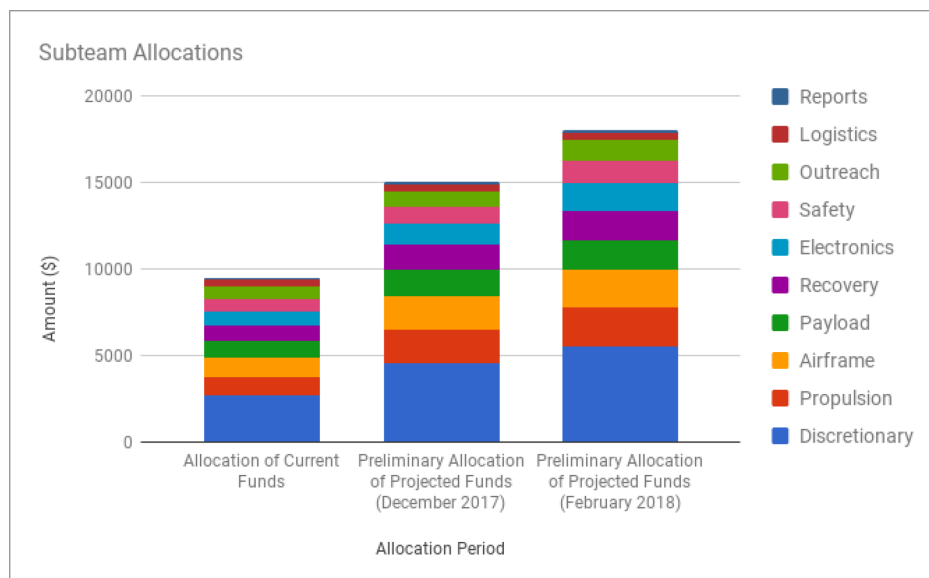
8.3   Sustainability

STAR was formed in the fall of 2015. That semester the club consisted of approximately four members. In the spring of 2016 the club, the club grew to about eight members. The club grew to approximately twenty members during the 2016-2017 NASA SL competition. Through an aggressive recruitment campaign, heightened social media presence, and high visibility at many events, STAR as a whole has grown to approximately 140 members. Not all of these members will be working on Student Launch, but instead other competitions and space related research. However, the increased membership base will allow the club to thrive long into the future.

8.3.1   Social Media

STAR's social media serves the ultimate goal of improving the club's sustainability. Currently, the club has a Facebook Page, Instagram Page, YouTube Channel, and Flickr. The social media is used to update the community, UC Berkeley students, and kin of members as to the progress of active projects. The social media also serves as a platform for crowdfunding campaigns.

8.3.2   Maintaining Communication

The Outreach Subteam will help the club sustain itself by maintaining regular contact with sponsors, partners, mentors, educators, faculty, and participants of events. A detailed document of contacts will be kept so that communication lines will remain open in the future.

8.3.3   Data Inheritance

The club maintains all data for all projects on one common Google Drive account. This will ensure that information, tests results, graphics, and all STAR owned material will be preserved so that future members can learn from past successes and failures.

8.3.4   Visibility on Campus

While fall 2017 recruitment was extremely successful, STAR is always looking for ways to make itself more visible on campus. Currently the Outreach subteam is developing demos for on campus events, creating STAR apparel, and engaging UC Berkeley students.

8.3.5   Aerospace Curriculum at Berkeley

Although UC Berkeley has one of the best engineering programs in the world, there is currently not an aerospace engineering major, nor is there many aerospace related classes. STAR is currently forming partnerships with other space related clubs, the Space Sciences Laboratory, and sponsors in order to work with the school to create an aerospace engineering major.

Appendix A Safety Agreement

It is a particular interest and duty of the safety team to ensure that requirements of safety codes and regulations are met when constructing, assembling, and launching a rocket. To abide by these regulations, and in order to maintain overall safety, each team member must follow these rules:

1. Before any launch, pay attention to the pre-launch and safety briefings.

2. At any launch of our main rocket (not sub-scale), stay at least 200 feet away from the launch site when the rocket is ready to launch, and focus on safety.

3. When constructing the rocket, always wear appropriate clothing (no loose clothing near machinery and power tools) and proper personal protective equipment (PPE), and make sure to read relevant MSDS.

4. If there is any confusion over how to use a tool or machine, ask a more experienced person for help.

5. Always follow instructions of launch officers at a launch site, including the Range Safety Officer.

6. If our rocket does not pass a safety inspection or does not meet all relevant safety requirements, then we must comply with the determination of the inspection and not launch the rocket.

7. Before a launch the team's Safety Officer and team mentor, along with the Range Safety Officer, have the right to deny the launch of our rocket for safety reasons.

Furthermore, each member must agree to abide by all of the following codes and regulations, at the direction of the safety team:

1. NAR High Power Safety Code

2. FAA regulations, including 14 CFR Subchapter F Part 101 Subpart C

3. NFPA 1127

The team as a whole agrees to abide by the following regulations from the Student Launch Handbook:

1. Range safety inspections of 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. Any team that does not comply with the safety requirements will not be allowed to launch their rocket.

Any team member who does not agree to any of the rules above may be refused access to rocket construction or assembly, may not be allowed to attend launches, or may even be removed from the team if necessary.

Appendix B   NAR High Power Rocket Safety Code

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.

2. Materials. I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.

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.

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 on-board energetics and firing circuits will be inhibited except when my rocket is in the launching position.

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.

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 on-board energetics and firing circuits I will ensure that no person is at the pad except safety personnel and 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.

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.

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 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).

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.

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.

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 approaches the ground.

Installed Total Impulse (Newton—Seconds)	Equivalent High Power Motor Type	Minimum Diameter of Cleared Area (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket[1]) (ft.)
0 — 320.00	H or smaller	50	100	200
320.01 — 640.00	I	50	100	200
640.01 — 1,280.00	J	50	100	200
1,280.01 — 2,560.00	K	75	200	300
2,560.01 — 5,120.00	L	100	300	500
5,120.01 — 10,240.00	M	125	500	1000
10,240.01 — 20,480.00	N	125	1000	1500
20,480.01 — 40,960.00	O	125	1500	2000